Accounting for Environmental Activity: Measuring Public Environmental Expenditures and the Environmental Goods and Services Sector in the US

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Abstract

How much of the economy is focused on protecting, rehabilitating, or managing the environment? To answer this question, we develop a proof-of-concept environmental activity account to quantify the environmental goods and services sector (EGSS) in the United States. Methodologically, we employ a satellite account approach similar to the method used by the US Bureau of Economic Analysis (BEA) to quantify other sectors of the economy (e.g., Outdoor Recreation Account, Marine Economy Account) while following the accounting principles and methods outlined in the SEEA Central Framework (SEEA-CF). This approach draws on detailed internal supply-use data, drawn primarily from Census's Industry and Product data along with other supplemental sources. Overall, we estimate gross output of the EGSS was $725 billion in 2019, or about 1.9% of the total gross output of the US economy. Government expenditures (across all levels) comprise a substantial portion of the EGSS in the US, as the public sector accounted for about 27% of total EGSS output ($197 billion) in 2019. Although these estimates are still preliminary and are not official statistics, the goals of this research are to provide new insights into classification and measurement challenges in producing environmental activity accounts more generally, while also documenting data gaps and accounting issues in the US context more specifically.

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1. Introduction

During the 20th century, the national economic accounts had largely focused on measuring the economy and its conventional components, like consumption or investment expenditures as parts of Gross Domestic Product (GDP). While the United States and many other countries' governments had produced various economic statistics earlier in the 20th century, it was not until the last half of the century when most countries coalesced around a common set of accounting principles and standards for measuring aggregate economic activity and its component parts, namely the United Nation's System of National Accounts (SNA).[1] The most well-known of these official estimates, GDP, provides one measure of a country's economy – the market value of all final goods and services in a country over a given period of time. Generally, these aggregate statistics are critical for tracking a nation's economic growth and performance over time. Yet, as the economy changes, national statistical offices (NSOs) that produce these statistics must also continually adapt to the needs of decision-makers in the public and private sectors by developing new accounts. For instance, 21st century environmental challenges and policy demands have spurred rapidly expanding interest in environmental-economic accounts, which would track the stocks and flows of environmental (natural capital) assets, ecosystem services, and aspects of the economy related to environmental protection, preservation, and natural resource management (Obst and Vardon 2014; Vardon et al. 2016; Boyd et al. 2018; Hein et al. 2020).

As a step toward addressing these challenges and to standardize collection and dissemination of economic information related to the environment, the UN Statistical Commission had adopted two manuals as new statistical standards in the last decade or so: the System of Environmental-Economic Accounting (SEEA) Central Framework (2012 – SEEA-CF) and Ecosystem Accounting (2021 – SEEA EA).[2] These serve to complement the SNA and extend the scope of the national accounts by measuring the assets and services flowing from the environment. To do this, the manuals prescribe methods for producing satellite accounts or supplementary

[1] See Coyle's (2015) book *GDP: A Brief but Affectionate History* for a more detailed history of GDP measurement, the national economic accounts, and what is (and is not) measured in these accounts.

[2] Only a portion of the latter manual, SEEA EA, was approved by the UNSC as a statistical standard, designating the chapters on valuation of ecosystem services as still experimental and in need of further development. When it was up for approval, experts from numerous national statistical offices voiced objections to the valuation methods in the manual (e.g., see Brown et al. 2021), agreeing with the UNSC, as the SEEA EA chapters included valuation methods seen as incompatible with the SNA framework, among other criticisms.

environmental-economic statistics to complement the core SNA accounts by using a common accounting and valuation framework.[3] Specifically, SEEA accounts measure physical flows and monetary values of environmental-economic activities, assets, and ecosystem services, including land, water, fisheries, timber, mineral resources, and other types of natural resources. According to the UN Statistical Division as of 2020,[4] 90 countries now compile or produce at least one account using the accounting approaches prescribed by the SEEA-CF or SEEA-EA. Many of these countries use these accounts to support public and private decision-making at national and local levels, as well as support international reporting on global conventions and agreements like the UN Framework Convention on Climate Change, Convention to Combat Desertification, and the Sustainable Development Goals (SDGs). The UN and non-governmental institutions like the International Monetary Fund (IMF) also use information from these accounts for a variety of purposes, like global climate change indicators and to track international progress on the environment for the purposes of policy analysis.[5]

One notably absent country from reporting official environmental-economic accounts is the United States. While the US government reports a vast amount of information on the environment and the economy across its federal statistical system, it does not yet construct cohesive SEEA-based environmental economic accounts,[6] as official work on these types of accounts was halted in the 1990s.[7] In more recent years, the US has, however, developed pilot accounts as part of a multi-agency research effort to explore the feasibility of constructing accounts using existing data. This included SEEA-based pilot accounts for water (Bagstad, et al. 2020), land (Wentland, et al. 2020; Wentland, et al. 2023), air emissions (Chambers 2023), and various ecosystem services (Warnell, et al. 2020, Heris, et al. 2021). We extend this research effort by constructing a pilot environmental goods and services sector (EGSS) account, drawing new

[3] For more information about BEA's current satellite accounts, see: https://www.bea.gov/resources/learning-center/what-to-know-special-topics

[4] For more information, see: https://seea.un.org/content/frequently-asked-questions#How_many_countries

[5] See, for example, the IMF's Climate Change Indicators Dashboard which came online in April 2021: https://climatedata.imf.org/

[6] The US Bureau of Economic Analysis (BEA) does, however, produce thematic satellite accounts for Outdoor Recreation and the Marine Economy. They both provide timely and useful statistics for specific aspects of the economy, but this industry-specific approach accounts for only part of the role that environmental activity plays in the US economy and is narrower in scope than the suite of SEEA-based accounts. For more information on these accounts, see: https://www.bea.gov/data/special-topics

[7] For a summary of this effort by the BEA and recommendations for the future of environmental economic accounts in the US, see: National Research Council. 1999. *Nature's Numbers: Expanding the National Economic Accounts to Include the Environment*. Washington, DC: The National Academies Press. https://doi.org/10.17226/6374.

insights about this sector from our (albeit preliminary) estimates. Further, this research also documents measurement and classification challenges that would be relevant for a more comprehensive implementation, both in the US and abroad.

Environmental activity accounts include a set of functional satellite accounts that quantify transactions in the economy undertaken to protect, rehabilitate, or preserve the environment.[8] To be clear, output like solar panels, wind turbines, catalytic converters, and forest management expenditures are already a part of the economy as traditionally measured in the National Income and Product Accounts, but are not currently disaggregated in the US accounts to areas relevant for understanding the size and scope of environmental-economic activity. Collectively, these accounts would comprise three areas of environmental activities in the economy: 1) environmental protection expenditures (EPE) and resource management expenditures, 2) environmental taxes and subsidies, and 3) environmental goods and services sector (EGSS). The scope of this paper concentrates on the last area, including a breakout quantifying gross output across both private and public sectors. While preliminary, the pilot estimates we construct in this paper provide the first SEEA-based accounting of the size and growth of the EGSS in the US across two recent periods (2015 and 2019). This includes information about the relative size of its components and the estimates are broken down by categories consistent with international guidelines. We then discuss how a preliminary EGSS account can provide new insights into the supply and use of products for environmental protection and resource management in the US economy.

This work builds on prior efforts within the US Government (described in the next section) that set out to measure the "green economy" or "green jobs" in ways that predated the SEEA-CF. Methodologically, our research marks the first time the US has constructed this type of account following the prevailing methods and scope outlined in Chapter 4 of SEEA-CF for classifying environmental goods and services, which is key for both international comparability and consistency with our own national economic accounts. While the data for this account come from multiple sources, our approach chiefly relies on leveraging detailed internal supply-use tables (SUT) data, drawn primarily from Census's Industry and Product data, to classify economic output that are primarily environmental in nature. This approach borrows from the established approach

[8] More specifically, according to the SEEA-CF manual, these accounts quantify and value "economic activities whose primary purpose is to reduce or eliminate pressures on the environment or to make more efficient use of natural resources" (SEEA-CF, §1.30).

used by the US Bureau of Economic Analysis (BEA) to produce other satellite accounts (albeit different in scope) like Outdoor Recreation and Marine Economy accounts. The structure of this data follows the North American Product Classification System (NAPCS) for products associated with North American Industry Classification System (NAICS) industries, which align well with SEEA-CF definitions in many cases (and, in other cases not so well, as we will discuss at more length later in the paper).

This paper contributes to the economic measurement literature by advancing practical solutions to a number of key classification and valuation issues faced by users of either NAICS or the European Nomenclature of Economic Activities (NACE) system. A common thread through prior research efforts in the US on environmental-economic accounting is that little is known about how far we can get with existing data until we actually try to construct an account (Bagstad, et al. 2021). Thus, our goals in constructing this pilot account are to illustrate some solutions to common problems facing national statistical offices while also posing new questions and challenges for the international statistical community to consider. As part of this process, both in this study and prior research, we learn more about the limitations of existing data and catalog multiple issues that would need to be remedied prior to being produced as a formal statistical product of the national accounts that would be of comparable quality to official estimates in the National Income and Product Accounts (NIPA). These include data gaps of existing official (government) data sources and limitations to private sector ESG disclosures that offer firm-level expenditures and revenues related to environmental goods and services (e.g., environmental R&D).

Though the scope of this NBER-CRIW volume focuses on measuring and accounting for environmental public goods in particular, this research also fits into a broader strategy of the US Government to develop natural capital accounts over the next decade or so. An interagency group led by the White House's Office of Science and Technology Policy (OSTP), Office of Management and Budget (OMB), and Department of Commerce (DOC) recently released a national strategy for measuring natural capital and environmental-economic statistics, titled "National Strategy to Develop Statistics for Environmental-Economic Decisions: A US System of Natural Capital Accounting and Associated Environmental-Economic Statistics" (2023). This Strategy recommends the development of environmental activity accounts at the initial phase (Phase I) of a long-term plan to produce a full suite of SEEA-based environmental-economic

accounts to complement the National Income and Product Accounts. Understanding the landscape of the data and the accompanying accounting challenges are necessary prerequisites for producing timely, high-quality accounts measuring economic activities that are undertaken to protect, rehabilitate, or preserve the environment. Further, as private sector accounting standards evolve to account for environmental expenditures and revenues, this research may also offer insights for how private sector data might be used by the national accounts and the limitations of firm-level ESG data in their current form. We return to this point and further discussion of limitations of the data in the Discussion section below.

2. Background

2.1 Satellite Accounts and Statistical Standards: The System of National Accounts (SNA), Classification of Environmental Protection Activities (CEPA), and System of Environmental-Economic Accounts Central Framework (SEEA-CF)

The System of National Accounts (SNA) – the international statistical standard that governs the prevailing national economic accounting methodology – provides guidance for extensions or satellite accounts that move away from a focus about *what* is purchased to *why* or *for what purpose* do these outlays occur. Specifically, in chapter 29 of the 2008 System of National Accounts (SNA2008), it presents extensions to the system of national accounts that support the development of satellite accounts like, for example, tourism, health, and the environment. Regarding the latter, an environmental satellite account identifies the various monetary transactions in the SNA that are directly related to the environment.[9] However, as we noted in the introduction above, international interest in environmental satellite accounts had led to its own manual, the System of Environmental-Economic Accounts 2012 – Central Framework (SEEA-CF), which extended and applied the methodology from the SNA to establish three main types of accounts: physical flow accounts, monetary flow accounts, and asset accounts (both physical and monetary).

For many years prior to the 2008 SNA or 2012 SEEA-CF, however, numerous countries had classified economic activity as 'environmental' in their national accounts, or they produced

[9] Specifically, the SNA defines the scope of this account as measuring the following: "environmental taxes, property income and property rights, and environmental protection, natural resource use and management expenditures" (SNA2008, §29.110).

some variant of an environmental industry satellite account prior to the adoption of the SEEA-CF. Initially, the Classification of Environmental Protection Activities (CEPA) was established in the late 1980s to serve this purpose, with a focus on pollution and environmental protection. By the time the SEEA-CF was established as an international statistical standard in 2012, there was also a focus on natural resource management which led to the development of the Classification of Environmental Activities (CEA). The CEA has two parts: Part I focuses on environmental protection, and Part II on resource management. In recent years, there is an additional focus on resource efficiency. Extending from these traditions, the fourth chapter of the SEEA-CF now serves as the methodological foundation of environmental activity accounts, which includes guidance on how to produce satellite accounts for environmental protection expenditures, environmental goods and services sector (EGSS), and tax and subsidy accounts.

