Environmentally Sustainable Preservation of Physical and Digital Materials

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RBMS Conference
June 20, 2019
Baltimore, MD
The Physical Storage Environment: Impact and Solutions

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IPI is an academic research center in the College of Art and Design at the Rochester Institute of Technology (RIT) dedicated to supporting the preservation of cultural heritage collections in libraries, archives, and museums around the world.
An **optimal storage environment** is one that achieves the best possible preservation of collections with the least possible consumption of energy, and is sustainable over time.
Opportunities to Use Less Energy for the Physical Preservation of Collections

Average energy consumption in commercial buildings

- Lighting: 39%
- HVACR: 30%
- Other: 17%
- Office Equipment: 8%
- Water Heating: 5%
- Cooking: 1%
Use of constant temperature all day

Lights on the collection

Windows
Lights on more than needed

Bad thermostat placement

Collection space too warm

Staff office or work area in collection space

Same environmental conditions used year round
Lighting

Many institutions are still using T-12 and T-8 bulbs

Less is more

Some institutions still have the lights running 24 hours.

Lighting can generate heat in a space
Cooling

Heating

Fans
Not all efficiency methods help collections

- More outside air/economizer
  - 2012 Energy Conservation Code recommends an economizer to be capable of supplying 100% outside air

- 5°F temperature dead band
  - Can lead to significant change in RH
Methodology

Achieving sustainable mechanical system operation without sacrificing preservation quality

▶ Employs multiple strategies
  ▶ Lighting adjustments
  ▶ Shutdowns
  ▶ Setbacks
    ▶ Seasonal
    ▶ Nightly
  ▶ Fan speed adjustments
Example of Shutdowns
Example of Shutdowns
Seasonal Adjustments

Temperature

Relative Humidity
Example of Light Load
Conclusions

Mechanical systems represent a significant energy consumer in your facility, that provides the potential to improve your collection environment while reducing energy consumption. **Not all strategies will work for everyone.**

Energy savings and improved preservation are both possible in many instances but requires an understanding of:

- Your Facility
- Your Collection
- Your Goals
Thank you!

ipisustainability.org

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Data Storage Materiality, E-waste, and Mitigating the Environmental Impact of Audiovisual Digital Content

Linda Tadic

June 20, 2019
RBMS / Baltimore
Full presentation slides: https://www.digitalbedrock.com/resources-2

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Audiovisual preservation: two parts

• Archives **must** digitize analog magnetic media (video and audio) for preservation.
  
  ➢ Focus on magnetic media rather than film, since magnetic media must be digitized within the next few decades to preserve the content.

• The subsequent digital files must be preserved on data storage devices.
• The original analog media must be discarded.

• Archives also receive audiovisual content as born-digital files
Analog-to-digital transfers

How much magnetic media (sound and video) is there in the world that will be migrated to digital files? **What’s the extent of our impact?**

Eventually, there will only be “media carcasses” on vault shelves.
Impossible to estimate total number of hours

Audiovisual collections are held by:

- Libraries, archives, museums (cultural heritage organizations)
- Media and Entertainment (studios, broadcasters, independent producers)
- Corporate
- Consumer
Some attempts at estimates

These estimates are only for cultural heritage organizations:

• **UNESCO (2000 report):** 200,000,000 hours globally (video and audio)
• **LC National Recording Preservation Plan (2012):** 46,000,000 hours (audio only; US libraries and archives only)
• **NEDCC report (2015):** 570,000,000 hours (250,800,000 hours migration-worthy) (audio only; US libraries, archives, and museums only)

Library of Congress: September 2018: 16 PB AV content (x2 locations) (120TB/month). In 5 years: 1.3 PB per month (both digitized and acquired born-digital).
Let’s say 400,000,000 hours total from all sectors (global)

250,000,000 hours audio
150,000,000 hours video

Physical media digitized at a recommended high resolution open file format:

Audio: WAV 96/24 (2 GB per hour)
Video: uncompressed 10-bit (SD) (94 GB per hour)
400,000,000 hours legacy magnetic media = 14,600 PB

**AUDIO**
250,000,000 x 2 GB = 500 PB

**VIDEO**
150,000,000 x 94 GB = 14,100 PB

TOTAL: 14,600 PB (14.6 Exabytes)

... and that’s only one set of files. **2 sets for redundancy: 29.2 Exabytes**
Hard numbers:

