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1. Introduction

As societal challenges have increasingly become global, the need for global governance increases (Finkelstein, 1995). Global governance involves global structures, procedures, and common goals (Rosenau, 2005) with no central authority that can exercise a legitimate use of force (Zürn, 2010). Moreover, apart from governments multiple actors have key roles in achieving the common goals (Rosenau, 2005).

A critical global challenge is climate change. According to the Intergovernmental Panel on Climate Change (IPCC), urgent and ambitious action at all scales is necessary to meet the temperature goal (1.5-2°C) of the Paris Agreement (IPCC, 2021). Since the Climate Convention was adopted in 1992, regular Conference of the Parties (COP) summits have brought together world leaders and an increasing number of stakeholders. COP is the supreme decision-making body of the Climate Convention where decisions and agreements are made regarding global climate governance (UNFCCC, 2022a). COP26 was held in Glasgow (UNFCCC, 2021a) in November 2021.

In the international climate agreements, reporting on emissions and measures has been an important component. The aim of the reporting is to make it possible to monitor greenhouse gas emissions; follow individual and collective progress; and inform decision-making (UNFCCC, 2020a). With the Paris Agreement, the reporting procedures have been further developed into an Enhanced Transparency Framework (UNFCCC, 2018). Collection of information and monitoring as a basis for evaluation of progress towards governance goals gives information systems a key role in governance (Hendrick, 1994). Furthermore, digital governance is argued to strengthen institutions and governance (Janowski, 2016) to implement the sustainable development goals (SDGs). To respond to global challenges, it is imperative to explore how digital technologies can support global governance. In general, there is a need to better understand the digital infrastructure in governance (Dawes, 2009) and particularly the global dimension of digital governance (Geiselhart, 2007).

Given the above, we found the international climate reporting to the UNFCCC to be a suitable case to increase our knowledge of digital global governance. When studying climate reporting, implementations both at national and international levels are relevant. This article analyzes Sweden's climate reporting to the UNFCCC using information infrastructures as an interpretive lens. The article offers insights into hitherto unexplored areas of digitalization in global governance. The research question guiding the research was:

> *RQ1.* 'How are digital technologies used in climate reporting, and to what level of sophistication?'

2. Conceptual Foundation

2.1 Global governance

In the *Handbook on Theories of Governance,* governance is defined as

> 'The process of steering society and the economy through collective action and in accordance with common goals' (Ansell and Torfing, 2016, p. 4).

Governance is backed by shared goals but does not have to derive from legal and formally prescribed rules (even though it can) and has both formal and informal mechanisms to

achieve the goals (Rosenau, Czempiel, & Smith, 1992). Global governance is justified by transnational problems or global common goods (Zürn, 2018), and has been defined as:

> 'Global governance is governing, without sovereign authority, relationships that transcend national frontiers' (Finkelstein, 1995, p. 369).

It means that there is no central authority such as a government that can wield a legitimate use of force (Zürn, 2010). Global governance as a concept emerged in response to the development of an increasing global interdependence and the development of international and transnational organizations, structures, and processes. Furthermore, the transformation from a state-centric to a multi-centric world with various spheres of authority and vast number of actors playing an important role in global development, is reflected in the concept of 'global governance' (Rosenau, 2005). In the case of climate governance, to mobilize climate action, two high-level champions have been assigned to connect the work of voluntary initiatives by cities, regions, investors, businesses, and other organizations with the work of governments (UNFCCC, 2022b).

2.2 Information Infrastructure

'Information Infrastructure' in this article will be used as an analytical lens to examine climate reporting and, the way information systems support climate governance.

