Reinwardt Academy, Amsterdam University of the Arts
BA Cultural Heritage and Archivistiek B

Research Report

# Walking a tightrope across the gap of digital preservation and environmental sustainability:

## The National Archives of the Netherlands and the challenge of achieving a climate-neutral digital archive

How can the National Archives of the Netherlands
achieve a balance
between digital and environmental sustainability
in their digital preservation approach?

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# Abstract

In response to the National Climate Agreement of the Netherlands, the National Archives of the Netherlands (NANETH) needs to become more environmentally sustainable in every part of the organisation. This includes the category IT & Data storage (and thus the digital archive). How can NANETH responsibly reduce without sacrificing the necessary digital sustainability? Taking the first step towards a green digital archive, this paper describes several examples of more climate-friendly considerations in digital preservation. Described cases tackle emulation versus migration as a method to preserve access to digital objects, preservation tools for performing impact assessments, and fixity checking to preserve the integrity of the digital objects, resulting in realistic advice for NANETH. This paper is also intended to be an open appeal to the international GLAM sector to be aware of the impact of the digital archive on the environment, and that further research on minimising our digital footprint is highly required.



Keywords – **Digital preservation, Environmental sustainability, Emulation, Preservation tools, Fixity checking**

# Table of contents

# Chapter 1, Introduction

Since there have been digital objects[1], there has been digital preservation.[2] However, it was not until the arrival of the Internet in the 1990s, and with that an exponential increase in the number and types of digital objects, that archivists and records managers started developing a comprehensive and collective approach to digital preservation.[3] Following this movement, the National Archives of the Netherlands (NANETH) released the first version of their preservation policy in 2015.[4] NANETH has the formal status of 'the national repository for archives transferred from national government bodies after 20 years.' This status has been enshrined since the 1995 Public Records Act (Archiefwet 1995).[5]

NANETH defines preservation in their digital preservation policy as follows: "The documentation, storage, management, and provision of digital documents (in the broad sense of the word) to ensure that they are accessible, authentic and available for consultation in the long term."[6] This definition indicates an emphasis on digital sustainability[7] in the form of accessible, authentic, and available digital objects, and is similar to the definition given by the Digital Preservation Coalition: "The series of managed activities necessary to ensure continued access to digital materials for as long as necessary. It refers to all the actions required to maintain access to digital materials beyond the limits of media failure or technological and organisational change."[8] This definition shows that the practice of digital preservation relies heavily on information technology (IT), which can have a negative impact on the environment.[9]

Discussion of sustainability in preservation is common in the GLAM sector[10], however, the term most often refers to ensuring the accessibility and permanence of digital objects (digital sustainability). Through literature such as the article "Toward Environmentally Sustainable Digital Preservation" by Keith L. Pendergrass et al[11], a new form of sustainability has been introduced to the preservation community; environmental sustainability[12]. Although the rising awareness of environmental sustainability in digital preservation is something to be celebrated, I wish to see more organisations actively

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[1] **Digital object:** "An abstraction that can refer to any type of information. The object may be simple or complex, ranging from values used in databases to graphics and sounds."
*Source:* Society of American Archivists, "Dictionary of Archives Terminology, Digital object" (version unknown), https://dictionary.archivists.org/entry/digital-object.html, accessed April 24, 2023.

[2] E. Baucom, "A Brief History of Digital Preservation", in: edited by J. Myntti and J. Zoom, *Digital Preservation in Libraries: Preparing for a Sustainable Future.* (Chicago: American Library Association, 2019), 31-47, 31 & 32.

[3] Ibidem.

[4] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015).

[5] National Archives of the Netherlands, https://www.coretrustseal.org/wp-content/uploads/2019/07/e-Depot-of-the-National-Archives-of-the-Netherlands.pdf. *E-Depot of the National Archives of the Netherlands. Application for CoreTrustSeal certification.* (The Hague: 2017).

[6] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015). 4.

[7] **Digital sustainability:** "To ensure the accessibility and readability of digital information for future generations."
*This definition is based on the following source:* Nederlandse Overheid Referentie Architectuur, "Wat is Digitale duurzaamheid?" (version December 8, 2015), https://www.noraonline.nl/wiki/Wat_is_Digitale_duurzaamheid%3F, accessed February 27, 2023.

[8] Digital Preservation Coalition, "What Is Digital Preservation? - Digital Preservation Coalition" (version 2023), https://www.dpconline.org/digipres/what-is-digipres, accessed April 19, 2023.

[9] Keith L. Pendergrass et al., "Toward Environmentally Sustainable Digital Preservation", *The American Archivist 82, no. 1* (March 1, 2019), 166.

[10] **GLAM** refers to galleries, libraries, archives, and museums.
*Source:* Australian Society of Archivists, "Australian Society of Archivists Annual Conference 2003" (version; archived from the original on August 1, 2003), https://web.archive.org/web/20030801224434/http://www.archivists.org.au/events/conf2003/, accessed January 28. 2023.

[11] Keith L. Pendergrass et al., "Toward Environmentally Sustainable Digital Preservation", *The American Archivist 82, no. 1* (March 1, 2019), 165–206.

[12] **Environmental sustainability:** "The quality of causing little or no damage to the environment and therefore able to continue for a long time."
*Source:* Cambridge University Press & Assessment 2023, "Cambridge Advanced Learner's Dictionary & Thesaurus, Meaning of sustainability in English" (version 2023), https://dictionary.cambridge.org/dictionary/english/sustainability, accessed April 19, 2023.

consider more climate-friendly preservation practices. Therefore, I am pleased that NANETH strives to reach the goals set by the National Climate Agreement of the Netherlands.[13] Nonetheless, NANETH is a custodian of digital objects and thus must keep the digital information that it manages authentic and useable.[14] Therefore, NANETH must reach those goals without sacrificing the necessary digital sustainability. To help minimise their ecological footprint, NANETH has established the working group 'Duurzaam NA'.[15] The workgroup is currently researching the impact of NANETH on the environment and what can be done to lower that impact.[16] Thanks to research done by the organisation Copper8, Duurzaam NA has discovered that the total emission of NANETH is 3879 tons of $CO_2eq$[17]. Shockingly, 87 per cent (3382 tons of $CO_2eq$) of that is caused by IT & Data storage. Digital preservation activities are included in this.[18] As stated by archivist Jan Zastrow: "It is ironic that digitisation was supposed to make us greener, more sustainable from the perspective of infrastructure, budget, and the environment. But the fact is, our current digital preservation strategies rely heavily on server farms and cloud storage. We did not see this one coming."[19]

During my research, I have attempted to find ways to make the digital preservation approach[20] of NANETH more environmentally sustainable without sacrificing the necessary digital sustainability. However, because of the limitations of this research, I had to focus on three preservation activities that are part of NANETH'S preservation approach. After an initial assessment, the three activities that were chosen are emulation[21], preservation tools[22] in impact assessments, and fixity checks[23]. I intended to give realistic and well-considered advice, that will hopefully inspire the preservation approach of NANETH, and change the minds of those who are doubtful of the possibility that digital sustainability can be balanced with environmental sustainability.

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[13] J. Van der Mark, project leader and coordinator Sustainability at the National Archives of the Netherlands during a webinar hosted by network group Green IT from the Network Digital Heritage on March 27, 2023. Not recorded.

[14] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015). 9.

[15] J. Van der Mark, project leader and coordinator Sustainability at the National Archives of the Netherlands during a webinar hosted by network group Green IT from the Network Digital Heritage on March 27, 2023. Not recorded.

[16] Ibidem.

[17] **$CO_2eq$:** "Carbon dioxide equivalent (CO2eq) stands for a unit based on the global warming potential (GWP) of different greenhouse gases. The CO2eq unit measures the environmental impact of one ton of these greenhouse gases in comparison to the impact of one ton of CO2."
*Source:* Climate Policy Info Hub, "CO2eq" (version unknown), https://climatepolicyinfohub.eu/glossary/co2eq, accessed February 29, 2023.

[18] National Archives of the Netherlands, https://proza.ocw.local/otcs/cs.exe/app/nodes/36919304. *Kopie van Organisatorisch impactmodel Nationaal Archief.* (The Hague: 2023).

[19] Sabrica, 'Session 1A: Can Digital Go Green? The Myth of Sustainable Digital Preservation', keynote, 5:55, (2022), https://nlb.ap.panopto.com/Panopto/Pages/Viewer.aspx?id=41f9deed-8e9a-4512-a694-afa50081a334, accessed June 7, 2023.

[20] **Approach** refers to policy and practice.

[21] **Emulation:** "An 'emulator' is software which mimics the behaviour of another computer environment. It is used in digital preservation to access software and digital files which require obsolete technological environments to run. For example, an organisation could use a Windows 3.1 emulator to access a WordPerfect file from 1994 on the document editing software which originally created it (Corel WordPerfect version 7.x)."
*Source:* University of the Free State, "Emulation" (version January 14, 2021), https://ufs.libguides.com/c.php?g=1113411&p=8118680, accessed April 19, 2023.

[22] The following explanation by Van Veenendaal gives insight into what '**preservation tools**' are: "To support the conversation, we use preservation tools to analyse the representative dataset. Among other things, the tools can show if the file extensions and extension information from the source system's metadata match the file formats found by the tools, if file formats are well-formed and valid, if encryption / password protection has been applied, and if the tools can help fix certain (date) metadata."
*Source:* R. Van Veenendaal, "Preservation impact assessments: how preservation tools support NANETH's connection projects", Open Preservation Foundation (blog), (May 17, 2017), https://openpreservation.org/blogs/preservation-impact-assessments-how-preservation-tools-support-naneths-connection-projects/, accessed April 19, 2023.

[23] **Fixity checking:** "Fixity means the state of being unchanged or permanent. Confirming a digital file's fixity means that it has remained the same over time. Often this process of confirming is called fixity checking or integrity checking. This process will verify that a digital object has not been altered or corrupted."
*Source:* University of the Free State, "Fixity" (version January 14, 2021).
https://ufs.libguides.com/c.php?g=1113411&p=8118678#:~:text=Fixity%20means%20the%20state%20of,not%20been%20altered%20or%20corrupted, accessed April 19, 2023.

