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Setting the stage for a Shared Environmental Information System

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ABSTRACT

There has been a significant increase in efforts to improve environmental data sharing practices in the past decade. One such initiative is the Shared Environmental Information System (SEIS), initiated by the European Commission in 2008, as part of a process to facilitate regular environmental assessments and State-of-the-Environment Reporting (SOER). Using SEIS as a case study example, this paper takes its departure from the 8th Environment for Europe (EFE) Ministerial conference to identify ongoing processes and challenges surrounding environmental data and information sharing. The paper relies on data obtained for the 2016 report on progress in establishing SEIS in support of regular reporting in the pan-European region. The article demonstrates a number of gaps with regards to the availability and accessibility of certain environmental datasets and indicators and highlights the suboptimal use of information, where comprehensive data flows and high-quality information is not being used adequately in support of policymaking or where there is selective use of environmental indicators. Against this background, questions arise as to whether applied models for data sharing can be implemented with equal success across different regions and countries that are characterized by heterogeneous and complex data practices and data flows. Most importantly, results from the SEIS progress report demonstrate the pressing need for a better understanding of environmental data types, data packaging and data flows across multiples contexts, epistemic cultures and policy making.

1. Introduction

There has been a longstanding demand from and efforts by the environmental community for data sharing and methodological uniformity as regards State-of-the-Environment Reporting (SOER), including information on environmental trends, pressures and drivers (EEA, 2015a, 2015b; FAO, 2016; UNEP, 2016). Recognition of the historical and indeed ever-increasing importance of collecting this environmental data is demonstrated through activities being carried out by institutions, agencies and networks such as the European Environment Agency (EEA), the statistical office of the European Union (EUROSTAT) and the European Environment Information and Observation Network (Eionet). However, with the passage of time, data is now not only being collected for policy-making purposes and expert analysis, but also to facilitate increased public awareness and access to environmental information with the results thereof being reported on through a wide range of media, including scientific publications, policy briefs and social media, to note only a few examples.

One part of this complex web of data flows, processes and reporting streams on the environment has been the introduction of the Shared Environmental Information System (SEIS) by the European Commission in 2008 (European Commission, 2008). The main argument for establishing SEIS was the pursuit of a policy instrument to help maximise the use of environmental data and ensure the provision of a coherent, streamlined and up-to-date framework for high-quality information about the state-of-the-environment. Other regulatory examples in this area include the EU INSPIRE Directive on spatial data infrastructure (Directive, 2007/2), Copernicus, as the EU's Earth Observation Programme (REGULATION, 337/2014) and the UNECE Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters (Arhus Convention) in Europe and Central Asia. On a more technical level, SEIS serves to connect existing databases (e.g., data infrastructure), make data more accessible (e.g., integrated data portals) and ensure better use and harmonisation of environmental data and information, such as increased use of SOERs in policy-making (EEA, 2015a, 2015b). Even though we now find ourselves living in an era of 'alternative facts', some of which poignantly impact both perceptions and condition of the environment. Overcoming such problems is an underlying driver for SEIS as we cannot improve the environment without also improving the availability of relevant information upon which decisions should be made.

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SEIS is for this reason – as a policy instrument – meant to facilitate regular environmental assessments and reporting. It is furthermore designed to link existing data flows relevant for national authorities' monitoring and assessment activities by means of information and communication technologies (ICTs) and, more importantly, increase the dissemination, application and comparability of environmental indicators. This is set against increasing demands for harmonised environmental monitoring requirements across countries, not only within the EU but worldwide (de Haan, 1999; Köhl et al., 2000; Bernard et al., 2005). However, while SEIS makes conceptual sense, experience has shown that enabling meaningful data exchange, sharing and use is a complex and difficult process. The establishment of a harmonised, integrated, and long-term environmental monitoring system remains a major challenge for public and scientific institutions (Mollenhauer et al., 2018).

This paper proceeds from the Eight Environment for Europe (EFE) Ministerial conference[1] and seeks to identify ongoing processes and challenges surrounding environmental data and information sharing, using SEIS as a case study example. The objective is to clarify how SEIS may affect environment-related reporting and policy-making as well as to address a gap in the scientific literature on this policy initiative. The paper makes use of data obtained through the 2016 progress report on SEIS (UNECE, 2016). To better clarify the purpose and background of SEIS, this article is divided into six sections: Section two provides a brief historical overview of SEIS and the ways in which the initiative has evolved from its inception in 2008. Section three explains the methodology and limitations of the current study. Section four elucidates the main findings, focusing in part on the implications on SOERs and the use of environmental data and information. Section five takes the initial analysis and the primary findings then expands these into an analytical discussion on the use of environmental data and information in policy-making. Lastly, section six serves as a conclusion and puts forward considerations for the broader practical implications of the research.