2018: 92 Exabytes Seagate HDDs shipped Q2 2018
2017: 108,457 PB LTO media sold (March 2018 LTO consortium statistics)
2012: 430,000 PB of storage media sold (HDD, tape, NAND)*

- HDD: 577M units shipped
- LTO: 27.7M units shipped [note this doesn’t include other data tape models]
- NAND: 14,000M 2GB units shipped

Global IP traffic is expected to reach 3.3 zettabytes by 2021. **

1 zettabyte = 1,000 exabytes = 1 billion PB


** Cisco Visual Networking Index: Forecast and Methodology, 2016–2021
Preserving this content and making it accessible will impact the environment:

**Legacy media destruction**: 400,000,000 magnetic media items will ultimately be **destroyed** (“media carcasses”).

**Electricity use**: 29 Exabytes of data must be preserved through storage and management, using **energy resources** that can be dirty or clean.

**Hardware/media destruction**: Media and hardware used to store and manage the data will be changed every 5-10 years, with the old media/hardware either **recycled, incinerated, or dumped in a landfill**.
Email received early May 2019:

“One of our [companies] needs to dispose of 55 tons of videotapes that contain Mylar with a Chromium film on it. It has been VERY difficult to find companies that could dispose those videotapes properly or companies that are willing to recycle them.

We have 200 more tons of videotapes that will have to be disposed in the near future and are worried about probable contamination of chromium into soils and groundwater, in case they get crushed and tossed in a landfill, which is the only solution that has been envisioned so far.”
Data storage and magnetic media materiality

Data storage devices don’t last forever.

When their useful life is over, they’re disposed of one way or another.
Electronics products lifespans:

• Initial service life (original owner use): 2-8 years
  • Manufacturers also build-in “end of life” as new models are released
• Second service life (after original owner to end of life): (5-20 years)

End-of-life options:

• Landfill
• Incineration
• Recycling
• Exportation

E-waste: cables, monitors, computers, servers, circuit boards, telephones, data storage devices, batteries, etc.
E-waste exportation

Countries export electronics to Asian and under-developed countries for re-use and/or recycling (often calling shipments “second-hand goods” or “metal scrap” to avoid Basel Convention ban).

Often the hardware isn’t used but stripped of copper and other metals.
Open burning of e-waste in some countries

E-waste is incinerated to extract copper, aluminum and other metals.

Toxins go into the air and soil, appearing in food.

From the soil, the toxins migrate into groundwater.

© Greenpeace / Kate Davison
Direct toxic endangerment to people

200 million people are at risk to toxic exposure
- The World Health Organization, in conjunction with the World Bank, estimates that 23% of deaths in the developing world are attributable to environmental factors.

Types of toxin-producing entities (“usual suspects”):
- Coal and oil refineries
- Tanneries
- Chemical manufacturing
- Heavy metals mining and smelting
- Nuclear accidents

And now:
- E-waste open incineration
- Battery recycling plants

Sign at Cottonwood Springs, Joshua Tree National Park, California (March 2015) [mine closed in 1910]
Heavy and Rare earth metals

Heavy and rare earth metals: used in making phones, computers, TVs, servers, external hard drives, solid state drives, magnets, batteries – anything electronic. Rare earth metals are used in solar energy technology, lasers, automobiles....

**Less than one percent of rare earth elements are currently recycled.**

**Heavy metals are toxic by their nature.** They include: mercury, arsenic, copper, aluminum, lead, cadmium, chromium, cobalt, nickel, zinc, selenium, silver, antimony, and thallium.
Plastic e-waste (e-plastic)

Recycling plastic is an established industry, with methods for recycling plastic bottles the best-established.

Plastics in computers, servers, phones, monitors, video and data tape shells have different formulations so the plastic parts must be separated for recycling and processing.
Videotape as e-waste

Three components for recycling:

1. plastic shell
2. metal screws & parts
3. tape itself

Videotape as e-waste

Videotape ribbon itself is made of (simplified):

- **Base film**: mylar (PET)
- **Binder**: lubricants, adhesives, polymers (no binder in Metal Evaporated tapes)
- **Magnetic particles**: iron oxide, chromium oxide (CrO2), cobalt, barium ferrite (BaFe)

Mylar base (PET) can be recycled, but currently there is no process to separate the magnetic particles and binder from the mylar.