# *Research methodology*

| (Main) research question |
|---|
| How can the National Archives of the Netherlands achieve a balance between digital and environmental sustainability in their digital preservation approach? |

| | Sub-questions | Method |
|---|---|---|
| 1 | *Prioritisation of preservation activities*<br>Based on the current preservation approach of NANETH, which three preservation activities should be prioritised in this research? | - Literature review.<br>- Interviews:<br>• Remco van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands.<br>• Jacob Takema, Senior Advisor Preservation at the National Archives of the Netherlands. |
| 2 | *The ecological cost of emulation as compared to migration*<br>Between emulation and migration as an access strategy, which method is more environmentally sustainable? | - Literature review.<br>- Interviews:<br>• Remco van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands. |
| 3 | *The use of preservation tools in impact assessments*<br>Based on technical capabilities, efficiency, and resource use, which preservation tool should NANETH use in impact assessments? | - Literature review.<br>- Performing a manual, planned test of tools FITS, Niflheim, and C3PO.<br>- Interviews and help with/demonstrations of tools FITS, Niflheim, and C3po:<br>• Remco van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands.<br>• Jacob Takema, Senior Advisor Preservation at the National Archives of the Netherlands. |
| 4 | *Fixity checks as an integrity strategy*<br>In what ways can NANETH responsibly reduce the ecological cost of fixity checks<br>that protect the integrity and authenticity of their digital information? | - Literature review.<br>- Interviews:<br>• Remco van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands.<br>• Jacob Takema, Senior Advisor Preservation at the National Archives of the Netherlands.<br>• Remke Verdegem, ProductOwner e-Depot and ProductOwner PG Overheid & Archieven. |

## Clarification position at NANETH

While conducting the research, I was working as an intern at NANETH's Preservation team. Part of my internship was being a member of the network group Green IT. However, this research is not conducted on behalf of NANETH (or Green IT for that matter), only in collaboration. This research is done independently as part of my BA Cultural Heritage and Archivistiek B at the Reinwardt Academy.

# Chapter 2, Results

## *Chapter 2.1, Prioritisation of preservation activities*

Based on the current preservation approach of NANETH,
which three preservation activities should be prioritised in this research?

With NANETH's 'preservation approach' I refer to the combination of policy and practice of preservation. "The policy is a policy plan that stipulates how (NANETH) keeps the digital information that it manages authentic and useable. [...] Developing a policy enables (NANETH) to shape processes and procedures regarding long-term accessibility[24]", writes the organisation about the objective of their preservation policy. If we want to learn exactly how those processes and procedures are shaped, it is essential to analyse the practice of preservation. The practice tells us which and/or how these strategies are implemented and executed. NANETH's preservation approach involves many activities that are meant to ensure the preservation of the digital objects that are managed. Because of the limitations of this research, I will be focusing on three of these preservation activities.

Before deciding what to prioritise, it is crucial to understand what parts of digital preservation have already been researched by NANETH, as it tells us where changes have already been considered. The research done by the organisation Copper8 and the working group 'Duurzaam NA' covered the following bases. The two parties have discovered that at least 87 per cent of the total emission of the organisation is caused by the category IT & Data storage, this includes digital preservation.[25] The research on the impact of IT & Data storage has a focus on hardware[26], total energy use measured in watt, and the total data storage used by NANETH.[27] It is no surprise that these aspects have been researched first, as it retrieves clear numbers and tangible analytics, making it a great place to start. Having said that, the research on software[28] is not complete yet.[29] This seems to be a problem that is shared by the wider field, as I was not able to find many examples of research that give realistic ways of minimising the footprint of software. Could this be blamed on the current level of maturity of the (green) digital preservation field?

Now that we know to focus on software-based activities, the next step is analysing both the policy and practice. First, I reviewed the preservation policy; what activities does it mention? I learned more about the practice by speaking with the Preservation team, who are responsible for advising on and monitoring digital preservation at NANETH. Asking questions about what are essential preservation activities and what kind of challenges require new solutions, helped me identify the following activities: emulation, preservation tools, and fixity checks. Naturally, these activities involve hardware as software is dependent on hardware, yet it is not the main principle. In the following

[24] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015), 6.

[25] Ibidem.

[26] **Hardware:** "The physical and electronic parts of a computer, rather than the instructions it follows."
*Source:* Cambridge University Press & Assessment 2023, "Cambridge Advanced Learner's Dictionary & Thesaurus, Meaning of hardware in English" (version 2023), https://dictionary.cambridge.org/dictionary/english/hardware, accessed April 19, 2023.

[27] National Archives of the Netherlands, https://proza.ocw.local/otcs/cs.exe/app/nodes/36919304. *Kopie van Organisatorisch impactmodel Nationaal Archief.* (The Hague: 2023).

[28] **Software:** "The instructions that control what a computer can do; computer programs."
*Source:* Cambridge University Press & Assessment 2023, "Cambridge Advanced Learner's Dictionary & Thesaurus, Meaning of software in Business English" (version 2023), https://dictionary.cambridge.org/dictionary/english/software, accessed April 19, 2023.

[29] National Archives of the Netherlands, https://proza.ocw.local/otcs/cs.exe/app/nodes/36919304. *Kopie van Organisatorisch impactmodel Nationaal Archief.* (The Hague: 2023).

paragraphs, I speak on the current state of each activity and what issues have made NANETH reconsider its methods. In the later chapters of this report, I go into further detail about what the activities exactly are.

During a conversation with Remco van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands, the first activity introduced was emulation.[30] While emulation is mentioned in the preservation policy as a possible strategy, the policy does not elaborate on how NANETH puts the strategy to practice.[31] Before the policy, NANETH released a case study in the Planets project in 2010 on using emulation in their preservation approach.[32] The case study was concluded by stating: "(NANETH) aims to use solutions developed in Planets to provide the preservation component of its (e-Depot)[33] and envisages implementing two emulation approaches to address these challenges: emulation for rendering and emulation as an intermediate step in migration[34]."[35] To this day, these strategies have not been implemented, because, at the time of publishing the policy, emulation did not seem to be an option for the organisation. "At the time, emulation was an unrealistic option. It only worked in theory," according to Van Veenendaal.[36] Recently, the digital preservation community has slowly started considering emulation strategies, including NANETH: "Since then, the University of Freiburg and the Emulation as a Service Infrastructure (EaaSI) program of Yale University Library have shown that it is practically feasible and scalable. We are now looking at it with interest."[37] Additionally, NANETH has the hypothesis that using emulation instead of migration could have a positive impact on reducing the digital footprint of the organisation.

The second activity that came up during the conversation mentioned above was the use of preservation tools in impact assessments. When a governmental department wants to connect its information system and the accompanying digital objects to the e-Depot of NANETH, it is preceded by an 'impact assessment.'[38] "In the impact assessments, experts from various NANETH departments and representatives of the responsible authority (provider) investigate what organisational, content, and technical measures are required for the connection[39]," writes Van Veenendaal in a blog on the website of the Open Preservation Foundation. NANETH has been performing such assessments for years.

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[30] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands spoken with S. van Hoek during a conversation at the National Archives of the Netherlands on February 8, 2023.

[31] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015), 18.

[32] National Archives of the Netherlands, https://planets-project.eu/docs/casestudies/PlanetsCasestudy_NationalArchiefandemulation.pdf. *The Nationaal Archief and the Use of Emulation. A Study of the Use of Planets in Preserving the Digital Collection of the Nationaal Archief of the Netherlands.* (The Hague: 2010).

[33] **e-Depot:** NANETH's digital facility. "The combination of equipment, software, procedures, methods, knowledge, and skills to ensure the ingest, management, preservation and provision of digital objects and metadata in the long term."
*Source:* National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015), 7.

[34] **Migration:** "Also known as file format migration or sometimes called file format conversion, [...] It involves transferring, or migrating, data from an ageing or obsolete file format into a new file format, possibly using new application systems at each stage to interpret the information. [...] This preservation action is particularly useful when the software used to render the file format type is now obsolete and modern software cannot render it correctly."
*Source:* University of the Free State, "Migration" (version January 14, 2021), https://ufs.libguides.com/c.php?g=1113411&p=8118679, accessed June 11, 2023.

[35] National Archives of the Netherlands, https://planets-project.eu/docs/casestudies/PlanetsCasestudy_NationalArchiefandemulation.pdf. *The Nationaal Archief and the Use of Emulation. A Study of the Use of Planets in Preserving the Digital Collection of the Nationaal Archief of the Netherlands.* (The Hague: 2010), 7.

[36] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands. Answer to a question through e-mail. April 6, 2023.

[37] Ibidem.

[38] R. Van Veenendaal, "Preservation impact assessments: how preservation tools support NANETH's connection projects", Open Preservation Foundation (blog), (May 17, 2017), https://openpreservation.org/blogs/preservation-impact-assessments-how-preservation-tools-support-naneths-connection-projects/, accessed March 3, 2023.

[39] Ibidem.

However, the Preservation team has noticed that they do not have adequate enough preservation tools for certain types of formats at their disposal.[40] One of those tools is C3PO[41] (Clever, Crafty, Content Profiling of Objects), developed by the Technical University of Vienna[42].[43] NANETH has found a possible alternative for C3PO called Niflheim[44].[45] Niflheim, developed by the Royal Danish Library[46], has the same necessary functionalities as C3PO without some of the extra (unnecessary for NANETH) functions and technical issues.[47] NANETH is considering replacing C3PO with Niflheim. Before doing that, it is helpful to be aware of the resources that the tools require. As Niflheim technically 'does less', the hypothesis is that it requires less energy and data storage than C3PO.

During an interview with Van Veenendaal and Senior Advisor Preservation at the National Archives of the Netherlands Jacob Takema, we discussed how NANETH handles fixity checks.[48] NANETH uses the common method of creating a checksum[49] when fixity checking, following the recommendations of digital preservation models such as the "Levels of Digital Preservation" from the National Digital Stewardship Alliance[50], which recommends that archival repositories make sure to verify and record integrity information (gained by fixity checking), and that repositories periodically reverify their checksums to ensure that the file contents remain unchanged.[51] Depending on how many files you want to verify, fixity checking can be a lengthy, high-energy task.[52] To verify your checksum, a file has to be opened, read, and then closed.[53] In the case of NANETH, when using an automated script, it can take up to five months to verify every file in their e-Depot.[54] Not only is this method inefficient, it also requires a great investment of resources, making the ecological cost of fixity checking high.