A common theme across environmental activity satellite accounts, whether they are SEEA-based or some variation of its predecessors (CEA or CEPA), is that they measure economic activity that is currently in the scope of the current National Income and Product Accounts. Compared to other environmental-economic accounts, this is relatively "low-hanging fruit" in the sense that the valuation of these transactions is already being measured by national statistical offices and folded into more aggregated statistics. In contrast, valuing other environmental assets, flows, or ecosystems services often involves taking on difficult valuation challenges due to the unique and heterogeneous nature of many natural capital assets, which accompany valuation issues that the academic literature has tackled in a variety of settings and applications (e.g., Muller 2009; Fenichel and Abbott 2014; Banzhaf et al. 2016; Cavender-Bares et al. 2022). Hence, rather than a valuation challenge, the principal methodological challenge for environmental activity accounts is to classify activity that has already been valued in the accounts while identifying the right data to do so.

2.2 What is Environmental Activity? Some Conceptual Classification Challenges

Before turning to the environmental classifications and what other countries do in a practical sense, it is important to explain more precisely what economic activity we are trying to describe conceptually. The SEEA-CF provides the following guidance for deciding whether a given transaction's scope is categorically environmental or not. It is based on the concept of main or primary purpose. The SEEA-CF explains this concept as follows:

> *"4.11 The scope of environmental activities encompasses those economic activities whose primary purpose is to reduce or eliminate pressures on the environment or to make more efficient use of natural resources.*
>
> *4.12 These various activities are grouped into two broad types of environmental activity: environmental protection and resource management. Environmental protection activities are those activities whose primary purpose is the prevention, reduction and elimination of pollution and other forms of degradation of the environment…*
>
> 4.13 *Resource management activities are those activities whose primary purpose is preserving and maintaining the stock of natural resources and hence safeguarding against depletion.*" (SEEA-CF 2012, §4.11-4.13)

Determining the primary purpose needs to follow general principles of classification, i.e., its purpose is consistent with the definitions of the two types of environmental activity: environmental protection and resource management. This includes a wide range of activities in the economy such as: waste treatment and disposal; hydroelectric, nuclear electric, solar electric, wind electric, geothermal, and biomass electric power generation; sewage treatment facilities; materials recovery facilities; septic tank and related services; expenses of environmental, conservation and wildlife organizations; and environmental consulting services. See Appendix 1 for a more complete list.

In practice, a Department/Ministry of Transportation might claim that all output for railroads were "environmental expenditures," for example. Their argument might be that the trains reduced the use of road and air transportation, and thus the air emissions from these modes of transportation. Therefore, all expenditures for the railroads should be classified as part of the environmental goods and services sector (EGSS). Based on the application of the 'primary purpose' principle, a national statistical office would likely evaluate this claim and conclude that, although this may have been one of the results of the expenditures on the railroads, the *primary* purpose of the expenditures for railroads was rail transport and not primarily for environmental protection. Thus, the total expenditures on railroads would not be included in the environmental protection expenditure statistics of the government sector as developed by the national statistical office.[10] This example (via exception) helps illustrate the broader rule from the SEEA-CF that, from a national accounts perspective, it is not sufficient to be *related* to environmental protection or resource management, but its *primary purpose* must be oriented toward these ends. From an

[10] It is worth noting, however, that expenditures of the Department/Ministry of Transport that did have a primary purpose of environmental protection, such as the construction of noise barriers along railway lines and roads, would be included.

accounting standpoint, drawing a line is necessary, given that virtually any economic activity is in some way *related* to the environment somewhere along the supply chain or in its use. For the purposes of this paper, however, we take the standards and definitions as given, leaving the debate about where these definitional lines should be drawn to others.

The example above highlights an important challenge for the US and other countries implementing environmental activity accounts using existing, repurposed statistics: the context through which one set of statistics or estimates was initially developed may not have been initially constructed to be consistent with the guidance regarding the 'primary purpose' principle or other principles set forth in the SNA and SEEA-CF. Therefore, it requires expertise in national accounting to sort through the initial purpose and accounting guidelines of, for example, the North American Product Classification System (NAPCS) products codes associated with NAICS industries to determine whether these definitions are sufficiently close to the scope of the corresponding expenditure for a formal environmental activity account line item. In the rail example above, if the federal budgeting policymakers include all rail infrastructure expenditures in their definition of environmental protection expenditures on a balance sheet line item, it is necessary that this type of difference is flagged so that a roadmap for constructing the formal accounts would include recommendations for separating out these kinds of expenditures in the underlying source data to be more consistent with SNA and SEEA-CF guidelines and principles.

2.3 Environmental activity accounts – SEEA Central Framework and its predecessors

Methodologies and corresponding statistics describing the Environmental Goods and Services Industry/Sector (EGSS), also called the Environment Industry (or "Green Economy"), have been developed by both national and international institutions. As mentioned in the prior section, the SEEA Central Framework's fourth chapter is devoted primarily to environmental activity accounts, describing the scope of these accounts and methods used for measurement.[11] However, while this is the current statistical standard, it is not the first international guidance devoted to environmental activity. Eurostat, the statistics agency of the European Statistical

[11] In particular, the environmental goods and services sector is defined and described in Section 4.2 "Environmental activities, products and producers." See Chapter 4 of the SEEA Central Framework and on the UN's website for more detail: https://seea.un.org/content/environmental-activity-accounts

System (ESS), along with the members of the ESS, have years of experience in collecting data and developing statistics related to environmental activity.

As early as 1999, the OECD and Eurostat provided relatively detailed guidelines for compiling an accounting of this sector. Earlier work on resource management classification was pioneered by Istat, the Italian national statistical office, using techniques from government budget analysis.[12] Building on this work, Eurostat developed several iterations of a Classification for Resource Management Activities (CReMA) which helped inform the SEEA-CF's CEA although categories for aquatic and mineral resources were not part of the CreMA. Eurostat has since published a number of manuals and guidelines for EGSS statistics (e.g., see 2009, 2016a, 2016b). Along with a number of other countries around the world, the EU and the ESS member states now produce a regular set of environmental economic accounts, including an environmental goods and services sector (EGSS) account,[13] environmental protection expenditure accounts (EPEA),[14] and environmental tax statistics.[15] In fact, since 2017, EGSS statistics are now required to be reported annually for countries of the European Statistical System (ESS) using standardized questionnaires. Statistics Canada, on the other hand, has taken a slightly different approach in definitions and categories (see Statistics Canada SEGS Survey information).

2.4 A brief history of the US experience with "Green" classification

The US Government has long collected rich data on economic activity at product and industry levels, which follow NAPCS and NAICS. This fine-grained, detailed data make it possible for US statistical agencies like BEA to compile industry breakdowns of economic activity (e.g., GDP by Industry), Input-Output Accounts, and satellite accounts organized around a specific theme (e.g., Outdoor Recreation, Marine Economy). Other US agencies like the Bureau of Labor Statistics (BLS) and the Census Bureau have used this data and/or this classification system for a

[12] Ardi, Carolina and Frederico Falcitelli (2007) The Classification of Resource Use and Management Activities and expenditure – CRUMA: Developed by Istat consistently with CEPA2000 for the Resource Use and Management Expenditure Accounts of SERIEE.
(https://unstats.un.org/unsd/envaccounting/LondonGroup/meeting12/CRUMA.pdf)
[13] See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Environmental_goods_and_services_sector_(EGSS)
[14] See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Environmental_protection_expenditure_accounts
[15] See: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Environmental_tax_statistics

variety of purposes, including earlier initiatives to measure the "Green Economy" or "Green Jobs" that predate the SEEA-CF. We briefly describe some of these initiatives below.

One of the notable predecessors to the SEEA EGSS was undertaken by a partnership among the US Census Bureau, Environmental Protection Agency (EPA), and the International Trade Administration (ITA). In 1998, the Census Bureau published the results from its Survey of Environmental Products and Services (SEPS), conducted on behalf of the EPA and ITA.[16] Specifically, they defined the environmental industry as, "the manufacture of products, performance of services and the construction of projects used, or that potentially could be used, for measuring, preventing, limiting, or correcting environmental damage to air, water, and soil." The definition also included services related to the removal, transportation, storage, or abatement of waste, noise, and other contaminants. As we noted in the example in section 2.2 above, a key departure from prior efforts and the SEEA-CF is the extent to which transportation is included, particularly if its primary purpose is not environmental. Nevertheless, they found that forty-nine (49) industries (4-digit SIC) met their definitional requirements for produced environmental goods and services: 24 in manufacturing, 22 in services, and 3 in construction. The survey's reference year was 1995. Overall, the results from SEPS estimated the green industry to be $102.8 billion in revenue in 1995, employing 774,000 employees. Tables further categorized the revenue by specific products and services and by media (e.g., air, water, solid waste, energy conservation, etc.).[17]

More than a decade ago, BLS launched a closely related initiative in the US to measure the number of jobs associated with the environment, so-called "green jobs." Officially titled the "Measuring Green Jobs Initiative," BLS collected data in the early 2010s for two reference years (2010, 2011). The initiative had three components: Green Goods and Services (GGS), Green Goods and Services occupation survey (GGS-OCC), and Green Technologies and Practices (GTP). The GSS measured employment associated with the production of green goods and services from sampled establishments, which included breakdowns by industry. They identified 325 industries (6-digit NAICS) as potential producers of green goods and services.[18] The GGS identified occupational employment and wages in establishments that produced green goods and services.

[16] For more information, see: https://www.epa.gov/sites/default/files/2017-08/documents/ee-0413_acc.pdf
[17] A more recent study by Census and EPA researchers matched SEPS microdata to data from the Annual Survey of Manufactures and surrounding Census of Manufactures. See Becker and Shadbegian 2009: https://www.degruyter.com/document/doi/10.2202/1935-1682.2117/html
[18] For more information, see: https://www.bls.gov/ggs/.

They defined employment related to GGS that benefited the environment or conserved natural resources. To do this, BLS linked data provided to the existing BLS Occupational Employment and Wage Survey (OEWS) with the same establishment's response to the Green Goods and Services industry survey.[19] Finally, the GTP collected information on more than 35,000 business establishments on their use of green technologies and practices. They defined green technologies and practices as, "those that make their establishment's production processes more environmentally friendly or use fewer natural resources."[20]

Ultimately, the BLS initiative was ended due to budget cuts. This was a critical effort that illustrated tremendous challenges in defining and measuring a new sector of the economy that did not, at the time, have a widely accepted definition or production boundary. The SEEA-CF and subsequent work around the world have clarified many of the issues faced by BLS, but significant challenges remain (which we return to later in the paper).

Around the same time the BLS initiative began, the Economics and Statistics Administration (ESA) of the US Department of Commerce issued a report *Measuring the Green Economy* in 2010.[21] ESA's report defined green products and services as "those with a predominant function of conserving energy and other natural resources, or reducing pollution," providing options for both a "narrow" interpretation and a "broad" interpretation of the underlying activity. The "narrow" definition identified 497 green products/services among the 22,000 overall products/services, while the "broad" interpretation included 732 green products/services, which included products/services where the extent to which they were "green" was more ambiguous. Lists of these products and services appear in Appendix 1 of the ESA report. Overall, the report concluded that, "green products and services comprised 1% to 2% of the total private business economy in 2007," with the 1% ($371 billion) corresponding to the "narrow" definition and 2% ($516 billion) corresponding to the more expansive "broad" definition of green products and services. To illustrate how sensitive the figures are to classification choices, we take a similar

[19] See www.bls.gov/ggsocc/home.htm.
[20] See also www.bls.gov/gtp/home.htm.
[21] https://www.commerce.gov/data-and-reports/reports/2010/04/measuring-green-economy
https://www.commerce.gov/sites/default/files/migrated/reports/greeneconomyreport_0.pdf
https://www.commerce.gov/sites/default/files/migrated/reports/appendix2_0.pdf

approach to this effort by offering both a narrower, more conservative estimate of EGSS and a broader definition that is inclusive of partial categories. We return to this point in the next section.

3. Classifying Environmental Activities for the EGSS - Methodology

3.1 Methodological foundations

As the background history of prior "Green Economy" efforts illustrated in the prior section, we are not the first to attack this problem of classifying economic activities for the purposes of constructing an environmental goods and services sector (EGSS) account. We thus leverage both national and international experience that preceded this one to develop our methodology. Given that European EGSS accounts are already in production and their SEEA-based classification methodologies are published, we began by closely examining European classifications and the products and industries identified as relevant. Indeed, one of the foundational accounting goals of the SNA, and by extension the SEEA-CF and SEEA-EA, is that economic accounts produced by national statistical offices should be comparable as they are anchored to a common statistical standard. Thus, by beginning with aligning our approach to existing methods used in the European statistical system, our initial objective was to facilitate comparability while simultaneously "standing on the shoulders of giants" (to borrow from the Newtonian expression) of those who have been grappling with similar issues implementing SEEA-CF for years. We then draw on prior efforts from the US experience described in the last section, filling in some of the gaps along the way with our own expertise in national income accounting.

