THE NECESSITY OF ENVIRONMENTALLY SUSTAINABLE DIGITAL PRESERVATION AND ITS EFFECTS ON PRESERVATION WORKFLOW

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"You are never too small to make a difference." -- Greta Thunberg, 2018

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Abstract

This essay is an investigation into which aspects of digital preservation affect Global Warming and how cultural heritage institutions can mitigate their participation in the Climate Emergency while maintaining good preservation standards and practices. It describes why an awareness of the environmental impacts of digital preservation is necessary, and what those effects are. It describes which aspects of digital preservation affect an institution's carbon footprint and how. It then explores which climate-mitigating aspects of digital preservation are within an institutions ability to control and which they are advised to take. In doing so, an assessment of which options are most suitable for small and mid-sized institutions is discussed, and the likely effects these alterations will have on preservation workflow. This research is based on a review of literature on the effects of digital storage and ICT infrastructure energy consumption, and on information obtained by the author in personal communications with officials at selected cultural heritage institutions in Baltimore City, Maryland.

Introduction

The Baltimore Museum of Industry (BMI) is a mid-sized history museum which is developing goals for their next 3-year strategic plan; the goals of the Collections and Archives Department include introducing a Digital Preservation Plan and incorporating a policy of environmental awareness into that plan. This essay is a product of the investigation of environmentally sustainable digital preservation pursuant the incorporation of its findings into the BMIs upcoming Digital Preservation Plan, which will additionally incorporate a cloud-storage service into their collections and archives backup workflows, and rework the in-house server hardware.

This essay investigates the impacts of digital preservation on the Climate Emergency and how cultural heritage institution can and should play their part in mitigating the worst of the effects of a warming planet. Specifically, the essay is channeled to discuss how small and mid-sized cultural heritage institutions can participate in this endeavor, as they are likely to be least-prepared, lowest-funded, and most-susceptible to the harshest realities of changing practices. This essay investigates how cultural heritage institutions can implement a preservation workflow paradigm shift necessary to lower institutional carbon footprints. How can institutions with limited funds ethically conduct digital preservation and management? What resources are available to them? What are the impacts likely to be on their preservation workflow?

To this end, a recent publication by Pendergrass, Sampson, Walsh and Alagna's recent publication, "Toward Environmentally Sustainable Digital Preservation" (2019) was taken as the foundation of research, channeling their recommendations into actionable plans in small institutions. The flow of this essay begins by briefly exploring why sustainable preservation is a worthy, necessary endeavor before moving into a discussion of digital preservation acts which affect the Climate Emergency, sustainable actions available to cultural heritage institutions, and how these actions are likely to affect the preservation workflows of small, local institutions.

These will include, but are not limited to, shifting standards of digitization en-masse, asset verification, modes of accessibility and use, and acceptable loss. Also discussed are measures available to cultural heritage institutions to mitigate, offset or otherwise avoid traditional energy consumption, including sustainable cloud-storage options currently available on the open market, and recycling options for in-house hardware.

That smaller institutions are able to maintain an acceptable standard of control over their digital assets, provide continued access, use and security of these assets in the shifting standards of climate change is paramount. How this is done responsibly in the wake of the Climate Emergency is the focus of this essay.

Methodology

The research methodologies employed in the production of this essay include published scientific research, case studies, and open-ended interviews with local preservation professionals at cultural heritage institutions in Baltimore City, Maryland. historical research was performed on current literature and resources available on sustainable digital preservation, in addition to materials relating to contemporary digital preservation theory, and standards currently employed by larger institutions.

The initial intent in researching scientific publication, case studies and the preservation practices of larger institutions was to use these standards to perform a comparative analysis of the workflow currently being performed by smaller cultural heritage institutions at the local level. However, no large institution investigated in the production of this essay, herein defined as a cultural heritage institution on a state or nation-wide level of operation, utilizes any form of environmental sustainability in their digital preservation plans. The analysis of preservation practices at smaller institutions is based on open-ended interviews with local professionals, since no data is publicly available.

These interviews were comparatively used to analyze the state of local sustainable digital preservation standards against the information obtained by research in scientific publication and case studies. This analysis has been used to make recommendations in preservation workflow for local institutions to most effectively reduce their carbon footprint and contribute to combating the Climate Emergency.

Literature Review

Research gathered in the production of this essay falls into three categories: case-studies, scientific and research publications, and information gathered from open-ended interviews. Information gathered from case studies comprises academic research on the subject of sustainability in digital libraries, archives and museums. The collection of publications within this category have been narrowed to the publication dates no later than 2000 to ensure an accurate depiction of technological standards and humanity's understanding of the Climate Emergency. Topics of interest concern the use of energy through technological infrastructure, the physical functionality of preservation storage systems, and recommended alterations to digital preservation workflows.

Scientific and research publications comprise topics of the effects of energy production and digital preservation hardware on the natural environment. These include global publications such as those by the United Nations Intergovernmental Panel on Climate Change, and journal and non-profit publications on digital preservation, technological energy consumption, and electronic waste pollution. Also investigated were national regulations on the exportation of electronic waste, local laws of Maryland state and Baltimore City concerning the organization of energy production and use, and internal publications and news stories about the technology corporations Google, Inc. and Amazon, Inc., who provide cloud-storage services useful to cultural heritage institutions.

Case studies link the analysis of these publications with the final research group, open-ended interviews with preservation professionals. Four professionals from cultural heritage institutions in Baltimore City provided information on the preservation practices of their respective institutions. This information was used to gauge the effects environmentally sustainable digital preservations practices is likely to have on the preservation workflows of small to mid-size museums.

The Necessity of Environmentally Sustainable Digital Preservation and its Effects on Preservation Workflow

The Climate Change is the greatest existential challenge the human race has ever faced. This essay will discuss the environmental effects of digital preservation and how cultural heritage institutions can contribute meaningfully to sustainable solutions to combat the Climate Emergency. The essay will begin with an overview of the contemporary state of the Climate Emergency, followed by a detailed discussion of which aspects of digital preservation contribute to that Emergency, namely by carbon emissions produced through energy production. This will be followed by a discussion of environmentally sustainable digital preservation resources available to cultural heritage institutions. Finally, several preservation professionals at cultural heritage institutions were interviewed on their digital preservation practices. The effects environmentally sustainable digital preservation actions on the preservation workflows of those institutions is discussed.

First and foremost, semantics are important. On November 28, 2019, the European Parliament “approved a resolution declaring a climate and environmental emergency in Europe and globally” (European Parliament, 2019, para. 01). The term ‘Climate Change’ is therefore no longer sufficient to describe the seriousness of the planetary environmental state. The climate has changed. To simply say ‘change’ is not stark enough to bring to mind the full force of cascading effects a rapidly altering global climate has and will continue to wrought. This essay will therefore use the terms ‘Climate Emergency’ and ‘Global Warming.’ It is hoped that by using these terms in this essay, as well as outside of it, they will serve as a portent of doom to accurately dictate the importance of action, and warn against effects wrought by inaction.

Current State of the Climate Emergency

As of this writing, the most recent publication from the United Nations Intergovernmental Panel on Climate Change (IPCC) is a report for policy makers on the effects of Global Warming on the Ocean and Cryosphere. “Global mean sea level (GMSL) is rising, with acceleration in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets (very high confidence), as well as continued glacier mass loss and ocean thermal expansion. Increases in tropical cyclone winds and rainfall, and increases in extreme waves, combined with relative sea level rise, exacerbate extreme sea level events and coastal hazards (high confidence)" (IPCC, 2019, p. 10). In other words, as more carbon emissions are released, the global mean temperature increases; this, in turn, causes ice to melt at the polar caps. This trend has been known for decades. However, the effects of this increase in water and the temperature of that water on the oceans and atmospheric climate has increased formerly rare weather events, from floods to hurricanes, in frequency and intensity.