[40] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.
[41] **C3PO:** "C3PO is a software tool, which uses metadata extracted from files of a digital collection as input to generate a profile of the content set. It is designed in a way so that different metadata formats originating from different tools can be easily integrated. Currently it supports FITS metadata and Apache TIKA metadata."
*Source:* peshkira, "peshkira/c3po", GitHub (blog), (Version May 20, 2013), https://github.com/peshkira/c3po, accessed March 3, 2023.
[42] R. Van Veenendaal, "Preservation impact assessments: how preservation tools support NANETH's connection projects", Open Preservation Foundation (blog), (May 17, 2017), https://openpreservation.org/blogs/preservation-impact-assessments-how-preservation-tools-support-naneths-connection-projects/, accessed March 3, 2023.
[43] Ibidem.
[44] **Niflheim:** "Traverses a given folder and its subfolders searching for XML files with a given suffix. Based on a configuration giving specifying XML attributes and values Niflheim will extract these and insert them as values in rows into a CSV formatted spreadsheet."
*Source*: kb-dk, "kb-dk/niflheim", GitHub (blog), (Version October 17, 2018), https://github.com/kb-dk/niflheim, accessed March 6, 2023.
[45] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.
[46] kb-dk, "kb-dk/niflheim", GitHub (blog), (Version October 17, 2018), https://github.com/kb-dk/niflheim, accessed March 6, 2023.
[47] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.
[48] Ibidem.
[49] **Checksum:** "A string of numbers and letters generated using a mathematical algorithm. A checksum is like a digital fingerprint for a file, because it will be unique for each file."
*Source:* University of the Free State, "Fixity" (version January 14, 2021), https://ufs.libguides.com/c.php?g=1113411&p=8118678#:~:text=Fixity%20means%20the%20state%20of,not%20been%20altered%20or%20corrupted, accessed March 4, 2023.
[50] National Digital Stewardship Alliance, "Levels of Digital Preservation" (version unknown), https://ndsa.org/publications/levels-of-digital-preservation/, accessed March 4, 2023.
[51] Ibidem.
[52] Keith L. Pendergrass et al., 'Toward Environmentally Sustainable Digital Preservation', *The American Archivist 82, no. 1* (March 1, 2019), 179, https://doi.org/10.17723/0360-9081-82.1.165.
[53] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.
[54] J. Takema, Senior advisor Preservation at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.

# *Chapter 2.2, The ecological cost of emulation as compared to migration*

Between emulation and migration as an access strategy,
which method is more environmentally sustainable?

Emulation can be utilised to preserve meaningful access to the original digital object(s).[55] The emulation method is generally based on the premise that as much of the original look and feel of the digital object is preserved as possible.[56] It requires an 'emulator': software which mimics the behaviour of another digital environment.[57] These 'emulation environments' were originally seen as complex to set up and that complexity has caused debate about emulation as a realistic solution in the digital preservation community.[58] By virtue of new technology developments, the obstacle of complexity has decreased.[59] Unlike emulation, migration involves changing the digital object.[60] The general aim of migration is to ensure that first and foremost the content is preserved, rather than the look and feel of the digital object.[61] Emulation instead allows the digital object to be accessed using the originally used software.[62]

NANETH has the hypothesis that the ecological cost of emulation can be significantly lower than that of file format migration[63], their standard approach[64]. This theory is based on a particular benefit of emulation; a single solution can be utilized to gain access to a larger collection of digital objects, as long as all the objects in this collection require the same operating system or hardware components.[65] Unlike migration, which involves transferring (migrating) the data from an obsolete or ageing format to a new and more future-proof format and thus having to create a new solution with risk assessment for each case[66], it is less labour-intensive and more efficient when considering storage and (probably) processor power.[67]

Literature such as the publication "Avoiding Technological Quicksand: Finding a Viable Technical Foundation for Digital Preservation[68]" by senior research scientist of the RAND

[55] P. Wheatley, D. Holdsworth, "Emulation, Preservation and Abstraction" (version unknown), http://sw.ccs.bcs.org/CAMiLEON/dh/ep5.html (date unknown), accessed April 10, 2023.
[56] H. Heslop, S. Davis, A. Wilson, National Archives of Australia, *An Approach to the Preservation of Digital Records.* (Australia, 2002), 12. https://www.naa.gov.au/sites/default/files/2020-01/An-Approach-to-the-Preservation-of-Digital-Records.pdf, accessed March 27, 2023.
[57] University of the Free State, "Emulation" (version January 14, 2021), https://ufs.libguides.com/c.php?g=1113411&p=8118680, accessed April 19, 2023.
[58] B. Lohman, B. Kiers, D. Michel, J. Van der Hoeven, "Emulation as a Business Solution: the Emulation Framework" in: Digital Preservation Coalition, ed., *iPRES 2011 – 8th International Conference on Preservation of Digital Object. Proceedings.* (Singapore: Digital Preservation Coalition, 2011) 167-170, 167.
[59] University of the Free State, "Emulation" (version January 14, 2021), https://ufs.libguides.com/c.php?g=1113411&p=8118680, accessed February 30, 2023.
[60] National Archives of Australia, "Emulation as a preservation strategy" (version unknown), https://www.naa.gov.au/information-management/information-management-legislation/digital-preservation-planning/emulation-preservation-strategy, accessed February 30, 2023.
[61] H. Heslop, S. Davis, A. Wilson, National Archives of Australia, *An Approach to the Preservation of Digital Records.* (Australia, 2002), 12. https://www.naa.gov.au/sites/default/files/2020-01/An-Approach-to-the-Preservation-of-Digital-Records.pdf, accessed March 27, 2023.
[62] Ibidem.
[63] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands spoken with S. van Hoek during a conversation at the National Archives of the Netherlands on February 8, 2023.
[64] Ibidem.
[65] Digital Preservation Coalition, "Preservation action" (version 2023), https://www.dpconline.org/handbook/organisational-activities/preservation-action, accessed February 30, 2023.
[66] Ibidem.
[67] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands spoken with S. van Hoek during a conversation at the National Archives of the Netherlands on February 8, 2023.
[68] J. Rothenberg, *Avoiding Technological Quicksand: Finding a Viable Technical Foundation for Digital Preservation.* (Washington: Council on Library and Information Resources, 1999).

Corporation Jeff Rothenberg[69] supports NANETH's theory about the ecological cost of emulation. "... migration is labour-intensive, time-consuming, expensive, error-prone, and fraught with the danger of losing or corrupting information. Migration requires a unique new solution for each new format or paradigm[70]," concludes Rothenberg.

In addition, the paper "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work[71]" from the iPRES 2022 proceedings[72] gives several arguments in favour of emulation. "[...] Emulation is a 'just in time' method, i.e., it is only used just in time for when it is needed[73]." The counterpart to the 'just in time' method is the 'just in case' method; it is done in case it will ever be needed. Consequently, the 'just in time' method requires fewer resources than the 'just in case' one, as the 'just in time' method means you transform a smaller portion of digital objects; only the ones truly needed, instead of all that potentially do.[74] The 'just in time' method has already successfully been implemented in NANETH's migration approach, saving energy, time, and storage.[75] A 'just in time' method has proven to work for NANETH and requires fewer resources; if emulation is a 'just in time' method, it reaps those same benefits. Continuing the argument, the paper states: "Furthermore, if future users want to reuse data from preserved objects, the data could still be migrated out into new files by using the original software to do so [...]. This would have the dual benefit of also enabling users to see what was lost during the migration [...][76]." The reuse of data and the mentioned use of emulation to assist the migration of data out into new files, thus combining the two methods, forms a more efficient and less error-prone strategy. A higher level of efficiency with fewer errors may lead to significant savings of resources. Besides that, the paper states that the storage requirement for migration has a considerable environmental impact, especially over time: "[...] most archives retain the original primary data files from a digital object when they migrate content from the object. This means that normally their storage requirements roughly double after the migration has completed[77]." NANETH also retains the original primary data files from digital objects.[78]

The case study "De CO2-impact van opslag en gebruik van digitaal erfgoed: Met platform Delpher als casus[79]", done by PHI Factory and the network group Green IT from the Dutch Digital Heritage Network concludes that the sharing of servers (and thus sharing one

[69] J. Rothenberg, *Avoiding Technological Quicksand: Finding a Viable Technical Foundation for Digital Preservation.* (Washington: Council on Library and Information Resources, 1999), iv.

[70] J. Rothenberg, *Avoiding Technological Quicksand: Finding a Viable Technical Foundation for Digital Preservation.* (Washington: Council on Library and Information Resources, 1999), 13 & 14.

[71] E. Cochrane, K. Rechert, J. Oberhauser, S. Anderson, C. Fox, E. Gates, "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work" in: Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022) 40-52.

[72] Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022).

[73] E. Cochrane, K. Rechert, J. Oberhauser, S. Anderson, C. Fox, E. Gates, "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work" in: Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022) 40-52, 45.

[74] E. Cochrane, K. Rechert, J. Oberhauser, S. Anderson, C. Fox, E. Gates, "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work" in: Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022) 40-52, 44.

[75] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015). 12.

[76] E. Cochrane, K. Rechert, J. Oberhauser, S. Anderson, C. Fox, E. Gates, "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work" in: Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022) 40-52, 45.

[77] E. Cochrane, K. Rechert, J. Oberhauser, S. Anderson, C. Fox, E. Gates, "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work" in: Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022) 40-52, 43.

[78] R. Verdegem, ProductOwner e-Depot and ProductOwner PG Overheid & Archieven at the National Archives of the Netherlands spoken with S. van Hoek during a conversation at the National Archives of the Netherlands on January 25, 2023. (No summary available.)

[79] PHI Factory, & network group Green IT, https://doi.org/10.5281/zenodo.6341483. *De CO2-impact van opslag en gebruik van digitaal erfgoed: Met platform Delpher als casus.* Netherlands: 2021.

location) with multiple parties effectively saves resources.[80] NANETH has previously applied the method of sharing server locations.[81] This method could also be applied to emulators: "[...] One emulator can ensure access to many emulated computers which can each ensure access to many legacy software applications which in turn can each ensure access to virtually unlimited digital objects. It is also possible to preserve emulated computers at one organisation permanently [...][82]."

Speaking of hardware, the paper "Replicating Installed Application and Information Environments onto Emulated or Virtualized Hardware"[83] from the iPRES 2011 proceedings[84] states that "Software that provides emulated hardware is the only viable option for digital preservation as emulating hardware does not require running the emulator application on hardware that is compatible with the emulated hardware[85]." The argument is amplified by stating that migration on the other hand "relies (for the most part) on the underlying hardware, which the software that provides the virtualized hardware runs on, to be compatible with the virtualized hardware[86]." This argument of longevity is (presumably) only placed in the context of digital sustainability, but there is also an argument to be made about the lifecycle of the deployed hardware. If emulator applications are not dependent on certain hardware, in theory, there is no need to purchase new hardware specifically for this purpose. NANETH can use hardware that is already in its possession (if it is equipped with the requirements to run the software that provides emulated hardware).