One reason this approach is possible is due to a legal reporting requirement under Regulation (EU) No 2015/2174,[22] which directed the development of an indicative compendium of environmental goods and services and economic activities for the European statistical system. These lists outline where the relevant activities and products for the EGSS can be identified in the European statistical system. European countries that report to Eurostat often base their work on these lists. As mentioned earlier in the paper, the US statistical system uses different product and economic activity classifications (for example, NAICS rather than NACE or ISIC, NAPSC rather than CPA or CPC).[23] But, the list of EGSS activities and products as well as their corresponding

[22] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2015.307.01.0017.01.ENG

[23] NAICS is the North American Industry Classification System, NACE is the European Statistical System's Nomenclature of Economic Activities, ISIC is the International Standard Industrial Classification of All Economic

NACE industries and (CPA and CPC) product classifications from the European system are a very helpful starting point for trying to identify these environmental activities, products, and services in the US BEA system.

3.2 Challenges with translating NACE/ISIC to NAICS

A fundamental challenge with drawing on the European experience is the imperfect mapping of product and industry classifications across these systems. There are well-trotted conversion tables for industry classifications, i.e., between NACE/ISIC and NAICS, which can be helpful in this process. However, the environmentally relevant portions of the NACE that need to be matched with NAICS can often be easier to find comparing the verbiage of the categories directly (using keyword searches for example), given that the activities of interest may be found in other categories than what are referenced in the conversion tables. One example of this is the renewable environmental product, "fuel wood." This would be in both NACE 02.20 and 16.10, and the partial activity covering only fuel wood would need to be determined using additional information. NAICS-based product codes developed by BEA from the NAPCS, on the other hand, have only one product: "Firewood and fuel wood containing fuel binder manufacturing." In this instance, the NAICS-based classification system makes it easier to identify this product within US data, which more cleanly aligns with the SEEA-CF defined boundary.

Another example where the NAICS classification is more specific, and thus more cleanly aligns with the SEEA-CF definition, is environmental consulting services. NACE classifies this in 74.9 as "Other professional, scientific and technical activities n.e.c.". This means that the environmental portion of this NACE needs to be separated out from other activities, likely necessitating supplementary data to estimate the proportion that is specific to environmental activity. NAICS, on the other hand, has a separate six-digit category, 541620, as "Environmental Consulting Services." In other cases, sometimes the terminology is altogether different between the classifications, where the NACE verbiage makes the classification more straightforward. For example, the term 'Biofuels' can be found in the European lists but not in the BEA SUT product lists. In this case, the US uses the narrower term 'Fuel Ethanol' in the product classification rather than the broader term, biofuels. With 6,000 to 10,000 categories in each of the different

Activities, NAPSC is the North American Product Classification System, CPA is the ESS (EU) Statistical Classification of Products by Activities, and CPC is the UN Central Product Classification.

classifications, finding the relevant industries, products, and services is a massive undertaking. And, among these categories there are numerous "mixed categories" which contain a subset of products and services whose primary purpose is environmental.[24]

As we summarized in section 2.4 above, a number of studies were undertaken by different US Agencies and Departments prior to the SEEA-CF. While the methodologies of these studies were all different (e.g., EPA and BLS used surveys, ESA used a type of supply-use table (SUT) approach, and Brookings (2011) used secondary sources), these initiatives and surveys were helpful in identifying the industries and products in a US context. Especially helpful was the ESA 2010 report, "Measuring the Green Economy," because there was an extensive Appendix with lists that identified green products and services. Although, we should reiterate that, while useful, the definition used by the ESA is not the same as the definition of Environmental Goods and Services in the SEEA-CF, so it could not be used without careful consideration. But, as a starting point, it was still very helpful, given the lack of extended description of the NAPCS.[25]

Finally, another practical challenge was the differences between the product codes used in the internal BEA SUT database and the US NAPCS classification. Recently, BEA has been working on converting its internal categories to be better aligned with the most recent version of the NAPCS classification system. However, this will take some time to complete. Though there are correspondence tables BEA uses, and only the environmental portion of some of the categories is needed here, there are still instances where the official conversion is not appropriate. There are similar issues using the Eurostat CPC/CPA to NAPCS and ISIC/NACE to NACE matching.

3.3 Coding environmental activities and supplemental data sources

One of the core issues with classifying environmental activity is that some economic activity does not neatly fit into a finite classification system. In many cases, a particular good or service product/industry category may have a purpose that only partially fits the definition in the

[24] The other challenge related to the US version of the product classification, NAPCS, is the lack of a description of the product code classification; there is only the name of the group – no extended description. Canada's NAPCS has an extensive description of each of the items in the classification (2017, 2022), but this does not currently exist for US data.

[25] Currently, only the US Department Of Commerce International Trade Administration (ITA), analyzing data purchased from Environmental Business International, Inc. (EBI), regularly publish data covering the US environmental technologies industry. Although the focus is primarily on export potential, there are also estimates of the total revenues of environmental technologies. This would be a subset of the total environmental goods and services sector.

SEEA-CF, or there is some ambiguity as to the extent a set of goods/services with a particular production or industry cost fits within the appropriate boundary. We thus developed a three-part coding system to identify the environmental portion of the NAPCS/NAICS category, and every product category was coded drawing on comparisons to corresponding NACE categories coded by the European statistical system as well as our own expertise. If the whole category was environmentally relevant the category was coded "1", partially relevant was "2", and not relevant or outside the boundary was "3." For all categories coded 1 and 2, we further coded it according to the CEPA and CReMA classifications currently used by Eurostat for comparability. This additional coding allowed for splitting the commodities according to environmental domains, which is useful for understanding the breakout of this activity across domains. [26]

Despite the fact that the US has very fine product categories relative to many other countries, they were not initially devised with the environmental goods and services sector in mind. Hence, as noted above, one of the chief data challenges for the US (as well as most other countries for that matter) is that there are many mixed categories that contain both non-environmental and environmental output. As we examined those coded '2' (partially relevant category) in more detail, when possible, we leveraged data from other sources to identify the environmentally relevant portion of that category. For example, agricultural categories may contain both conventional commodities and more environmentally friendly organic commodities; or, appliances and other durable goods may not separate out Energy Star (or similar energy-saving appliances) from other conventional ones. [27] So, US Agriculture Department data for organic agriculture production was used for the applicable agriculture products. EPA data for sales of Energy Star labelled appliances (both industrial and household) were used for estimating the production of energy efficient appliances. Fuel-efficient vehicle sales were used to identify the portion of fuel-efficient (hybrid and electric) vehicles that were manufactured. Having identified the environmental portions of the

[26] See the Appendix 1 for a table listing of identified product categories and source data details.

[27] Energy Star ratings are binary by nature, requiring varying thresholds of energy savings (depending on the product) over some minimum standard. One complicating factor these examples is that they highlight some products that are more environmentally friendly (in the sense that their purpose is to conserve energy or protect environmental resources) as compared to their more traditional counterparts on the market; yet, SEEA prescribes that we count the entire product rather than the portion or marginal value of the product that is environmental-related in its purpose. We follow international conventions on this issue by counting the full product/service, but we revisit this point in our discussion in Section 5.3 below regarding how to consider partial categories in the future. Another complicating factor for future versions of this account might be if regulations change such that certain products are required to be uniformly above an Energy Star standard the baseline/minimum product or are outlawed.

products used in the BEA supply and use system as best as possible, we then use BEA's internal SUT data to develop the satellite account for the US environment industry.

Both CEPA and CReMA contain classification categories for environmental research and development (R&D) undertaken for either environmental protection (CEPA 80) or resource management (CReMA 150). To supplement our internal SUT data, we consider additional sources for quantifying environmental R&D in the US. The National Center for Science and Engineering Statistics (NCSES) within the National Science Foundation (NSF) conducts annual surveys on R&D activities. In addition, we examine microdata from Refinitiv's ESG dataset,[28] which includes firm-level information from thousands of public and private companies regarding their environmental R&D expenditures. While this data is often paired with other financial data for its ESG scores, we instead consider using the raw accounting information reported by firms for their environmental R&D expenditures. Because this information is only available for a subset of firms, as environmental R&D is not (yet) a required disclosure by the SEC for public companies, we explore how useful data like this might be for estimating the portion of total R&D companies undertake that is environmental in its primary purpose. For reasons which we discuss in more detail in our Discussion section below, we do not yet use this data for deriving estimates for CEPA 80 and CReMA 150.

3.4 Methodology – a satellite account approach

Our method for constructing a pilot environmental goods and services sector (EGSS) account follows BEA's satellite account approach. This approach relies on using detailed internal data within BEA's supply-use tables (SUTs), which breaks out industry output for the entire US economy into more than 5,300 distinct product categories.[29] In fact, most of BEA's satellite accounts begin with detailed supply-use tables (SUTs).[30] BEA uses this data in a variety of ways, including disaggregating economic output by industry or sector-specific satellite accounts. These are useful for understanding areas of the economy that are not easily identifiable under standard

[28] For more information on this data, see: https://www.refinitiv.com/en/financial-data/company-data/esg-data

[29] For reference, the U.K.'s environmental activity accounts draw from the UK's SUTs which have 112 industries and 112 products. In this regard, the US data is among the finest, most detailed source data in the world for the product/industry categories underlying its SUTs.

[30] BEA's growing suite of satellite accounts currently includes: travel and tourism; arts and culture; the marine economy; the space economy; and outdoor recreation. See: https://www.bea.gov/data/special-topics.

industry classifications, such as NAICS.[31] The relatively fine product-level detail of the internal SUTs data allow BEA to construct specific accounts that reveal insight into the internal workings of the US economy by detailing the contribution of specific industries and commodities to gross output and value added.[32] Hence, the goal of a satellite account is to identify and isolate the production and spending already present in the SUTs for the subject area of interest.

For this EGSS account, we estimate gross output for environmental goods and services by first identifying relevant commodities (goods and services) within the SUTs as described in the prior subsection. Then, in the cases where production of the environmental commodity was comingled with production outside of scope, we used external source data to isolate the share of the commodity's gross output considered to be "environmental," which we discussed in section 3.3 above. For example, the vintage of SUT data we use in this study does not differentiate between organic agriculture and conventional crop production. We thus use the NASS Survey,[33] which collects detailed crop production and value of sales data from certified organic farms. This detailed crop level information is then matched to the respective BEA product to develop the percentage of the total production that is considered environmental (organic) in its purpose. Most of the agriculture products in the BEA system were able to be matched to the USDA certified organic crops, including wheat, corn, rice, rye, soybeans, potatoes, lettuce, tomatoes, apples, grapes, strawberries, milk, broilers and chickens, eggs, etc.

Official BEA satellite accounts typically include estimates of gross output by NAICS industry. Some satellite accounts also present gross output by activities that are salient to data users. For example, the outdoor recreation satellite account provides estimates of gross output by type of recreational activity, such as boating or bicycling, that includes production from all industries that produce boating or bicycling commodities. Presenting the EGSS estimates by industry would require translating commodity-level data to industries, which is outside of the scope of these preliminary estimates. For this paper, we instead use the CEPA/CReMA

[31] For example, if you want to understand how the Construction industry in the US evolves over time, the standard two-digit NAICS code (23) provides a breakout of this industry by aggregating the products that make up this industry.
[32]Gross output represents the market value of the goods and services, reflecting both the value of goods and services that are used in other production processes (intermediate inputs) and the value of goods and services purchased by end-use consumers (final products). Value added or gross domestic product (GDP) represents just the value of final products.
[33] See: https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Organic_Production/index.php

aggregations to present our gross output estimates, similar to BEA satellite accounts that present gross output by activity. This also facilitates comparability with the European statistical system and countries who have adopted something similar to CEPA/CReMA aggregations.[34]

Currently, the most relevant SUT data we use come from 2015 and 2019, which have the finest level of detail for this exercise. Hence, we provide estimates of gross output for 2015 and 2019 in both producer and purchaser values. The purchaser values include trade margins, or the value added by wholesalers and retailers in the distribution of a commodity from producers to final purchasers and the transport costs paid separately by the purchaser in taking delivery of goods. All values are in current-dollar or nominal terms, meaning there is no adjustment for inflation.[35]

3.5 Alternative scenarios and sensitivity tests

In some cases, source data were not available to separate economic activity for Environmental Goods and Services (EGS) where the product categories were too coarse and included both environmental and non-environmental commodities. In order to explore how sensitive the estimates are to the exclusion of these categories that may be partially relevant, we present tables under two scenarios. In the first scenario, we exclude EGS where we do not have sufficient source data to estimate the portion of the commodity (or group of commodities in particular product category) that are "environmental" in their primary purpose. This is a more conservative approach to estimating output of this sector that wholly and unambiguously aligns with the definition of environmental activity in the SEEA-CF. In the second scenario, we estimate the environmental share as 10 percent as a way to give some weight to these relevant commodities that were designated as partially relevant. This is still a somewhat conservative approach, but it accomplishes two objectives. First, it ensures we account for at least some of the relevant EGS in our estimates, albeit assuming that the partial category is at least 10 percent relevant. Second, and most importantly, it is a sensitivity check for illustrating the relative magnitude of the categories designated as partially relevant. If the gap between these two scenarios turns out to be obscenely

[34] An important aspect of a proof-of-concept account is that it not only demonstrates feasibility, but the estimates can also be compared to other accounts that have undergone substantial scrutiny like those in the EU as part of a vetting process. Hence, CEPA/CReMA categories make sense here for this purpose.