This rise in sea level is increasing at a steeper exponential trend than previously thought. A new model called CoastalDEM (digital elevation models) decreases the probability of error with a previous modeling system which uses information from NASA's Shuttle Radar Topography Mission (SRTM) to estimate coastline elevations. With the use of an artificial neural network to incorporate 23 additional variables, CoastalDEM increases the geographical area and rate of extreme-level flooding at the year 2050 by a factor of three or more. "Even with low carbon emissions and stable Antarctic ice sheets, leading to optimistically low future sea levels, we find that the global impacts of sea-level rise and coastal flooding this century will likely be far greater than indicated by the most pessimistic past analyses relying on SRTM," (Kulp and Strauss, 2019, p. 9).

Nearly three quarters of the affected land is concentrated in seven east and southeast Asian countries: Bangladesh, China, India, Indonesia, Japan, the Philippines, and Vietnam. "[S]ea levels projected by 2050 are high enough to threaten land currently home to a total of 150 (140–170) million people to a future permanently below the high tide line," (Kulp and Strauss, 2019, p. 2). In the case of Arctic and Antarctic instability, this number more than doubles. Within Vietnam, the entirety of the Mekong River Delta and Ho Chi Minh City is affected, along with its 20 million inhabitants - one quarter of the Vietnamese population. Similarly inundated will be the cities of Hanoi, Shanghai and the province of Jiangsu, Bangkok, Alexandria, Venice, San Francisco, New Orleans, the entire nation of The Bahamas, and the coastlines of Bangladesh and the Netherlands.

CoastalDEM's algorithm and population estimates do not account for future population growth and coastal erosion, meaning these estimates may be low. As land currently occupied by human populations is claimed by the sea, these people will become displaced, creating the largest wave of climate refugees to date. As a comparison to the optimistic number of 150 million displaced persons above, the United Nations High Commissioner for Refugees (UNHCR) estimates the Syrian Civil War has produced 5.6 million externally displaced persons since 2011. (UNHCR, 2019). Population shifts in the hundreds of millions will put a strain on the resources and economies of neighboring nations and cause an entirely new age of never before seen international crises.

To what extent cultural heritage institutions contribute to the Climate Emergency? Put simply, each and every person and institution which uses electrical power in the United States contributes indirectly to Global Warming. This is due to the use of fossil fuels in energy production, which necessarily produces carbon emissions. Institutions which practice digital preservation require an additional amount of electrical energy which is not used by institutions which do not practice digital preservation, regardless of the institution's size.

While the actions of nations, states and corporate conglomerates can bring about the most dramatic change necessary to reverse the worst predictions of the Climate Emergency, the actions of cultural heritage institutions are no less influential. Cultural heritage institutions have a duty to extend the awareness of their actions beyond the boundaries of their local communities. Traditionally, the concept of sustainable digital preservation has extended only so far as to the integrity of digital assets and to economics. While to perform preservation on digital assets in a way consistent to their long term retention insofar as their lifecycles will allow, and to do so in a fiscally responsible way so as to ensure no funds are needlessly wasted on redundant features, it is time to implement the next and herein argued more imperative definition of digital sustainability: environmental digital sustainability.

“For an organization to conduct its affairs in a sustainable manner, success must be measured against not only income, but also against impact upon a community, or society at large, and the natural environment,” (Abbey, 2012, P. 94). Here is invoked the concept of social responsibility, but expanded. Cultural heritage institutions have a responsibility to participate in and provide a safe and open forum for all members of the community in which that institution resides. To be sustainable, a cultural heritage institution must expand its concept of community to include all people of the earth, and of the planet itself. Within the context of this paper, the focus is how cultural heritage institutions can participate in efforts of solving the Climate Emergency, i.e. achieving environmental sustainability while maintaining good digital preservation practices. To do so, an institution will have to gauge how their preservation practices impact the world at large by carefully considering each aspect of the preservation workflow which contributes directly or indirectly to Global Warming. “In other words, for a museum to operate in an environmentally sustainable way, success must always be gauged against the impact upon and consideration for human, natural, and fiscal resources, as well as whether or not decisions support or impede the primary mission, values, and programming of the institution,” (Abbey, 2012, p. 100). Cultural heritage institutions must commit themselves to performing only those acts which are absolutely necessary to maintain the integrity of their assets, and to participate in and purchase only those services and hardware which can be accredited as environmentally responsible or which otherwise offset the institutions carbon footprint.

It should be the goal of every cultural heritage institution to decrease their carbon footprint to the fullest extent they are able.

Digital Preservation Affecting the Climate Emergency

There are three main sources through which cultural heritage institutions which practice digital preservation contribute to the Climate Emergency. These are: energy consumption through standard use of electronics and preservation equipment; the use of cloud-computing services; and the use and eventual replacement of in-house hardware. Each of these three sources contribute to an institution's carbon footprint, while the continual replacement of in-house hardware can result in additional environmental contamination known as electronic waste (e-waste), which often results in a unique and unequally distributed form of pollution.

Energy Consumption by Infrastructure

Practically, the act of digital preservation requires both energy and physical resources, each of which contribute to an institution's carbon footprint. There is a direct causal relation between a reduction in energy use from fossil fuels and a reduction in carbon emissions. That is, if less energy is consumed, less carbon is put into the atmosphere and the lower an individual or institution's carbon footprint is.

The two main sources of electrical consumption through digital preservation come from the infrastructure from which an institution draws its power, and through the use of cloud-storage services. By infrastructure it is meant the energy through which preservation means are powered. This is commonly referred to as Information and Communication Technology (ICT) (Pendergrass, et al, 2019, p. 166). ICT comprises multiple layers of complex societal and engineering systems, including the internet, transcontinental underwater cables, cellular towers, low-orbit satellites, data centers, and the gamut of national and international governmental organizations and NGOs which oversee the operation of these component parts. ICT can be described in three tiers: "Tier 1 consists of the hardware that makes modern computing possible… Tier 2 is the telecommunications infrastructure required to network Tiers 1 and 3… [and] Tier 3 consists of devices with embedded processors connected to the network," (Pendergrass, et al, 2012, p. 173). ICT essentially comprises all that lies between ingesting a digital asset onto a storage medium to the access of that asset by an end-user device. Part of a cultural heritage institution’s carbon footprint can therefore be understood in reference to how much energy is used in each of the ICT Tiers and in what capacity.

According to a 2014 study compiled by the Institute of Museum and Library Services (IMLS), “there are 35,144 museums in the U.S., more than double the agency’s working estimate of 17,500 from the 1990s” (Bullard, 2014, para. 1). This includes all manner of cultural heritage institutions, from art and history museums to historical societies and zoos. These numbers may seem small when gauging the contributions of one institution, but when looking at the entirety of ICT emission contributions, the effects compound. Global ICT carbon emissions were expected to surpass 2.3% of the total greenhouse gas emissions by 2020 (Tadic, 2016, slide 15) and could “exceed 14% of the 2016-level worldwide [greenhouse gas emissions] by 2040, accounting for more than half of the current relative contribution of the whole transportation sector,” (Belkhir and Elmeligi, 2017, p. 448). If left unchecked, ICT will continue to produce an exponential amount of carbon emissions through the consumption of fossil fuels, establishing itself as a major contributor to the Climate Emergency.

As “buildings and their operations required the use of fossil fuels that consumed as much energy as the industry and transportation sectors combined and contributed almost half of the carbon emissions and greenhouse gases that are linked to global climate,” (Abbey, 2012, p. 92), the physical infrastructure of cultural heritage institutions is put under even more scrutiny. Energy consumption by buildings arises from a multitude of sources, some of them from construction inefficiencies and basic preservation necessities, such the use of controlled environmental spaces for analog objects. This is why “practices such as green building adoption, integrated pest management, and humidity and temperature controls,” (Pendergrass, et al, 2019, p. 171) are so important. Every reduction in fossil fuel energy consumption in cultural heritage institutions matters, especially as both the total number of cultural heritage institutions and the number of institutions which conduct digital preservation continues to climb exponentially.