Information Infrastructure (II) is a form of information system (IS) with a set of distinct characteristics. IIs are large and complex socio-technical networks (Hanseth and Lyytinen, 2016). An II is intertwined with organizational structures and work practices and co-evolves with them (Aanestad *et al*., 2017).
An infrastructure is a common foundation on which different activities are developed (Hanseth, 2010). An II is a shared resource for a community (or multiple communities) for developing and using information services (Hanseth and Lyytinen, 2004). An II involves interrelated social, organizational, and technical components, including hardware, software, services, and personnel with expertise (Bowker *et al.* 2009). IIs are characterized by six aspects;
(1) They have an enabling or supporting function to a range of activities;
(2) They are shared by a community and cannot be split into parts that are used independently by different groups;
(3) They are open to be used by an unlimited number of users and use areas, which may also change over time;
(4) They are socio-technical networks that encompass hardware & software, organizations, people, information, and standards and are embedded in social structures;
(5) They are interconnected and interdependent networks that integrate various components;
(6) They are continuously evolving by extending and improving the installed base, which new elements have to adapt to (Hanseth and Monteiro, 1998).

This description by Hanseth and Monteiro (1998), elucidates an II as a socio-technical system and not just as technology per se, which is also the perspective we have in this article.

An II involves many interconnected elements. Development of new components must adapt to and be interoperable with what already exists in the installed base (Hanseth and Monteiro, 1998). The *installed base* includes 'existing practices, conventions, tools, and systems (…) the organizational, institutional, regulatory, sociotechnical arrangements that are already in

place' (Aanestad *et al*., 2017, pp. 28-29). This indicates the complexity of IIs.
An important aspect of IIs are standards that enable interaction, interoperability, and compatibility of components into a larger system. However, as user needs change over time, there must also be a level of flexibility, which is often achieved by modularization (Hanseth and Monteiro, 1998). Due to their complexity, the development and design of IIs are complex; the challenges of attracting large user groups and adapting to increasing heterogeneity need to be considered (Hanseth and Lyytinen, 2016).

IIs are embedded in, and coevolve with, other infrastructures (Aanestad *et al.,* 2017). To emphasize the specific characteristics of the public sector, Hornnes et al (2010) articulated the concept of government information infrastructure (GII), including technical, organizational, and legal structures (Hornnes, Jansen, & Langeland, 2010). A GII is thus also part of a governance infrastructure (Johnston, 2010, p. 122).

3. Method

This paper is based on an interpretive case study of climate reporting to the UNFCCC. The aim of interpretive research is to develop an understanding and make sense of a social phenomenon. An interpretivist view is that knowledge about a phenomenon is gained through understanding the meanings individuals and groups assign to it (Klein and Myers, 1999). Case studies are appropriate in research about information systems embedded in a certain context, since the method embraces real-world dynamics (Shanks and Bekmamedova, 2013). As empirical material, semi structured interviews was carried out with professionals in the Swedish public administration, the UNFCCC, and international experts. Semi-structured interviews enabled us to capture the respondents' views (Williamson, 2013). The study adopted a process perspective to understand and describe the climate reporting process, from the national to international level, and analyzed the use of digital technologies in this process. In research with a process perspective, the focus is on entities and actors involved in events in a process (Burton-Jones*et al*., 2015). Interviews were constructed to describe the reporting process, and to identify and understand the characteristics of reporting information and the IT artefacts used. Respondents were purposefully selected based on their experience of reporting. Twenty interviews were conducted via Zoom or telephone that lasted for 45-60 minutes each. Interviews with two of the respondents were not recorded, respecting their wish. However, extensive notes were taken in each case. The other interviews were recorded and transcribed. Each interview guide was prepared with questions relevant to the role of the respondent, their expertise, and the role of the public body they work at. The respondents (see Table 1) were asked about their role related to the reporting, the reporting process, what should be reported, what IT artefacts are used, challenges they experience, the meaning of reporting and IT artefacts, organizational arrangements, and follow up questions based on their answers.