According to the National Archives of Australia, migration and emulation both require "a large commitment in resources up-front and over a long term[87]." Both methods have been proven to work for the preservation of digital objects, yet both methods have several limitations that must be considered carefully.[88] Either choice would place a large, potentially unsustainable burden on an organisation.[89] Ongoing migration involves an intense cycle of work to convert objects in obsolete formats to more future-proof formats and emulation comes with legal issues and demands highly skilled programmers to write the emulator code.[90] Other arguments made in this chapter suggest that over the long term, emulation requires fewer resources than migration does. Despite that, the argument that both methods require a large commitment in resources up-front cannot be disproven at this point, making the ecological cost of either method at this stage in the process equal.

Nevertheless, as stated by David Holdsworth from the University of Leeds[91] and Paul Wheatley from the Digital Preservation Coalition[92]: "Emulation should not be over-sold as

[80] Ibidem.
[81] National Archives of the Netherlands, https://proza.ocw.local/otcs/cs.exe/app/nodes/36919304. *Kopie van Organisatorisch impactmodel Nationaal Archief.* (The Hague: 2023).
[82] E. Cochrane, K. Rechert, J. Oberhauser, S. Anderson, C. Fox, E. Gates, "Usable Software Forever. The Emulation as a Service Infrastructure (EaaSI) Program of Work" in: Digital Preservation Coalition, ed., *iPRES 2022 - 18th International Conference on Digital Preservation. Proceedings.* (Scotland: Digital Preservation Coalition, 2022) 40-52, 44.
[83] D. Von Suchodoletz, E. Cochrane, "Replicating Installed Application and Information Environments onto Emulated or Virtualized Hardware" in: Digital Preservation Coalition, ed., iPRES 2011 – 8th International Conference on Preservation of Digital Object. Proceedings. (Singapore: Digital Preservation Coalition, 2011) 148-157.
[84] Digital Preservation Coalition, ed., *iPRES 2011 – 8th International Conference on Preservation of Digital Object. Proceedings.* (Singapore, 2011).
[85] D. Von Suchodoletz, E. Cochrane, "Replicating Installed Application and Information Environments onto Emulated or Virtualized Hardware" in: Digital Preservation Coalition, ed., *iPRES 2011 – 8th International Conference on Preservation of Digital Object. Proceedings.* (Singapore: Digital Preservation Coalition, 2011) 148-157, 153.
[86] Ibidem.
[87] H. Heslop, S. Davis, A. Wilson, National Archives of Australia, *An Approach to the Preservation of Digital Records.* (Australia, 2002), 12. https://www.naa.gov.au/sites/default/files/2020-01/An-Approach-to-the-Preservation-of-Digital-Records.pdf, accessed March 27, 2023.
[88] Ibidem.
[89] Ibidem.
[90] Ibidem.
[91] P. Wheatley, D. Holdsworth, "Emulation, Preservation and Abstraction" (version unknown), http://sw.ccs.bcs.org/CAMiLEON/dh/ep5.html (date unknown), accessed April 10, 2023.
[92] Digital Preservation Coalition, "Paul Wheatley" (version 2023), https://www.dpconline.org/component/comprofiler/userprofile/711-pwheatley?tab=10, accessed April 17, 2023.

the answer to all digital preservation issues[93]." In any case, it is vital to first identify the significant properties that need to be preserved, before deciding if emulation would be the right choice.[94] Environmental sustainability is only one of the many deciding factors. This research solely addresses if there are benefits to emulation when considering environmental sustainability, versus file format migration. Based on the arguments from the theoretical framework above, there are multiple arguments in favour of emulation being the more climate-friendly method, but a correct combination of both methods could form the most efficient (and least error-prone) strategy. Efficiency does not instantaneously result in a lower digital footprint.[95] However, it can influence the saving of resources such as energy and processor power.

[93] P. Wheatley, D. Holdsworth, "Emulation, Preservation and Abstraction" (version unknown), http://sw.ccs.bcs.org/CAMiLEON/dh/ep5.html (date unknown), accessed April 10, 2023.
[94] P. Wheatley, D. Holdsworth, "Emulation, Preservation and Abstraction" (version unknown), http://sw.ccs.bcs.org/CAMiLEON/dh/ep5.html (date unknown), accessed April 10, 2023.
[95] Keith L. Pendergrass et al., 'Toward Environmentally Sustainable Digital Preservation', *The American Archivist 82, no. 1* (March 1, 2019), 172, https://doi.org/10.17723/0360-9081-82.1.165.

# *Chapter 2.3, The use of preservation tools in impact assessments*

Based on technical capabilities, efficiency, and resource use,
which preservation tool should NANETH use in impact assessments?

Three essential concepts in the preservation of digital objects are identification, validation, and characterisation. It tells us how to best approach long-term preservation, what kinds of objects you are dealing with, and what kinds of information it contains.[96] Can the object be reliably preserved and accessed?[97] By using certain tools, as part of the impact assessment that precedes the connection of an information system and the accompanying digital objects, digital preservation experts can gain insight into these conundrums.[98] The tools that the experts of NANETH currently use in impact assessments are FITS (File Information Tool Set), developed and managed by Harvard University, and C3PO developed by the Technical University of Vienna.[99] However, as previously mentioned in Chapter 2.1, NANETH is considering replacing C3PO with a tool called Niflheim.[100] Before doing that, it is helpful to be aware of the resources that the tools require.

FITS identifies, validates, and extracts metadata, creating the 'input' for C3PO and Niflheim in the form of FITS.XML files.[101] C3PO and Niflheim are software tools that convert the FITS.XML files into profiles, making it possible to analyse the extracted metadata[102] and learn more about the digital objects that need to be preserved.[103] "C3PO consists of two parts; a CLI (Command Line Interface) application and a Web Application. The CLI app reads in, and processes FITS metadata files and stores them in a document store. The Web Application offers visualisation, filtering, export of the data and much more[104]," writes developer 'peshkira' about the tool. Niflheim on the other hand will directly extract the profiles and insert them as values in rows into a CSV-formatted spreadsheet.[105] The fact that Niflheim skips half of the steps that C3PO has (for example the Web Application) is what makes it an attractive alternative for NANETH. This is illustrated by Takema during a demonstration of Niflheim: "I have now used Niflheim and immediately received a spreadsheet containing the 'output' that I need. I did not need to do all the 'C3PO work'; I do not need to launch C3PO, have it read the files, put the results in a database, have C3PO make a profile, et cetera. It bypasses many steps."[106] In addition, Niflheim can limit itself to finding metadata (in other words, information) in the form of

[96] Scholars Portal, "Identification/Validation/Characterization" (version unknown), https://learn.scholarsportal.info/all-guides/handling-digital-archives/concepts/, accessed May 1, 2023.
[97] Ibidem.
[98] R. Van Veenendaal, "Preservation impact assessments: how preservation tools support NANETH's connection projects", Open Preservation Foundation (blog), (May 17, 2017), https://openpreservation.org/blogs/preservation-impact-assessments-how-preservation-tools-support-naneths-connection-projects/, accessed April 19, 2023.
[99] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.
[100] Ibidem.
[101] Harvard, "FITS Introduction" (version unknown), https://projects.iq.harvard.edu/fits, accessed March 3, 2023.
[102] **Metadata:** "The broad definition of metadata is 'data about data'. For digital preservation, metadata is any secondary information about a digital record that makes it easier to find and use that record."
*Source:* Digital Preservation Coalition, *Metadata. Digital Preservation Topical Note 5.* (Location unknown, date unknown). https://www.dpconline.org/docs/dpc-technology-watch-publications/topical-notes-series/1866-dp-note-5-metadata/file, accessed May 27, 2023.
[103] R. Van Veenendaal, "README voor het werken met de tools FITS en C3PO in een 64-bits Windowsomgeving", GitHub (blog), (Version April 2023), https://github.com/RvanVeenendaal/FITS_C3PO, accessed May 14, 2023.
[104] peshkira, "C3PO: a content profiling tool for preservation analysis", Open Preservation Foundation (blog), (November 19, 2012), https://openpreservation.org/blogs/c3po-content-profiling-tool-preservation-analysis/, accessed May 1, 2023.
[105] kb-dk, "kb-dk/niflheim", GitHub (blog), (Version October 17, 2018), https://github.com/kb-dk/niflheim, accessed March 6, 2023.
[106] J. Takema, Senior advisor Preservation at the National Archives of the Netherlands spoken with S. van Hoek during a demonstration of the tools FITS and Niflheim in a Teams meeting on March 27, 2023.

tags.[107] An example of a tag is 'size' or 'file name'. On the other hand, C3po gives you a complete export with all the metadata that you might need. As stated by Van Veenendaal: "We will always need to consider what weighs the most."[108]

Based on the win in efficiency and deliberate filtering, we can hypothesise that Niflheim uses fewer resources than C3PO does. To find out if this theory is correct, I wanted to assess and compare both tools in an equal way. To do that, I planned out the following.

- First, it is important to use the same test set of files for both tools. Considering transparency, reproducibility, and relevancy for the digital preservation community, I wanted to use an open test set which is representative of the datasets that preservation experts deal with.[109] This led me to use the format corpus from the Open Preservation Foundation, which is described as "An openly-licensed corpus of small example files, covering a wide range of formats and creation tools".[110] I did need to transform this test set into FITS.XML files with FITS before using it as input for the tools.
- Secondly, I wanted to leave out some of the steps in C3PO to best approach what Niflheim does. Following Van Veenendaal's advice, this meant skipping C3PO's Web Application (step 6 in the Dutch guide by Van Veenendaal[111] that I followed).[112]
- Lastly, I would need to retrieve the information about the used resources. I did this in two ways. First, when running the tools, I plugged my computer into a watt-hour meter.[113] This showed the amount of energy (in the unit watt) used by the device in real time. After that, when both tools had finished running, I would document the storage needed for the CSV spreadsheets that the tools produced.

The results were as follows. Before running both tools, the watt-hour meter showed that my computer used around 39 watts, without much fluctuation. Running Niflheim only took a few seconds, as I had access to an automated script which required only one command line. It quickly peaked at 42.9 watts, and then went down to 39 watts again when it finished. C3PO on the other hand took a bit longer because I had to manually enter different commands. There does exist a similar automated script for C3PO, but this also includes FITS: it would not be fair to use here. While trying to enter each command as smoothly and quickly as possible, I filmed the watt-hour meter. The lowest percentage of watts was 48.3, the highest was 57.7 watts. The many fluctuations between those two numbers make it hard to pinpoint the exact number of watts that C3PO used. For the sake of this research, I will take an average of 53 watts; almost exactly 10 watts more than Niflheim used. On top of that, Niflheim's spreadsheet (this includes 16 tags) storage size was 42 KB. This is a shocking difference from C3PO's spreadsheet (97 tags) of 802 KB, meaning that Niflheim's output used only around 5 per cent of the data storage that C3PO used. Clearly, Niflheim is the winner when it comes to the use of the least resources, proving the theory that Niflheim is the more climate-friendly tool in this situation.