Where cultural institutions source their electrical power is therefore of paramount importance in assessing their individual carbon footprint. Being aware of the amount of energy consumed by various preservation acts is equally important, although often much more difficult to quantify. “[O]rganizations focus on the management of digital content, often tracking success based on the total storage size or file count of digital content under management and the implementation of preservation risk reduction strategies, most commonly frequent fixity checking and redundancy,” (Pendergrass, et al, 2019, p. 180-181). Institutions thus employ certain standard techniques, each action of which requires a certain consumption of energy. These include ingesting and processing assets, accessing them throughout the preservation lifecycle, performing file fixity checks and other verification methods, migrating digital assets to new file formats or storage mediums, and the use of backup and redundant storage systems such as RAIDs (redundant array of independent discs), a storage technology which utilizes multiple volumes to maintain digital asset security through the use of redundant copies. Also important to consider is how many persons within an institution require and access assets during different parts of a digital preservation workflow; six individuals on six different computers utilized more energy than one individual on one computer. Additionally, if the use of two or three backup systems are employed, that necessarily increases the amount of energy required by a factor of two or three. Thus, it is recommended that “Cultural heritage professionals should evaluate a potential digital acquisition by carefully considering its environmental costs throughout its life cycle, from the point of transfer to preservation and access, accounting for the storage and computational resources needed for all copies,” (Pendergrass, et al, 2019, p. 182).

The necessary use of energy consumption by cultural heritage institutions will only increase as digitized and born digital materials become more commonplace in preservation. This increase in energy consumption may or may not be offset by an increase in storage medium efficiency as the demand for storage capacity also increases.

Cloud Storage

The use of cloud storage has quickly become a main staple of digital preservation. Cloud storage is economical and convenient: it allows an institution to store massive amounts of information to a holding company for a nominal fee. By paying an outside company to store, duplicate and physically maintain digital assets, the burden of in-house storage hardware is lessened. Cloud storage also generally allows for greater access to assets, in that they can be accessed from anywhere on the planet where internet is available. Additionally, depending on the service, a company assumes the responsibility to verify and maintain the integrity of assets, performing checksums and creating redundant copies in different data centers across the United States or the planet. At the least, this makes cloud storage essential for archival storage redundancy; at the most, it is an essential component in the daily operation of cultural institutions which store and manage digital files.

This ease of access and seemingly limitless storage capacity comes at a cost, however. Data centers have quickly established themselves as a significant consumer in energy, comparable to energy consumed by entire markets. “The energy costs of powering a typical data centre [sic] double every five years… data centres in the USA alone consumed a significant amount of energy, accounting for 1.5 per cent of the total US electricity consumption in 2010 at a cost of $4.5 billion annually. Natural Resources Defence Council reported that US data centres in total used 77 billion KWhr of electrical energy in 2011, and 91 billion KWhr in 2013,” (Bhat, 2018, p. 544).

As a comparison, the total amount of non-ethanol gasoline consumed for transportation in the state of Maryland in 2017 was approximately 302.8 trillion BTU (British thermal units) (EIA, 2018), which equates to 88.7 billion KWhr (Kilowatt hours), right between the national electrical energy consumption of data centers between 2011 and 2013. This means that the energy consumption of all data centers in the United States is comparable to the yearly energy consumption of motor vehicles in a mid-sized state. This also means that the carbon footprint of

US data centers is equally comparable to the vehicle emissions of a mid-sized state, if the energy consumed by data centers relied exclusively on fossil fuels.

In actuality, the carbon footprint could be slightly higher, because energy used in commercial buildings typically comes from a combination of coal and natural gas, the former of which emits more pounds of carbon dioxide (CO2) per BTU than non-ethanol gasoline, the latter slightly less. “The amount of CO2 produced when a fuel is burned is a function of the carbon content of the fuel,” (EIA, 2019). Because coal contains a higher concentration of carbon than non-ethanol gasoline and natural gas - the latter of which has a higher concentration of methane - it produces a higher amount of carbon dioxide when combined with oxygen used in combustion.

There are approximately 157.2 pounds of CO2 emitted for every million BTU of energy used in the consumption of non-ethanol gasoline, 117 pounds of CO2 for natural gas, and between 205 and 228 pounds in the consumption of coal (EIA, 2019). If the energy consumption data from above for US data centers in 2011 and 2013 are converted from KWhr to BTU, that equates to approximately 242.252 trillion BTU in electrical energy consumption for US data centers in 2011, and 310.492 trillion BTU in 2013. This means that if all data centers in the US received their energy from natural gas, at the lower end of the carbon emission spectrum, approximately 28.343 billion pounds of CO2 would have been released in 2011, and 36.327 billion pounds in 2013. If all data centers in the US received their energy from coal production, at a much higher rate of carbon emissions, 55.233 billion pounds of CO2 would have been released in 2011, and 70.792 billion pounds in 2013. A table of these calculations can be found in Appendix B.

These numbers have a direct causal relation on global mean temperature and their myriad effects on the natural world. A 2016 study published the measurable effects of CO2 by coalescing monthly-mean summer Arctic sea ice. “The observed linear relationship allows us to estimate a sensitivity of 3.0 ± 0.3 m2 of September Arctic sea-ice loss per metric ton of anthropogenic CO2 emissions during the observational period 1953 to 2015," (Notz and Stroeve, 2016, p. 747). This means that the amount of energy consumed by US data centers would have resulted in the direct loss of between 38.6 and 75.1 million square meters of Arctic sea-ice in 2011 and 49.4 and 96.3 million in 2013, if taken solely from natural gas and coal, respectively. As a size comparison, the island of Manhattan in New York City is approximately 59 million square meters.

As the demand for cloud storage increases, the amount of carbon emissions released by these data centers comparably increases. Sourcing the energy which US data centers use with sustainable resources is paramount.

In-House Hardware and E-Waste

The final form of digital preservation related to environmental sustainability is electronic waste (e-waste). Digital preservation requires the use of multiple, often redundant systems of storage and backups. The components of data storage and backup systems include computers, hard drives, RAM and circuit boards, wires and cables, monitors, and entire servers and component parts. Each of these components has a designated lifespan, necessitated through either technological obsolescence or digital asset safety, in that the risk of loss necessitates an evolutionary technological replacement. Desktop computers and servers gradually fade from support services, wherein operating systems and software used for access, distribution or management will no longer function on older models. Specific storage media - such as VHS, optical discs, digital tape and magnetic drives - also need to be replaced as they face accessibility obsolescence, physical deterioration, or as newer models with higher storage capacity become practically more desirable.

With each replacement these digital preservation components are discarded. In the case of magnetic hard drive discs (HDDs) utilized for back-ups, "[h]ard drives should be stored unplugged and replaced every 3-5 years," (Wanda, et al, 2011, p. 100). This is an accepted best practice for digital asset safety and security; while many drives may last between 8-10 years, the odds of data loss are greatly reduced by being proactive. If a single backup drive is replaced every five years for every one of the estimated 35,000 cultural heritage institutions across the United States, that is at least 70,000 hard drives discarded every decade. However, "Ideally, your archival master files should be maintained onsite where you update them as needed, and they should be on at least two separate drives," (Wanda, et al, 2011, p. 99). This means there could be as many as 140,000 hard drives replaced and discarded every decade by cultural heritage institutions in the United States alone. A third copy of digital files is further recommended, ideally stored in a separate geographic location. If an institution utilizes a third off-site copy, this increases to 280,000 hard drives every decade, with the added environmental variable of transportation required to physically replace the drive.

This first iteration of a magnetic drive's lifecycle is called its primary service life. In the United States, there are generally three different ways to dispose of electronic media after its primary service life: to grant it a secondary service life, electronic recycling, or dispose of it in a landfill. From these descriptors, the first and second option appear the accepted best practices. Granting electronic components a secondary service life means donating them to another institution or service-center, wherein they are sold to and used by another person or institution. This method is preferable for computers, monitors, cables and hard drives, the latter of which should be formatted for security. In the case of other storage mediums, such as magnetic tape and optical discs, media cannot be rewritten or is impractical with technological improvements freely available - they are thus single use storage mediums to be recycled or disposed of.