Organizational body	**Role of respondent**	**Code**
The Swedish Environmental Protection Agency (EPA)	Project Manager	R1
EPA	Climate advisor	R2
EPA	Senior Advisor at the climate department	R3
SMED (Swedish Environmental Emission Data)	Project Manager for Sweden's calculations of greenhouse gas emissions	R4
EPA	Climate negotiator	R5
EPA	Climate negotiator and legal expert	R6

Government Offices Sweden, Ministry of the Environment	Ministry Secretary at the Ministry of the Environment	R7
EPA	Climate analyst	R8
EPA	Climate analyst	R9
Panorama	Project Manager	R10
Swedish Climate Policy Council	Senior Analyst	R11
Ministry of the Environment, Sweden	Policy Analyst	R12
UNFCCC secretariat	Data and information expert	R13
UNFCCC secretariat	GHG national inventory submissions	R14
UNFCCC secretariat	Global stocktake expert	R15
UNFCCC secretariat	Global stocktake expert	R16
UNFCCC secretariat	Coordinates technical analysis of reports	R17
Expert reviewer for the UNFCCC	Expert reviewer	R18
Anonymous	International expert	R19
UNFCCC secretariat	Expert on National Communications for developing countries	R20

Table 1. List of respondents

4. Findings

The findings section outlines the processes and ISs used for climate reporting to the UNFCCC. Our analysis had two focal points: the international level represented by the UNFCCC, and the national level represented by Sweden.

4.1 United Nations climate governance framework

Climate change has been discussed internationally within the United Nations since the 1980s, resulting in a series of agreements. The current agreement, the Paris Agreement (2015), was adopted in 2015. Central to the climate agreements is reporting (UNFCCC, 2021). All agreements have had reporting requirements, but with the Paris Agreement, this has been further developed into the Enhanced Transparency Framework (ETF), to strengthen the tracking of progress and transparency. Every fifth year a global stocktake will evaluate global progress. Specifications regarding reporting are negotiated and decided at UNFCCC COP meetings, which are annual meetings under the UNFCCC umbrella (UN, 2015).

4.2 Swedish framework for climate policy and climate reporting

Sweden has developed a climate reporting system based on international requirements, and the Swedish *Climate reporting regulation* (The Swedish Parliament, 2014). Sweden is a member of the European Union (EU) and has signed the Paris Agreement. Further, it has adopted a national climate policy framework in 2017, which includes a Climate Act, climate goals and a Climate policy council. In Sweden, the reporting system serves both national, EU and UNFCCC reporting requirements. The overall responsibility for the national system for international climate reporting is held by the Ministry of the Environment. The Swedish Environmental Protection Agency (EPA) is responsible for coordinating and maintaining the national reporting system and produces the required reports. SMED (Swedish Environmental Emission Data), a constellation of four agencies, gathers data and makes calculations of GHG (greenhouse gas) emissions (Government Offices of Sweden, 2019).

4.3 Reporting to the United Nations Framework Convention on Climate Change

Countries report climate data, plans and actions to the UNFCCC. There have been different reporting requirements for Annex I (developed) and non-Annex I (developing) countries. However, under the Paris Agreement all countries will report according to the same obligations, although there will be certain flexibilities for non-Annex I countries. This article will primarily focus on reporting from Annex I countries (to which Sweden belongs).

The reporting to the UNFCCC consists of different processes, and consequently different reports on different formats. The reporting includes the following three main processes:

- Statistics of CO2 emissions
    - Reported annually in the National Inventory Report (NIR) and Common Reporting Format (CRF) tables (greenhouse gas emission inventory)

- Description of the climate actions in a country
    - Reported in the National Communication (NC) (under the Climate Convention) every four years and Biennial Report (which will be replaced by Biennial Transparency Report from 2024) every two years

- Commitments on national efforts
    - Nationally Determined Contribution (NDC) (under the Paris Agreement), reported every five years

4.3.1 Statistics of C02 emissions

All Annex I countries annually report a national inventory of statistics of emissions and uptakes of greenhouse gases. In Sweden, various government agencies have statistical responsibilities and provide data for the reporting (R1). SMED collects the data and makes the calculations (Government Offices of Sweden, M.o.t.E, 2019). This way, statistics are produced independent of politics (R7). As was explained by the respondent from SMED (R4):

> ‘Emissions for different sectors are calculated, and figures are entered into a common database called Technical Production System (TPS). UNFCCC reporting guidelines and IPCC methodology guidelines should be followed as a standard and deviations must be explained. An important requirement is to have a Quality Assurance and Quality Control system’ (R4).