2. Background: explaining SEIS

SEIS was metaphorically born in 2008 when the European Commission released a communication entitled "*Towards a Shared Environmental Information System (SEIS)*" as a solution for the "environmental information challenge" in the EU and as part of developing a knowledge-based economy (European Commission, 2003; 2008). The objective was to address obsolete reporting obligations, modernise the European environmental reporting streams and facilitate the development of improved state-of-the-art environmental knowledge base. This was followed by a SEIS implementation outlook in 2013, which set out new priority areas for SEIS implementation (European Commission, 2013). These priorities included streamlining of EU reporting obligations, improving public access to information and supporting the implementation and review of the INSPIRE Directive (Directive, 2007/2).

Efforts to improve access to environmental information, as well as maximising and expanding its use, have been underpinned by seven "SEIS principles", reiterated in both the above-noted communication and outlook. These state that information should be:

1 Managed as close as possible to its source.
2 Collected once and shared with others for many purposes.
3 Readily available to easily fulfil reporting obligations.
4 Easily accessible to all users.
5 Accessible to enable comparisons at the appropriate geographical scale and the participation of citizens.
6 Fully available to the general public and at national level in the relevant national language(s).
7 Supported through common, free, open software standards.

The EEA has taken the above principles and have structured its functional definition of SEIS around three pillars, namely, **content**, **infrastructure** and **cooperation**. The first relates to identifying the types of content (data) required and their sources. The second relates to having effective, web-enabled technical infrastructure that can take advantage of cutting-edge information and communication technologies, including web services. The third relates to the cooperation and governance structures that are required to manage human resources, inputs and networking in relation to environmental information and data collection as well as its use in policy-making.

SEIS has become a collaborative initiative since its inception, including EU institutions and networks (e.g., EEA and Eionet) and international organisations (e.g., United Nations Economic Commission for Europe (UNECE) and the United Nations Environment Programme (UNEP), successfully expanding its influence beyond the EU. However, despite institutional buy-in and endorsement, SEIS has seen limited activity in practical terms. This is demonstrated by its low level of uptake by the scientific community. No peer-reviewed publications that specifically review and/or address SEIS was in fact found by the author as compared to other information-sharing initiatives, such as earth observation systems (e.g., Withee et al., 2004; Lucas et al., 2015; Nativi et al., 2015). Even with data sharing and streamlining of environmental reporting being high on the EU agenda (e.g., European Commission, 2017a), SEIS has had limited impact on EU and national policy. SEIS has furthermore only been notably implemented through four EU-funded projects to date, namely ENI SEIS I and II (which are ongoing) projects[2], the concluded MONECA (Environmental Monitoring in Central Asia) project,[3] and an ongoing project managed by UNEP on capacity building for environmental data sharing and reporting in support of SEIS.[4] Reporting activities by Eionet also take into account the principles and goals of SEIS.

The implementation of SEIS in the Pan-European region is moreover being conducted through the UNECE Committee on Environmental Policy, more specifically, the Working Group on Environmental Monitoring and Assessment and the Joint Task Force on Environmental Statistics and Indicators.[5] Other regional capacity building projects that focus on SEIS and on environmental statistics are being implemented through the UNECE and UNEP. These projects have a strong focus on building national capacities to produce data and indicators for reporting on the environmental dimension of the Sustainable Development Goals (SDGs). As such, while the impact on policy and science has been low (e.g., not referenced in scientific literature), international collaboration on SEIS has been a success with, amongst other things, the 2016 progress report on SEIS being launched during the Eight Environment for Europe (EFE) Ministerial Conference in Batumi, Georgia (UNECE, 2016). One highlight in this context was the declaration from the ministerial conference setting out that all countries in Europe and Central Asia should have SEIS in place by 2021 (Batumi Declaration, para. 10) as a part of efforts to establish a regular process of environmental reporting based on the framework it provides.

Having this background in mind, SEIS primarily functions within this framework of enhanced cooperative networking with and among national authorities concerning environmental data and statistics in Europe and Central Asia. The underlying driver being that all the environmental data being produced should serve multiple policy purposes, including reporting under multilateral environmental agreements. This includes, but is not limited to, efforts that simplify,

[1] The Eigth EFE ministerial conference took place on 8-10 June 2016, Batumi, Georgia.

[2] See https://eni-seis.eionet.europa.eu.

[3] See http://naturalresources-centralasia.org/flermoneca/index.php?id=17.

[4] See https://www.unenvironment.org/explore-topics/environment-under-review/what-we-do/seis-project/why-do-shared-environmental.

[5] See http://www.unece.org.

streamline and modernise existing environmental monitoring systems and processes as well as make them web-enabled. Moreover, SEIS should overhaul the accepted approach towards environmental reporting, moving it from individual countries and regions to making it available to international organisations, facilitating the creation of online systems that supply information to multiple users (people and machines) as well as making data comparable across wider regions. This is reflected in the proliferation of real-time and integrative web-based data portals, such as UNEP Live[6] and the EU's Open Data Portal.[7]

3. Method

The present paper utilises data collected for the 2016 progress report on the establishment of SEIS in the pan-European region (UNECE, 2016). The following sub-sections will detail the approach taken by the author and some limitations with regards to the available data.