[35] For real values, future work would need to develop a more specific price index for this particular basket of goods and services. For example, if we deflated the nominal values by a GDP price index, it would remove a common inflation trend, but it would not provide a true real value of expenditures—that would require activity-specific price indexes which do not currently exist.

large, it would be evidence that partially relevant categories might be the primary driver of the overall size of the account. If the gap is small, partially relevant categories could still be economically important, but it would provide some confidence that the conservative approach of including unambiguous categories is a reasonable starting point for EGSS estimates.[36]

There are two additional caveats to consider when reviewing these estimates. First, in practice, gross output is composed of sales or receipts, other operating income, commodity taxes, and inventory change. For this paper, we did not have the source data to estimate inventory change for the EGSS. However, this exclusion is unlikely to substantially impacts our results (based experience with other satellite accounts), but we leave this for future work. The second consideration is the potential for double-counting electricity and/or heat produced from renewable sources. To the extent that energy produced from renewable sources is used in the production of other environmental goods and services (as part of intermediate consumption), our estimates would double-count the value of that energy use. There may also be double-counting if government purchases include high levels of environmental products that are identified separately such as, for example, electric vehicles (EVs). The total sales of EVs are identified and separated from other vehicles but who purchases these EVs is not identified. If both the entire budgets of certain government agencies/departments are included those agencies' purchases of EVs would be double-counted. Double-counting of government transfers and subsidies are avoided since these are already balanced out of the SUTs, which is one of the advantages of using the SUT methodology. These types of double-counting issues are topics that should be pursued in future work on this account, not only in the US but also abroad.

4. Results

4.1 Summary of the US Environmental Goods and Services Sector (EGSS) – Overall

Our first set of results summarizes the pilot estimates for the US environmental goods and services sector (EGSS) under two sets of assumptions to assess the sensitivity of our method.

[36] One coarse analogy for this approach might be instructive. Suppose we have a bunch of rooms in a zoo, and we are trying to add up how much the animals weigh. In many of the rooms, we can see into them fine and measure how much they weigh. But, suppose there is a dark room, and we can hear that there might be either elephants or mice in there (or both), but we do not know in what proportion. If we knew how much the room weighed (or how much 10% of the room weighed), we would have a sense of whether there are elephants in there. And, if so, perhaps we should focus more of our future efforts on shining light in that particular room and finding out for sure. Or, if not, additional effort into shining light in there may not change our total estimates much, and we prioritize accordingly.

Specifically, Table 1a shows gross output estimates of environmental goods and services in both producer and purchaser values for 2015 and 2019 by CEPA/CReMA category under the first scenario (excluding EGS where we do not have source data to estimate the precise "environmental" portion of the product category). We divide each year's EGSS output into three columns (Producer Value, Margins, and Purchaser Value) across 16 different categories along the rows, containing aggregations of EGS by CEPA category (14 of which come from the relevant CEPA/CReMA categories, one "Mixed" category that includes cross-category activity, and one "Unclassified" category). The totals for each column are tallied along the bottom row. Overall, the estimates in Table 1a (columns 3 and 6) show EGS in purchaser values accounted for $620.6 billion of US gross output in 2015, growing to $724.5 billion in 2019. This translates to about 1.9 percent of total US gross output in both years. Nominal growth for the EGSS averaged 3.8 percent over the period, slightly slower than the overall US growth rate of output of 4.2 percent.

One insight gained from this exercise is that Table 1a provides new estimates of the magnitudes of each CEPA/CReMA domain for the US economy, highlighting the relative prominence of some categories like waste management and management of water, in particular. Waste management represented the largest category in both years, responsible for just over one-quarter of the EGS purchaser value total. Management of water was the second largest category, followed closely by wastewater management and protection of biodiversity and landscapes. These four categories accounted for about 70 percent of total EGS production in 2015 and 2019 in terms of purchaser value. This result is relatively common when compared to other EGSS accounts internationally. For example, in 2015 and 2019 in the EU-27 countries, waste management accounted for 26-27 percent of Gross Value Added (GVA) of the environment industry, and wastewater management accounted for 12-15 percent. One takeaway from this exercise is that the make-up of the environmental goods and services sector may look different in aggregate than preconceived notions of solar panels, electric cars, and other more high-profile green technologies. While these types of transactions are important components of EGSS output, and may grow in prominence over time, one takeaway is that water/resource management and waste management activities factor in more prominently in the most recent years for which we have data. [37]

[37] If markets for solar panels, electric cars, and others high-profile green products continue to outpace growth in other categories, the relative proportions by category reported in these tables could look much different in the future.

Table 1a. Estimates of gross output for environmental goods and services (EGSS) (in millions $)

		2015 EGSS Gross Output			2019 EGSS Gross Output		
CEPA/CReMA	**CEPA/CReMA category**	**Producer Value (1)**	**Margins (2)**	**Purchaser Value (3)**	**Producer Value (4)**	**Margins (5)**	**Purchaser Value (6)**
10	Protection of ambient air and climate	$2,976	$2,686	$5,662	$2,611	$4,513	$7,124
20	Wastewater management	$84,384	$1,370	$85,754	$95,508	$2,192	$97,700
30	Waste management	$126,204	$27,298	$153,502	$152,873	$33,605	$186,478
40	Protection and remediation of soil, groundwater and surface water	$7,581	$3,626	$11,207	$12,379	$7,810	$20,189
60	Protection of biodiversity and landscapes	$79,665	$0	$79,665	$93,494	$0	$93,494
70	Protection against radiation	$1,765	$484	$2,249	$2,950	$981	$3,931
90	Other environmental protection	$6,160	$0	$6,160	$6,798	$0	$6,798
100	Management of water	$103,391	$1,802	$105,193	$122,391	$2,228	$124,618
110	Management of forest resources	$2,185	$0	$2,185	$4,357	$0	$4,357
111	Management of forest areas	$3,537	$0	$3,537	$3,578	$0	$3,578
112	Minimisation of the intake of forest resources	$339	$0	$339	$368	$0	$368
120	Management of wild flora and fauna	$4,072	$0	$4,072	$3,378	$0	$3,378
131	Production of energy from renewable sources	$53,131	$2,323	$55,454	$56,824	$3,097	$59,920
132	Heat/Energy saving and management	$27,077	$41,878	$68,955	$30,119	$40,190	$70,309
Mixed	Mixed	$31,101	$709	$31,810	$35,941	$702	$36,644
Unclassified	Unclassified	$3,910	$898	$4,808	$4,711	$928	$5,639
	Yearly Totals	**$537,479**	**$83,074**	**$620,553**	**$628,280**	**$96,246**	**$724,526**

Note: Scenario 1 – Includes product categories that align fully with EGS definitions or where supplemental data can be used to estimate the EGS component. Excluding partial categories of EGS where we do not yet have source data to estimate the "environmental" portion of the commodity.

Table 1b. Estimates of gross output for environmental goods and services (EGSS) (in millions $) (Scenario with 10% environmental portion)

		2015 EGSS Gross Output			2019 EGSS Gross Output		
CEPA/CReMA	**CEPA/CReMA category**	**Producer Value (1)**	**Margins (2)**	**Purchaser Value (3)**	**Producer Value (4)**	**Margins (5)**	**Purchaser Value (6)**
10	Protection of ambient air and climate	$2,976	$2,686	$5,662	$2,611	$4,513	$7,124
20	Wastewater management	$84,384	$1,370	$85,754	$95,508	$2,192	$97,700
30	Waste management	$126,494	$27,390	$153,884	$153,281	$33,744	$187,025
40	Protection and remediation of soil, groundwater and surface water	$9,771	$3,626	$13,397	$14,592	$7,810	$22,402
60	Protection of biodiversity and landscapes	$79,665	$0	$79,665	$93,494	$0	$93,494
70	Protection against radiation	$1,765	$484	$2,249	$2,950	$981	$3,931
90	Other environmental protection	$6,160	$0	$6,160	$6,798	$0	$6,798
100	Management of water	$103,391	$1,802	$105,193	$122,391	$2,228	$124,618
110	Management of forest resources	$4,873	$835	$5,708	$6,686	$845	$7,531
111	Management of forest areas	$3,537	$0	$3,537	$3,578	$0	$3,578
112	Minimisation of the intake of forest resources	$566	$55	$622	$565	$59	$624
120	Management of wild flora and fauna	$4,422	$9	$4,431	$3,877	$11	$3,889
131	Production of energy from renewable sources	$55,617	$2,571	$58,188	$59,190	$3,239	$62,429
132	Heat/Energy saving and management	$27,208	$41,915	$69,123	$30,233	$40,223	$70,456
Mixed	Mixed	$34,411	$1,076	$35,487	$39,539	$1,044	$40,583
Unclassified	Unclassified	$4,544	$960	$5,504	$5,113	$994	$6,107
	Yearly Totals	**$549,784**	**$84,779**	**$634,563**	**$640,407**	**$97,882**	**$738,288**

Note: Scenario 2 - Beginning with Table 1a as a baseline, for a sensitivity analysis we use a placeholder of 10% for EGS for partial categories without source data to estimate the "environmental" portion of the commodity.

Table 2. 2015 Environmental goods and services sector (EGSS) output by type – public sector vs. private sector output (in millions $)

		2015 EGSS Gross Output					
CEPA/CReMA	**CEPA/CReMA category**	**Government Portion of EGSS Gross Output (Producer Value) (1)**	**Government Portion of Margins (2)**	**Government Portion of EGSS Gross Output (Purchaser Value) (3)**	**Public Sector % of Total EGSS Gross Output (Purchaser Value) (4)**	**Private Sector EGSS (Purchaser Value) (5)**	**Private Sector % of Total EGSS Gross Output (Purchaser Value) (6)**
10	Protection of ambient air and climate	$2,098	$267	$2,366	*41.8*	$3,296	*58.2*
20	Wastewater management	$41,629	$0	$41,629	*48.5*	$44,125	*51.5*
30	Waste management	$16,834	$0	$16,834	*11.0*	$136,668	*89.0*
40	Protection and remediation of soil, groundwater and surface water	$1,607	$0	$1,607	*14.3*	$9,600	*85.7*
60	Protection of biodiversity and landscapes	$79,665	$0	$79,665	*100.0*	$0	*0.0*
70	Protection against radiation	$128	$24	$152	*6.8*	$2,097	*93.2*
90	Other environmental protection	$1,235	$0	$1,235	20.0	$4,925	80.0
100	Management of water	$18,632	$3	$18,635	*17.7*	$86,558	*82.3*
110	Management of forest resources	$2,185	$0	$2,185	*100.0*	$0	*0.0*
111	Management of forest areas	$3,537	$0	$3,537	*100.0*	$0	*0.0*
112	Minimisation of the intake of forest resources	$339	$0	$339	*100.0*	$0	*0.0*
120	Management of wild flora and fauna	$3,031	$0	$3,031	*74.4*	$1,041	*25.6*
131	Production of energy from renewable sources	$23	$0	$23	*0.0*	$55,431	*100.0*
132	Heat/Energy saving and management	$1,123	$378	$1,501	*2.2*	$67,454	*97.8*
Mixed	Mixed	$2,823	$0	$2,823	8.9	$28,987	91.1
Unclassified	Unclassified	$20	$1	$22	0.4	$5,518	99.6
	Yearly Totals	**$174,908**	**$674**	**$175,582**	***28.3***	**$445,702**	***71.7***

Note: This table divides the portion of the EGSS estimates from Table 1a into public and private sector output for 2015.

Table 3. 2019 Environmental goods and services sector (EGSS) output by type – public sector vs. private sector output (in millions $)

		2019 EGSS Gross Output					
CEPA/CReMA	**CEPA/CReMA category**	**Government Portion of EGSS Gross Output (Producer Value) (1)**	**Government Portion of Margins (2)**	**Government Portion of EGSS Gross Output (Purchaser Value) (3)**	**Public Sector % of Total EGSS Gross Output (Purchaser Value) (4)**	**Private Sector EGSS (Purchaser Value) (5)**	**Private Sector % of Total EGSS Gross Output (Purchaser Value) (6)**
10	Protection of ambient air and climate	$2,611	$809	$3,420	*48.0*	$3,704	*52.0*
20	Wastewater management	$43,790	$0	$43,790	*44.8*	$53,910	*55.2*
30	Waste management	$15,642	$0	$15,642	*8.4*	$170,836	*91.6*
40	Protection and remediation of soil, groundwater and surface water	$2,351	$0	$2,351	*11.6*	$17,838	*88.4*
60	Protection of biodiversity and landscapes	$93,494	$0	$93,494	*100.0*	$0	*0.0*
70	Protection against radiation	$65	$14	$79	*2.0*	$3,852	*98.0*
90	Other environmental protection	$788	$0	$788	*11.6*	$6,010	*88.4*
100	Management of water	$22,480	$2	$22,482	*18.0*	$102,136	*82.0*
110	Management of forest resources	$4,357	$0	$4,357	*100.0*	$0	*0.0*
111	Management of forest areas	$3,578	$0	$3,578	*100.0*	$0	*0.0*
112	Minimisation of the intake of forest resources	$368	$0	$368	*100.0*	$0	*0.0*
120	Management of wild flora and fauna	$3,177	$0	$3,177	*94.0*	$201	*6.0*
131	Production of energy from renewable sources	$21	$0	$21	*0.0*	$59,899	*100.0*
132	Heat/Energy saving and management	$469	$139	$608	*0.9*	$69,701	*99.1*
Mixed	Mixed	$2,763	$0	$2,763	*7.5*	$33,881	*92.5*
Unclassified	Unclassified	$104	$11	$115	*1.8*	$6,366	*98.2*
	Yearly Totals	**$196,056**	**$976**	**$197,032**	***27.2***	**$528,336**	***72.8***

Note: This table divides the portion of the EGSS estimates from Table 1a into public and private sector output for 2019.