There is no third service life for electrical components. Electronics experience the same form of entropy which motorized vehicles do. Once a magnetic drive fails or becomes corrupt, or the circuitry of a computer no longer functions, it must either be replaced or the entire system scrapped. Given the exponential rate of technological expansion exhibited by the electronic components used in digital preservation, it is almost always cheaper to dispose of or recycle a product than it is to replace specific parts. Both of these methods result in nearly identical environmental effects for electronic components disposed of in the United States.

In disposal, the heavy metals, plastics and other toxic ingredients in electrical components leach into the surrounding environment. “Due to legal exemptions in the definitions of solid and hazardous wastes, household and small business users are legally allowed to simply dump their computers into their trash cans for disposal in the local landfill or incinerator,” (BAN, 2005, p. 6). When discarded into a landfill, these objects are incinerated along with the rest of household detritus, releasing particulate matter into the atmosphere of surrounding communities. “About 70% of heavy metals (including mercury and cadmium) found in landfills come from electronic discards,” (Ban, 2005, p. 7). As there is no such thing as a leak-proof landfill, these elements can often be found in surrounding soil and waterways, adversely affecting flora and fauna.

In the case of electronic recycling, there is little actual recycling involved; in reality, “it simply moves the hazards into secondary products that eventually have to be disposed of,” (BAN, 2005, p. 6). This is because the United States is one of two nations which has signed but not ratified the Basel Convention and is thereby not bound by its contents (BAN, 2019). The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal, which formed in 1989 and went into effect in 1992, is an international treaty which bans the exportation of hazardous materials from industrialized developed nations to less economically stable developing nations. Specifically, the Basel Convention states that signatory States shall “[n]ot allow the export of hazardous wastes or other wastes to a State or group of States belonging to an economic and/or political integration organization that are Parties, particularly developing countries, which have prohibited by their legislation all imports, or if it has reason to believe that the wastes in question will not be managed in an environmentally sound manner,” (The Basel Convention, Article 4, Section 2, E, p. 11). This means that all signatory States must become self-sufficient in the responsible disposal of electronic waste.

This physical waste has a more direct environmental impact than any other part of digital preservation, in that it results in the direct toxic poisoning of people and ecosystems in developing nations.

In processing this ‘recycled’ electronic waste, it is sorted, disassembled and burned in order to extract the valuable components. The most valuable components are heavy and precious metals, such as copper, silver and gold, which retain a higher melting point than other parts of electronics. “According to researchers at U.N.U. [United Nations University], the raw materials contained in e-waste were worth roughly $61 billion in 2016, more than the gross domestic product of even middle-income countries like Croatia or Costa Rica,” (Larmer, 2018, para. 7). E-waste processing is thus a lucrative business for those able and willing to perform the necessary work.

One of the most infamous e-waste processing sites is Agbogbloshie, a slum in Accra, the capital of Ghana. This electronic dumping ground is known not only for its size, but for the state of poverty of its workers and the health effects wrought on these people and their community by electronic waste. “Blood samples of e-waste workers have been shown to exhibit elevated concentrations of heavy metals and flame retardants. For the exposed population, sampled mean serum levels of cobalt, chromium, copper, iron, selenium, and zinc were significantly higher compared to a control group,” (Daum, Stoler and Grant, 2017, p. 4). These particulates have a detrimental effect on the safety and wellbeing of not only e-waste workers, but of the surrounding population. Plastic and flame-retardant particles have been found in the breast milk of nursing mothers, posing a level of risks to fetuses and children not tolerated in the United States. “Lead, mercury, and cadmium exposure… are all linked to negative cognitive development effects in children maturing in e-waste neighborhoods,” (Daum, Stoler and Grant, 2017, p. 5). In this way, ‘recycled’ electronic waste exported from the United States is literally inhibiting the cognitive development of children in developing nations.

Agbogbloshie is not the only e-waste processing location in which electronics bearing American provenance have been found. Computers from Los Angeles school districts and the Kentucky Department of Education, and a monitor from the US Defense Intelligence Agency have been found in Guiyu, China (BAN, 2002, p. 47). Electronic waste processing facilities also exist across other parts of China, Thailand, India and Pakistan.

The United States is the largest exporter of electronic waste on the planet. It is estimated that 50-80% of all electronic waste collected for recycling is being exported (BAN, 2002, p. 4). Without the Basel Convention as international law to impose regulations on the republic, e-waste in the United States is instead regulated by individual states, with the Environmental Protection Agency (EPA) and the Resource Conservation and Recovery Act (RCRA) providing some overarching regulations. But under these two bodies, one a federal agency and one a legislative act, most forms of electronic waste are exempt from federal regulation, including circuit boards, computer monitors, and plastics. Exemptions are also made for household e-waste, small businesses which generate less than 200 lbs. of waste per month, and process scrap metal, i.e. shredded electronic waste (BAN, 2002, p. 29-30). This staggering volume of exported waste is difficult to estimate, specifically because the system of classification used within the Harmonized Tariff Schedule - the US government classification system for imports and exports - does not have a designation for electronic waste; instead, electrical equipment and component waste is categorized along with new electronics (USITC, 2019). This opacity, along with the relative lack of federal regulations and the non-participation in the Basel Convention, essentially allows the export of US electronic waste to under-developed and impoverished nations. There is a high probability this includes recycled digital preservation materials from cultural heritage institutions regardless of the electronic recycling methods used by institutions, as many smaller institutions may qualify by the less than 200 lbs. of waste per month.

It should be the goal of every cultural heritage institution in the United States to investigate the disposal methods of digital preservation hardware to ensure it is not endangering the safety and well-being of another community.

Assessments and Actions

Thus far, institutions in the United States have focused the term 'sustainability' solely on economic models and modes of perpetual preservation through the migration and verification of digital bits. Environmental sustainability in digital preservation has only begun to seep into contemporary digital preservation conversations outside of the European Union (EU). Within the EU, the structure of that continental government body has made it possible to implement large scale environmental sustainability plans which directly affect the ICT within and around Europe. These include adherence to the Paris Climate Agreement, the Basel Convention and the development of ICT infrastructure powered by renewable resources which necessarily supports the use of environmentally sustainable digital preservation by European cultural heritage institutions.

No records of the use of the concept of environmental sustainability in the digital strategic plans of any major governmental cultural heritage organization, including the Smithsonian Institution and the Library of Congress, have been found in the production of this essay.

Sustainable Energy by Infrastructure

Methods of environmental sustainability available to cultural heritage institutions within the US are limited in several respects. First, the system through which energy is transferred to an institution is outside of their means of control: electrical grids are regulated by governmental organizations to ensure their efficient operations during peak demand periods, as well as maintain the safety and security of the entire infrastructure. That said, the energy delivered to an institution is dependent on their geographic location and the types of energy available in that location.

Within the state of Maryland, the Electrical Consumer Choice and Competition Act was passed by the General Assembly in 1999 (Jackson, 2019). This act “deregulated the pricing of electric generation and opened retail markets to competitive suppliers,” (PSC, 2014, p. 4), resulting in more competitive energy providers in the state. The service dominant utility in a given area still charges customers a fee for the use of the electrical infrastructure which delivers energy, but the source of the energy itself may be chosen from energy suppliers in the area, including companies which supply renewable resources. In Baltimore City, Baltimore Gas and Electric (BGE) is the dominant energy supplier and owner of the electrical infrastructure components in the city. BGE charges consumers both for electrical delivery and electrical supply if a competitive supplier is not selected. This is known as a Standard Offer Service (SOS), wherein a default energy supplier is selected for the customer unless an alternative is selected (PSC, 2014, p. 2). The SOS is thus invariably the energy supplied by the utility company itself; this selection is justified not only as the prerogative of the utility as per the Electrical Choice Act, but also as the cheapest rate available. However, the production source of a utility’s SOS is not labeled on electric bills. Consumers - cultural heritage institutions included - therefore do not know whether their energy is sourced from fossil fuels or renewable energy unless they specifically chose to investigate the list of energy suppliers maintained by the utility company.

