A Framework for Sustainability Indicators at EPA

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Foreword

Science provides the foundation for credible decision-making. Only through adequate knowledge about the risks to human health and ecosystems, and innovative solutions to prevent pollution and reduce risk, can we continue to enjoy a high quality life. With a better understanding of environmental risks to people and ecosystems, the U.S. Environmental Protection Agency can target the hazards that pose the greatest risks and anticipate environmental problems before they reach a critical level.

EPA balances its scientific research activities across the two broad categories of problem-driven research (to solve current environmental problems of high risk and high scientific uncertainty) and core research (to improve the underlying scientific foundation for understanding and protecting human health and the environment). These two aspects of EPA's research program at times overlap, and can be mutually reinforcing--work on a particular problem can lead to a fundamental breakthrough, and discoveries made while conducting core research can solve a particular environmental problem. EPA needs both types of research, and the synergy between them enhances EPA's overall research program.

This publication has been produced as part of the Office of Research and Development's strategic long-term research plan. It is published and made available by EPA to assist the user community and to link researcher s with their clients.

Cynthia Sonich-Mullin, Director

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Table of Contents

Figures and Tables

A Framework for Sustainability Indicators at EPA

1. Introduction

1.1. Purpose

The purpose of this document is to provide useful methods and guidance to support the application of sustainability indicators in EPA decision making, and particularly within the Office of Research and Development's (ORD) research programs. The primary target audience is EPA researchers, as well as Program and Regional Office staff, that have a need for measurement of progress in some aspect of sustainability. However, it is anticipated that external organizations will find this information useful, as well.

When choosing goals and indicators, it is important to consider the intended use of the indicators and how they will be received and interpreted. There are at least four different "lenses" or perspectives that may be considered in EPA's use of indicators.

1. **Public Reporting**. The EPA Report on the Environment (ROE) is an example of an informational document that describes the current state of the environment and observed trends in the US (USEPA, 2008). It is not related to any particular decision, but serves to characterize overall environmental conditions. The relevant sustainability indicators should similarly be broad measures that relate to economic, environmental, and social conditions, mainly at a national scale. Potential indicators for the ROE are discussed in Section 5.1.

2. **Decision Making**. In the context of specific environmental problems or agency programs, EPA will need to make decisions about alternative actions that are possible. These actions could range from statutory enforcement to voluntary collaboration or communication. As discussed below, a recent report by the National Resources Council (NRC) of the National Academies (NRC, 2011) provides a detailed blueprint for how EPA can incorporate sustainability considerations into such decisions. In this case, decision makers should select **primary** sustainability indicators that will be used to track specific outcomes of the decision and will be meaningful to the concerned stakeholders. Guidelines for selection of such indicators are presented in Section 5.2.

3. **Research Planning**. For ORD's purposes, priorities need to be established across a number of broad research domains, driven by the needs of EPA Program and Regional offices. The primary indicators used for agency decision making will provide a basis for identification of additional indicators to be incorporated into research projects that investigate the causal relationships among environmental, economic, and social conditions. Thus, the additional sustainability indicators adopted by ORD will typically correspond either to underlying **drivers** or to unintended **consequences** of changes in the primary sustainability indicators. Selection of indicators for such investigation is further discussed in Section 6.

4. **Program Evaluation**. For purposes of analyzing the productivity and effectiveness of ORD programs, it is necessary to use program evaluation indicators that measure the **outputs** and **direct outcomes** of research activities relative to the time and funds invested. For example, an output indicator is the number of research publications and a direct outcome indicator is the number of citations. However, program evaluation is outside the scope of this document. The primary indicators addressed in this document are measures of **ultimate outcomes** that are meaningful to stakeholders, such as reduction in greenhouse gas emissions due to adoption of energy conservation practices. While there is a presumed link between research outcomes and ultimate outcomes, attribution can often be difficult.