3.1. Approach

The SEIS report is based on the review of 67 data flows that should be accessible in common formats and standards, as agreed by the Member States of the UNECE Committee on Environmental Policy (ECE/CEP/2015/2). The data flows cover 36 indicators (plus 4 placeholders) that are grouped into seven thematic areas (see Appendix 1):

(1) Air pollution, air quality and ozone depletion: 3 indicators and 25 data flows.
(2) Climate change: 3 indicators and 4 data flows.
(3) Water: 16 indicators (one integrated) and 20 data flows.
(4) Biodiversity: 4 indicators (plus 2 placeholders) and 4 data flows.
(5) Land and soil: 2 indicators and 2 data flows.
(6) Energy: 4 indicators (plus 2 placeholders) and 4 data flows.
(7) Waste: 4 indicators and 8 data flows.

It can also be noted that the complete list of UNECE indicators includes 3 additional thematic areas (agriculture, transport and environmental accounting), covering 6 indicators and 3 placeholders, which were not included into the review. This was based on a decision made by the Working Group on Environmental Monitoring and Assessment.[8]

Data collection and analysis for the SEIS report was conducted by the author in 2015 as part of a desktop study. The review process was implemented in three steps:

- First, data was collected on all relevant information related to each data flow available online and across all national platforms.
- Second, all data flows were rated according to five review criteria (see Table 1). The rating process was achieved by evaluating the collected material and asking simple dichotomous (yes/no) questions in line with each review criteria. The rating was done with a "yes" (value of 1) or "no" (value of 0) depending on whether the requirements for each review criterion were met. This generated a score that ranged between 0 and 5 for each data flow.
- Third, the analysis included a validation process whereby the respective agencies and ministries in charge of the data flows were requested to validate the results.

Each criterion for review was given equal weight when assessing the effective production and sharing of the data flow. This yielded an aggregated performance score, which is presented as a quantitative measurement as a percentage that refers to a country's overall progress in implementing SEIS.

3.2. Limitations to the study

The review criteria (see Table 1) had some inherent limitations, such as "online accessibility", which does not fully reflect how data flows are being published in practice. This issue was, in part, addressed by complementing the review with an extended and more comprehensive analysis for a smaller sample that was available online (see UNECE (2016)).

Neither data quality nor accepted standards for data production were adequately reflected as part of the review criteria. While it was not possible to amend this issue for the 2016 SEIS progress report, a new collaborative assessment framework has been developed for the next reporting cycle. The trade-off is that a comparison of SEIS establishment will be difficult (e.g., having a baseline), but it will allow for in-depth analysis of data quality, which is lacking to date, as well as assessing the practical uses of SEIS indicators (e.g., SOERs, use in policy formulation and international reporting).

4. Results and analysis

The following presents some of the generic results from the SEIS review:

- The performance status – as related to the availability and accessibility of the 67 data flows – was reviewed for 50 pan-European countries, see UNECE (2016) for a complete list of countries. 27 countries validated the results.
- 55% of all data flows were, as an aggregated average, available online. The reviewed countries do however differ significantly, ranging from having all (100%) to no data flows (0%) available online. The aggregated performance score for all countries was 51%; see Fig. 1 and Appendix 1.
- The thematic performance score for biodiversity (63%), climate change (63%), energy (61%), air pollution and ozone depletion (53%) is above the aggregated performance score and at an average level or below for waste (51%), land and soil (45%) as well as water (42%). Countries vary significantly for each thematic area, running the gamut from 0 to 100%.
- Individual data flows demonstrate that the emissions of nitrogen oxides (94%) and sulphur dioxide into the air (91%) are the most accessible data flows. These are followed by other types of air emission data (e.g., carbon monoxide, non-methane volatile organic compounds and ammonia), some waste data (e.g., total waste generation), greenhouse gas emissions, biodiversity data (e.g., total area under protection) and air quality data (e.g., concentration of nitrogen dioxide). See Appendix 1.
- Least accessible data flows are those related to water (e.g., populations connected and not connected to water supply infrastructure and a water exploitation index). These are followed by other water-related data flows, persistent organic pollutants air emission data and some data flows for waste. These range across an average of 24%–39% in terms of accessibility, see Appendix 1.
- Information on data sources (96% for the available data flows and 53% of the total) and interpretation (97% for the available data flows and 53% of the total) is provided, including information on applied methodologies (90% for the available data flows and 49% of the total). Again, the results vary significantly across countries and thematic areas.
- In many cases, time series are out of date, meaning that times series more recent than 2012 were not available. 79% for the available data flows (44% of the total) were considered as up to date.

The varied availability of quantitative information across the respective thematic areas highlights that certain domains may be more

[6] See https://environmentlive.unep.org/.
[7] See https://data.europa.eu/euodp/data/.
[8] See http://www.unece.org/env/indicators.html.

Table 1
Review Criteria.

Criteria	Description
I. Online accessibility	Dataset can be easily accessed by anybody, at any time, online.
II. Update regularity	Dataset is updated with figures of the latest agreed production period.
III. Production methodology	Detailed information on standard methodologies and calculation methods for the production of the dataset is provided. The detailed information should further confirm that the applied methodology is in accordance with the agreed standard methodology for the production of the dataset.
IV. Data interpretation and use	Dataset is supported by information about what it presents and how to understand the changes in datasets over time. Information should also be provided on how the collected data was interpreted and used (e.g., for SOERs or to support environmental policymaking). Information should furthermore be provided in the national language and in an international language (English and/or Russian).
V. Data sources	The institution responsible for the production of the dataset, its source and contact details are available.