The raw magnetic materials are toxic; unknown how they will break down in their tape formulations if dumped in landfills.
Videotape as e-waste

Recyclers have these options:

1. Shred the full item and incinerate or dump the pieces into a landfill.

2. Disassemble the tape: melt the plastic cassette and screws. Shred the videotape itself, and dump into landfill or incinerate.
Videotape as e-waste: Recycling vendors examples

**Sims Recycling Solutions** (California facility):
- Will separate video parts for higher fee since more labor-intensive.
- Videotape is incinerated, following California incinerator regulations.
- Standard procedure is to shred the full case with tape and incinerate.

**GreenDisk** (Washington State):
- Separates videotape parts.
- Videotape is shredded, but not disposed. 100,000 lbs (45 metric tons) currently stored in a warehouse until a recycling solution is developed.
Data storage

Once the audio/videotape is digitized, the digital files must be stored and managed.

New Facebook data center (Altoona, Iowa) powered by a wind farm.
Data storage options

Physical carriers:
- Spinning disk (servers, hard drives)
- Digital tape
- NAND (Solid state/flash)

Often storage is a mix (Hierarchical Storage Management, or HSM):
- online (spinning disk)
- nearline (tape in a robotic system)
- offline (tape or other media not using power)
Data storage options: Spinning disk

**Servers** (single or networked)

Electricity use: High
- Internal fans; power to operate/process
- Environment must be maintained at constant temperature
- **Helium-filled drives reduce energy use by 23%**

Life expectancy: Replaced every 3-5 years (initial service life)

Potential recyclable parts: plastics, rare earth metals, heavy metals (copper, aluminum, steel). Re-use potential (2nd life), but servers will eventually likely end up in landfills after stripping some metals.
Data storage options: Spinning disk

External hard drives (single or networked) (in enclosures)

Electricity use: Low-medium
- Internal fans; power to operate
- Can be used as offline storage (powered up only when needed)
- Environment must be maintained at constant temperature

Life expectancy: Replaced every 3-5 years

Potential recyclable parts: plastics, rare earth metals, heavy metals, magnets. Failure rates make this medium not as re-usable as servers. Likely candidate for landfills.
Recycling spinning disks

Three HDD manufacturers:

• Western Digital (WD owns HGST/Hitachi) (43%)
• Seagate (39.38%)
• Toshiba (17%)


They publish lifecycle data (LCA) that includes “Bill of Substances” and environmental impact.


Recycling spinning disks: manufacturer’s perspective

Material recovery if components harvested:
- Aluminum substrate (largest raw material)
- Magnetic coating (rare earth material; China controls 90%)

But difficult for recyclers to disassemble ("death by screws"). Calculate cost to dissemble and recycled raw materials value vs. simple shredding.

They recommend recycle through re-use, but only lower capacity HDDs.
Promising recent efforts

Dell, Seagate, and Teleplan developed method to scrape rare earth metals and magnets from HDDs and recycle into new devices.

“Reborn magnets will be used in hard drives for the Dell Latitude 5000 notebook series. The goal is to produce about 25,000 drives initially, but ... Seagate could manufacture 300,000 annually.” [https://www.greenbiz.com/article/dells-discovery-closed-loops-require-open-mind](https://www.greenbiz.com/article/dells-discovery-closed-loops-require-open-mind) (May 2019)

Gold from recycled smartphones will be put into Dell notebook-tablet hybrids.
Promising recent efforts

REMADE recently funded two projects to recover precious metals and plastics from end-of-life electronics.

https://resource-recycling.com/e-scrap/2019/05/16/federally-backed-research-effort-eyes-e-scrap/
Data storage options: Data storage tape

LTO, Oracle (Sun/StorageTek) T10000 series, IBM 3592

Electricity use: Low-Medium
  • On shelf: no power. In drive or robotic system: low-medium
  • Can be used as offline storage (used only when needed)
  • Environment must be maintained at constant temperature (but higher than electronics)

Life expectancy: LTO: Replaced every 2 generations (LTO7 released Dec. 2015, LTO8 Oct 2017). Oracle is discontinuing the T10k series (announced 2017)

Potential recyclable parts: plastics, screws (metal). No process yet to separate mylar ribbon (recyclable) from barium ferrite (BaFe), metal particle, or other components. Generational obsolescence, finite number of “reads,” and WORM technology limits this medium’s re-usability.
Spinning disk and tape: Total Cost of Ownership (TCO)

TCO includes: cost of hardware, maintenance, media, energy, floor space. **TCO for disk-based storage is 26 times that of tape-based.**

- Cost of **energy**: disk-based storage uses **105 times** more energy than tape-based
- Floor space: disk needs **4 times** the space as tape
- Cost of media is 25% the TCO for tape-based solution

Mixed storage:
- With 50% on tape, the TCO is reduced by 48%
- With 90% on tape, the TCO is reduced by 87%

This doesn’t include staff costs.