Table 1b is organized the same way as Table 1a, but shows gross output estimates under the second scenario, where we use 10 percent as the environmental portion for mixed commodity categories that we do not have source data to precisely separate environmental-specific activities from output whose purposes are more conventional or non-environmental. There are many commodity categories in the internal SUT data that contain a subset of output whose primary purpose is environmental. Yet, without supplemental data to separate these out, it is difficult to discern *ex ante* whether the output from these categories is large. However, Table 1b provides evidence that our primary results Table 1a that leave out many of these partial product categories are likely a reasonable starting point for these pilot accounts. Specifically, when we compare the bottom row of both tables, the overall effect is to add about $12 billion to the producer values and $14 billion to the purchaser values for each year. This modest increase represents initial evidence that the partial categories do not contain an overwhelming bulk of the EGSS output. That is, the conservative approach used by Table 1a is not *too* conservative by only including product categories that are unambiguously regarded as environmental in their primary purpose. We return to this issue of using additional data in our Discussion section below.

4.2 Public and private sector breakout of the EGSS in the US

In our second set of tables (Tables 2 and 3), we separate government output from the EGSS to shed new light on the magnitude of government expenditures relative to non-government output in this sector. This is an explicit step toward better measuring and accounting for environmental public goods, a key goal of this NBER-CRIW volume, by tallying output at all levels of government that are environmental in their primary purpose. Tables 2 and 3 show the government portion of the gross output in the EGSS for 2015 and 2019, respectively, separating out producer value, margins, and producer value as in Table 1a and Table 1b. The government portions represent the share of total gross output attributable to government spending.[38] Government spending can

[38] The value of non-market government output is typically valued in the SNA by sum of costs. However, it is possible for there to be both non-market and market output. Paragraph 6.132 in the SNA states: "Government units and NPISHs may be engaged in both market and non-market production. Whenever possible, separate establishments should be distinguished for these two types of activities, but this may not always be feasible. Thus, a non-market establishment may have some receipts from sales of market output produced by a secondary activity: for example, sales of reproductions by a nonmarket museum. However, even though a non-market establishment may have sales receipts, its total output covering both its market and its non-market output is still valued by the production costs. The value of its market output is given by its receipts from sales of market products, the value of its non-market output being obtained residually as the difference between the values of its total output and its market output. The value of receipts

represent production by the government sector, such as the federal government's budget for wildland fire management, or procurement of goods and services, such as government purchases of Energy Star equipment. The "government portion of environmental margins" in the tables are the margins associated with government purchases of goods and services. Since intermediate inputs are not typically separately identified as government production in the SUT data, our estimates likely underestimate the government portion of EGSS output.[39]

Overall, the results from Tables 2 and 3 (bottom row, columns 4 and 6) show the public sector accounted for about 27 or 28% of the EGSS in 2019 and 2015, respectively. Alternatively, we depict the results from Table 3 in Figure 1 below. This proportion of public sector output, however, varies widely by category – as some categories are either fully or almost entirely composed of government expenditures (like those associated with forest management or management of wild flora/fauna). Other categories fall on the other side of the spectrum and are dominated by the private sector, which include the energy-related categories and protection against radiation. The largest categories, those related to management of water, wastewater, and waste, are dominated by the private sector in the US in 2015 and 2019; but, because of their overall magnitude in the EGSS overall, these three categories still constitute a large proportion of the overall public expenditure on the EGSS (about $82 billion of the $197 billion in gross EGSS output by the public sector in 2019). These relative proportions also appear in the lower panel of Figure 1 (Panel B), which underscore this point more visually.

Comparisons across years underscore the necessity for building out a longer time series of data points. For example, the government portion of CEPA 10 (protection of ambient air and climate) category in 2015 represented 41.8 percent of output, but in 2019 it was 48 percent.[40] While these tables represent a proof-of-concept and not a comprehensive time series, the results motivate the need for a fuller time series to make the data more complete for users. For example, production of a longer time series of EGSS could indicate whether a shift like we see with CEPA 10 is part of a longer trend over time or merely represents an outlier for a particular year.

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from the sale of non-market goods or services at prices that are not economically significant remains as part of the value of its non-market output."

[39] For example, hydroelectric power generation is an intermediate input and is not separately identified as government or private production in the SUT data, so we did not allocate any of this value to government.

[40] There was also a large jump in margins for some categories, like protection of air and climate, which raises a similar question regarding whether some of these changes over time are sustained increases or one-off outliers.

Figure 1
Panel A - Private vs. Public Environmental Goods & Services Sector (2019)

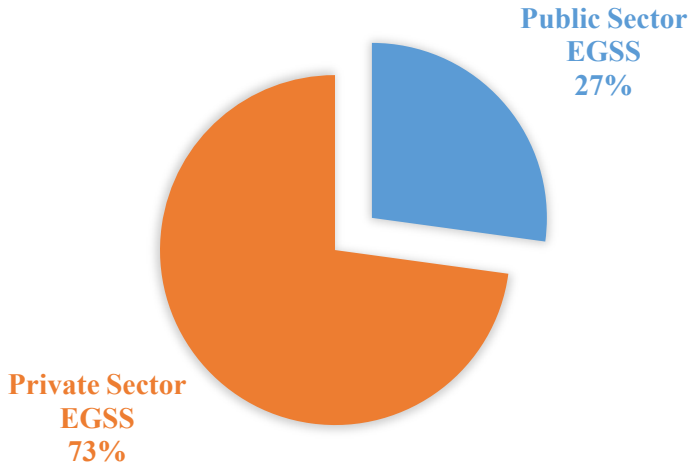
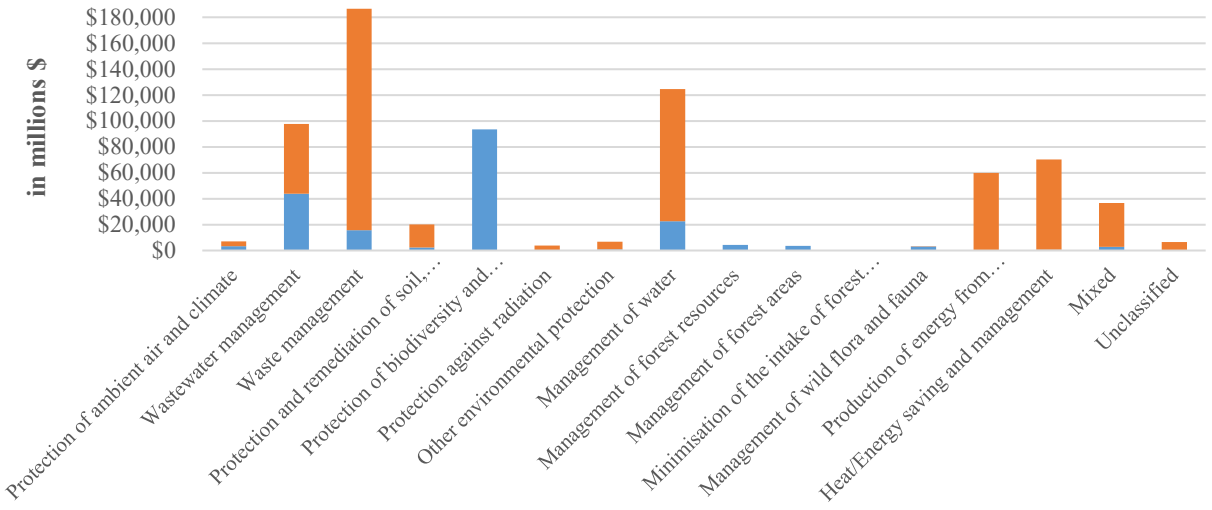


Figure 1
Panel B - Private Sector EGSS vs. Public Sector EGSS by Category (2019)



Notes: Results above come from Table 3 - EGSS Gross Output (Purchaser Value, Scenario 1) by CEPA/CREMA Category. Private Sector depicted in **orange**, Public Sector depicted in **blue**.

Finally, when developing environmental activity accounts, such as EGSS, it can be helpful to compare the monetary flows to the owner of the natural resources to see if there is some agreement between the expenditures identified and the ownership of the resources. For example, in the eastern parts of the US, the forests used for timber production are primarily owned and managed by private individuals and companies. In contrast, many of the forest areas in the West

and Alaska are owned by federal and state government agencies.[41] That management of forest resources in Tables 2 and 3 only shows figures for government output, which suggests that further work is needed to identify the private contributions to this activity. That the protection of biodiversity and landscapes is shown as solely a government activity is also not so surprising, given that this is where the management activities of the national parks, wilderness areas, and wildlife sanctuaries would be found.[42] These are just a few examples of how knowledge about the physical environment, the roles and responsibilities of the various levels of government (Federal, State, and local), and the role of the private sector need to be considered and matched before the EGSS statistics can be more comprehensive in its scope.[43]

4.3 International comparisons – are these estimates reasonable?

We can also compare these pilot estimates of the US EGSS to their counterparts in Europe. A recent Eurostat publication (29 June 2022)[44] stated that the environmental economy as a whole was 2.3 percent of the 2018 GDP of the EU-27. This includes market output, ancillary or final and non-market production. If only market output is considered, the contribution to 2018 EU-27 GDP was 1.2 percent. In this current study of the US EGSS, only gross output is developed so the figures are not directly comparable. Despite this, overall, we find the comparison of the reported magnitudes to be reasonable, given that differences will remain due to measurement differences (e.g., our preliminary, incomplete estimation of partial categories) and underlying differences in the economies. For this proof-of-concept, pilot account to transition to production of an official

[41] Western states have a much higher proportion of public lands compared to the eastern US. For a more detailed breakdown on public land management, see for example: https://www.blm.gov/sites/default/files/docs/2021-08/PublicLandStatistics2020_1.pdf

[42] On the other hand, that the majority of water management is located in the private sector may indicate that government expenditures are underrepresented. Water management in the Western States is very important and seven state agreements regulate the use of the water in the Colorado River Basin, for example. The Bureau of Reclamation plays a prominent role in the management of this Basin. Future work might identify government activity at finer scales using supplemental data, which would improve the estimates of the EGSS.

[43] We should also provide the caveat that there are conceptual issues that complicate the distinction between the public and private sector in a complex economy like the US. The US economic system itself is mixed (like most economies around the world), as the public sector plays a prominent role in the US's market economy, as both regulator and direct producer of output. For the purposes of national accounts, we draw the distinction by institutional unit producing the output. Even if a regulation from the public sector requires a private sector firm to make investments in environmental protection, for example, it would count as private sector gross output (or an intermediate good allocated to the private sector). So, when we split "protection of ambient air and climate" among private and public sectors, the current standards do not require (nor would the data allow) us to answer *why* private sector units are doing this.

[44] See https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Environmental_economy_%E2%80%93_statistics_by_Member_State

account, numerous challenges would need to be overcome, including filling data gaps and addressing key classification issues. We discuss some of these in the next section.

5. Discussion

One of the purposes of this project is to push the existing data as far as possible, exploring what is currently feasible and what issues remain. In this section, we discuss several remaining challenges that would need to be overcome prior to production of an official EGSS account, including data gaps and classification/methodological issues. The subsections below are not intended to be exhaustive; but they are meant to illustrate the types of challenges facing the US and other countries implementing an EGSS account, along with potential solutions and practical considerations.

5.1 Classification Alignment, Data Gaps, and Other Issues

The first issue, which was discussed at some length above, is a well-known issue with constructing satellite accounts based on NAPCS/NAICS (or CPA/NACE or CPC/ISIC) classifications – the definitions of the product and industry categories do not perfectly align with the underlying account being constructed. In some examples above, a category might contain multiple products, where only a subset has a purpose that is primarily environmental. In the case of organic farming, an example we discussed above, one can estimate what proportion of the reported agricultural products are organic using alternative data sources (e.g., the US Department of Agriculture's Organic Survey). In other cases, the alternative data source might be less clear cut or more difficult to access. To be conservative, we explored how our estimates might change if we assigned a low percentage (10% proportion) to these categories. If the US were to produce a formal account to the standards BEA produces other National Income and Product Accounts (NIPAs), then it would require extensive work in estimating these partial product/industry categories. This would require additional source data from government agencies (in some cases, special data collections or internal data) and the private sector. In other cases, simple statistics and tabulations from alternative data may not be sufficient, as it may also require more sophisticated statistical analysis or modeling based on that data. This is not a problem unique to the US, as numerous countries around the world face similar challenges to align product/industry categories with environmental purposes.