A cultural heritage institution striving for environmental sustainability should therefore confirm that the energy supplied to the institution is sourced from renewable resources. As the source of all energy consumed in digital preservation is supplied in this manner, choosing to source energy by renewable resources will directly affect an institution’s carbon footprint more than any other workflow decision.

Sustainable Workflow Alterations

Sustainable workflow alteration to digital preservation involve the reduction of energy use in preservation activities.

One basic method of energy reduction within the means of an institution’s control is employing the concept of More Product, Less Process (MPLP). Developed by the University of California Libraries to aid in the processing of archival backlogs, “MPLP emphasizes making more collections available to users by reducing the amount of staff resources spent doing detailed arrangement, preservation, and description of collections,” (Bachli, 2012, p. 4). An appraisal in the volume and access needs of digital assets prior to ingestion will decrease the necessity for constant revision of the information surrounding assets, thereby lessening energy used by processors with every access.

Another form of energy reduction corresponds to a reduction in the amount of data owned and managed by an institution. “Data-reduction techniques reduce the storage demand by optimising [sic] capacity and reducing data footprint. Compression and de-duplication are two popular data-reduction techniques by which long-term preservation of big data can be significantly benefited… Reported de-duplication ratios in common business settings range from 1:10 to 1:500 resulting in disc and bandwidth savings of more than 90 per cent” (Bhat, 2018, p. 548). Compression has been discussed previously; while an acceptable form of data-reduction in that it decreases the amount of storage space necessary for files, the continual act of decompression and recompression simply shifts the power load from drive to processor resulting in a comparable amount of consumed energy. Constant decompression and recompression additionally increases the risk of bit loss.

The effects of de-duplication, however - the simple act of removing duplicate files - is relatively obvious: with less data comes less energy consumption necessary to manage that data. That said, “there is a strong correlation between the degree of redundancy and energy consumption overhead… [implying] that employing data-reduction techniques to overcome storage shortage in digital libraries adds significant energy consumption costs,” (Bhat, 2018, p.

549). Meaning that for an institution to perform a hunt-and-destroy mission for duplicate files there will still be considerable energy consumption costs. An institution should therefore implement standards as to what kind of files are acceptable to be duplicated and into how many duplications, waging the potential loss of non-duplicate assets against their potential use, access needs, maintenance needs, and the economic and social cost of maintaining a duplicate.

Responsible Use of Hardware

Total energy consumption is not the only factor in data center and in-house hardware operations, however. It matters, too, how this energy is used. “Servers and storage devices consume about 26 per cent of the energy consumed by a data centre while as cooling infrastructure consumes about 50 per cent. Magnetic drives consume energy in both idle and operating states and require cooling systems to dissipate the heat generated by them,” (Bhat, 2018, p. 544). This means that, even when not in use, magnetic drives directly affect the energy consumption of a cultural heritage institution.

Unfortunately, magnetic drives retain an inherent plateau in their storage capacity: “As magnetic particles on the platter get smaller, the temperature below which they can retain information for a given time decreases. When bits are too small, thermal fluctuations can easily flip the direction of magnetization [sic] in each bit that results into permanent loss of information,” (Bhat, 2018, p. 545). This inevitable limit in the size of particles on magnetic drives, called the super-paramagnetic limit, is expected to be reached around the year 2030, so long as the exponential trend in storage size maintains its current trajectory. This will pose a real issue with cultural heritage institutions which use digital storage particularly when combined with the anticipated manufacturing storage shortage and the increase in storage demand in an increasingly digital-dominant society.

As Magnetic drives are the primary storage medium in computers and backup RAID and JBOD systems, a replacement comparable in physical size and price is necessary. The best contender remains Solid-State Drives (SSDs) and flash memory, although the cost of SSDs are far higher by comparison to magnetic drives while storage capacity remains much lower. This means, despite an influx of SSD technology in personal computer and backup drives, using SSDs in cloud storage data centers is almost certainly out of the question: “it is highly expensive to build [SSD] facilities. The cost of making 1 TB of flash is around 49-162 times more expensive than that of making 1 TB of magnetic storage,” (Bhat, 2018, p. 545). The high cost of SSDs are prohibitive enough to ensure HDDs remain the storage status quo for cloud-based storage systems and in-house hardware for cultural heritage institutions whose budget favors capacity over efficiency.

Additionally, obsolete or soon to be obsolete forms of storage must no longer be manufactured. The cost of production is simply too high to bear, both in the amount of natural and unnatural resources they require to produce, and in the effects production has on the human condition. These include secondary backup storage mediums, such as: optical discs, whose storage capacity is too low to meet demand without an unacceptable amount of plastic created; digital tape and previous iterations of magnetic tape (VHS) whose tape and plastic components cannot be recycled; and smaller, disposable forms of flash storage devices (thumb drive) unless its composite components can be responsibly sourced and recycled.

Optical discs have served their short purpose. While economical in bulk packaging and retain minimal storage costs in that they do not need temperature-controlled storage environment, their storage capacity is too miniscule compared to contemporary expectations. Blu-Ray discs can hold a maximum 50GB, the size of a contemporary video game, and the safest forms cannot be rewritten (ASMP, 2019). This means that, while it is possible to recycle them through certain local and state resources (DPW, 2018), they will have no second life cycle as electronic hardware may have; their size gives them the assumption of disposability, which in turn contributes to environmental plastic pollution. Digital tape, by comparison, maintains a higher rate of storage capacity, “providing a physical storage capacity of up to 30 TB per cartridge," (IBM, 2019, p. 1). But the overhead cost of a digital tape player makes this option unappealing to smaller institutions on a tight budget, and their demand is decreasing: "the number of LTO cartridges supplied in year 2015 was around eight times lesser [sic] than that of magnetic drives" (Bhat, 2018, p. 550). And while digital tape, too, can be recycled through certain local and state recycling programs, the effectiveness of these programs has already been detailed. "Digital tape is also very difficult to validate" (ASMP, 2019). Technical validation, the increase in access demands brought on by magnetic drives, and the continued influx of cloud storage make digital tape all but a temporary regent. At most, digital tape and optical discs must be seen as a temporary stay in the inevitable, to be replaced by the next most efficient, safe and sustainable storage alternative. The environmentally conscious cultural heritage institutions should prepare itself for this eventuality.

These next most promising emerging technologies are two: holographic storage and DNA storage. "[H]olographic storage is a volumetric storage in which information is stored throughout the volume of the media and not just on its surface," (Bhat, 2018, p. 550). DNA storage is not dissimilar in its ability to encode information at an unprecedented microscopic level: "DNA storage is incredibly dense as it can store one bit per base, and a base is only a few atoms large," (Bhat, 2018, p. 551). Each of these technologies involve encoding information at a level not yet achieved. While neither have yet come to fruition to make a lasting mark on the field of digital preservation or information storage in general, their promise is not without merit and each holds the potential to release information storage from the technological singularity it finds itself facing.

Environmentally Responsible Cloud Storage

Cloud storage services continue to increase in popularity and demand year by year among cultural heritage institutions. An institution's use of cloud storage data centers that receive its energy from environmentally sustainable resources is absolutely attainable. There are two services which will herein be compared: Google and Amazon. While there are other, smaller companies who supply cloud-based services, Google and Amazon remain the two largest cloud storage services available to cultural heritage institutions. The effect of these two companies on the overall cloud-storage market cannot compare, nor can their indirect contribution to Global Warming.

Cultural heritage institutions should choose a cloud storage service after reading all applicable user-agreements, gauging the cost against the institutions need for access to stored digital assets and their various usability. Cultural heritage institutions should also be mindful of the corporate ethos by which such companies, including Amazon Web Services (AWS), a subsidiary of Amazon Incorporated, and Google, a subsidiary of Alphabet Incorporated.