[107] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on February 27, 2023.
[108] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands. Answer to a question through e-mail. April 25, 2023.
[109] J. Takema, Senior Advisor Preservation at the National Archives of the Netherlands spoken with S. van Hoek during a demonstration of the tools FITS and Niflheim in a Teams meeting on March 27, 2023.
[110] Open Preservation Foundation, "format-corpus", GitHub (blog), (Version May 10, 2023), https://github.com/openpreserve/format-corpus, accessed May 2, 2023.
[111] R. Van Veenendaal, "README voor het werken met de tools FITS en C3PO in een 64-bits Windowsomgeving", GitHub (blog), (Version April 2023), https://github.com/RvanVeenendaal/FITS_C3PO, accessed May 14, 2023.
[112] R. Van Veenendaal, Preservation team coordinator and Preservation officer at the National Archives of the Netherlands. Answer to a question through e-mail. April 25, 2023.
[113] S. Bergman, "How To Measure The Power Consumption of Your Frontend Application", Microsoft (blog), (November 16, 2020), https://devblogs.microsoft.com/sustainable-software/how-to-measure-the-power-consumption-of-your-frontend-application/, accessed March 6, 2023.

# *Chapter 2.4, Fixity checks as an integrity strategy*

In what ways can NANETH responsibly reduce the ecological cost of fixity checks that protect the integrity and authenticity of their digital information?

The definition for the word fixity is the state of being unchanged, or permanent.[114] Performing a fixity check is to confirm if the condition of a digital object has remained free from corruption and if the integrity of the object has been protected.[115] Digital objects (in other words, digital files) can be damaged due to human error or viruses, but the chance that the content deteriorates at the bit level without warning (also known as bit rot) exists as well.[116] Protecting the integrity and therefore authenticity of the digital archive is a crucial task for any repository that strives to preserve the objects in their intended state, as not doing so can lead to trouble like the loss of information.[117] There are a few ways to perform a fixity check. As mentioned in Chapter 2.1, NANETH has opted to use the method of periodically reverifying the checksums, which could be referred to as the digital fingerprint that is unique for every object.[118]

The Digital Preservation Coalition recommends that digital files "should be checked against their checksums regularly."[119] This advice is followed up by explaining that "how often to perform checks depends on many factors including the type of storage, how well it is maintained, and how often it is being used. [...] More frequent checks allow problems to be detected and fixed sooner but at the expense of more load on the storage system and more processing resources."[120] This quote shows the dilemma that many organisations face, including NANETH. Because there is no single solution that works for every organisation, the article "Toward Environmentally Sustainable Digital Preservation" by Keith L. Pendergrass et al., offers a guide to navigate this dilemma, the goal being to reduce as much of the ecological cost as possible. According to the article, an organisation needs to ask itself four questions[121], as quoted below. That is why I spoke with two experts on the process of NANETH's fixity checks: Takema from the Preservation team and Remke Verdegem, ProductOwner e-Depot and ProductOwner PG Overheid & Archieven. Takema represents the Preservation team, the ones who set up NANETH's preservation policy (which establishes that NANETH performs fixity checks). Verdegem represents the Department of Infrastructure & Services (I&S) at NANETH, who are the ones responsible for the technical implementation of the process. In the following paragraphs, I summarise and analyse their answers to the four questions.

[114] University of the Free State, "Fixity" (version January 14, 2021), https://ufs.libguides.com/c.php?g=1113411&p=8118678#:~:text=Fixity%20means%20the%20state%20of,not%20been%20altered%20or%20corrupted, accessed March 4, 2023.
[115] Ibidem.
[116] Center for Digital Scholarship and Curation, *The Three Essentials of Digital Preservation. Part 2: File Integrity.* (Location unknown, updated March 14, 2018). https://sustainableheritagenetwork.org/system/files/atoms/file/The_Three_Essentials_of_Digital_Preservation_Part2_File_Integrity.pdf, accessed May 27, 2023.
[117] Ibidem.
[118] National Digital Stewardship Alliance, "Levels of Digital Preservation" (version unknown), https://ndsa.org/publications/levels-of-digital-preservation/, accessed March 4, 2023.
[119] Digital Preservation Coalition, "Fixity and checksums" (version 2023), https://www.dpconline.org/handbook/technical-solutions-and-tools/fixity-and-checksums, accessed May 27, 2023.
[120] Ibidem.
[121] Keith L. Pendergrass et al., 'Toward Environmentally Sustainable Digital Preservation', *The American Archivist 82, no. 1* (March 1, 2019), 191.

*"How often do you run scheduled fixity checks?"*[122]

Takema believes that NANETH should perform fixity checks during every part of the chain. Meaning pre-ingest[123], ingest[124] in the e-Depot, transferring the e-Depot to the object storage[125], a (regular) check on the object storage itself, and when a visitor (in other words, a citizen) requests a file that has to be retrieved.[126] This system should be automated, reported on, and fully embedded into the workflow of the organisation, leaving little room for (human) error.[127] As ProductOwner, Verdegem holds the same importance to a well-functioning system.[128] She wants to be able to guarantee the authenticity and integrity of NANETH's digital collection.[129] Sadly, both conversations made it clear that NANETH still has work to do to standardise this process, especially for the regular checks as they have not been run since the former person responsible left the organisation.[130] When it comes to the regular checks, Takema deems it safest to perform them every six months, but at least every year.[131] Verdegem also mentioned every year, in alignment with how long replicates of the files are stored; if the fixity check finds a corrupt file in that year, it can still be replaced with the uncorrupted replicate.[132]

*"Do you run fixity checks during peak or off-peak energy and network hours?"*[133]

There is currently no standardised schedule for running fixity checks on the object storage.[134] When standardising this process, both Verdegem[135] and Takema[136] are interested in scheduling fixity checks during off-peak energy and network hours in the form of running them in certain seasons. "As long as they are performed regularly, I don't mind during which season[137]", stated Takema. According to Pendergrass, the best time is often during spring and fall, as overall demand is generally low, and emission-free resources make up a large percentage of electricity generation.[138]

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[122] Ibidem.

[123] **Pre-ingest:** "Pre-ingest concerns all the preparations, decisions, steps, and actions required before digital objects can be included in an institution's records management system."
*Translated from source:* Leren Preserveren, "Pre-ingest" (version 2021), https://lerenpreserveren.nl/woordenlijst/pre-ingest/#:~:text=Pre%2Dingest%20betreft%20alle%20voorbereidingen,archiefbeheersysteem%20van%20een%20instelling%20%7C%20LOPD, accessed May 27, 2023.

[124] **Ingest:** Ingest is the insertion of a digital object in an archive that focuses on the sustainable storage, management, and accessibility of the selected material."
*Translated from source:* Leren Preserveren, "Ingest" (version 2021), https://lerenpreserveren.nl/woordenlijst/ingest/, accessed May 27, 2023.

[125] **Object storage:** "Object storage, also known as object-based storage, is a strategy that manages and manipulates data storage as distinct units, called objects. These objects are kept in a single storehouse and are not ingrained in files inside other folders. Instead, object storage combines the pieces of data that make up a file, adds all its relevant metadata to that file, and attaches a custom identifier."
*Source:* NetApp, "What is object storage?" (version 2023), https://www.netapp.com/data-storage/storagegrid/what-is-object-storage/, accessed May 27, 2023.

[126] J. Takema, Senior Advisor Preservation at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on May 4, 2023.

[127] Ibidem.

[128] R. Verdegem, ProductOwner e-Depot and ProductOwner PG Overheid & Archieven at the National Archives of the Netherlands interviewed by S. van Hoek during a Teams meeting on May 1, 2023.

[129] Ibidem.

[130] Ibidem.

[131] J. Takema, Senior Advisor Preservation at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on May 4, 2023.

[132] R. Verdegem, ProductOwner e-Depot and ProductOwner PG Overheid & Archieven at the National Archives of the Netherlands interviewed by S. van Hoek during a Teams meeting on May 1, 2023.

[133] Ibidem.

[134] J. Takema, Senior Advisor Preservation at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on May 4, 2023.

[135] R. Verdegem, ProductOwner e-Depot and ProductOwner PG Overheid & Archieven at the National Archives of the Netherlands interviewed by S. van Hoek during a Teams meeting on May 1, 2023.

[136] J. Takema, Senior Advisor Preservation at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on May 4, 2023.

[137] Ibidem.

[138] Keith L. Pendergrass et al., 'Toward Environmentally Sustainable Digital Preservation', *The American Archivist 82, no. 1* (March 1, 2019), 179.

*"Is it necessary to run fixity checks on all AIPS[139], or is verifying a sample of AIPS adequate enough to meet organisational needs?[140]"*

Both Takema and Verdegem find it highly necessary to run fixity checks on all AIPS. They agree that verifying a sample of AIPS is not adequate to meet organisational needs, because of the strong probability that a corrupt AIP would not be spotted. Guaranteeing the integrity and authenticity of the collection is an integral part of NANETH's tasks as the national repository.

*"Are file-based checksums supplemented by other integrity checks, such as natively checksumming file systems or block/media-level hardware checks? If so, can you responsibly reduce the frequency of file-by-file fixity checks?"[141]*

NANETH is currently transferring the digital collection to a new object storage called MinIO. "One of its qualities is bit rot detection, which is a form of a fixity check on the storage with a self-healing principal[142]", stated Takema. This new solution involves fewer steps than file-by-file fixity checks (what NANETH currently does), which means it might require less energy.[143] It is not yet clear if this solution allows NANETH to conscientiously lessen the frequency of file-by-file fixity checks, as it comes with its own challenges, but it has potential.[144]

The answers to the first, second, and fourth question show room for improvement. The fact that fixity checks are not yet a standardised process might seem only negative. However, I would like to challenge that. For example, it has not yet been decided when the regular checks on the storage take place; why not schedule them during off-peak seasons? Following that way of thinking, the move to MinIO comes with new storage solutions that can potentially enable NANETH to responsibly reduce resources. If anything, this chapter tells us that NANETH's practice of fixity checking still has opportunity for environmental-friendly change.