Having a uniform, consistent framework of sustainability indicators will facilitate communication among ORD and the Regional and Program Offices, and will enable integration across the six major ORD programs focused on air, water, energy, products, communities, human health risks, and national security. Effective choice of indicators will assure that the benefits of sustainable solutions can be identified and validated and will enable an adaptive management process that responds to changing conditions.

1.2. The Role of Sustainability Indicators at EPA

The recently published NRC report, known as the "Green Book", provides a framework for implementing sustainability at EPA (see Figure 1) (NRC, 2011). An important component of this framework is the establishment of sustainability objectives, goals, indicators, and metrics as a basis for evaluating and reporting of the agency's progress. NRC recommends that EPA set breakthrough 3 to 5-year sustainability objectives based on an overarching vision for the agency and suggests establishing measurable short-term goals using appropriate indicators to measure progress toward these objectives.

Moreover, it defines the following concepts relevant to performance measurement:

- **Goal**—what is specifically sought to be achieved. Progress toward a goal is determined through the use of measurable indicators. An example of a goal is: Reduce mercury emissions from electric utility steam generating units.

- **Indicator**—a summary measure that provides information on the state of, or change in, the system that is being measured. An example of an indicator for the above goal is: Mass of mercury emitted per unit of energy delivered.

- **Metric** –the measured value(s) used to assess specific indicators. It defines the units and how the indicator is being measured. An example of a metric for the above indicator is: Grams of mercury per kilowatt-hour.