AWS offers an array of services - from migration and storage, to software developer tools, to systems relating to the Internet of Things and AR games - in addition to cloud storage. Within the subsets of cloud storage, product services and pricing are dependent on an institution’s need. Some products are priced based on how much data is written onto AWS servers, others are prices for how often data is accessed and downloaded, while others are prices based on a combination of files size and length of storage time. The least expensive option is Amazon S3 Glacier, advertised as long-term, low access archival storage; the cost of storage for this package is $0.004 per GB or lower “[f]or long-term backups and archives with retrieval option from 1 minute to 12 hours” (AWS, S3, 2019). If an institution wishes AWS to perform and provide information on metadata metrics, such as usage, monitoring and log analytics, these services are charged for an additional fee per GB (AWS, CloudWatch, 2019).

This may be an acceptable balance for digital assets stored as auxiliary backup, or for institutions who manage assets which need to be accessed only a few times per year. But for an institution which needs constant access to its digital assets, either for the management of physical objects or for the management of digital assets themselves, to retain metrics on verification logs, or which needs massive data transfers on a daily or weekly basis, a monthly rate can quickly skyrocket well past the several hundred dollar mark. At the time of this writing, 1

TB of information in AWS S3 Standard storage which is not accessed in a month costs the user over $23.00 (AWS, Simple Monthly Calculator, 2019), as compared to approximately $10 per month for 2 TB which Google charges (Google, 2019) for continual, global access to its storage service.

In terms of environmental ethics, Amazon presents far more cause for concern than Google, particularly when addressing its own carbon footprint. “Amazon is now pledging to reach 80% renewable energy by 2024 and 100% renewable energy by 2030 on its path to net zero carbon by 2040,” (Amazon, 2019, para. 6). Google, by comparison, has been operating at net zero carbon emissions since 2007 (Google, 2018, p. 16). Net zero, i.e. carbon neutrality, simply means that an institution produces no more carbon emissions than it uses. This is an important definition, because it means that even if Amazon consumed 100% of its energy from renewable sources in 2030, it would still produce more than twice the amount of carbon emissions in its normal operations for ten years before becoming carbon neutral due to the vastness of its own ICT and transportation network.

Google achieves carbon neutrality by employing energy efficiency in all aspects of its operations, “match 100% of the electricity consumption of [its] operations with purchases of renewable energy” and purchases carbon offsets any remainder by partnering with various companies, initiatives and non-profits which fund carbon reduction programs (Google, 2018, p. 33). What’s more, Google has specifically designed its data centers to be as energy efficient as possible. With the use of smart lighting and temperature controls, “evaporative cooling” and non-potable water, “a Google data center is twice as energy efficient as a typical enterprise data center” and delivers “seven times as much computing power with the same amount of electrical power” as was used in 2014 (Google, 2018, p. 19). So while unverifiable statistics such as “[i]n processing 3.5 billion searches a day, the world’s most popular website accounts for about 40% of the internet’s carbon footprint” (Quito, 2018, para. 1) can often be found to describe the energy output of Google as an internet giant, that 40% does not contribute directly to the Climate Emergency in the way the other 60% of the internet's carbon footprint does.

If anything, the reverse is true. Google has been producing an Environmental Report every year since 2016, and a report on Conflict Minerals, Modern Enslavement and/or Responsible Supply Chain management every year since 2013. These reports, some of which are required by European and California law, detail the projects, initiatives and accomplishment benchmarks for the company. Google's Supplier Code of Conduct covers expectations concerning Labor and Human Rights, the occupational safety of laborers, and requires environmental efficiency and reporting from its suppliers (Google, Supplier Code, n.d.). And beginning in 2018, Google has produced a comprehensive environmental report on each of its physical products, from cell phones to smart speakers, detailing the amount of emissions and substances used in their production, and how best to recycle them. While Amazon and AWS websites are resplendent with advertisements for environmental partnerships and the company's recent commitment to the Paris Climate Accord, no comparable internal reports on Amazon emission reduction numbers or product sourcing could be located in the production of this essay.

In fact, "Amazon remains one of the least transparent companies in the world in terms of its environmental performance, as it still refuses to report the greenhouse gas footprint of its own operations," (Cook and Jardim, 2017, p. 4). This is a major problem given that Amazon is one of the largest corporations in the world (Forbes, 2019). A series of protests by Amazon works, inspired by climate strikes across the planet, highlights the issue: in an open letter from September 2019, employees wrote "Amazon contributes directly to climate change through intensive use of fossil fuels throughout our businesses and pollutes communities with our fossil fuel infrastructure; we have custom solutions to help oil and gas companies accelerate extraction and exploration of new oil and gas reserves; we're funding the premier climate denying think tank and we funded 68 members of Congress in 2018 who voted against climate legislation 100% of the time," (Amazon Employees for Climate Justice, 2019, para. 4). The ICT infrastructure of AWS and its energy sourcing opacity has already been covered, but the use of business models which actively aid in the production of fossil fuels and funding campaigns for congressional representatives which deny climate science is a clear ethical violation for cultural heritage institutions which wish to use Amazon products and services.

From a public relations perspective these claims reveal the dualism with which Amazon and AWS has operated. On the one hand, "Amazon is launching the Right Now Climate Fund, committing $100 million to restore and protect forests, wetlands, and peatlands around the world in partnership with The Nature Conservancy" (Amazon, 2019, para. 7). They have also partnered with Rivian, an electric automobile company, with a "$440 million investment [that] will accelerate the production of electric vehicles critical to reducing emissions from transportation," (Amazon, 2019, para. 5). But on the other, Amazon has also announced "a new $800 million investment in speeding up shipping for Prime members" (Kim, 2019, para. 5) involving cargo planes and more delivery vehicles, and in early 2019 disclosed "that it spent $1.7 billion on video and music content in the first quarter" of that year (Kim, 2019, para. 1). Clearly, if Amazon wanted to match the kind of environmental transparency which Google has exhibited for over a decade, funding is not the issue.

If a cultural heritage institution is to commit to the use of a digital preservation service which necessarily impacts their carbon footprint, they should perform all due diligence in investigating the social and environmental impacts of that service. With respect to cloud storage, supply chain ethics and commitments to carbon reduction and carbon offset plans, the choice is clear: Google has more transparency in its operations and has shown a greater ethical commitment to solving problems affecting the human condition and the Climate Emergency than its greatest competitor.

Baltimore City Cultural Heritage Institutions

In the production of this essay, numerous cultural heritage institutions were contacted in an effort to see how the workflows of these institutions would be altered with the implementation of environmentally sound digital preservation practices. The following institutions will be detailed below: The Baltimore Museum of Art (BMA), The Baltimore Museum of Industry (BMI), The Jewish Museum of Maryland (JMM), and The Walters Art Museum (the Walters). In corresponding with representatives of these institutions, several aspects of environmental digital preservation apply universally to all four.

First, each exist within Baltimore City, the controlling energy supplier for which is Baltimore Gas and Electric (BGE). As previously stated, BGE is required to maintain a list of energy suppliers from which consumers can select, including suppliers which produce energy from sustainable resources such as wind and solar. It is therefore within the rights of each cultural heritage institution to request the energy supplied to that institution to come from renewable resources. Requesting energy to come from renewable resources would directly affect that institution’s carbon footprint positively as it relates to digital preservation. This includes all aspects of digital preservation which require the use of electricity, either from in-house operation or through the use of Baltimore City’s ICT infrastructure. Requesting energy from sustainable suppliers decreases the demand of energy from fossil fuels, reduces local pollution levels from burning coal and natural gas, and may even create a public relations opportunity for each cultural heritage institution vis a vis their commitment to environmental sustainability.

Second, each institution must necessarily use physical storage mediums to store and manage their digital assets, including some combination of in-house servers and web-based systems. As these physical components are replaced through necessity or by institutional standards, those components are disposed of by local recycling programs. Two institutions - the JMM and the BMI - use third-parties to perform IT duties, including backups and hardware migration; the BMA and the Walters employ in-house IT personnel who handle such operations.