National Inventories are reported in the CRF, to the CRF Reporter at the UNFCCC secretariat. The reporting consists of standardized CRF tables and a NIR that describes the procedure applied (R4). As a respondent at the secretariat explained:

> ‘The CRF reporter is an online reporting tool where each Annex I country has its own account. The CRF reporter generates a reporting template with excel tables that is populated with data by the reporter, and aggregations and conversions are made by the software. Then the report is submitted through the submission module in the CRF reporter’ (R13).

When reports are submitted, the UNFCCC secretariat makes an initial assessment (partly automated and partly manual) on whether the report is complete, consistent, timely, and in the correct format. The software notifies the reporting country after the automated check, but will not refuse any reports (R13). An assessment report is then created, involving an automated statistical analysis of outliers, using implied emission factors (i.e., if there are deviations from what is normal to a sector or emission source) (R14). An expert review team (ERT) verifies whether the submitted reports are in accordance with reporting requirements and guidelines and provides recommendations. The review ensures that countries have

reported their emissions correctly (R18). A digital platform called iVTR is used to communicate questions and answers in the review process (R8; R13). An analysis of outliers and comparisons with previous years are conducted (R13; R18). There can sometimes be a re-submission of data (R19). The respondent said that the guideline for the review process becomes increasingly more comprehensive, and suggested that:

> 'In general, the review process should be more efficient if you utilize digitalization better, to make information that is key for the review process more searchable; now it can be quite cumbersome to look at all these heavy documents' (R18)

The reports are stored in a data warehouse, which is connected to the CRF Reporter, and the final version is published on the website (R13). On the website there is an online tool to make queries on the emission data, called GHG interface (R13).

With the changes under the Paris Agreement, the CRF format will be replaced by CRT (Common Reporting Tables), and the reporting tool will be developed based on the reporting format (R13). A new storage of inventories might be needed (R14) and there will also be a need to develop functionality to generate reports on the data, and interfaces to visualize the information (R13). Furthermore, the most appropriate tools for reviews are being explored and will be implemented, subject to the availability of financial resources (R17). The reporting process of GHG emissions is illustrated in Figure 1 below .