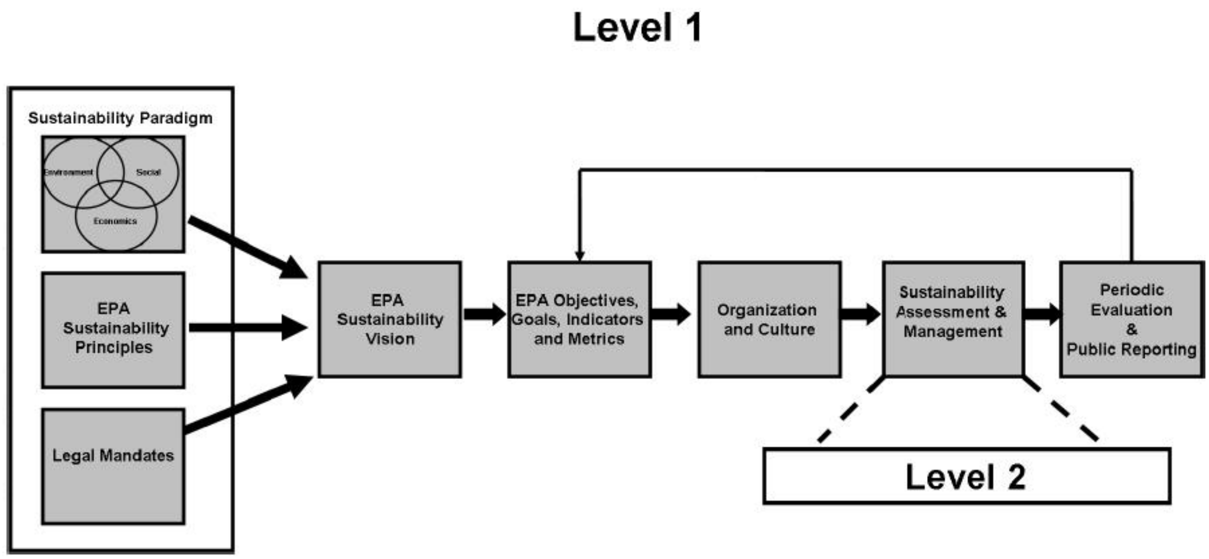

Figure 1 - Agency-wide process for implementing sustainability at EPA

The report also provides guidelines for the Level 2 Sustainability Assessment and Management process, in which indicators and corresponding metrics play a key role in problem definition, trade-off analysis, and tracking the outcomes of Agency decisions. Once indicators and metrics are chosen, it is necessary to define the methods that will be used for data collection and interpretation to calculate the value of the metric. These methods should be transparent and well documented in order to enable verification and replication over time. As discussed in Section 5, to apply this process to the investigation of specific decisions or problems there will be a need to identify indicators at an appropriate spatial and temporal scale to match the scope of the application. In particular, for purposes of ORD research programs, a variety of different tools and metrics will be needed to characterize the environmental, social, and economic aspects that are addressed within the project portfolio. Frameworks like those presented by Zamagni et al. (2009) and Eason et al. (2011) provide guidance on tools and key considerations useful for sustainability based development and decision making. In conjunction with these frameworks, this report provides guidelines for the selection of metrics relevant to sustainability assessment and management, ranging from broad national indicators for annual reporting to detailed, problem-specific indicators that address individual communities, regions, watersheds, chemicals, media, receptors, or categories of impacts.

1.3. Origin of this Document

This document is primarily the result of a Sustainability Indicator project completed in September 2011 by a team of researchers drawn from several ORD laboratories and centers. The principal goals of the project were:

- To support the development and inclusion of sustainability indicators in a new EPA ROE to be released in electronic form in 2012.
- To assist ORD's national research programs in the selection of appropriate sustainability indicators that are compatible across programs at the national level.
- To enable monitoring of long-term trends which are relevant to sustainability.

Accordingly, the project team established a conceptual framework for research planning and performance measurement and developed a comprehensive inventory of sustainability indicators based on worldwide benchmarking. This work has since been developed into a task within the EPA Sustainable and Healthy Communities Research Program (SHCRP) and will be discussed further in Section 4. It is expected that this document will provide a shared language for the application of sustainability indicators within EPA, as well as a common framework for guiding the selection and use of sustainability indicators in specific research projects and decision contexts.

2. Conceptual Foundations

2.1. Definitions of Sustainability

The concept of sustainability is based on the interdependence between human societies and the natural environment. Current patterns of economic and social development are placing pressures upon natural resources, and may threaten the continued health and prosperity of human societies. In recognition of these concerns, the National Environmental Policy Act of 1969 articulated a growing interest in understanding the importance of the relationship between humans and the environment. The very language of the act foreshadows ideals soon to be of great significance globally:

"…to declare a national policy which will encourage productive and enjoyable harmony between man and his environment; to promote efforts which will prevent or eliminate damage to the environment and biosphere and stimulate the health and welfare of man."

In 1987, a World Commission on Environment and Development report (UN, 1987) entitled, Our Common Future (also known as the Brundtland report) called for the global adoption of these principles and presented the classic and most quoted definition of sustainable development:

> "…development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

It is clear that a significant transformation of human production and consumption patterns will be needed in order to enable continued economic growth while protecting critical environmental resources. International agencies such as the United Nations (UN), the Organization for Economic

Cooperation and Development (OECD), and the World Bank have focused considerable attention on the challenge of achieving sustainability while promoting poverty alleviation and economic development. As stated in the Green Book, "…current approaches aimed at decreasing existing risks, however successful, are not capable of avoiding the complex problems in the United States and globally that threaten the planet's critical natural resources and put current and future human generations at risk, including population growth, the widening gaps between the rich and the poor, depletion of finite natural resources, biodiversity loss, climate change, and disruption of nutrient cycles" (NRC, 2011). Likewise, the international business community has recognized the practical and economic consequences of the sustainability challenge (WBCSD, 2011). With increasing commitments to corporate responsibility, many companies have adopted global environmental management system standards such as ISO 14001 (ISO, 2004), which specify performance indicators as a required element. The emergence of the Global Reporting Initiative (GRI; http://www.globalreporting.org/Home) (GRI, 2006) and other sustainability reporting schemes has placed renewed emphasis on the selection, monitoring, and verification of sustainability indicators.