Data storage options: NAND Flash Memory on Solid State Drives (SSD)

- No moving parts (power down when not in use)
- Runs cooler than spinning disk
- Finite number of writes; infinite number of reads

Electricity use: Low-medium
- Powered up only when used, but uses a lot of power when starting up
- Works in extreme environments (up to 70°C / 158°F)

Life expectancy: Depends on number of writes. Data “fades” over time; not a good archival storage medium.

Potential recyclable parts: silicon, copper
Data storage options: “Cloud” (e.g., storing your files on other people’s servers)

“Cloud” storage (not preservation): online or nearline (tape). You pay for what you use, and don’t need to purchase hardware.

Consider your vendor’s power source. Is it dirty?
• The 6 major “cloud” service providers are moving towards using 100% renewable energy: Apple, Box, Facebook, Google, Salesforce and Rackspace.

Facebook, Google, and Apple are investing in building wind and solar farms to power their data centers and to supply neighbors.
# Company Scorecard

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<th>Company</th>
<th>Final Grade</th>
<th>Energy Transparency</th>
<th>Renewable Energy Commitment &amp; Sourcing Policy</th>
<th>Energy Efficiency &amp; Mitigation</th>
<th>Renewable Procurement</th>
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From: *Clicking Clean: Who is Winning the Race to Build a Green Internet?*  
What can archives do to mitigate their environmental impact AND improve their sustainability?

**Technology choices**
- Storage medium (spinning disks, digital tape)
- Decrease electricity use
- Consider storage medium recycling potential
- Use recycled devices
- Power supply choices
  “Green” cloud and colocation vendors
Technology: Use less energy

Using less electricity helps the environment plus saves money.

1. Store large and infrequently accessed files offline on data tape.

   Spinning disk takes 26x more energy than storing and infrequently accessing data tapes.
Technology: Use less energy

2. If LTO: Migrate to new media every two (or even three) generations LTO (~ every 5-6 years) or more.

More files will be stored on the new generation tape (fewer media items).

Recycle the old data tape through destruction (not re-use) for security, but also since the tape format will be obsolete and overly-used. Data tape has a maximum number of “reads.”

- Recycle the plastic cartridge and metal screws if possible.
Technology: Use less energy

*If you have a server room on-site:*

3. Set the room temperature higher: no more than 27° C / 81° F.

Rooms with data tape:

15 – 32° C / 59 - 89° F  (rate of change less than 5° C per hour)
20 – 80% RH     (rate of change less than 5% per hour)

*Thermal Guidelines for Data Processing Environments. 3rd ed. (2012)*
Technology: Use less energy

4. Turn off unused servers.
5. Set servers to go to inactive mode when not in use.
6. Consolidate and virtualize several applications on one server.
   - This also results in fewer servers to replace/recycle.
7. Use the cloud for some applications (but verify the provider’s “green” record).
8. Question your data/colocation center on its power source and “green” record.
Technology: Environmental planning

1. Purchase clean energy where possible, not coal-generated.

2. Purchase hardware that is energy efficient.

3. Purchase recycled devices (recycled materials or recycled by re-use).

4. Upgrade servers by upgrading drives (not the entire box).

5. If recycle by re-use, use vendors who don’t ship overseas.

6. Recycle data tape and hard drives with vendors who strip out parts and recycle components where possible. If media is shredded and incinerated, verify the incineration process.
Thank you.

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Photo: NASA
Toward Environmentally Sustainable Digital Preservation
Part 1: Digital Preservation and the Environment

RBMS
June 20, 2019

Laura Alagna, Northwestern University
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Introduction

● More available at:
Sustainability and Cultural Heritage

- “Sustainability” is often used in terms of:
  - Adapting to climate change
  - Mitigating the negative effects of the built environment
  - Financial or staffing sustainability
- Few authors address environmental sustainability in terms of digital preservation, though more work is being done on this recently
Environmental Impact of Digital Preservation

● There’s currently no quantitative research on the complete environmental impact of digital preservation practices
● However, we can get an idea of the impact by looking at the environmental impact of the infrastructure required for digital preservation
● This infrastructure is known as Information and Communication Technology (ICT)
Environmental Impact of ICT