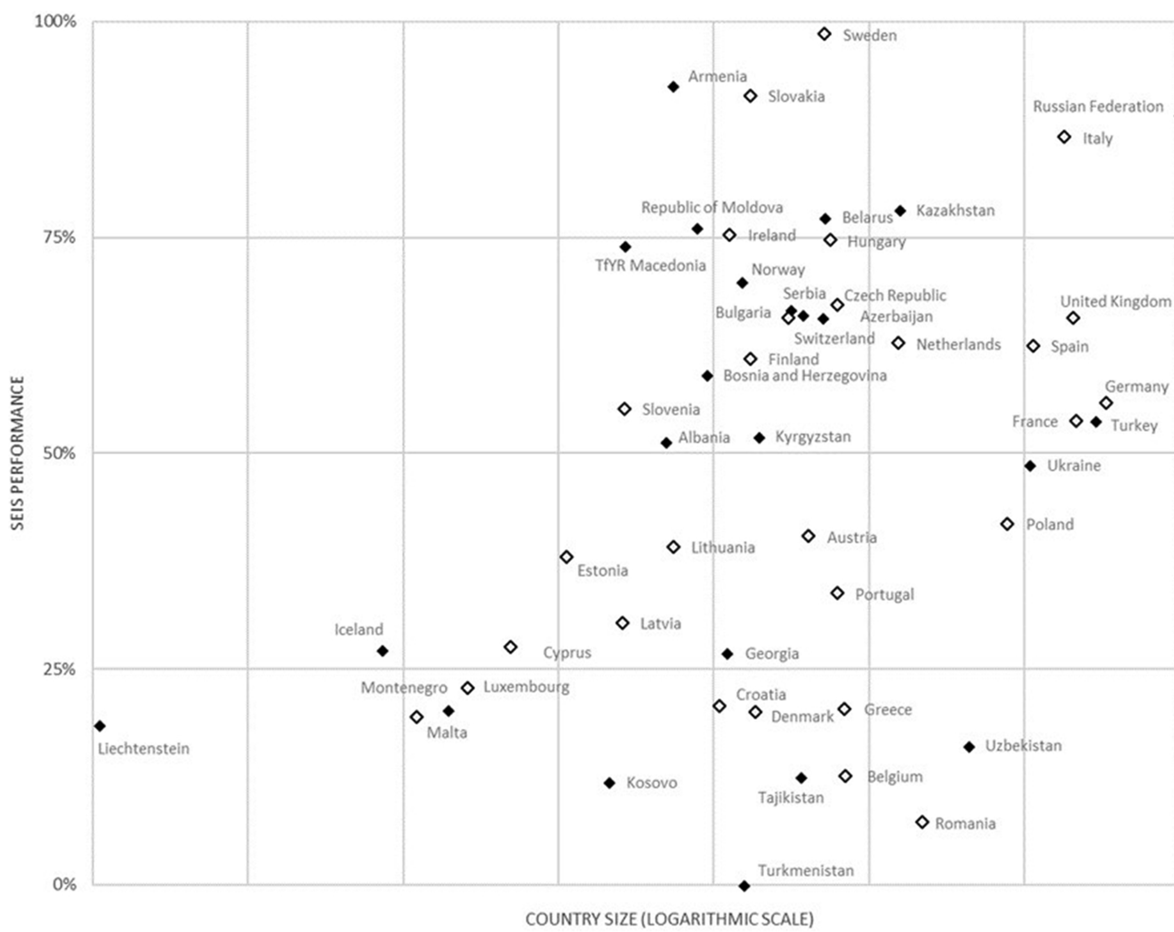

Fig. 1. SEIS performance across Europe and Central Asia.

prioritised than others. For example, the recent global attention given to air quality and climate change, both in public media and through recent international developments (e.g., Paris Agreement), may explain why these data flows are more readily accessible. This relates not only to those data flows associated with SEIS but also other national and international agencies and platforms that provide real-time access to information on air emissions (e.g., European Air Quality Index)[9]. The absence of waste statistics emphasises another issue, namely, the lack of an international framework and classification for waste. This would suggest on the one hand that countries do not collect data on waste and on the other hand that it is not comparable in cases where waste statistics are being collected, as such this is an issue related not only to data content but also to data governance. Water-related data flows are also seemingly not adequately published online. Differences in the accessibility of water-related data flows can presently not be fully explained in terms of variations in legal reporting obligations nor by variations in national legislation (e.g., confidentiality requirements). It may as such be an issue of infrastructure deficiencies needed to make data accessible. What these variations tell us is that different sectors face different challenges associated with the respective SEIS pillars and that the corresponding solutions are contextually specific.