Although the Brundtland Commission definition succinctly captures the essence of sustainability, it is too abstract for purposes of program planning and operational management. Many organizations have developed more functional definitions that are aligned with their specific focus and values. These are often based on the concept of the "three pillars" of sustainability—environmental, economic, and social—and may place more or less emphasis on each of the three pillars. For example, the following definition was used in a recent EPA Executive Order:

> ''sustainability'' and ''sustainable" mean to create and maintain conditions, under which humans and nature can exist in productive harmony, that permit fulfilling the social, economic, and other requirements of present and future generations (Federal Register, 2009)

Human health is frequently considered to be a component of the social pillar of sustainability. However, for EPA's purposes, the following may be a useful definition of sustainability, appropriately emphasizing human health and the environment: Sustainability is the continued protection of human health and the environment while fostering economic prosperity and societal wellbeing.

In response to the large and growing need for better understanding of how sustainability trends relate to EPA's mission, the ORD has aligned its research programs with the overarching theme of sustainability. This is an opportune time for EPA to act as a catalyst for innovation in technologies, policies, and business models that will enable society to prosper within the limits of available natural capital. Therefore, ORD's research will focus on understanding the interplay between environmental, social and economic systems. This approach is required to enable the Agency to fundamentally change the manner in which it addresses systemic environmental problems (e.g., climate change, eutrophication, mercury, etc.) – and relates to the "…difference between treating disease and pursuing wellness" US EPA Lisa Jackson remarks (Greenley, 2012).

2.2. Sustainability Indicator Frameworks

From the perspective of environmental research and regulatory policy, there are two fundamental questions that underscore the need for indicators of progress toward sustainability (Kates et al., 2001):

- How can today's operational systems for monitoring and reporting on environmental and social conditions be integrated or extended to provide more useful guidance for efforts to navigate a transition toward sustainability?
- How can today's relatively independent activities of research planning, monitoring, assessment and decision support be better integrated into systems of adaptive management and social learning?

Based on the three pillars concept, a **sustainability indicator** can be defined as a measurable aspect of environmental, economic, or social systems that is useful for monitoring changes in system characteristics relevant to the continuation of human and environmental well being.

The use of sustainability indicators and corresponding metrics is essential for an integrated systems approach to the addressing challenges of sustainability. When carefully chosen and implemented, indicators can help managers and policy makers to (modified from "An overview of sustainability assessment methodologies" (Singh et al., 2009):

- Anticipate and assess conditions or historical trends
- Provide early warning information to prevent adverse outcomes
- Benchmark against other systems
- Communicate ideas
- Support decision-making
- Formulate strategies and establish improvement goals
- Track progress

The **conceptual framework** in which indicators are to be applied is an important consideration in the selection of indicators. Many sustainability frameworks have been proposed and used by different organizations around the world. These include the three pillars concept mentioned above, the driver/pressure/state/impact/response (DPSIR) model (European Commission et al., 1999), the driver/pressure/state/exposure/effects/action (DPSEEA) model (Kjellström and Corvalán, 1995; Briggs et al., 1996; Corvalán et al., 1999)(Serageldin, 1996) and the Daly (Daly, 1973) triangle as discussed by (Meadows, 1998). System dynamic models can provide more detailed information on the structure and behavior of complex dynamic systems and can enable the more informed selection of indicators (Gustavson et al. 1999). The choice of an appropriate conceptual framework and corresponding indicators is heavily dependent upon an individual's purpose, worldview, and system of values. The approach presented here is compatible with any and all of these schemes.

The logic of these frameworks can also serve as a basis for aggregating individual indicators into an integrated/composite indicator or index. An index is a quantitative aggregation of many indicators and can provide a simplified, coherent, multidimensional view of a system (Mayer, 2008). Many schemes have been proposed for creating an integrated sustainability index and examples include the Environmental Quality Index, Genuine progress, the Yale Environmental Sustainability Index, Fisher information, Ecological Footprint, Emergy, and Genuine Savings Index (Redefining Progress, 1995; The World Bank, 1997; The World Economic Forum, 2001; USEPA, 2010)(Redefining Progress 1995), (http://envirocenter.research.yale.edu/programs/environmental-performance-management/environmental-sustainability-index/). However, construction or adoption of such an aggregation scheme requires insight and careful considered as discussed in Section 5.3.