One way to address misalignment of product/industry categories is to alter the survey collection process or identify data that could stand in for firm-level or entity-level microdata. In fact, the US EPA and Census used to survey firms regularly on their pollution abatement costs and expenditures (PACE) starting in the 1970s and continued until 2005.[45] A recent trend for statistical agencies in the US, however, has been to find ways to shed their reliance on costly surveys that firms and individuals find increasingly burdensome. Agencies like BEA and the US Census Bureau have progressively found ways to incorporate "Big Data" and administrative data as supplements to, or in some cases replacements for, traditional survey data.[46] Hence, if the US would begin devoting significant resources to constructing official environmental-economic accounts in the coming years, there may be opportunities to employ these 21st century approaches using existing data. By exploring additional ways data sources that already exist (i.e., "nontraditional data" that is collected for some other purpose, but that may be of sufficient quality to be used for statistical purposes) and, to the extent that gaps remain, subsequently deploying more limited (less burdensome) surveys may fill those gaps. For example, if there are ways the Economic Census could be altered to address some of the key data gaps, one avenue to mitigate these gaps would be for BEA to work with the Census Bureau and other agencies on subsequent revisions to survey collections such that the underlying SUT data (and other government data) would better align with environmental classifications. Some key mixed categories could be disaggregated further to provide cleaner breaks of environmental and conventional, non-environmental output along the lines of its primary purpose.

The imperfect alignment of NAPCS/NAICS can also be addressed, at least in part, as part of the ongoing NAPCS/NAICS revision cycle. These classification systems are continuously revised over time to accommodate changing aspects of the economy. However, to this point, since the US does not yet formally produce SEEA-based accounts, this revision process has not had a focus on altering classifications in ways to better align some of these definitions with SEEA explicitly. We cannot speak for our partnering countries like Canada and Mexico, however, as they

[45] https://www.epa.gov/environmental-economics/pollution-abatement-costs-and-expenditures-2005-survey#History
[46] For a summary of some of these Big Data efforts by the BEA, see: Moyer, B.C. and Dunn, A., 2020. Measuring the Gross Domestic Product (GDP): The Ultimate Data Science Project. *Harvard Data Science Review*, 2(1). https://doi.org/10.1162/99608f92.414caadb. For a summary of uses of nontraditional data sources across the US government and academia for economic measurement, see: Abraham et al. (2019), Editor's Introduction, *Big Data for 21st Century Economic Statistics: The Future Is Now*. National Bureau of Economic Research.

may (or may not) have been actively prodding revisions in this direction. If the US were to fund the regular production of environmental activity accounts, BEA would need to cooperate with the BLS, Census Bureau, and others on the White House Office of Management and Budget (OMB)-led Economic Classification Policy Committee (ECPC) to explore how NAPCS/NAICS could be altered in future revision cycles to better align with collection and classification related to environmental activity. We should note that this is a careful, deliberate process, as what revisions are made would need to maintain current levels of usability and quality for existing users of NAPCS/NAICS (like the NIPA accounts). The process could take several years, at least.[47]

The US may also need to consider whether there are important areas that are included in the Classification of Environmental Activities (See SEEA-CF Table 4.1) but which are excluded from the CEPA/CReMA classification developed for the European Statistical System. For example, the management of aquatic resources and management of mineral resources have not been explicitly part of the CEPA/CReMA system in prior years. The BEA has already developed Marine Satellite Accounts, so that the management of aquatic resources – including, for example, the relevant work of the National Oceanic and Atmospheric Administration (NOAA) – would seem to be a logical extension of the EGSS for the US. Both Canada and the UK have developed country specific classifications for this area of statistics, and future iterations of the US EGSS would likely consider additional categories needed for domestic users in addition to the categories developed by the international institutions.[48]

5.2 Environmental R&D and the Limitations of Firm-level ESG Data

We briefly mentioned in section 3.3 that, due to data limitations, we omit environmental R&D from the EGSS tables presented in this paper. In this subsection we discuss in greater depth why this is an important omission and how limitations of firm-level ESG data present challenges for filling this data gap. Indeed, the lessons we learned from examining this data more closely may

[47] The proposed production timelines for the OSTP-OMB-DOC *National Strategy* for various environmental-economic accounts extend many years into the future. One reason for this, among many, is that the deliberative processes altering source data collections can take years in the US federal statistical system. Likewise, the revision process to potentially alter NAPCS/NAICS categories relevant for environmental activity accounts would also extend years into the future.

[48] Other areas for improvements include working with the US Forest Service to identify ways to identify timber harvest quantities from sustainably managed forests and expenditures related to sustainable forest management; and isolating US production of Energy Star appliances and electric and hybrid vehicles rather than total sales in the US which include imported products.

have broader implications for how national statistical offices (NSOs) use this data in the future (or how this data might evolve to be more useful for national accounts).

R&D expenditures represent a critical component of our economy and are likely an important omission in the initial pilot version of this EGSS account, given the long history of research linking R&D activity, innovation, and economic growth (see, for example, Stokey 1995; Ulku 2007; Aghion and Jaravel 2015). Yet, this omission is not unique in the development of national economic accounts. Historically, R&D has been a difficult issue for the national accounts given that the intangibility of its output has been difficult to measure. In fact, it was not until the BEA's comprehensive revision back in 2013 that R&D was incorporated into the investment component of GDP. The incorporation came after several iterations of a R&D satellite account—the first one being created in 1994.[49]

Though R&D output is now in the supply-use data (i.e., purchases of R&D are capitalized in the SUTs since they are recorded as investments) and is also part of GDP. It is not, however, broken down by function in a way that is directly useable for the purposes of the EGSS pilot account.[50] As part of this pilot study, we therefore investigated supplemental data to estimate the proportion of total R&D that is undertaken for primarily an environmental purpose. One potential source of non-traditional data is firm-level disclosures in their annual reports (10Ks) and supplemental/voluntary environmental, social, and governance (ESG) disclosures.[51] According to a recent report by KPMG, 96 percent of the largest (and 80 percent of large and mid-cap) firms

[49] Several iterations of the satellite account were needed to resolve some fundamental measurement questions such as: What is the output? How can R&D expenditures be transformed into an R&D capital stock? How should the output of R&D be valued? And how fast does R&D capital depreciate? For an excellent review, see "Evolving Treatment of R&D in the US National Economic Accounts" Moylan and Okubo (2020) https://www.bea.gov/system/files/2020-04/the-evolving-treatment-of-rd-in-the-us-national-economic-accounts.pdf

[50] The discussion in this section focuses on environmental R&D in the private sector, but there is potentially important data related to public sector R&D as well. For example, the NCSES NSF Federal budget statistics include an environmental function (Table 11) and an energy function (Table 10), which includes energy efficiency and other relevant topics (https://ncses.nsf.gov/pubs/nsf22316/#section9397). See also Boroush (2022) for a broader discussion of these statistics, including data sources and methods. The government performs an R&D function, but it also funds private sector activity. Although the R&D function can be separately identified, these could be double-counted since the budgets of relevant agencies have already been included in the estimates. As a result, the use of the NSF R&D statistics for government expenditures needs to be considered carefully so as to not introduce double-counting.

[51] Under US GAAP, firms generally expense R&D whereas in the NIPAs R&D is capitalized following SNA standards (Rassier 2014). While environmental R&D expenditures are not (currently) a required disclosure for US GAAP, US firms more generally follow an expensing approach (in line with US GAAP) rather than a capitalization approach when reporting these values.

around the world already publicly report on sustainability (KPMG, December 2020).[52] To help evaluate the coverage and availability of current (voluntary) private industry information on environmental activity, BEA purchased a database from Refinitiv's ESG Bulk Data that captures detailed firm-level environmental disclosures from across the globe (for 106 countries) over 2002-2021. While much of the ESG data used in academic studies corresponds to firm-level environmental category scores (e.g., climate change risk scores)) produced by various vendors, Refinitiv is presently the only data vendor we are aware of that offers a centralized database on monetized estimates of environmental activity, such as environmental R&D expenditures, environmental fines, and environmental provisions, which are the most relevant for the national accounts.[53]

While proprietary, Refinitiv pulls information from a number of different public documents in which firms report ESG information: annual reports, CSR or sustainability reports, company websites, NGO websites, stock exchange filings, and news sources. For US firms in this global database, we linked these records with Compustat North America based on the firm's CUSIP supplemented by its ticker and year to be able to compare the degree of environmental R&D expenditures reported in Refinitiv relative to the overall annual R&D expenditures reported by the firm in its annual 10-K filings following US GAAP. Overall R&D expense and other financial statement information for US firms come from Compustat. We report descriptive statistics and examples of the coverage of environmental R&D reporting in Appendix 2 and 3 in the Annex.[54]

In Appendix 2, we report an array of descriptive statistics to help illustrate the potential landscape for public disclosures about environmental activity in private industry as a resource for populating national accounts. Several takeaways from these statistics are important to this discussion. First, in line with the conclusions from KPMG report discussed above, we find that a

[52] The large firms sample (labeled "G250") is based on the world's 250 largest companies by revenue as defined in the Fortune 500 ranking of 2019. The large and mid-cap firm sample (labeled "N100") is based on a worldwide sample of 5,200 complies that represent the top 100 companies by revenue in each of the 52 countries and jurisdictions captured in the study.

[53] ESG data vendors, like MSCI, Sustainalytics, and others generally provide ratings or scores and a number of indicators or (binary) flags that contribute to these ratings. But, they do not provide monetized environmental expenditure and revenue values for firms that are relevant for evaluating environmental goods and services accounts.

[54] We had initially considered developing a regression model to predict environmental R&D based on existing firm data in the Refinitiv data and linked firm characteristics from Compustat; then, we would evaluate the proportion of environmental R&D for a broader, more representative sample of firms. As we show in Appendix 2, the US data for environmental R&D is very limited. We would like to explore this further (and whether using global data for prediction proportion estimates may be relevant) in future research.

substantial number of firms around the world report at least some type of environmental activity to the public and a large proportion of the reported activity corresponds with US firms (roughly 50 percent) (see Panel C of Appendix 2). Further, we observe that the extent of reported environmental activity has increased over time (see Panel B). For example, the number of firms captured in the global Refinitiv data reporting relevant environmental data globally in 2002, 2010, and 2021 was 982, 7,106, and 12,587, respectively.

The statistics in Appendix 2 also reveal a couple of key limitations of the private sector data's potential as a resource for national accounts, particularly for environmental R&D. First, only a very small percent of the global database provides monetized values that correspond to EGSS activities like environmental R&D expenditures (e.g., CEPA 80). For example, only about three percent of observations with environmental activity report environmental R&D expenditures (see Appendix 2 Panel D). Further, only 1 percent of the global database provides the firm's country information in addition to the environmental R&D expenditure to be able to evaluate which country would include the activity in its national accounts.[55] Second, when we examine the small sample of US firms that did report environmental R&D expenditures and benchmark this with the overall R&D expense reported by these firms for US GAAP (Panel B),we identify some additional concerns relevant whether the nature of these activities falls within the definitional scope relevant for a national account. For example, we observe that about 12 percent (13 percent) reported environmental R&D expenditure values that exceeded (exactly equaled) their overall GAAP annual R&D expense whereas the remaining 74 percent report environmental R&D expenditures less than the firm's GAAP annual R&D expense.[56] The types of firms that report a very high amount of environmental R&D relative to GAAP annual R&D expense could represent differences in definitional distinctions for how US firms report their environmental values relative to GAAP classifications (e.g., a firm could allocate more overhead or labor costs to R&D than

[55] In Appendix 2 Panel D, we report that a total of 3,368 out of the 123,169 firm-year observations provide environmental R&D expenditures (3,368/123,169 = 2.7 percent) but in Panel C we show that only 1,160 firm-years provide a country address attached with the disclosure (1,160/123,169 firm-years = 0.9 percent). While not broken out in the Appendix 2 table, it is worth noting that this is not unique to environmental R&D expenditure coverage. The percentage of the database with other monetized environmental costs like environmental fines and environmental expenditures, while higher than environmental R&D expenditures, is still relatively small (8.5 and 10.9 percent, respectively).