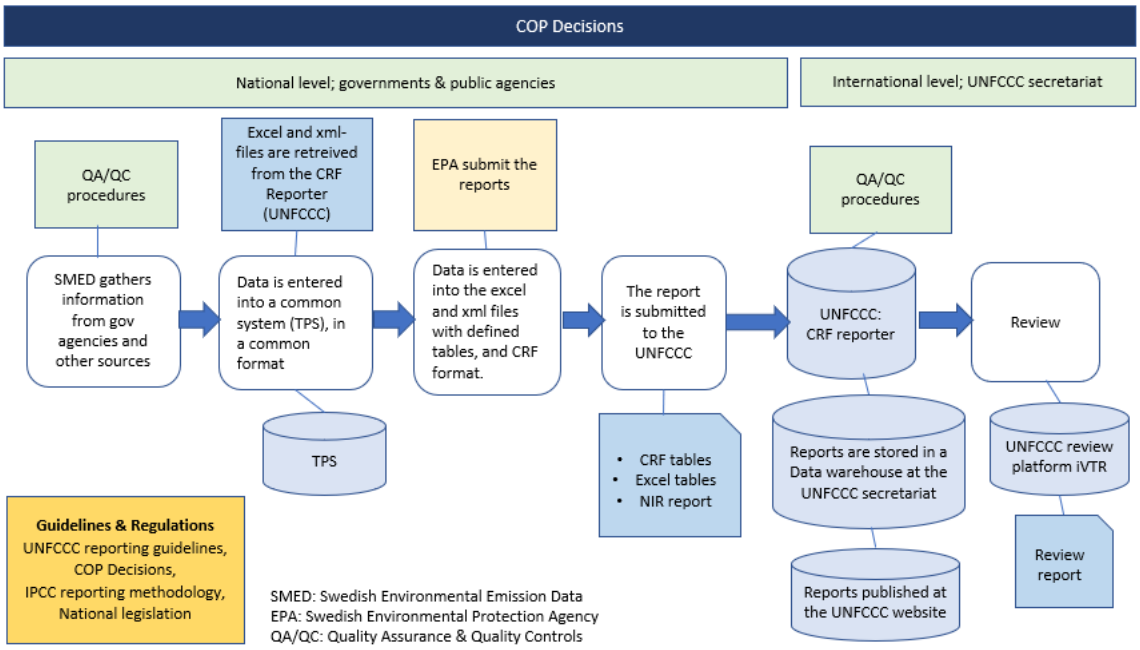

Figure 1: *Overview of the GHG inventory reporting process*

4.3.2 Reporting of climate actions

The NC report describes a country's climate work, and is a pdf text report submitted every fourth year by all countries (R5). Annex I countries report a Biennial Report (BR) every second year, which follows up on policies, measures, and projections (R3). If possible, they should also include effects of policies and measures, and for this work digital technologies are crucial.

> 'In the work with scenarios and impact assessments in Sweden, advanced digital models have been developed, which comprises a variety of complex relationships that cannot be calculated manually' (R9).

This illustrates that digital technologies have a significant role in managing the complexity of interrelated aspects of climate policy.
To compile the report, the EPA gathers information from SMED and various agencies and sends a draft report to the Ministry of the Environment. The report is processed in the governments offices and then returned to the EPA, which finalizes and submits it to the UNFCCC (R8).

> 'The National Communications (NC) and Biennial Reports (BR) are submitted in the National Reports Submissions Portal (NRSP), which has a link to a records management system where the reports are preserved at the UNFCCC secretariat. They are also published on the UNFCCC website' (R13).

The secretariat verifies that it is the right type of report, but no quality checks are conducted (R19). The NC and BR are reviewed by international expert review teams; there can also be multilateral assessments. A digital platform is used in the review to communicate questions and answers. One of the respondents (R8) had experienced technical problems with the review platform. BRs will be replaced by the Biennial Transparency Report (BTR), starting December 2024. All countries will then report in the same format, but the level of extent of the reports may differ (R17).

4.3.3 National commitments

Countries should report their commitments on what they will contribute to the Paris Agreement goal in the NDC. NDCs should be in the Information for Clarity, Transparency and Understanding (ICTU) format, and are submitted to a common NDC register at the UNFCCC (R6). The EU submits a common NDC (R2), and the Effort Sharing Regulation specifies how much emission each EU member state should reduce (European Union, 2018). There is no review or assessment of the NDC, but countries report on their implementation. Commitments in the NDC should increase every fifth year. However, it is not yet clear how this will be assessed (R19).

There is a table called 'Track in progress' to follow up on commitments and progress of each country (R13). As one of the respondents said

> 'In the table "track in progress", the country has its targets and a set of indicators. Then they have a balance in the "structured summary", and they can see if the data from the inventory translated into indicators is meeting their commitments in their NDC' (R14).

The track in progress will be reported in Excel in the Common Tabular Format (CTF). Individual countries' progress will be considered during a "facilitative multilateral consideration of progress" (R13).

4.3.4 Synthetization of global progress

Based on reported information, the UNFCCC secretariat is mandated to develop synthesis reports, which provide a view on global commitments (UNFCCC, 2021b), and is an input to the global stocktake (R16). The first global stocktake starts in June 2022 and continues throughout 2023 (R15). The new demands on global synthetization of information, along with increased volumes of reports will place new challenges on information management and analysis at the international level (R14). One of the respondents emphasized that smart ways to manage huge volumes of reports and to make them usable must be developed:

> 'Imagine as of 2024 we will receive biennial transparency reports every 2 years from almost 200 countries. These reports can be excessive and they come as a pdf. That will be a huge amount of information to read. They should be summarized and synthesized, and there should be a discussion on how to do this. If

> something could be standardized or put into tables, for example. If digitalization should be used to support this, it must first be decided what information people want to get out of it. Nevertheless, it is important to find what is relevant in the reports in an easier way' (R19).