While the results demonstrate gaps and areas in need of improvement, such as the problems associated with waste statistics, it also validates efforts to establish SEIS and data harmonisation based on the increasing volume of comparable environmental data across the pan-European region. This would suggest that SEIS, as a policy instrument, has the potential to accelerate and strengthen pan-European cooperation around a shared framework for environmental data collection (e.g., improving national capacities to meet international reporting obligations and report on the state of the environment). For instance, the review demonstrates that public authorities are increasingly providing access to relevant information such as data production methodologies,

[9] See http://airindex.eea.europa.eu/.

how data is being used and data sources, this can in turn be accessed (e.g., by private individuals) and used for different purposes. These developments are in line with the SEIS principles and other data-related initiatives (e.g., Arhus convention). However, the lack of systematic online publishing as part of certain thematic areas (e.g., water, land and soil) and significant national variations regarding data accessibility, including the prevalence of fragmented data platforms, highlight that there are still significant challenges ahead, particularly pertaining to content, infrastructure and governance. Moreover, the 2016 SEIS progress report does not address certain fundamental issues, namely, the extent to which SEIS indicators are being used in SOERs and by extension also in policy-making. This will be a crucial element for the next review as it will help to determine the real added value of SEIS.

Fig. 1 also makes a distinction between EU Member States and other European and Central Asian countries. It is interesting to note that many EU Member States are underperforming when compared to other countries, despite the European Commission being the driving force behind the SEIS concept. Two main reasons for this were identified: The first is the varying definitions of SEIS compliance. In the case of this review, it was presumed – in line with the SEIS principles – that a data flow would have to be accessible to be considered. This varies somewhat from the standard applied by the EEA and Eionet, where data flows are managed by the EEA but not always made publicly available. Several EU Members States consequently view themselves as being SEIS compliant by providing relevant data flows to the EEA as a data custodian. This is however seen as a misconception as SEIS principles articulate the need to make data readily accessible to all users (European Commission, 2008; 2013). The second reason some EU Member States lag behind is their varied engagement in the pan-European SEIS process. Many do not actively participate in the Working Group on Environmental Monitoring and Assessment, which can be considered as a key driver for the uptake of the SEIS concept in countries outside the EU. This also alludes to a lack of awareness and/or importance attached to SEIS within the EU.

In line with this later argumentation, it can be noted that steps were taken by some countries during the period of the SEIS review to improve accessibility of SEIS-related data and information. One interesting observation from this process is that the absence of certain data flows online does not imply that they do not exist and accordingly, in certain cases, countries could improve their performance score by simply uploading and updating content on pre-existing platforms that facilitate data sharing and exchange. This emphasises the relevance and equal importance of all three SEIS pillars (content, infrastructure and cooperation). Accessibility is not only about updating content and improving data infrastructure but about improving institutional practices (or data governance). It highlights that enhanced data sharing, in the short-term, does not need to be expensive and can be improved through better practice and raising public awareness.

5. Discussion

Current expectation is that environmental data and information should flow unproblematically between data producers, repositories and users – be they public institutions, private organisations or the public. However, the mechanisms behind environmental data flows, which may range from the collection to the iterative work of processing and reformatting data, strive to produce, interpret and evaluate an integrated result, although this only captures a fraction of the complexity of data work. Beyond the production of understandable information are its use, uptake and dissemination, whether for policy-making or raising awareness (Rennie, 2016; Azzone, 2018). There is, for example, a paradox in the fact that relevant assessments, reports and publications are not being used in policy-making even though their production is obligatory (Engel-Cox and Hoff, 2005; Holmes and Clark, 2008; Bilotta et al., 2014; Soomai, 2017). This may be due to organisational traditions and perspectives that assessments should only support rather than determine policy, the political context or other policy commitments (Turnpenny et al., 2008). Policy development is ultimately framed by the political and social context in which it is formed, making it challenging to transform policy-making to be data-driven.

Research on data sharing furthermore largely takes place in thematic silos that focus on specific issues, without taking an integrated approach that allows for a more complete understanding of the data flows and lifecycles involved. This is compounded by the fact that most of these efforts only focus on one SEIS pillar at a time. Take for example data infrastructuring, where there is a significant body of literature on the topic (Star and Ruhleder, 1996; Star and Bowker, 2002), ranging from cyberinfrastructures (Pipek and Wulf, 2009; Tenopir et al., 2011) to new forms of knowledge production (Hessels and van Lente, 2008; Gustavsen, 2003; Gibbons et al., 1994) and data-driven sciences (Arms and Larsen, 2007). On the governance side, there is extensive research on the ethics of data sharing, in particular considering confidentiality in medical research (Pearce and Smith, 2011), new issues of data interoperability (Visser et al., 2001; Baker et al., 2005; Ribes et al., 2005) and research on data repositories and the interdependent relationships among and between multiple institutional arrangements (Cragin et al., 2010; Baker and Yarmey, 2009). On the content side, there is research on biodiversity data (Wetzel et al., 2018; Proença et al., 2017), environmental accounting (Liu et al., 2018; Lomas and Giampietro, 2017), and big data (Azzone, 2018; Lokers et al., 2016).