[56] Appendix 2 Panel B shows reports that out of 105 US firm-years with available environmental R&D expenditure and GAAP annual R&D expenditure data available in Compustat North America, 13 observations (12 percent) had an environmental value greater than the annual GAAP value, 14 (13 percent) had values that equaled, and 78 (74 percent) had environmental values less than their annual GAAP R&D expenditure value.

what GAAP would consider as R&D). Alternatively, it could represent different horizons for how environmental values are reported in public disclosures (e.g., if firms only provide forward-looking, multi-year expenditure values rather than annual values) or other aspects of reporting discretion with environmental R&D given it is a voluntary disclosure. Each of these considerations present challenges with using voluntary, private firm environmental disclosures for national accounts, not only for the US but also NSOs abroad that might consider this kind of data for national accounts purposes.[57]

Overall, our investigation of the Refinitiv global data offers a few lessons regarding the use of firm-level data in constructing environmental activity accounts. First, the current data reported by US firms for their environmental R&D is very limited and only disclosed by a small percentage of public firms, making extrapolations from such a small sample problematic. The rate of growth in reporting on this data over time, however, presents the possibility that the data may be more representative in future years. Second, an additional limitation of private sector data is that currently ESG disclosures are largely voluntary where much of the information is not standardized and the information is not harmonized around a common set of definitions and classifications.[58] From a national accounts perspective, this data would be most useful when the accounting definition in the firm-level disclosure is sufficiently aligned with the SEEA/NIPA accounting definitions. In other words, even if there would eventually be rich/representative enough data reported with ESG disclosures,[59] if the accounting definitions are sufficiently far apart, then its usefulness would still be limited for national statistical offices.

[57] To illustrate where the environmental R&D data comes from, in Appendix 3 we present excerpts of sustainability reports for two different firms covered in the Refinitiv data, Weyerhaeuser and AAON, which show the linkage between their reported GAAP R&D expense, environmental R&D expenditures, and environmental R&D as a percent of annual GAAP R&D expense. We provide these examples for three reasons. First, these excerpts present examples of different firm-years in the Refinitiv data in each of the categories above (when environmental values exceed, equal, or are less than GAAP values). Second, they depict one aspect of the substantial variation with which this information is presented in sustainability reports (e.g., a table (Weyerhaeuser) vs. a narrative (AAON) summary). Finally, providing the report excerpts helps to give context on the nature of the R&D the firm considers as serving an environmental function. For instance, while the Weyerhaeuser report decomposes aspects of its R&D into percentage breakdowns that relatively clear ties to the environment in its timberland business (e.g., "water quality," "ecosystems and biodiversity"), AAON's explains that the R&D it ascribes to serve an environmental function may also more generally engineer its HVAC products for "performance, flexibility, and serviceability."

[58] For example, recent work by Berg et al. (2022) raise concerns with the noisiness of ESG ratings and scores. This is one reason why we emphasize using the underlying expenditure data, as it is not clear how these scores would be of use for the national accounts.

[59] We should note that there are different conventions in the literature that define "ESG" activities and the reporting of those activities. We follow Christensen, Hail, and Leuz (2021, p. 1,179), and use the terms "ESG," "CSR," and

More recently, US accounting standard setters and regulators have laid out plans to consider environmental disclosure standards and requirements for US firms. One notable example came in March of 2022, when the Securities and Exchange Commission (SEC) released a climate-disclosure proposal targeting an initial effective date in December 2022. The proposed rules would require SEC registrants (both domestic and foreign private issuers) to phase-in disclosures on climate-related financial statement metrics and emissions information in firm registration statements and annual reports. These proposed rules were built from the Task Force on Climate-related Financial Disclosures (TCFD) framework. The proposal received more than 5,000 comments from the public that debate the legality of the proposal and different aspects of the disclosure requirements.[60] For example, the comments questioned the relevant materiality threshold that should be used to assess when companies must report climate costs for line items in the financial statements. The original proposal required that any climate costs that are 1 percent or more of each line item of a company's financial statements (e.g., like R&D expense, SEC 2022, p. 135) would have to be reported.[61]

While weighing in on the private industry climate disclosure debate falls outside the scope of this paper, our analysis from examining private sector ESG data suggests that if environmental information reported by firms (whether mandated or voluntary) becomes more standardized and commonly reported, its usefulness to statistical agencies will directly relate to how well the accounting used by firms aligns with the SEEA-CF and SNA. From a public goods perspective, if firm environmental disclosures are highly compatible with national accounts information in a standardized way, it would aid their broader use by policymakers and users in the national accounts. Information that can be more readily aggregated into national statistics can help provide

"sustainability" interchangeably while recognizing that there are subtle differences in these terms. In particular, we define ESG activities are those that "assess, manage, and govern" a firm's impacts on society and the environment. Further, we define reporting as "measurement, disclosure, and communication" about these activities.

[60] The discussion of comments on the proposal is based on a Harvard Law School Forum discussion and related review of the comments on SEC climate rulemaking by the Commonwealth Climate and Law Initiative, which prepared a summary classification of more than 1,000 comments made by "trade associations, politicians, NGO and third sector entities, companies, investors and academics, as well as lawyers, professional organizations, regulators and standards bodies" (Williams and Eccles 2022).

[61] However, the proposal did not specifically address how to treat "expensed or capitalized costs that are *partially* incurred towards the climate-related events and transition activities (*e.g.*, the expenditure relates to research and development expenses that are meant to address both the risks associated with the climate-related events and other risks)" (SEC 2022, p. 138-139).

a broader perspective on the economy than any single datapoint disclosed by a firm, as we know from the use of other national (and regional) statistics like GDP or the unemployment rate.[62]

5.3 Future Challenges and Concluding Remarks

Overall, while this pilot effort identifies an important list of challenges to consider for potential EGSS accounts, it also shows that there are reasonable, tangible avenues for tackling these challenges. The data gaps discussed above are significant, though not insurmountable if production of official environmental activity accounts are sufficiently funded in the US. Further, future work could expand the scope of the EGSS to incorporate other aspects of this sector besides output to fill out a more complete picture of the "green economy" (as prior efforts had called it). For example, funding for an "official" satellite account might also produce measures of GDP (value added), employment, and compensation in this sector. Using BEA's established satellite account module would also allow for adding in inventories and removing double-counting of electricity produced from renewable sources and help address a number of other issues discussed above. Taken together, the results of our proof-of-concept EGSS account show that quantifying the environmental goods and services sector would not only be feasible (conditional on resources to fill aforementioned data gaps), but would also offer a potentially valuable part of a suite of accounts that could help further our understanding of the intersection of the environment and the economy in the 21st century.

Looking forward, another challenge is a conceptual one. Like the other pilot accounts cited above, this study largely takes the SEEA Central Framework and other international standards as given, applying their principles and methods to US data. As these standards evolve over time to incorporate new/revised methods and periodically change their scope, standard setters may reevaluate key measurement issues we discussed earlier in the paper. For example, we noted in the description of our current methodology that energy saving appliances and electric cars are part of the EGSS. This binary, "in-out" treatment of these products is consistent with international standards. Yet should the *full* product be considered environmental, even if the overall product fits the primary purpose criterion? For example, if two luxury cars are both plug-in electric vehicles, but one has a higher-end features that have nothing to do with environmental protection (e.g., nicer

[62] See also Vardon et al. (2016) and Keith et al. (2017) for additional discussion of the use of environmental-economic accounts information for policymakers and natural resource management.

interior or a fancier sound system), should the marginal difference in value between those cars be included in the EGSS account? Prior academic work in environmental economics has attempted to disentangle the environmental component from output (e.g., Shadbegian and Gray, 2005; Färe et al., 2007), but the data and methodological demands to disentangle these components may be insurmountable to do at scale for an entire economy currently. Or, if a once-considered environmental product becomes the only option (via regulation or otherwise), do we classify it differently going forward? Future standard setters, potentially armed with better data and more developed methods to tackle these nuances, may revisit these issues in the years ahead.

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ANNEX

Appendix 1 – Environmental Goods and Services Identified in BEA Supply-Use Tables

Products in the Supply-Use Tables	Environmental portion	Data used to isolate environmental portion
Agriculture products by type	Certified Organic agriculture products	US Dept of Agriculture Certified Organic Surveys for 2015 and 2019; Value of Sales. See below for link
Forestry and logging	Timber harvested from sustainably managed forests	n/a (see note)
Game preserves	Portion that is for protection and not only for hunting	n/a
Support activities for agriculture and forestry	Portion of support activities that is for certified organic agriculture and sustainable forestry	n/a
Electric power generation from: Hydroelectric, Nuclear electric, Solar electric, Wind electric, Geothermal, and Biomass	All	Supply-use tables
Water supply services	All	Supply-use tables
Sewage treatment facilities	All	Supply-use tables
Construction and maintenance of: - Sewage and waste disposal structures; - water supply structures; - conservation and development facilities; - sewer facilities	All	Supply-use tables
Construction and maintenance of electric utilities structures	Renewable energy structures and facilities portion	n/a
Durable goods manufacturing	Energy star appliances	EPA ENERGY STAR® Unit Shipment and Market Penetration Report Calendar Year 20xx Summary
	Electric vehicles	US Department of Energy, Energy Efficiency & Renewable Energy, Alternative Fuels Data Center: https://afdc.energy.gov/data/ Calculated as number of HEV+PEV+AltFuel vehicles sold in US as percent of total number of Light Duty Vehicles produced in USA

	Various products including Diverse insulation products; Mineral wool; Firewood; Diverse repair and rebuilding works; Solar energy collectors; Air source heat pumps	Supply-use tables
	Various products including Particle board – portion that reduces virgin materials; Products made from wastes; Construction papers for insulation; Sealed insulating glass products; Fabricated steel plate containers for trash (only); Turbine generators – those used in hydropower plants;	n/a
Non-durable goods manufacturing	Various products including Fuel ethanol, water treatment compounds, plastic water and sewer pipe, water pipe, sewer pipe, tire retreading	Supply-use tables
	Various products including Plastic drain, waste and vent pipe; Latex foam products for insulation	n/a
Testing Laboratories	There are many different types of testing laboratories, need portion that tests environmental media such as water, soil, air, etc.	n/a
Environmental Consulting Services	All	Supply-use tables
Waste Collection	All	Supply-use tables
Waste Treatment and Disposal	All	Supply-use tables
Remediation Services	All	Supply-use tables
Materials Recovery Facilities	All	Supply-use tables
Septic tank and related services	All	Supply-use tables
All other miscellaneous waste management services	All	Supply-use tables
Expenses of Environment, Conservation and Wildlife Organizations (tax exempt)	All	Supply-use tables
Tax exempt receipts of Environment, Conservation and Wildlife Organizations (tax exempt)	All	Supply-use tables
Sales of scrap and refuse of manufactured goods	All	Supply-use tables

Federal nondefense government services	US EPA US Dept of Agriculture: - Forest Service; US Dept of Interior: - Bureau of Land Management; - Bureau of Ocean Energy Management; - Bureau of Reclamation; - Fish and Wildlife Service; - US Geological Survey; - Wildland Fire Management; - National Park Service - Office of Surface Mining Reclamation and Enforcement; - Natural Resource Damage Assessment and Restoration Program;	Public budget documents for 2017 & 2021 which show the 2015 & 2019 actual figures. US Environmental Protection Agency: See Budget in Brief documents (link below) Forest service: https://www.fs.usda.gov/about-agency/budget-performance Dept of Interior Agencies: https://www.doi.gov/bpp/budget-justifications
State & Local government services: - Agriculture and natural resources; - Parks and recreation; - Water utilities; - Sewerage systems	All	Supply-use tables
Sales of scrap and refuse of manufactured goods	All	Supply-use tables

Note: n/a means environmental portion could not be ascertained so these products were excluded from the estimates in tables 1a, 2, and 3. For table 1b, the environmental portion of these products was estimated to be 10% of total output.