In the three pillars model, one common approach is to select and consider a set of indicators unique to each of the three overlapping domains (environmental, economic and social), as illustrated in Figure 2.

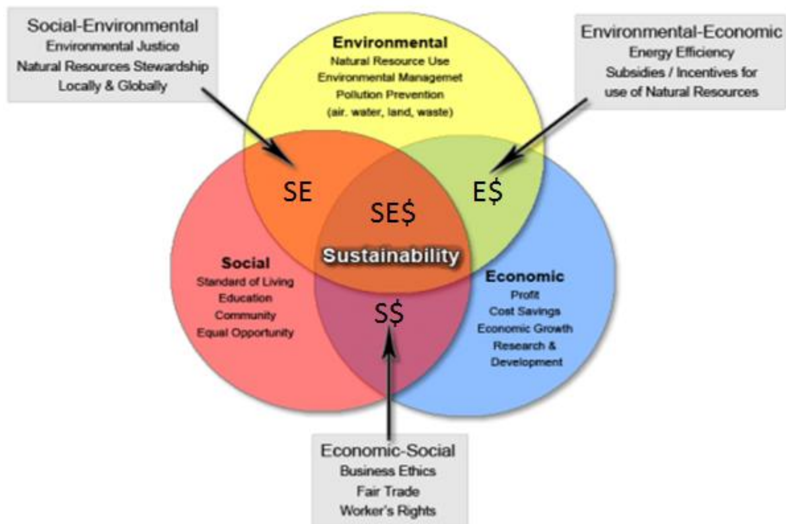

Figure 2 - The three dimensions (pillars) of sustainability (modified from Beach (2010)) to show the selection of 1-D, 2-D and 3-D indicators proposed by Sikdar (2003).

The indicators chosen from each domain and their relative importance in a decision-making process are important considerations and should be explicitly discussed because they reflect the focus and values of the decision makers. An analysis of the system to determine which indicators capture aspects that significantly contribute to movement toward or away from sustainability may provide additional insight on indicator selection.

Some indicators that reside in only one domain (1-D) can be normalized to create two-dimensional (2-D) indicators that are more meaningful and comparable. For example, water use, population, and economic output are 1-D indicators that can be combined to create 2-D indicators such as water consumption per capita, water consumption per $ of GDP, or GDP per capita. This type of normalization approach is proposed for inclusion of "resource intensity" indicators in the ROE (see Section 3).

It has been argued that "'...an environmental indicator becomes a sustainability indicator with the addition of time, limit or target." (Meadows, 1998). Indeed, any 1-D indicator can be tracked over time to examine the degree of change relative to either a historical baseline or a future objective. As discussed in Section 4, the rate or amount of improvement is a relative measure, indicating whether the system is moving toward or away from sustainability (USEPA 2010).

In some cases, a single indicator can be chosen that provides information relevant to two overlapping domains. For example, average concentration of blood lead (Pb) in humans is an indicator of both environmental exposures and possible impairment of human health (Fig. 2; SE). Similarly, changes in industrial employment as a result of green chemistry innovations (Fig. 2; E$) is an indicator of both natural resource protection and economic development. The annual amount of charitable donations (Fig. 2; S$) provides an indicator of both economic prosperity and improvements in human well-being. Some carefully selected single indicators can be relevant to all three domains (Fig. 2; SE$); for example, the per capita floor space of residential dwellings is a useful indicator because it correlates with both energy consumption and poverty alleviation, thus capturing the tension between financial prosperity, quality of life, and resource depletion.