It can also be noted that thematic areas, such as earth observations and spatial data infrastructure, which facilitate the sharing of environmental data and information (Giuliani et al., 2011; Uhlir et al., 2009), are fundamentally driven by policy, examples being the EU's INSPIRE directive and Copernicus programme. Consequently these topics not only occupy a large space in the scientific literature (Kansakar and Hossain, 2016) but they also represent areas of research supported through significant public funding. This also relates to work on public participation and the access to environmental information, where the Arhus Convention has been instrumental in the adoption of two EU directives (Directive, 2003/4/ECa; 2003/35/ECb) as well as several other environmental directives. In this context, the European Commission recently issued a guidance document that clarifies how individuals and organisations can challenge decisions, acts and omissions by public authorities related to EU environmental law at the national level (European Commission, 2017b). There also continues to be a significant volume of academic work on public participation and access to environmental information (e.g., Hartley and Wood, 2005; Kierkegaard, 2009; Mauerhofer, 2016). These examples demonstrate the relevance of research on data sharing as well as the extent to which the scientific community is being driven by policy priorities (and vice versa).

Having this contextual background in mind, this article set out to present the evolutionary state of SEIS and to consider how SEIS may affect SOER as well as policy-making. Little is in fact still known about the connections and interactions with regards to the production, management and use of environmental data and information, even more so when it comes to the harmonisation and integration of environmental data and information on the international level. While there are limitations to the SEIS progress report, it spotlights one key element in this context, namely, the sharing and harmonisation of data. Sharing environmental data and information may seem straightforward, but it continues to be fraught by technical (e.g., ICT-related infrastructure), governance (e.g., institutional support) and resource-related (e.g., human resources) challenges. For instance, despite significant institutional support at the EU (e.g., EEA and Eionet) and international level (e.g., UNECE Working Group on Environmental Monitoring and Assessment), there are significant and persistent challenges in developing comparable environmental indicators even across just the pan-European region, despite the fact that these are based on long-standing international reporting obligations. This is without considering whether the environmental indicators are in turn used in SOERs. Furthermore, when thinking about data policy, the focus often falls on what is being withheld or what is missing rather than considering what is being provided. This similarly concerns the suboptimal use of information, particularly where comprehensive data flows and high-quality information is not being used adequately in support of policy-making or where there is selective use of statistical information. All these elements are of serious concern as it highlights the subjective and biased use of environmental information, often for political purposes rather than data-driven policy-making.

SEIS has then readily rectifiable flaws in this context, namely discrepancies with regards to the availability and accessibility of data flows and indicators, both in terms of variations across the themes (e.g., waste and water) and across countries, as well as improving data quality (e.g., up-to-date statistical indicators). From this the implementation of SEIS can only be achieved through concerted action between all actors involved in data production and that the solutions would need to be context specific. For instance, some countries lack the expertise and capacity necessary to regularly produce usable data and make available updated time series, some lack the necessary financial resources and infrastructure to make data accessible, while others lack the governance structures and institutional support needed to implement SEIS.

These obstacles are neither unsurmountable nor new, which essentially means that SEIS could become operational across the pan-European region if given sufficient political priority and financial resources. One fundamental concern nevertheless remains, namely, whether having an operational SEIS would equate to better policy-making? The initial premise would be that access to relevant, up-to-date and high-quality environmental data is the first step towards this objective, however, lessons from the past also demonstrate that larger information infrastructure projects frequently fail if they do not meet the needs of the end users (Edwards et al., 2007, 2009). This is often the case when neglecting either the technical, social or governance systems of the implementing environment. As such, if SEIS is to become a successful initiative, it is also clear that a better understanding of data use is needed, especially given the disconnect between data production and data use. We may be producing data just for the sake of fulfilling national and international reporting obligations, forgetting that relevant data should underpin policy-making. Even more, while we operate under the assumption that “better policy requires better data” we neglect the political and social dimensions that shape policy-making. While the use of data to inform policy decision making has clearly increased, we need to gain a better understanding of the willingness to use data.

6. Conclusions

It should right from the outset be recognised that SEIS is not a standalone initiative. The EU is engaged in several major initiatives aimed at improving access to environmental information and data, and SEIS finds itself in a field where it is provided comparatively little priority and attention. It is nevertheless an initiative through which important lessons can be learnt. For instance, when considering new initiatives within the context of changing data practices, on-going institutional rearrangements and emerging technological innovations, SEIS highlights the importance of bridging the gap between environmental data production, data sharing, and policy-making. Furthermore, it emphasises the importance of taking an integrative approach that assigns equal weight to each SEIS pillar, namely, content, infrastructure and governance.

The progress and gaps identified in the SEIS report demonstrate the continued need for assistance to achieve the production and sharing of agreed environmental indicators and associated data flows. Against this background, questions arise as to whether the applied models for data sharing can be implemented with equal success across different regions and countries that are characterised by heterogeneous and complex data practices and data flows. It would, as such, be relevant to provide a more holistic and complete picture relating to data sharing, access, practices and quality as well as information infrastructures. Even more important would be the need to address the use of environmental data and information as a prerequisite for policy-making at all levels of governance. For instance, national authorities need high-quality information to be prepared for emergencies such as floods or toxic spills as well as to fulfil the many legal obligations to report on issues such as air and water quality. Policy-makers also need high-quality, up-to-date and timely environmental data on the state of the environment to better develop and implement environmental policy and to then assess whether these policies are working.