- Our research used a life-cycle approach to examine the environmental impact of ICT.
- ICT components have significant environmental impacts throughout their complex life cycles:
  - Extraction and refining of raw materials
  - Shipping and manufacture
  - Electricity and cooling
  - Disposal
Environmental Impact of ICT

Bauxite mining

Photo: Bel Air mine in Guinea
Credit: International Mining, https://im-mining.com/2017/12/05/alufers-surface-miner-based-bel-air-bauxite-operation-half-way-complete/
Reducing the Impact of ICT

- Increase energy efficiency
- Schedule high-impact tasks for off-peak times
- Use clean energy
- Work with colleagues, information technology support, and vendors to reduce the environmental impact of ICT
Toward Environmentally Sustainable Digital Preservation
Part 2: Paradigm Shift

RBMS
June 20, 2019

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Digital Preservation Practitioners’ Response

- Digital preservation actions have environmental impacts throughout the ICT component life cycle
- Large amount of content preserved by cultural heritage organizations with rapid growth expected
- Reactive solutions are insufficient in the face of this scale and growth
Digital Preservation as a System

- Think of digital preservation as a system, from acquisition to access, not as a set of discrete tasks
- The most effective leverage point for change in a system is a paradigm shift
- Use this lever to responsibly reduce the amount of content we preserve and the energy intensity of our practices
Ehrenfeld provides a framework for shifting to sustainable practices:

- Analyze the system to meet user needs in different ways
- Enact a paradigm shift away from unsustainable practices

Ehrenfeld calls this creating sustainability.
Digital Preservation: Current Paradigm

- Focus on quantity, management, use (more is better)
- Frameworks and standards guide us toward intensive management
- Push-back limited to situations where there is a lack of funding or staffing
Digital Preservation: Sustainability Transition

- Build on Ehrenfeld’s framework
- Incorporate Abrams’ call to re-evaluate digital preservation success
- Expand on Goldman’s challenge to current practice for digital authenticity
Creating Sustainable Digital Preservation

- Re-evaluate what is required for successful sustainable digital preservation
- Explicitly integrate and balance management, successful use, and environmental sustainability
Digital Preservation Paradigm Shift

● Focus on high-value materials through a renewed emphasis on critical **appraisal**
● Reduce the resource intensity of digital storage and management by rethinking digital **permanence**
● Meet user needs in different ways by challenging assumptions about the **availability** of digital content
Paradigm Shift: Appraisal—Current State

- Difficulty of appraisal has increased with the growth of digital content
- Cost of storage has decreased
- When staff time is scarcer than digital storage, appraisal can suffer
Paradigm Shift: Appraisal—Strategies

- Assign level of preservation commitment based on value
- Conduct selective appraisal within and across collections and organizations
- Seize opportunities for low-impact re-appraisal at multiple points of an object’s life cycle
- Evaluate the environmental costs of a digital acquisition when making an appraisal decision
Paradigm Shift: Permanence--Current State

- Digital preservation models recommend active maintenance of digital files
- Bit-level preservation practices to ensure integrity and authenticity of files have an environmental cost
  - Frequent fixity checks
  - Geographic redundancy
Paradigm Shift: Permanence--Strategies

- Re-evaluate our assumed goal of zero change or loss to digital content over time
- Align with practice for analog content that accepts a certain amount of loss as inevitable
- Determine acceptable levels of loss and apply appropriate tiered preservation solutions
Paradigm Shift: Permanence--Strategies

- Create tiered preservation solutions by evaluating
  - Fixity check methods and frequency
  - Choice of storage technologies
  - File format migration policies
  - Number of redundant copies
Paradigm Shift: Availability—Current State

- There is a continued focus on (mass) digitization of analog materials
  - Often without documented user interest
  - Success is often based on the amount of content available, not measured successful use
- The expectation of instant delivery of digital content increases the environmental impact
Paradigm Shift: Availability—Strategies

- Implement on-demand digitization and delivery
- Design and advocate for nearline storage systems for digital delivery
- Create access copies on demand
- Improve discoverability and documentation to facilitate these strategies
Conclusion: Sustainable Digital Preservation

- Substantial and peer-reviewed literature on the impacts of ICT infrastructure
- Scientifically robust causal links between these impacts and climate change and biodiversity loss
- Time to critically evaluate current practices to create environmentally sustainable digital preservation
Thank you

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