Respondents have further emphasized the need for improved means to make sense of and illustrate progress towards the goal in the Paris Agreement (R5; R19), as well as to improve the website, as the content grows (R20). One of the respondents at the UNFCCC (R14) also said that their systems were not adjusted to analyze the global status because they lacked that mandate. Currently, they must add all countries' emissions manually. On the question on what the respondent would like to address in further digitalization, the response was:

> 'It would be helpful to see the contribution of different Parties and the trends on emissions, then the contributions of the gases, the contribution of the sectors, and then the same for the categories and then for each category. For example, what is the trend in agriculture in countries in a particular region of the world. It would also be good to see some indicators of the efficiency, like implied emission factors.' (R14).

The reporting structures to gather information at a global scale are in place, but there are growing challenges in managing large volumes of information, as well as making the information comprehensible. There are, however, some external initiatives that use the reporting information to make analyses. For example, the *Climate Action Tracker* makes independent scientific analyses and measures government climate action towards the goal in the Paris Agreement (Climateactiontracker, 2022), and *Climate Watch*, which visualizes countries' emissions, compares NDCs, and provides analyses on how countries can improve their efforts (Climatewatch, 2022).

4.3.5 Information infrastructure for global climate reporting

Our objective was to map global climate reporting as an instantiation of an information infrastructure, to achieve an increased understanding of the role of information systems in governing global problems. In Table 2 below is an overview of the key elements of the II and how these manifested in our case.

Element of II	**National level**	**International level**
Information systems	Office programs TPS (Technical Production System) Digital models	<u>For annual GHG inventories</u>: CRF Reporter Data warehouse <u>For NC & BR:</u> National Reports Submission Portal (NRSP) Records management system NDC Register Review platform UNFCCC (iVTR) UNFCCC website
Information	Reporting requirements; - GHG emissions - Climate action commitments - Climate action Multiple sources of information input for the reporting	Reports from countries Synthesis reports based on country reports
Standards	Reporting formats UNFCCC reporting guidelines IPCC methodology standard	CRF Reporter Reporting formats
Organizations	Environmental Protection Agency SMED Public agencies submitting data	UNFCCC secretariat COP & CMA meetings

	Ministry of the Environment Government & Parliament	
People	Public administration personnel Politicians	Personnel at the UNFCCC secretariat Government delegations
Social structures	National & international governance frameworks - National legislation & administrative arrangements - International negotiation of requirements and COP decisions - EU requirements	Governance framework at international level Climate Convention Paris Agreement COP & CMA processes and decisions

Table 2. Information infrastructure elements in global climate reporting

5. Discussion: climate reporting as an information infrastructure

In this section, we position our findings against key characteristics of IIs outlined by Hanseth & Monteiro (1998), and discuss the sophistication level of the II of climate reporting according to Hendrick's (1994) typology.

As illustrated in Table 2, the reporting II encompasses information systems, information, standards, organizations, people, and social structures. The reporting can thus be viewed as a socio-technical structure. The interviews revealed that standard reporting formats and reporting guidelines have been decided at a global level, which enables global coordination. Modalities, procedures, and guidelines (MPGs) for the reporting and review under the Paris Agreement have been decided in the rule book under the Paris Agreement (UNFCCC, 2018). Systems and software have been developed at the UNFCCC secretariat to facilitate and manage reporting. Procedures have been developed and there are requirements on countries to develop institutional arrangements for the reporting (UNFCCC, 2018). The elements of the II for climate governance are interconnected and interdependent. Digital technologies are embedded in reporting activities, which are then embedded in governance processes and structures, and involve various actors.