How replaced electronic hardware is disposed of beyond the term ‘recycled’, no institution could describe with confidence. “[A]nything we own, we ensure is taken to a tech recycling facility (Church and Rombro, Personal Communication, 2019). Here is displayed the assumption that electronic recycling is good for the environment. However, “[i]n 2005, Maryland became the third state to enact electronics recycling legislation,” (MDOE, 2017, p. 34). Under the terms of this legislation, the Statewide Electronics Recycling Program (SERP) requires electronic device manufacturers to register and pay a fee for the sale of their devices in the state; 20 of 24 Maryland counties and Baltimore City have since implemented permanent electronic recycling programs. Within Baltimore City, there are five drop off centers which accept e-waste, 40 electronics manufacturers which conduct free e-recycling, and a gamut of privately-owned electronics recycling businesses. Each of these operations perform various acts to electronic components, from HDD formatting to metal shredding.

The onus is thus on each cultural heritage institution and/or third-party IT service to investigate specifically how each of their electronic components are recycled, including how each recycling entity removes hazardous materials and where shredded materials go after leaving a respective facility, i.e. not shipped to places like Agbogbloshie, Ghana. It is recommended that each institution produce a section within their institutional policies concerning e-recycling, wherein due diligence is conducted by or on behalf of the institution to investigate electronic device sourcing and disposal of components. Such a section could relate both to everyday use of digital components, such as a networked drive used by multiple departments, as well as specific digital asset management hardware, such as backup systems and digitization equipment.

There are resources available to cultural heritage institutions to assess the environmental impact of their digital preservation hardware. “The most common way to assess the full environmental impact of a product is to conduct a life-cycle assessment (LCA), a process codified by the International Organization for Standardization as ISO 14040.70… An

LCA allows one to calculate the full cost of a product based on its environmental impact, not just its purchase price or recurring energy costs," (Pendergrass, et. al, 2019, p. 174). Performing an LCA on each product prior to acquisition would assure a cultural heritage institution their electronic components do not harm the environment or human workers prior to digital preservation; due diligence with reference to end-of-life disposal would ensure the same after digital preservation.

Finally, each institution employs various best practices and accepted digital preservation standard operations in the management of digital assets. Only the BMA maintains a Digital Preservation Plan "with a 3-year revision schedule" (Gross, Personal Communication, 2019), although all four institutions consider each digital asset produced or acquired in their operations to be permanently maintained. Only the Walters conducts checksums as "nightly maintenance scripts… and send[s] their results by email" (Walters, 2019) to verify the integrity of its assets, although the BMA is in the process of implementing such a procedure; all four institutions perform incremental backups daily and backup the entirety of their data once per week. Only the BMI utilizes cloud-based services for the storage and use of digital assets, and only the Walters participates in a repository consortium and stores mirrors of their data offsite. However, both the BMA and the Walters utilize TMS as their collections management software (CMS), a web-based service which has the option to bundle the CMS with online database web-publishing and digital asset management. This means that at least some of the energy required for digital preservation is conducted through the greater national ICT. The BMI and the JMM, on the other hand, utilize PastPerfect as their CMS, wherein all acts are performed in-house, including online database publishing.

All four institutions manage a considerable amount of digital assets, mostly digital images and digital surrogates of physical collections items, although the BMA and the Walters also manage a small amount of "interactives and media for use within the galleries," (Kinnett, Personal Communication, 2019). The BMA manages a nominal amount of audio-visual material, and the JMM has a considerable collection of oral histories. Only the BMA could give an accurate estimate of over 2TB worth of digital images “stored on physical on-prem [sic] server; master TIF [images are] ingested into the system and derivatives (4 sizes) are created and stored,” (Gross, Personal Communication, 2019). The JMM and the BMI have digital assets spread across multiple in-house serves, external hard drives and various outdated storage mediums. Assets are accessed daily by multiple personnel across multiple departments at every institution.

The BMA, the JMM and the Walters have most, if not all of their physical collections captured as digital images; the BMI is in the first stages of a comprehensive inventory, capturing items as personnel move through the galleries and offsite storage location. The BMI additionally captures digital archival images on an as-requested basis, meaning that the storage volume required will continue to rise to an as-yet unknown quantity; the other three institutions additionally produce digital image assets as their collections grow, but maintain a much more precise measurement of storage and assets management needs.

Given the range of variables each institution exhibits in the management of their digital assets, it is recommended that each institution perform an analysis of their digital asset storage and management needs pursuant to the development of a Digital Preservation Plan. Such an investigation need not require a heavy consumption in electrical energy in assessing every digital asset at the item level, only insofar as to educate staff on the environmental impact of each portion of the digital preservation process. “Cultural heritage organizations’ use of ICT infrastructure is growing as they increasingly preserve born-digital and digitized audiovisual materials, research data, personal digital archives, websites and social media, and digital records, and as users increasingly request access to these materials,” (Pendergrass, et. al, 2019, p. 175). It is imperative each institution understand their ICT infrastructure use. This is particularly important to the BMA and the Walters as art museums who are likely to see the management of audio-visual and born digital assets enter their management purview on a greater scale than the BMI and the JMM as more historical-based institutions. That said, historical based institutions such as the BMI and JMM contain more outdated storage mediums in their collections which must necessarily be digitized before the information they contain is lost due to deterioration of the storage medium or from inaccessibility through technological advancements. Performing an assessment of these assets prior to digitization will allow the institution and its personnel to more fully understand their contribution to the institutions carbon footprint and how such storage mediums should eventually be disposed of.

Each institution should additionally appraise a digital asset prior to ingesting it into its preservation system. The BMI already does this by only digitizing assets as they are requested for research purposes or in performing collections inventories. When these acts are performed, the digital image is captured in JPEG format unless requested by a researcher in a higher format for a higher fee. This thus decreases that assets storage volume requirements.

That said, “Appraising digital content is often resource intensive due to the ease and frequency of replication, arrangement in often complex hierarchies, diversity of file formats, and hardware and software dependencies,” (Pendergrass, et. al, 2019, p. 182). This is true of institutions such as the BMI and JMM, which store assets across multiple servers and external drives. Appraisal of digital assets prior to ingesting can thus lessen the environmental impact of the institution, “critically examining the content they deem worthy of longterm preservation to ensure that only content with enduring value is permanently retained,” (Pendergrass, et. al, 2019, p. 182), as can retaining them on a single, centralized storage system. This may require more initial energy consumption per asset, but will result in less overall energy consumption for the institution. For institutions such as the BMA, the JMM and the Walters, which are faced with a much greater amount of already digitized content than the BMI, “cultural heritage professionals can reappraise born-digital and digitized content while performing other tasks that require accessing the data—such as processing, making digital storage decisions, and migrating file formats—thus reducing the impact of reappraisal,” (Pendergrass, et. al, 2019, p.

184). By combining such acts, an institution can reduce its otherwise larger consumption of energy, use of ICT infrastructure and general wear on physical hardware. None of these acts will impact the integrity of digital assets or otherwise compromise a cultural heritage institution in retaining best management practices and standards.

Some environmentally sound practices will require more staff and resources than some cultural heritage institutions have available, such as the BMI and the JMM who use third-party IT services rather than employing personnel in-house. One such practice is to “schedule high-energy and high-bandwidth tasks for off-peak times,” (Pendergrass, et. al, 2019, p. 179). The BMA already “participate[s] in energy conservation during high-heat days” (Gross, Personal Communication, 2019) by calculating their Capacity Peak Load Contribution (PLC) and reducing overall energy consumption. “Not contributing to peak load helps to mitigate the need for new infrastructure and avoids the environmental impact that such investment would have,” (Pendergrass, et. al, 2019, p. 179). Scheduling-based preservation activities, such as backups, during “[o]ff-peak times on the electricity grid may also provide a higher percentage of emission-free generating resources, making it possible to reduce greenhouse gas emissions simply by shifting the time of electricity use,” (Pendergrass, et. al, 2019, p. 179). While only the Walters performs checksums, all institutions perform automatic backups scheduled to be performed at night. In this way, each institution has already implemented an environmentally sustainable digital preservation best practice.