[139] **Archival Information Package (AIP):** "An AIP is the digital equivalent of an archival item such as a book, a record album, or a motion picture. It consists of multiple data files that contain the digitized content of the archival item. In addition to the data files, the AIP contains metadata that describes the structure, content, and meaning of the data files."
Source: C. Fleischhauer, Archival Information Package (AIP) Design Study. (Washington: Library of Congress, 2001), 1.
[140] Keith L. Pendergrass et al., 'Toward Environmentally Sustainable Digital Preservation', *The American Archivist 82, no. 1* (March 1, 2019), 179.
[141] Ibidem.
[142] J. Takema, Senior Advisor Preservation at the National Archives of the Netherlands interviewed by S. van Hoek during a meeting at the National Archives of the Netherlands on May 4, 2023.
[143] Ibidem.
[144] Ibidem.

# Chapter 3, Conclusion

In May of 2023, I joined a workshop called 'Archives and the Environment' hosted by the National Archives of the United Kingdom. One of the speakers that day was Jo Walton of the Digital Humanities Climate Coalition. As part of his story on the influence of capitalism on effectively tackling climate change, he quoted: "Time and time again the left has expressed a prescient understanding of climate policy dysfunction. [...] Yet many of the same voices have struggled to articulate alternative policy strategies that are practical to implement at scale[145]." With this research, I could be characterised as one of the voices expressing worry. Even so, my intention has always been to find realistic answers. In this Conclusion, I summarise the results of this research, answering the question: *How can the National Archives of the Netherlands achieve a balance between digital and environmental sustainability in their digital preservation approach?*

In chapter 2.1 I answered the sub-question: *Based on the current preservation approach of NANETH, which three preservation activities should be prioritised in this research?* This chapter aimed to set a scope for the rest of the research in the form of three preservation activities and the corresponding sub-question. The first step was understanding the connection between policy and practice. For NANETH, the policy enables the organisation to shape processes and procedures regarding long-term accessibility.[146] The practice shows how those processes and procedures are shaped. An example of this is that the policy declares that NANETH performs fixity checks, but not exactly how or how often; to learn that we must look at the practice. The disadvantage of the way NANETH distributes information between the policy and the practice is that it might result in too little standardisation. Taking the same example of fixity checks, Chapter 2.4 shows NANETH's wish for an embedded process of fixity checking with no room for (human) error; to accomplish that, there needs to be a detailed, complete policy in combination with a guarantee that the guidelines are being followed, meaning that the necessary activities to protect the digital sustainability of the organisation are being carried out. The second step of learning what research had already been done showed a lack of research on software. It is worrying that the GLAM sector does not seem to know what the exact impact of software use is, and how to reduce it, which is why I wanted to research software-based activities. Combining this knowledge with the opinions of NANETH's Preservation team about what activities have room or for reconsideration resulted in the following activities: emulation, preservation tools in impact assessments, and fixity checking.

Chapter 2.2 tackled the sub-question: *Between emulation and migration as an access strategy, which method is more environmentally sustainable?* The theoretical framework in this chapter supports NANETH's hypothesis that the ecological cost of emulation as an access strategy can be significantly lower than that of migration. There are multiple arguments made in favour of emulation, calling it less labour-intensive and error-prone. However, a correct combination of emulation and migration is speculated to be the most efficient strategy. The arguments in this framework often rely on efficiency and effective use of resources to conclude that emulation is more environmentally sustainable. While non-refutable evidence based on strong analytics is missing, there exists enough justification for it to be worth the effort to continue researching and experimenting with emulation as an access strategy.

[145] D. Cullenward, D.G. Victor, Making Climate Policy Work. (Location unknown: Polity Press, 2020).
[146] National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* (The Hague: 2015), 6.

The sub-question covered in Chapter 2.3 was: *Based on technical capabilities, efficiency, and resource use, which preservation tool should NANETH use in impact assessments?* The conversations with Van Veenendaal and Takema from NANETH's Preservation team led to two choices: tools C3PO and Niflheim. C3PO and Niflheim are software tools that convert FITS.XML files into profiles, making it possible to analyse the extracted metadata and learn more about the digital objects that need to be preserved. The experimentation with the tools resulted in a clear winner. Niflheim uses less energy, less data storage, and fits well with the needs of the Preservation team. During the test, Niflheim's output used only around 5 per cent of the data storage that C3PO's output used, and on average Niflheim used 10 watts less than C3PO. However, just like with emulation and migration, it would be beneficial to combine both tools in the preservation approach. C3PO provides a more in-depth and broad analysis; that extra information could be necessary for some impact assessments. When it is not, Niflheim on its own should be able to provide enough.

Chapter 2.4 explored the sub-question: *In what ways can NANETH responsibly reduce the ecological cost of fixity checks that protect the integrity and authenticity of their digital information?* In comparison with Chapter 2.3, this chapter gives fewer clear answers about fixity checking. This is mostly caused by the lack of standardisation. Standardising fixity checks would support the digital sustainability of NANETH's collection. Because the process of fixity checking is not yet fully embedded into the organisation, it is difficult to pinpoint what exactly can be improved. However, this also means that there is a window of opportunity for NANETH to give thought to the ecological cost of fixity checking. For example, performing fixity checks during off-peak energy seasons can be a helpful way of lessening that cost.

The sub-questions describe different cases that contribute to answering the main-question of this research; *How can the National Archives of the Netherlands achieve a balance between digital and environmental sustainability in their digital preservation approach*. Three activities do not cover enough ground to be able to confidently declare NANETH's entire approach (environmentally) sustainable. However, it is a step in the right direction. The cases tell us that achieving a balance between digital and environmental sustainability in digital preservation is about being aware of the choices we make and the options we have. We need to know what the consequences of our actions are, and if they are worth the sacrifice. I do not believe that it is inherently wrong to prioritise digital sustainability, if there is good reason for it. Is our understanding of our methods profound enough to be able to confidently take accountability for it? Keywords are reducing responsibly and finding acceptable compromise. Each activity researched in this paper has resulted in potential ways to change for the better. This has convinced me that balance is possible. However, I am not convinced that many organisations or professionals share this sentiment. That is why I have written a manifesto (see Appendices). It is an open appeal to the international GLAM sector to be aware of the impact of our digital archive, and to find ways of minimising our digital footprint. This includes a matrix with my own research methods, the goal being to provide accessible and beginner-friendly examples, that hopefully inspires others to start finding that balance in their own organisation.

# *Limitations*

Tackling three preservation activities is not enough to be able to declare NANETH's approach environmentally sustainable. The reason for only researching three activities is because of the available time and the maximum word count provided by the Reinwardt Academy. If possible, I would like NANETH to continue this research with other processes and procedures in the organisation. This includes research on reducing the impact of software. Because, as far as I can tell, the (international) GLAM sector also has done little research on the impact of software. A more specific need for research comes from Chapter 2.4 about fixity checking. Chapter 2.4 mentions NANETH's move to object storage MinIO. MinIO provides storage solutions that could make fixity checking easier. Can those solutions replace other methods, like using a lengthy, automated script?

Missing in this research is representation of NANETH's Collection department. While the held interviews provided enough answers for this particular research paper, the department's opinion should not be absent when making decisions on NANETH's digital preservation approach. I am sure that NANETH knows that already. Besides that, the Service provision (*Dienstverlening*) department could be involved in further research on the impact of emulation on the environment. Chapter 2.2 lacks theory on emulation from the user's viewpoint, which the Service provision department focuses on. Lastly, while we are on the subject of users, the preservation tools FITS, C3PO, and Niflheim are not the most easy-to-use tools, especially for beginners in the field of digital preservation such as myself. As a message for the wider preservation field, are there ways of improving the user-friendliness of preservation tools?

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# Appendices

## *Glossary*

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| **AIP: Archival Information Package** | "An AIP is the digital equivalent of an archival item such as a book, a record album, or a motion picture. It consists of multiple data files that contain the digitized content of the archival item. In addition to the data files, the AIP contains metadata that describes the structure, content, and meaning of the data files."<br><br>*Source:* C. Fleischhauer, *Archival Information Package (AIP) Design Study*. Washington: Library of Congress, 2001. |
| **Checksum** | "A string of numbers and letters generated using a mathematical algorithm. A checksum is like a digital fingerprint for a file, because it will be unique for each file."<br><br>*Source:* University of the Free State, "Fixity" (version January 14, 2021). https://ufs.libguides.com/c.php?g=1113411&p=8118678#:~:text=Fixity%20means%20the%20state%20of,not%20been%20altered%20or%20corrupted. |
| **CO2eq: Carbon dioxide equivalent** | "Carbon dioxide equivalent stands for a unit based on the global warming potential (GWP) of different greenhouse gases. The $CO_2$eq unit measures the environmental impact of one tonne of these greenhouse gases in comparison to the impact of one tonne of $CO_2$."<br><br>*Source:* Climate Policy Info Hub, "CO2eq" (version unknown), https://climatepolicyinfohub.eu/glossary/co2eq, accessed February 29, 2023. |
| **C3PO: Clever, Crafty, Content Profiling of Objects** | "C3PO is a software tool, which uses metadata extracted from files of a digital collection as input to generate a profile of the content set. It is designed in a way so that different metadata formats originating from different tools can be easily integrated. Currently, it supports FITS metadata and Apache TIKA metadata."<br><br>*Source:* peshkira, "peshkira/c3po", GitHub (blog), (Version May 20, 2013), https://github.com/peshkira/c3po. |
| **Digital object** | "An abstraction that can refer to any type of information. The object may be simple or complex, ranging from values used in databases to graphics and sounds."<br><br>*Source:* Society of American Archivists, "Dictionary of Archives Terminology, Digital object" (version unknown). https://dictionary.archivists.org/entry/digital-object.html. |
| **Digital sustainability** | "To ensure the accessibility and readability of digital information for future generations."<br><br>*This definition is based on the following source:*<br>Nederlandse Overheid Referentie Architectuur, "Wat is Digitale duurzaamheid?" (version December 8, 2015). https://www.noraonline.nl/wiki/Wat_is_Digitale_duurzaamheid%3F. |