SEIS and on-going international collaborative efforts to foster data sharing practices in the pan-European region provide one development pathway that could improve policy-making. More importantly, it could provide the framework for a synthesis of knowledge on the environmental challenges facing not only the region but also the global community. As one example of this, SEIS could contribute to monitoring progress towards the Sustainable Development Goals (SDGs), helping to ensure that the SDG targets are turned into appropriate management tools and implementation strategies. This would include addressing the use of new types of data, data work and knowledge production. Perhaps most importantly, results from the SEIS progress report demonstrate the pressing need for a better understanding of environmental data types, data packaging and data flows across multiples contexts, epistemic cultures and policy-making, which warrants further investigation. Future research could look into whether SEIS-related data flows are truly comparable across the pan-European region and whether these data flows are being used by policy-makers and stakeholders to produce national SOERs as well as monitor progress towards policy targets and objectives.

Appendix 1

Table A1.

Table A1
Complete list of reviewed SEIS indicators.

		Accessibility	Up-to-date	Production methodology	Data int./use	Data source	Aggregated Score
Air pollution, air quality and ozone depletion							
1	*Emissions of sulphur expressed in sulphur dioxide (total, stationary and mobile sources)*	91%	70%	78%	89%	89%	**83%**
2	*Emissions of nitrogen oxides expressed in nitrogen dioxide (total, stationary and mobile sources)*	94%	76%	81%	94%	93%	**88%**
3	*Emissions of non-methane volatile organic compounds (NMVOCs) (total, stationary and mobile sources)*	78%	65%	70%	78%	76%	**73%**

(*continued on next page*)

Table A1 (*continued*)