Conclusion

UNESCO estimated there were over 200 million hours of digital audio and video being preserved by cultural heritage institutions globally (Tadic, 2016, slide 06). The Library of Congress estimated there were 46 million hours of audio alone in US libraries and archives in 2012 and that in 2018 there are 1.3PB of new digital audio and visual content added to preservation collections each month (Tadic, 2016, slide 06). This is nothing to say of the number of digital images in a multitude of formats and sizes which are far more common among cultural heritage institutions. As the world continues to grow, so too do the number of cultural heritage institutions and the demand at those institutions for digital storage. “New technological efficiencies in record-making practice can [also] increase the amount of material that an organization preserves, leading to a greater net environmental impact through increased use of physical storage,” (Pendergrass, et. al, 2019, p. 172). While the total volume of digital storage and ICT infrastructure use by cultural heritage institutions accounts for a small percentage compared to global use, it is nonetheless paramount that institutions are aware of their energy consumption and the environmental impact of that use.

It should be the goal of every cultural heritage institution - regardless of size, budget and mission - to limit their carbon footprint. This includes the impact of its digital preservation practices, which necessarily require the consumption of energy and the use of physical hardware which contain toxic components. Every cultural heritage institution should strive to source its energy from sustainably renewable resources, ethically source and dispose of preservation hardware, and implement digital preservation standards which use less energy, such as de-duplication and asset assessment prior to ingesting.

That said, more research is needed as to the specific impact of limiting certain practices on preservation workflow. These include limiting the number of checksums which are performed, although this assessment concluded that impact may be negligible as only one out of four small to mid-sized cultural heritage institutions in the Baltimore area which provided information in the production of this essay perform integrity checksums. Of a greater impact would be assessment of digital assets prior to ingesting them into an institution’s digital preservation system, as this may literally decrease the amount digital assets a cultural heritage institution deems worthy of preservation and thus the value of certain cultural assets.

It is also recommended that institutions maintain a comprehensive Disaster Preparedness Plan, which encompasses physical collections, digital assets and the buildings cultural heritage institutions inhabit. In Baltimore City, the BMI and JMM are geographically most at risk to sea-level rise. Estimating within the lowest margin, Climate Central projects "4.2 feet of rise locally by 2100… [with] 12 percent multi-year risk of at least one flood exceeding 6 feet from 2016 to 2030, a 33 percent risk by from 2016 to midcentury, and a 100 percent risk by 2100," (Climate Central, 2019, p. 1). In the most severe scenario, there is a "92% risk of at least one flood over 6 ft taking place between today and 2050 in the Baltimore area," (Climate Central, Baltimore, Maryland, 2019). However, all cultural institutions are vulnerable to other aspects of the Climate Emergency, including irregular and more frequent weather events, an increase in mean global temperatures, resulting in higher energy use for climate controls, and a potential influx of climate refugees, which may alter the cultural fabric of an institution's community and stakeholders. Cultural heritage institutions need to prepare and adapt for the world humanity has created for itself, and they need to prepare quickly.

To that end, cultural heritage institutions must vote, both with their dollars and in the ballot box. They must vote with their dollars for goods and services which are environmentally sustainable, and they must vote at the ballot box for representatives who will stand up for the needs of planet Earth and the people which inhabit it. The actions of a single cultural heritage institution may seem small, but combined have the power to enact comprehensive change. In the words of Greta Thunberg, "You are never too small to make a difference," (7.03, Thunberg, 2018).

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Appendix A

Resources for Environmentally Conscious Cultural Heritage Institutions

Here are listed a few references which the environmentally conscious small to mid-sized cultural heritage institutions may find useful.

The Basel Action Network, a non-profit dedicated to environmental health and justice.

Basel Action Network. (n.d.). Home page. Seattle, WA. Retrieved from: https://www.ban.org

An example of a private recycling company whose services are available in the greater Baltimore-metro area which publicly acknowledges regulations and certifications to which it subscribes. Not all such companies do so.

Back Thru the Future. (2019). Free CD/DVD Recycling. Franklin, NJ. Retrieved from: https://www.backthruthefuture.com/free-cddvd-recycling/

An example of a carbon footprint calculator. This calculator gauges results based on transportation and consumption of goods.

Carbon Footprint. (n.d.) Home page. Hampshire, UK. Retrieved from: https://www.carbonfootprint.com/calculator.aspx

An internet forum dedicated to environmental sustainability in urban environments.

City-data. (2019). City Data Forum: General Forums: Green Living. Retrieved from: http://www.city-data.com/forum/green-living/

An example of an energy supplier in the greater Baltimore-metro area which supplies electricity from renewable resources.

Clean Choice Energy. (n.d.). Home Page. Retrieved from: https://cleanchoiceenergy.com

A non-profit organization of climate scientists associated with the production and analysis of the most recent Climate Emergency prediction models.

Climate Central. (2019). Home page. Retrieved from: https://www.climatecentral.org

Third-party digital preservation services for cultural heritage institutions developed with environmental sustainability in mind.

Digital Bedrock. (January 2019). Home page. Los Angeles, CA. Retrieved from: https://www.digitalbedrock.com

An organization dedicated to aiding in the preservation of digital assets. Produces contemporary studies and information on digital preservation workflows.

Digital Preservation Coalition. (2019). Sustainability. Retrieved from: https://www.dpconline.org/knowledge-base/preservation-lifecycle/sustainability

Official United States government guidelines on electronic hardware management.

Environmental Protection Agency (EPA). (26 November 2019). Sustainable Management of Electronics. Washington, DC. Retrieved from: https://www.epa.gov/smm-electronics

Information and product guides to ethical technological hardware.

Ethical Consumer. (2019). Technology. Retrieved from: https://www.ethicalconsumer.org/technology

An example of a private company which ethically disposes of technological hardware. Hardware which cannot be environmentally recycled is stored until a solution is found.

Greendisk. (2005). Home page. Sammamish, WA. Retrieved from: https://www.greendisk.com/gdsite/Default.aspx

A non-profit which provides information on how to recycle objects in Maryland state.

MD-Recycles. (n.d.). Recycling Directories: Electronic Media. Retrieved from: https://www.mdrecycles.org/recycling-directory/?sec=electronic-media

Information about solar panels installation, co-ops, grants, and state by state regulations.

Solar United Neighborhoods. (n.d.). Solar for Nonprofits. Washington, DC. Retrieved from: https://www.solarunitedneighbors.org/go-solar/solar-for-organizations/nonprofits/

A consultancy organization and blog dedicated to environmental sustainability in cultural heritage institutions.

Sustainable Museums. (2019). Home page. Retrieved from: https://sustainablemuseums.net

Appendix B

Carbon Emission Calculations

These calculations are referenced in pages 16-18.

1M Btu = 293.07 KWhr

1 KWhr = 3412.141 BTU
1B KWhr = 3,412,141,633,000 BTU
= 3,412,000M BTU

2011 71B KWhr = 242,252,000M BTU
242,252,000,000,000
2013 91B KWhr = 310,492,000M BTU
310,492,000,000,000

Year	Source	Lbs CO2 / 1M Btu		Btu		Lbs of CO2
2011	Nat gas	117	x	242,252,000M	=	2.83435e10
					=	28,343,500,000
2013	Nat gas	117	x	310,492,000M	=	3.63276e10
					=	36,327,600,000
2011	Coal	228	x	242,252,000M	=	5.52335e10
					=	55,233,500,000
2013	Coal	228	x	310,492,000M	=	7.07922e10
					=	70,792,200,000

1 metric ton (tonne) = 2204.62 lbs
1 tonne CO2 = 3m2 sea ice loss

2011 nat gas 28,343,500,000 lbs / 2204.62 lbs = 12,856,410.6286 tonnes
= 38,569,231.8858 m2 ice loss
2013 nat gas 36,327,600,000 / 2204.62 = 16,477,941.7768 tonnes
= 49,433,825.3304 m2
2011 coal 55,233,500,000 / 2204.62 = 25,053,523.9633 tonnes
= 75,160,571.8899 m2
2013 coal 70,792,200,000 / 2204.62 = 32,110,839.9633 tonnes
= 96,332,519.8899 m2