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| **e-Depot** | NANETH's digital facility. "The combination of equipment, software, procedures, methods, knowledge, and skills to ensure the ingest, management, preservation and provision of digital objects and metadata in the long term."<br><br>*Source:* National Archives of the Netherlands, https://www.nationaalarchief.nl/sites/default/files/field-file/National%20Archives%20of%20the%20Netherlands%20preservation%20policy.pdf. *Preservation policy. Preservation policy of the National Archives of the Netherlands.* The Hague: 2015. |
| **Emulator** | "An 'emulator' is software which mimics the behaviour of another computer environment. It is used in digital preservation to access software and digital files which require obsolete technological environments to run. For example, an organisation could use a Windows 3.1 emulator to access a WordPerfect file from 1994 on the document editing software which originally created it (Corel WordPerfect version 7. x)."<br><br>*Source:* University of the Free State, "Emulation" (version January 14, 2021). https://ufs.libguides.com/c.php?g=1113411&p=8118680. |
| **Environmental sustainability** | "The quality of causing little or no damage to the environment and therefore able to continue for a long time."<br><br>*Source:* Cambridge University Press & Assessment 2023, "Cambridge Advanced Learner's Dictionary & Thesaurus, Meaning of sustainability in English" (version 2023). https://dictionary.cambridge.org/dictionary/english/sustainability. |
| **FITS: File Information Tool Set** | "The File Information Tool Set (FITS) identifies, validates, and extracts technical metadata for a wide range of file formats. It acts as a wrapper, invoking and managing the output from several other open-source tools. Output from these tools are converted into a common format, compared to one another, and consolidated into a single XML output file. FITS is written in Java and is compatible with Java 1.8 or higher."<br><br>*Source:* Harvard, "FITS Introduction" (version unknown). https://projects.iq.harvard.edu/fits. |
| **Fixity check** | "Fixity means the state of being unchanged or permanent. Confirming a digital file's fixity means that it has remained the same over time. Often this process of confirming is called fixity checking or integrity checking. This process will verify that a digital object has not been altered or corrupted."<br><br>*Source:* University of the Free State, "Fixity" (version January 14, 2021). https://ufs.libguides.com/c.php?g=1113411&p=8118678#:~:text=Fixity%20means%20the%20state%20of,not%20been%20altered%20or%20corrupted. |
| **GLAM sector** | GLAM refers to galleries, libraries, archives, and museums.<br><br>*Source:* Australian Society of Archivists, "Australian Society of Archivists Annual Conference 2003" (version; archived from the original on August 1, 2003). https://web.archive.org/web/20030801224434/http://www.archivists.org.au/events/conf2003/. |

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| Hardware | "The physical and electronic parts of a computer, rather than the instructions it follows."<br><br>*Source:* Cambridge University Press & Assessment 2023, "Cambridge Advanced Learner's Dictionary & Thesaurus, Meaning of hardware in English" (version 2023). https://dictionary.cambridge.org/dictionary/english/hardware. |
| Impact assessments | "In the impact assessments, experts from various NANETH departments and representatives of the responsible authority (provider) investigate what organisational, content and technical measures are required for the connection."<br><br>*Source:* Van Veenendaal, R. "Preservation impact assessments: how preservation tools support NANETH's connection projects", Open Preservation Foundation (blog), (May 17, 2017), https://openpreservation.org/blogs/preservation-impact-assessments-how-preservation-tools-support-naneths-connection-projects/. |
| Ingest | "Ingest is the insertion of a digital object in an archive that focuses on the sustainable storage, management, and accessibility of the selected material."<br><br>*Translated from source:* Leren Preserveren, "Ingest" (version 2021). https://lerenpreserveren.nl/woordenlijst/ingest/. |
| Metadata | "The broad definition of metadata is 'data about data'. For digital preservation, metadata is any secondary information about a digital record that makes it easier to find and use that record."<br><br>Source: Digital Preservation Coalition, *Metadata. Digital Preservation Topical Note 5.* Location unknown, date unknown. https://www.dpconline.org/docs/dpc-technology-watch-publications/topical-notes-series/1866-dp-note-5-metadata/file. |
| Migration | "Also known as file format migration or sometimes called file format conversion, [...] It involves transferring, or migrating, data from an ageing or obsolete file format into a new file format, possibly using new application systems at each stage to interpret the information. [...] This preservation action is particularly useful when the software used to render the file format type is now obsolete and modern watt cannot render it correctly."<br><br>*Source:* University of the Free State, "Migration" (version January 14, 2021). https://ufs.libguides.com/c.php?g=1113411&p=8118679. |
| Niflheim | "Traverses a given folder and its subfolders searching for XML files with a given suffix. Based on a configuration giving specifying XML attributes and values Niflheim will extract these and insert them as values in rows into a CSV formatted spreadsheet."<br><br>*Source:* kb-dk, "kb-dk/niflheim", GitHub (blog), (Version October 17, 2018), https://github.com/kb-dk/niflheim. |
| Object storage | "Object storage, also known as object-based storage, is a strategy that manages and manipulates data storage as distinct units, called objects. These objects are kept in a single storehouse and are not ingrained in files inside other folders. Instead, object storage combines the pieces of data that make up a file, adds all its relevant metadata to that file, and attaches a custom identifier." |

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| | *Source:* NetApp, "What is object storage?" (version 2023). https://www.netapp.com/data-storage/storagegrid/what-is-object-storage/. |
| (Digital) Preservation approach | Approach refers to policy and practice. |
| Pre-ingest | "Pre-ingest concerns all the preparations, decisions, steps, and actions required before digital objects can be included in an institution's records management system."<br><br>*Translated from source:* Leren Preserveren, "Pre-ingest" (version 2021). https://lerenpreserveren.nl/woordenlijst/pre-ingest/#:~:text=Pre%2Dingest%20betreft%20alle%20voorbereidingen,archiefbeheersysteem%20van%20een%20instelling%20%7C%20LOPD. |
| Preservation tools | The following explanation by Van Veenendaal gives insight into what 'preservation tools' are: "To support the conversation, we use preservation tools to analyse the representative dataset. Among other things, the tools can show if the file extensions and extension information from the source system's metadata match the file formats found by the tools, if file formats are well-formed and valid, if encryption/password protection has been applied, and if the tools can help fix certain (date) metadata."<br><br>*Source:* Van Veenendaal, R. "Preservation impact assessments: how preservation tools support NANETH's connection projects", Open Preservation Foundation (blog), (May 17, 2017), https://openpreservation.org/blogs/preservation-impact-assessments-how-preservation-tools-support-naneths-connection-projects/. |
| Software | "The instructions that control what a computer can do; computer programs."<br><br>*Source:* Cambridge University Press & Assessment 2023, "Cambridge Advanced Learner's Dictionary & Thesaurus, Meaning of software in Business English" (version 2023), https://dictionary.cambridge.org/dictionary/english/software. |

Reinwardt Academy
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# The Green Digital Archive:

## A Manifesto

*Dear galleries, libraries, archives, and museums,*

As a result of the climate crisis, many organisations need to reduce their impact on the environment. For the National Archives of the Netherlands (NANETH) the goal is to reduce the total CO2 emission of 3879 tons by at least 55 percent before 2030. For NANETH, the biggest culprit in creating emission is category IT & Data storage, with almost 90 per cent of the total impact. This includes digital preservation, meaning all the actions required to maintain access to digital materials beyond the limits of media failure or technological and organisational change.

NANETH's example teaches us that managing our digital heritage might create more trouble for the environment than we think. I would like to make clear that I do not believe that our sector should prioritise environmental sustainability above all else. Keywords are balance and acceptable compromise. Our responsibility is making sure that the current and following generations have access to our shared heritage. However, a mandatory responsibility assigned to us by the government should not be the only reason to reduce. We need to be mindful of the fact that without a planet, there is no need for our heritage.

I have dedicated my graduation research for my Bachelor of Arts in Cultural Heritage and Archivistiek B to this dilemma. Specifically, finding balance between digital sustainability and environmental sustainability in the digital preservation of NANETH. While the original intent of my research was to inspire and advise NANETH, I have also realised how little research has been done in the sector on reducing the impact of the digital archive. The research that has been done focuses heavily on hardware such as servers in datacentres. Activities involving software require more research. For example, NANETH's analytics on the impact of IT & Data storage do not fully include software.

**So, how can we reduce responsibly?**

***With our limited knowledge on the reducing of resources in digital preservation, are we prepared for the imminent mass influx of digital objects?***

The first step in minimising the digital footprint is to have a complete overview of all the processes and procedures in your organisation. What are we doing, how are we doing that, and why are we doing that? The best place to start is an activity that has room for different ways of thinking. For example, a strategy that is already being reconsidered. Choosing a more climate-friendly option can also result in a higher level of efficiency or the saving of (financial and labour) resources.

**It is about being aware of what choices we make and the options we have.**

In the following page, I give several examples of how to find that balance in certain digital preservation activities. This includes the measures I took to reach my recommendations for NANETH. I hope it can inspire you.

**June 13, 2023**

**By Sophia van Hoek**

## Prioritisation of (preservation) activities: Where to start

### Policy and practice

Step 1) Does your organisation have a policy for digital preservation?

⇒ What activities does it mention, and how detailed?

⇒ Is there something lacking?

2) How does the practice compare to the policy?

⇒ Is it different or conform the policy?

### Need for research

3) What has your organisation already done on the subject of environmental sustainability?

⇒ Is there a working group dedicated to sustainability?

⇒ What is the impact of your organisation on the environment?

⇒ What causes the highest percentage of emissions?

⇒ Which solutions have already been implemented?

4) What research has been done outside of your organisation?

⇒ Are there solutions from others in the sector that might work for your organisation?

⇒ What is missing?

### Expert opinion

5) According to the preservation experts of your organisation, which activity has space for more climate-friendly considerations?

⇒ Which activities are currently being challenged? (In any form.)

⇒ Are there any hypotheses about greener solutions for certain

## Emulation versus migration: Which method is more green

### Policy and practice

Step 1) Has emulation or migration already been implemented in the policy or practice?

⇒ If so, how and why?

⇒ If not, is there interest for it?

### Suitability

2) What has your organisation already done on the subject of emulation and migration?

⇒ Which option would fit better with the needs of your organisation? For example, what are the significant properties you want to persevere?

⇒ What expertise and resources are available?

⇒ Has your organisation experimented with both methods before?

### Theoretical framework

3) What research has been done outside of your organisation?

⇒ Are there solutions from others in the sector that might work for your organisation?

⇒ What conclusions can you find about the ecological cost of both methods?

4) A few interesting sources:

⇒ iPRES proceedings.

⇒ Open Preservation Foundation blogs.

⇒ Digital Preservation Coalition: discover good practice. Environmentally Sustainable Digital Preservation.

⇒ From the Netherlands: network group Green IT from the Network Digital Heritage. (KIA.)

⇒ Chapter 2.2 of the research paper that inspired this manifesto.

## Preservation tools: Finding the more resource-efficient tool

### Policy and practice

Step 1) Have tools already been implemented in the policy or practice?