The II serves governance functions and activities for various stakeholders. In a global governance context, various stakeholders have different roles. As one respondent (R5) said, NGOs (Non-Government Organizations) are important to put pressure on governments. Private investors can be instrumental in enabling the climate transition. Involving businesses is key to leverage the climate transition in the for-profit sector. The UNFCCC climate champions work to engage stakeholders to mobilize climate action (UNFCCC, 2022b). The information provided through the reporting is accessible to everyone via the UNFCCC website, and emissions and efforts can be aggregated to the global level. This information is potentially useful to all these stakeholders. As countries' emissions, measures, commitments, and needs are reported, the information can be used for monitoring and to inform decision-making in the UNFCCC process, support accountability, identify sectors that need attention, investment needs and business possibilities, and facilitate collaboration.

An II evolves incrementally through extension and improvement of the installed base (Hanseth & Monteiro, 1998). This means that the II for climate governance can be developed through innovation on existing II, where additional modules can be added to support governance towards the global climate goals.

5.1 Sophistication level of the II

Hendrick's (1994) three levels of types of information systems offers a way to analyze the sophistication of an information infrastructure. The first level is a *Transaction Processing System (TPS)* to collect, store and maintain quality control of information. The next level is a *Management Information System (MIS),* including capabilities to process, manipulate and link information, and to make comparisons with organizational goals. The most advanced level is a *Decision Support System (DSS),* which has more sophisticated data analysis and presentation capabilities to support planning and decision making. These types of systems build on each other. First, information is collected, validated and organized, after which more advanced analysis and presentations can be done (Hendrick, 1994). Our findings indicate that the information infrastructure of global climate reporting is evolving but currently at a rather basic level, where digital technologies are primarily used to gather, store, and maintain quality control of the information. This resembles a TPS. While plans for developing more sophisticated systems and functionality can be found both at the national and UN levels, several of our respondents pointed to a need for functionality at the MIS and DSS levels. With increased requirements for global synthetization and stocktaking of the global progress, there will be a need for further digital support to make comparative analyses at the global level, link that with the goals in the Paris Agreement, and to visualize information that clearly illustrate progress and gaps.

Additional functionality for data-driven decision making could be developed, based on the verified reporting information. The interviews indicate an increasing need of analytical capability, e.g., impact assessments at the national level as well as visualisations for improved decision support at the global level. The UNFCCC secretariat works on a very strict mandate from the COP, where extensive negotiations substantially slow down the speed of digital innovations. The development of the II needs to consider its inherent dynamic complexity, with increasing socio-technical heterogeneity of components and interactions, as the number of users and applications increase. Hanseth and Lyytinen (2016)'s 5 design principles for IIs (designing for usefulness, drawing upon the installed base, stimulating an expanding user base, making each application and IT capability simple, and modularising the II to enable continuous adaptability) offers concrete guidance to this end.

6. Conclusions

This study fills a knowledge gap by offering insights into the previously unexplored area of digitalization in global governance. Our analysis showed that information infrastructure offers considerable value as an instrument to open up and understand the black box of digitalization in global governance as a complex interplay between the information systems, information, standards, organizations, people and social structures.

Given the urgency of the global climate crisis and the obvious potential in digital technologies to contribute towards addressing the problem, we expected to find extensive and advanced applications of digital technologies in our case. However, our analysis of the sophistication level of the information infrastructure currently supporting climate reporting revealed a relatively basic use with much potential for improvement — for instance related to improving analytical capabilities and communicative services for various stakeholders, to support evidence based and data driven decision making, and more effective assessments of

progress towards established goals.

5.1 Implications

The UNFCCC and others should consider our results as a call to arms to quickly assess how they can speed up the implementation of digital technologies to increase their analytical capabilities to improve progress assessment, communicate more effectively with stakeholders and identify new ways of visualizing data to support decision making. The 5 design principles for IIs by Hanseth and Lyytinen (2016) offer useful guidance for practice.

Our investigation has only just started to reveal the complexities of digitalization in global governance. More research is needed on how global IIs can be enhanced to support effective implementation of global governance goals, considering the roles and needs of various actors. There is certainly a need for descriptive studies of different cases that can later be compared and synthesized. Moreover, we encourage colleagues to explore *why* digital technologies are not used more sophistically to address the imminent climate crisis. Finally, research on *how*, and under what circumstances, digital technologies can improve the global response to societal problems is suggested.

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