USDA Certified Organic Survey Data:
https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Organic_Production/
US EPA Budget documents:
https://www.epa.gov/planandbudget/archive

Appendix 2 – Private Industry Public Environmental Information

Panel A – Sample construction for the US environmental R&D sample (*N = firm-year observations*)		
Description	***N excluded***	***N remaining***
Refinitiv global environmental detail file for 2002-2021		123,169
Require firms to have country information (by address) to identify US firms	21,244	101,925
Limit to US firms [a] *To put this into perspective, there are 163,832 U.S. firm-years in Compustat North America (Compustat NA) for the same period. This suggests it is likely that roughly 31% of large US public firms both report some form of detailed environmental information publicly and have environmental information captured in the Refinitiv detail file.*	51,574	50,351
Limit to firms with non-missing values of environmental R&D expenditures [b] *For comparison, there are 61,898 US firm-years in Compustat NA in this period with GAAP R&D in Compustat NA. This suggest a much smaller % of large US public firms both report environmental R&D expenditures and have this information captured in the Refinitiv detail file (about 0.3%).* [c]*Coverage for other monetized US environmental values are also relatively small (environmental fines (N: 1,771 (1.1% of 163,832 in Compustat NA)); environmental expenditures (N: 2,261 (1.4% of 163,832 in Compustat NA))).*	50,186	165
Require non-missing and non-zero values of GAAP R&D expense ("XRD") in Compustat NA to calculate environmental R&D as a % of GAAP annual R&D expense	60	105

Panel B – Distribution of environmental R&D expenditures reported for US firms as a % of GAAP annual R&D expense

	N	***1%***	***5%***	***10%***	***25%***	***50%***	***75%***	***90%***	***95%***	***99%***	***Mean***
All	105	0.04	0.50	13.62	23.51	50.39	100.00	109.25	172.00	250.00	64.94
If >100%	13	100.03	100.03	101.38	116.25	157.50	191.30	250.00	283.95	283.95	165.48
if =100%	14	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
if <100%	78	0.03	0.49	0.50	19.37	37.99	66.67	85.82	99.38	99.99	41.90

Panel C – What is the cross-country coverage of global environmental detail and of environmental R&D expenditures? [d] *Excludes the 21,244 without country information by address*							
Refinitiv global environmental detail file (N = 101,925)						***Reported environmental R&D expenditures (N = 1,160)***	
ISO 3 country code	**Country**	**N**	**% of Total**	**Unique Firms**	**% of Total**	**N**	**% of Total**
AIA	Anguilla	13	0.01	2	0.01		
ARE	United Arab Emirates	120	0.12	38	0.23		
ARG	Argentina	300	0.29	61	0.38		
ATG	Antigua and Barbuda	2	0.00	1	0.01		
AUS	Australia	5,282	5.18	645	3.97	2	0.17
AUT	Austria	390	0.38	40	0.25	52	4.48
AZE	Azerbaijan	3	0.00	1	0.01		
BEL	Belgium	631	0.62	62	0.38	11	0.95
BGR	Bulgaria	3	0.00	2	0.01		
BHR	Bahrain	43	0.04	9	0.06		
BHS	Bahamas	13	0.01	3	0.02		
BMU	Bermuda	588	0.58	75	0.46		
BRA	Brazil	1,357	1.33	177	1.09	113	9.74
BRB	Barbados	3	0.00	1	0.01		
CAN	Canada	5,748	5.64	795	4.89	42	3.62
CHE	Switzerland	1,925	1.89	275	1.69	27	2.33
CHL	Chile	441	0.43	52	0.32	6	0.52
CHN	China	1,127	1.11	311	1.91		
CIV	Côte d'Ivoire	1	0.00	1	0.01		
COL	Colombia	213	0.21	28	0.17	3	0.26
CRI	Costa Rica	3	0.00	1	0.01		
CYM	Cayman Islands	90	0.09	17	0.10		
CYP	Cyprus	71	0.07	16	0.10		
CZE	Czechia	62	0.06	6	0.04		
DEU	Germany	2,323	2.28	371	2.28	123	10.60
DNK	Denmark	619	0.61	79	0.49		
ECU	Ecuador	4	0.00	1	0.01		
EGY	Egypt	61	0.06	16	0.10		
ESP	Spain	1,039	1.02	104	0.64	81	6.98
FIN	Finland	678	0.67	98	0.60	76	6.55
FRA	France	2,248	2.21	329	2.03	73	6.29
FRO	Faroe Islands	7	0.01	2	0.01		
GAB	Gabon	2	0.00	1	0.01		
GBR	United Kingdom of Great Britain and Northern Ireland	7,468	7.33	925	5.69	81	6.98
GEO	Georgia	6	0.01	1	0.01		
GGY	Guernsey	170	0.17	39	0.24		
GIB	Gibraltar	17	0.02	2	0.01		
GRC	Greece	192	0.19	28	0.17	3	0.26
GUF	French Guiana	1	0.00	1	0.01		
HKG	Hong Kong	294	0.29	56	0.34		
HRV	Croatia	9	0.01	1	0.01		
HUN	Hungary	64	0.06	7	0.04		
IDN	Indonesia	284	0.28	49	0.30	12	1.03
IMN	Isle of Man	28	0.03	5	0.03		
IND	India	2,561	2.51	718	4.42	38	3.28
IRL	Ireland	728	0.71	68	0.42	13	1.12
ISL	Iceland	38	0.04	16	0.10		
ISR	Israel	428	0.42	92	0.57		
ITA	Italy	1,283	1.26	232	1.43	33	2.84
JAM	Jamaica	6	0.01	1	0.01		

JEY	Jersey	122	0.12	17	0.10		
JPN	Japan	23	0.02	3	0.02		
KAZ	Kazakhstan	26	0.03	5	0.03	2	0.17
KEN	Kenya	7	0.01	1	0.01		
KHM	Cambodia	3	0.00	1	0.01		
KOR	Korea (the Republic of)	12	0.01	2	0.01	2	0.17
KWT	Kuwait	18	0.02	3	0.02		
LIE	Liechtenstein	7	0.01	2	0.01		
LKA	Sri Lanka	12	0.01	1	0.01		
LUX	Luxembourg	266	0.26	50	0.31	15	1.29
MAC	Macao	9	0.01	2	0.01		
MAR	Morocco	100	0.10	41	0.25		
MCO	Monaco	49	0.05	8	0.05		
MDG	Madagascar	3	0.00	1	0.01		
MEX	Mexico	656	0.64	115	0.71	6	0.52
MLT	Malta	44	0.04	10	0.06		
MNG	Mongolia	4	0.00	2	0.01		
MUS	Mauritius	3	0.00	1	0.01		
MYS	Malaysia	1,271	1.25	363	2.23		
NGA	Nigeria	21	0.02	5	0.03		
NLD	Netherlands	940	0.92	111	0.68	18	1.55
NOR	Norway	597	0.59	100	0.62	9	0.78
NZL	New Zealand	537	0.53	68	0.42		
OMN	Oman	3	0.00	2	0.01		
PAK	Pakistan	39	0.04	12	0.07		
PAN	Panama	20	0.02	2	0.01		
PER	Peru	236	0.23	42	0.26		
PHL	Philippines	341	0.33	43	0.26		
PNG	Papua New Guinea	24	0.02	3	0.02		
POL	Poland	421	0.41	45	0.28	2	0.17
PRI	Puerto Rico	51	0.05	7	0.04		
PRT	Portugal	211	0.21	19	0.12	13	1.12
QAT	Qatar	17	0.02	7	0.04		
REU	Réunion	1	0.00	1	0.01		
ROU	Romania	24	0.02	9	0.06		
RUS	Russian Federation	560	0.55	57	0.35	26	2.24
SAU	Saudi Arabia	22	0.02	7	0.04		
SGP	Singapore	1,027	1.01	128	0.79		
SVK	Slovakia	9	0.01	3	0.02		
SVN	Slovenia	9	0.01	3	0.02		
SWE	Sweden	1,987	1.95	430	2.65	29	2.50
TGO	Togo	2	0.00	1	0.01		
THA	Thailand	575	0.56	144	0.89	2	0.17
TUR	Türkiye	584	0.57	111	0.68	69	5.95
TWN	Taiwan (Province of China)	15	0.01	3	0.02		
TZA	Tanzania, the United Republic of	5	0.00	1	0.01		
UGA	Uganda	11	0.01	3	0.02		
UKR	Ukraine	14	0.01	2	0.01		
URY	Uruguay	12	0.01	2	0.01		
USA	United States of America	50,351	49.40	8,178	50.34	165	14.22
VEN	Venezuela (Bolivarian Republic of)	4	0.00	1	0.01		
VGB	Virgin Islands (British)	15	0.01	4	0.02		
VIR	Virgin Islands (U.S.)	10	0.01	2	0.01		
VNM	Viet Nam	75	0.07	34	0.21		
ZAF	South Africa	1,521	1.49	166	1.02	13	1.12
ZWE	Zimbabwe	12	0.01	1	0.01		
Total		***101,925***	***100***	***16,246***	***100***	***1,160***	***100***

Panel D – What is the trajectory of environmental detail information over time?

[e] *Because this does not require separation by country it includes the 21,244 without country information*

	Refinitiv global environmental detail file (N = 123,169)		***Reported global environmental R&D expenditures (N = 3,368)***	
Year	**# of Firms**	**% of Total**	**# of Firms**	**% of Total**
2002	982	0.80	25	0.74
2003	997	0.81	34	1.01
2004	1,840	1.49	74	2.2
2005	2,287	1.86	118	3.5
2006	2,310	1.88	106	3.15
2007	2,503	2.03	133	3.95
2008	3,013	2.45	157	4.66
2009	4,036	3.28	166	4.93
2010	7,106	5.77	191	5.67
2011	6,831	5.55	197	5.85
2012	6,961	5.65	218	6.47
2013	7,302	5.93	219	6.5
2014	7,422	6.03	214	6.35
2015	7,617	6.18	206	6.12
2016	7,847	6.37	201	5.97
2017	9,196	7.47	193	5.73
2018	9,446	7.67	204	6.06
2019	10,058	8.17	228	6.77
2020	12,828	10.41	241	7.16
2021	12,587	10.22	243	7.21
Total	***123,169***	***100***	***3,368***	***100***

Panel E – What is the allocation of this information by industry?

[f] *Industry classifications used are to be defined by earlier industry classifications in the paper*

	Refinitiv global environmental detail (N = 123,169)		***US environmental detail (N = 50,351)***		***Reported global environmental R&D expenditures (N = 3,368)***	
NAICS (2-digit)	**N**	**% of Total**	**N**	**% of Total**	**N**	**% of Total**
31 Manufacturing	5,112	4.15	1,565	3.11	78	2.32
32 Manufacturing	12,491	10.14	4,470	8.88	728	21.62
33 Manufacturing	22,113	17.95	9,668	19.20	1,446	42.93
54 Professional, scientific, and technical services	8,535	6.93	5,184	10.30	74	2.20
Other	74,918	60.83	29,464	58.52	1,042	30.94
Total	***123,169***	***100***	***50,351***	***100***	***3,368***	***100***

Appendix 3 – Private Industry Examples of Environmental R&D Expenditures as a Percent of Annual GAAP R&D Expense

Example 1 – Weyerhaeuser (Ticker WY) – an American timberland company

Year	Annual GAAP R&D expense (Millions of $)	Environmental R&D expenditure (Millions of $)	% of annual GAAP R&D expense
2018	$8	$9.3	116.25
2019	$6	$8.6	143.33
2020	$5	$8.6	172.00
2021	$5	$9	180.00

Sustainable Forest Management			
	2019	**2020**	**2021**
Millions of seedlings planted	139	132	137
Acres of timberlands harvested	253,503	205,420	181,244
Percent harvested, by region*			
US - West	2%	2%	2%
US - South	3%	2%	2%
US - North	1%	1%	2%
**The percentages shown above are clearcut acres only. In the Northeast and in select other instances, we also practice variable retention silviculture. Including these acres, the percent of land harvested increases slightly.*			
Harvest acres regenerated within five years (percent), U.S. only*	99%	100%	99%
Forestry research spending (millions of US$)	$8.6	$8.6	$9.0
Forest health and productivity	81%	77%	74%
Water quality	6%	6%	6%
Fish and wildlife	7%	11%	7%
Ecosystems and biodiversity	2%	1%	6%
Other	3%	4%	7%
Timberlands and manufacturing facilities certified to SFI's Sustainable Forest Management or Fiber Sourcing standards	100%	100%	100%
Manufacturing facilities and export yards certified to SFI and PEFC Chain of Custody standard	50%	50%	50%
**We are committed to replanting 100% of harvested acres. However, sometimes fire destroys young trees. Burned acres are replanted as soon as possible.*			

Source for manual comparison of environmental R&D expenditure amounts:
https://www.weyerhaeuser.com/sustainability/data-and-gri-index/

Example 2 – AAON (Ticker AAON) – an HVAC manufacturer

Year	Annual GAAP R&D expense (Millions of $)	Environmental R&D expenditure (Millions of $)	% of annual GAAP R&D expense
2019	14.8	14.8	100.00
2020	17.4	17.4	100.00
2021	16.6	14.8	89.16

RESEARCH AND DEVELOPMENT

Our products are engineered for performance, flexibility, and serviceability. Research and Development (R&D) has become a critical factor to compete in the HVAC equipment industry. We must continually develop new and improved products to compete effectively and to meet evolving regulatory standards in all of our major product lines. AAON self-sponsors our Research and Development activities, rather than relying on customer sponsored R&D.

Research and development activities have involved the RQ, RN, and RZ (rooftop units), F1, H3, SA, V3, and M2 (air handling units), LF (chillers), CB and CF (condensing units), SA and SB (self-contained units), and WH and WV (water source heat pumps), as well as component evaluation and refinement, development of control systems and new product development.

R&D expenses incurred were approximately $16.6 million, $17.4 million, and $14.8 million in 2021, 2020, and 2019, respectively.

The Norman Asbjornson Innovation Center (NAIC), a research and development laboratory facility that opened in 2019, includes many unique

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Source for manual comparison of environmental R&D expenditure amounts: https://www.aaon.com/download/AAON_ESGReport_2021_221017.pdf