⇒ If so, how and why?

⇒ If not, is there interest for it?

### Suitability

2) Which tools are currently being researched or used?

⇒ Which tools fit with the needs of your organisation? For example, what information do you need?

⇒ What expertise and resources are available?

⇒ Has your organisation experimented with the tools before?

### Experiment

3) What research has been done outside of your organisation?

⇒ Have others already tested the resource use of the tools? (See Chapter 2.3 of the research paper that inspired this manifesto for results about C3PO and Niflheim.)

4) What is an appropriate test set of files?

⇒ For example, an openly licensed test corpus from the Open Preservation Foundation.

5) How much energy (in watt) is used?

⇒ By using a watt-hour meter: plug into computer, use the tool.

* Does the meter only show snapshots of the watt used? Take the average.

* Keep in mind what your computer normally uses in watt.

6) How much data storage is needed for the output (such as a spreadsheet?)

## Fixity checking: Reducing the ecological cost

### Policy and practice

Step 1) Have fixity checks already been implemented in the policy or practice?

⇒ If so, how?

⇒ If not, is there interest for it?

### Theoretical framework

2) What research has been done outside of your organisation?

⇒ Are there solutions from others in the sector that might work for your organisation?

### Expert opinion

3) Ask the following questions to the experts of your organisation. *(Citated from Pendergrass, 'Toward Environmentally Sustainable Digital Preservation'.)*

⇒ How often do you run scheduled fixity checks?

⇒ Do you run fixity checks during peak or off-peak energy and network hours?

⇒ Is it necessary to run fixity checks on all AIPS, or is verifying a sample of AIPS adequate to meet organisational needs?

⇒ Are file-based checksums supplemented by other integrity checks, such as natively checksumming file systems or block/media-level hardware checks? If so, can you responsibly reduce the frequency of file-by-file fixity checks?

4) Analyse the results.

⇒ What opportunities for green improvement can be found in the answers of the experts?

Reinwardt Academie
Amsterdamse Hogeschool voor de Kunsten

# Het Groene Digitale Archief:

## Een Manifest

*Beste galerijen, bibliotheken, archieven en musea,*

Als gevolg van de klimaatcrisis moeten veel organisaties hun impact op het milieu verminderen, waaronder het Nationaal Archief (NA). Het NA moet de totale CO2-uitstoot van de organisatie voor 2030 met tenminste 55 procent te verminderen. Binnen het NA is de grootste boosdoener de categorie IT & data opslag, met bijna 90 procent van de totale impact. Hieronder valt digitale preservering: het geheel aan activiteiten en processen dat noodzakelijk is voor de intellectuele en technische instandhouding van de digitale collecties door de tijd heen.

De situatie bij het NA laat zien dat het beheren van ons digital erfgoed meer problemen kan veroorzaken dan we in eerste instantie denken. Ik zou graag duidelijk willen maken dat ik niet geloof dat onze sector ecologische duurzaamheid boven alles moet prioriteren. Het gaat om het vinden van balans en acceptabel verlies. Onze verantwoordelijkheid is het garanderen van de toegankelijkheid tot ons gedeeld cultureel erfgoed voor de huidige én toekomstige generaties. Maar, een verplichte verantwoordelijkheid die de overheid ons oplegt, mag niet de enige reden zijn om te verminderen. We moeten ons bewustzijn van het feit dat als er geen leefbare planeet is, er ook geen behoefte is voor ons erfgoed.

Ik heb mijn afstudeeronderzoek voor mijn Bachelor of Arts in Cultureel Erfgoed en Archivistiek B gewijd aan dit dilemma. Specifiek, het vinden van balans tussen digitale duurzaamheid en ecologische duurzaamheid in de digitale preservering van het NA. Hoewel de oorspronkelijke bedoeling van mijn onderzoek was om het NA te inspireren en te adviseren heb ik ook geleerd dat er in onze sector nog weinig onderzoek is gedaan naar het verminderen van de CO2 impact van het digitale archief. Het onderzoek dat is gedaan richt zich hoofdzakelijk op hardware, zoals servers in datacenters. Activiteiten waar software centraal staat vereisen meer onderzoek. Dat komt waarschijnlijk door het huidige niveau van volwassenheid van het digitale preserveringsveld.

**Dus, hoe kunnen we op verantwoordelijke wijzen verminderen?**

***Met onze beperkte kennis over het minimaliseren van onze voetprint in digitale preservering, is onze sector voorbereid op de komende, massale instroom van digitale objecten?***

De eerste stap in het minimaliseren van onze digitale voetprint is het vormen van een compleet beeld van alle processen en procedures binnen de organisatie. Wat zijn we aan het doen, hoe doen we het en waarom doen we het? De beste plek om te starten is een activiteit die ruimte heeft voor een andere manier van denken. Bijvoorbeeld een strategie waar al opnieuw over na wordt gedacht. Het kiezen van een groenere optie kan ook resulteren in een hoger level van efficiënte en het besparen van middelen.

**We moeten ons bewustzijn van de keuzes die we maken en de opties die we hebben.**

Op de volgende pagina geef ik een aantal voorbeelden van hoe dat evenwicht gevonden kan worden bij bepaalde digitale preserveringsactiviteiten, afkomstig uit mijn eigen onderzoek bij het NA. Ik hoop dat het je kan inspireren.

**13 juni 2023.**

**Sophia van Hoek**

## Prioritiseren van (digitale preservering) activiteiten: Waar te beginnen

### Beleid en praktijk

Stap 1) Heeft uw organisatie een beleid voor digitale preservering?

⇒ Welke activiteiten worden genoemd, en hoe uitgebreid?

⇒ Wat ontbreekt er?

2) Hoe verhoudt de praktijk zich tot het beleid?

⇒ Wat zijn de verschillen?

### Behoefte aan onderzoek

3) Wat heeft uw organisatie al gedaan op het gebied van (groene) duurzaamheid?

⇒ Bestaat er een werkgroep voor duurzaamheid?

⇒ Wat is de milieu impact van uw organisatie?

⇒ Wat veroorzaakt het hoogste percentage CO2 emissies?

⇒ Welke oplossingen zijn er al geïmplementeerd?

4) Welk onderzoek is er al gedaan buiten uw organisatie?

⇒ Zijn er oplossingen van anderen in de sector die zouden kunnen werken voor uw organisatie?

⇒ Wat ontbreekt er?

### De mening van experts

5) Welke activiteit heeft volgens de experts van uw organisatie ruimte voor meer klimaatvriendelijke overwegingen?

⇒ Welke activiteiten worden momenteel heroverwogen?

⇒ Bestaan er hypotheses over groenere oplossingen voor bepaalde activiteiten?

## Emulatie versus conversie: Welke methode is groener

### Beleid en praktijk

Stap 1) Is emulatie of conversie al geïmplementeerd in het beleid of de praktijk?

⇒ Zo ja, hoe en waarom?

⇒ Zo niet, is er belangstelling voor?

### Geschiktheid

2) Wat heeft uw organisatie al gedaan op het gebied van emulatie en conversie?

⇒ Welke methode sluit beter aan bij de behoeften van uw organisatie?

⇒ Welke expertise en middelen zijn er beschikbaar?

⇒ Heeft uw organisatie al geëxperimenteerd met beide methoden?

### Theorie

3) Welk onderzoek is er al gedaan buiten uw organisatie?

⇒ Zijn er oplossingen van anderen in de sector die zouden kunnen werken voor uw organisatie?

⇒ Welke conclusies kun je vinden over de ecologische kosten van beide methoden?

4) Enkele interessante bronnen:

⇒ iPRES proceedings.

⇒ Open Preservation Foundation blogs.

⇒ Digital Preservation Coalition: discover good practice. Environmentally Sustainable Digital Preservation.

⇒ Netwerkgroep Green IT. (KIA.)

⇒ Hoofdstuk 2.2 van het onderzoeksverslag dat de inspiratie vormde voor dit manifest.

## Digitale preservering tools: Het vinden van de meest efficiënte tool

### Beleid en praktijk

Stap 1) Zijn er al tools geïmplementeerd in het beleid of de praktijk?

⇒ Zo ja, hoe en waarom?

⇒ Zo niet, is er belangstelling voor?

### Geschiktheid

2) Welke tools worden momenteel onderzocht of gebruikt?

⇒ Welke tools sluiten aan bij de behoeften van uw organisatie?

⇒ Welke expertise en middelen zijn er beschikbaar?

⇒ Heeft uw organisatie al geëxperimenteerd met tools?

### Experiment

3) Welk onderzoek is er al gedaan buiten uw organisatie?

⇒ Hebben anderen het gebruik van middelen van de tools al getest? (Zie hoofdstuk 2.3 van het onderzoeksverslag voor resultaten over C3PO en Niflheim).

4) Wat is een geschikte testset bestanden?

⇒ Bijvoorbeeld een testcorpus met een open licentie van de Open Preservation Foundation.

5) Hoeveel energie wordt er gebruikt?

⇒ Door een watt-uur meter te gebruiken: aansluiten op de computer, dan de tool gebruiken.

* Toont de meter alleen momentopnamen van de verbruikte watt? Neem het gemiddelde.

6) Hoeveel data opslag is er nodig voor de output (zoals een spreadsheet)?

## Fixity checking: Het verminderen van de ecologische kost

### Beleid en praktijk

Stap 1) Zijn fixity checks al geïmplementeerd in het beleid of de praktijk?

⇒ Zo ja, hoe en waarom?

⇒ Zo niet, is er belangstelling voor?

### Theorie

2) Welk onderzoek is er al gedaan buiten uw organisatie?

⇒ Zijn er oplossingen van anderen in de sector die zouden kunnen werken voor uw organisatie?

### De mening van experts

3) Stel de volgende vragen aan de experts van uw organisatie. *(Geciteerd uit Pendergrass, 'Toward Environmentally Sustainable Digital Preservation'.)*

⇒ Hoe vaak voer je geplande fixity checks uit?

⇒ Voer je fixity checks uit tijdens piek- of daluren?

⇒ Is het nodig om fixity checks uit te voeren op alle AIPS, of is het controleren van een steekproef van AIPS genoeg om aan de behoeften van de organisatie te voldoen?

⇒ Worden 'file-based' checksums aangevuld met andere integriteitscontroles, zoals systemen die ingebouwde controles bevatten? Zo ja, kunt u de frequentie van 'file-by-file' fixity checks op verantwoorde wijze verminderen?

4) Analyseer de resultaten.

⇒ Welke mogelijkheden voor groene verbetering zijn te vinden in de antwoorden van de experts?