Once indicators are selected and corresponding metrics are identified, criteria must be established and methods (e.g., Life Cycle Assessment) employed to acquire the data for each metric to evaluate the systems under study. Zamagni et al. (2009) and Eason et al. (2009) provide further details on topics related to sustainability based decision making and key tools for evaluating the aspects of the system related to the pillars of sustainability.

3. Classification of Sustainability Indicators

As defined above, a sustainability indicator is a measurable aspect of environmental, economic, or social systems that is useful for monitoring changes in system characteristics relevant to the continuation of human and environmental well being. In order to support the selection of indicators for specific applications, it is useful to classify sustainability indicators according to clearly defined categories and subcategories. Such a classification scheme is referred to as a **taxonomy**. There are numerous taxonomies that have been developed in the field of sustainability, and most of these have been surveyed for purposes of this project (see Section 4). The following identifies several taxonomies that will be helpful to EPA for purposes of program planning and performance tracking.

3.1 Three "Pillars" of Sustainability

The most widely used taxonomy is based on the three pillars of sustainability described in the previous section, and commonly referenced in traditional definitions of sustainability. These pillars are characterized as follows environmental, social and economic. Each category can be further divided into subcategories; for example social sustainability indicators for industrial health and safety are distinguished from those for community well being. Sometimes classifying an indicator depends on the scale and type of system being considered: for example, water use can be a one-dimensional or a two-dimensional indicator depending on the scope of analysis. As discussed in the previous section, some indicators such as "energy intensity" may capture the intersection of multiple pillars or dimensions of sustainability.

3.2 Report on the Environment Topics

The 2008 EPA ROE is organized according to a number of topics that provide a taxonomy relevant to EPA's traditional statutory responsibilities:

- Air
- Ecological Condition
- Human Exposure and Health
- Land
- Water

Additional sustainability topics that could supplement the above might include Social Condition (e.g., educational attainment) and Economic Condition (e.g., household income).

3.3. ORD National Programs

Another useful way to organize indicators is by relevance to the newly realigned national research programs of ORD, listed below:

- Air, Climate and Energy (ACE)
- Chemical Safety for Sustainability (CSS)
- Homeland Security Research (HSR)
- Human Health Risk Assessment (HHRA)
- Sustainable and Healthy Communities (SHC)
- Safe and Sustainable Water Resources (SSWR)

Since these programs are linked to one another, there will be many indicators that are relevant to multiple programs. For example, sustainable water indicators, which are significant in SSWR, will also be an important issue for SHC. The scale of research conducted under these programs will vary from a broad national scope to a regional or local context. Therefore, the framework for sustainability indicators will support multi-scale applications. In some cases, indicators can be aggregated from a local or regional scale to national scale (e.g., total emissions of a specified pollutant). In other cases, local or regional indicators will be specific to the geographic context and cannot easily be aggregated to a broader scale.

3.4. System-Based Indicators

It is clear that the characterization of sustainability and the development of sustainable solutions require a comprehensive "holistic-systems" approach with integrated evaluation of the social, environmental, and economic consequences (NRC, 2011). ORD has developed an innovative "triple value" (3V) framework, depicted in Figure 3 that helps to capture the dynamic interactions among industrial, societal, and ecological systems (Fiksel, 2009). There are four major categories of indicators that are applicable to these systems:

- Adverse Outcome (AOI)—indicates destruction of value due to impacts upon individuals, communities, business enterprises, or the natural environment.

- Resource Flow (RFI)—indicates pressures associated with the rate of consumption of resources, including materials, energy, water, land, or biota.
- System Condition (SCI)—indicates state of the systems in question, i.e., individuals, communities, business enterprises, or the natural environment.
- Value Creation (VCI)—indicates creation of value (both economic and well being) through enrichment of individuals, communities, business enterprises, or the natural environment.