		Accessibility	Up-to-date	Production methodology	Data int./use	Data source	Aggregated Score
4	*Emissions of ammonia (total, stationary and mobile sources)*	76%	59%	70%	76%	76%	**71%**
5	*Emissions of carbon monoxide (total, stationary and mobile sources)*	81%	67%	74%	81%	81%	**77%**
6	*Emissions of lead (total, stationary and mobile sources)*	54%	46%	50%	52%	52%	**51%**
7	*Emissions of cadmium (total, stationary and mobile sources)*	52%	41%	50%	50%	52%	**49%**
8	*Emissions of mercury (total, stationary and mobile sources)*	52%	41%	46%	50%	50%	**48%**
9	*Emissions of polycyclic aromatic hydrocarbon (PAH) (total, stationary and mobile sources)*	43%	33%	37%	41%	39%	**39%**
10	*Emissions of polychlorinated biphenyl (PCB) (total, stationary and mobile sources)*	35%	24%	31%	33%	33%	**31%**
11	*Emissions of polychlorinated dibenzo-p-dioxin and polychlorinated dibenzofuran (PCDD/F) (total, stationary and mobile sources)*	34%	28%	31%	33%	33%	**32%**
12	*Emissions of total suspended particles (TSP) (total, stationary and mobile sources)*	48%	39%	39%	46%	44%	**43%**
13	*Emissions of PM_{10} (total, stationary and mobile sources)*	74%	56%	57%	74%	74%	**67%**
14	*Emissions of $PM_{2.5}$ (total, stationary and mobile sources)*	65%	48%	50%	61%	65%	**58%**
15	*Annual average concentration of sulphur dioxide*	72%	59%	63%	67%	67%	**66%**
16	*Annual average concentration of nitrogen dioxide*	72%	61%	65%	72%	70%	**68%**
17	*Annual average concentration of ground-level ozone*	72%	59%	67%	72%	72%	**69%**
18	*Annual average concentration of PM*	67%	54%	59%	67%	65%	**62%**
19	*Total ozone depleting potential(ODP) of chlorofluorocarbons (CFCs)*	52%	33%	41%	44%	46%	**43%**
20	*Total ODP of Halons*	37%	28%	31%	31%	31%	**32%**
21	*Total ODP of other fully halogenated CFCs*	35%	24%	31%	30%	33%	**31%**
22	*Total ODP of carbon tetrachloride*	35%	24%	31%	30%	33%	**31%**
23	*Total ODP of 1,1,1-trichloroethane*	35%	26%	31%	30%	33%	**31%**
24	*Total ODP of hydrochlorofluorocarbons (HCFCs)*	44%	35%	41%	39%	43%	**40%**
25	*Total ODP of methyl bromide*	39%	31%	35%	33%	37%	**35%**
Climate Change							
26	*Average annual deviation from the long-term average temperature*	67%	54%	63%	67%	67%	**63%**
27	*Annual deviation from the long-term average precipitation*	57%	46%	57%	57%	57%	**55%**
28	*Aggregated GHG emissions including emissions/removals from LULUCF*	72%	61%	69%	72%	70%	**69%**
29	*Aggregated GHG emissions by energy, industrial processes, solvent and other product use, agriculture, land use and forestry, waste*	69%	54%	65%	69%	67%	**64%**
Water							
30	*Renewable freshwater resources*	33%	26%	30%	31%	31%	**30%**
31	*Total freshwater abstraction (per river basin, season and year)*	52%	37%	44%	50%	46%	**46%**
32	*Freshwater abstraction by water supply industry, households, agriculture forestry and fishing, manufacturing, electric industry, other economic activities*	41%	33%	37%	39%	37%	**37%**
33	*Water exploitation index*	30%	20%	24%	28%	24%	**25%**
34	*Total freshwater available*	44%	37%	41%	44%	43%	**40%**
35	*Total freshwater use*	57%	44%	48%	54%	54%	**51%**
36	*Losses of water during transport*	35%	30%	33%	33%	31%	**32%**
37	*Freshwater use by households, agriculture forestry and fishing of which irrigation, manufacturing, electric industry, other economic activities*	50%	37%	44%	50%	48%	**46%**
38	*Population connected and not-connected to water supply industry*	24%	22%	24%	24%	24%	**24%**
39	*Mean concentration of BOD in major rivers*	56%	43%	44%	50%	48%	**48%**
40	*Mean concentration of ammonium in major rivers*	56%	44%	46%	54%	48%	**50%**
41	*Mean concentration of phosphates in major rivers*	65%	48%	54%	63%	61%	**58%**
42	*Mean concentration of nitrates in major rivers*	69%	54%	59%	67%	63%	**62%**
43	*Mean concentration of total phosphorus in major lakes*	52%	41%	43%	50%	48%	**51%**
44	*Mean concentration of nitrates in major lakes*	52%	43%	44%	50%	48%	**47%**
45	*Mean concentration of nitrates in groundwater*	52%	39%	44%	50%	52%	**47%**
46	*Population connected to a wastewater collecting system (with and without treatment facilities)*	31%	26%	26%	31%	31%	**29%**
47	*Wastewater treated in urban wastewater treatment plants (primary, secondary, tertiary)*	39%	30%	33%	39%	39%	**36%**
48	*Wastewater discharged*	46%	39%	46%	46%	46%	**45%**
49	*Non-treated/not adequately treated wastewater*	35%	33%	31%	35%	35%	**34%**
Biodiversity							
50	*Total areas under protection (IUCN-categories)*	76%	61%	65%	72%	70%	**69%**
51	*Total forest area (forest and other wooded land)*	74%	63%	63%	69%	70%	**68%**
52	*Number of species protected — mammals, birds, fishes, reptiles, amphibians, invertebrates, vascular plants, mosses, lichens, fungi, algae*	61%	52%	54%	61%	57%	**57%**
53	*Number of species threatened — mammals, birds, fishes, reptiles, amphibians, invertebrates, vascular plants, mosses, lichens, fungi, algae*	63%	46%	57%	63%	59%	**58%**
Land and Soil							
54	*Total land uptake*	54%	41%	52%	54%	52%	**50%**
55	*Land uptake by mining and quarrying, construction, manufacturing, technical infrastructure, transport and storage infrastructure, residential including recreational, landfills waste dumps tailing pits*	41%	33%	39%	41%	41%	**39%**
Energy							
56	*Total final energy consumption*	72%	59%	69%	72%	70%	**69%**
57	*Final energy consumption by category (industry, transport, households, commercial and public services, agriculture forestry and fishery, non-specified, non-energy use)*	67%	59%	65%	67%	67%	**65%**
58	*Total primary energy supply (production, export, import, bins, stock changes)*	57%	52%	56%	56%	57%	**56%**

(*continued on next page*)

Table A1 (*continued*)

		Accessibility	Up-to-date	Production methodology	Data int./use	Data source	Aggregated Score
59	*Total primary energy supply by source (coal, crude oil, oil products, natural gas, nuclear energy, hydropower, geothermal and solar energy, biofuels and waste, electricity, and heat)*	56%	52%	56%	54%	56%	**54%**
Waste							
60	*Total waste generation*	74%	56%	69%	74%	74%	**69%**
61	*Waste generation by source (agriculture forestry and fishery; mining and quarrying; manufacturing; electricity, gas, steam and air conditioning supply; construction; other economic activities; households)*	63%	48%	59%	63%	63%	**59%**
62	*Hazardous waste generated*	69%	52%	63%	67%	67%	**63%**
63	*Hazardous waste imported*	37%	31%	35%	35%	37%	**35%**
64	*Hazardous waste exported*	39%	31%	35%	39%	39%	**37%**
65	*Total hazardous waste treated or disposed*	57%	44%	52%	57%	57%	**54%**
66	*Hazardous waste treated or disposed of which recycling, incineration, landfilling, other disposal*	59%	39%	56%	59%	59%	**54%**
67	*Stock of hazardous waste*	37%	26%	35%	37%	37%	**34%**
	Aggregated Performance Score	**55%**	**44%**	**49%**	**53%**	**53%**	**51%**

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