Table 1 shows how these four major categories of indicators can be applied at different scales, and Figure 4 illustrates the detailed taxonomy of indicators associated with Resource Flow. This approach is intended to support both high-level aggregate indicators and more focused indicators associated with specific research areas or programs. Examples of the utilization of system-based indicators for the above ORD programs are provided in Section 6.

The Green Book (NRC, 2011)describes other types of indicator classifications that have been proposed. For example, one can distinguish between "policy-oriented' indicators that will respond in the short-term to policy initiatives and "outcome-oriented" indicators that reflect changes in fundamental stocks and flows of natural resources such as water, energy, and minerals. However, this distinction is often ambiguous, and was not deemed useful for present purposes.

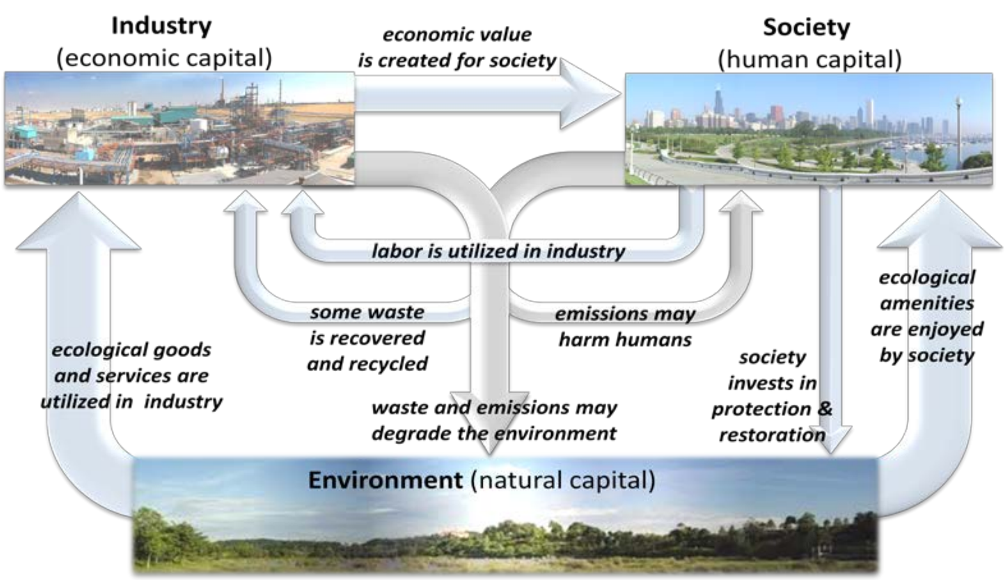

Figure 3 – Systems taxonomy for resource flow indicators, with examples (in yellow) of specific metrics for material intensity, recovery, and impact

Table 1 - Major Categories of System-Based Indicators

Indicator Category	Indicator Types	National Scale Examples	Community Scale Examples
Resource Flow Indicators	• Volume • Intensity • Recovery • Impact • Quality	• Greenhouse gas emissions • Material flow volume • Resource depletion rate	• Greenhouse gas emissions • Material flow volume • Water treatment efficacy • Recycling rate • Land use
Value Creation Indicators	• Profitability • Economic Output • Income • Capital Investment • Human Development	• Cost (reduction) • Fuel efficiency (gain) • Energy efficiency (gain)	• Cost (reduction) • Fuel efficiency (gain) • Energy efficiency (gain) • Vehicle use (miles per capita)
Adverse Outcome Indicators	• Exposure • Risk • Incidence • Impact • Loss • Impairment	• Health impacts of air pollution • Public safety • Life cycle footprint of energy use	• Health impacts of air pollution • Public safety • Sewer overflow frequency
System Condition Indicators	• Health • Wealth • Satisfaction • Growth • Dignity • Capacity • Quality of Life	• Air quality • Water quality • Employment • Household income	• Air & water quality • Local employment • Local household income • Housing Density • Infrastructure durability • Community educational equity

4. Global Inventory of Sustainability Indicators

4.1. Motivation

In accordance with the alignment of EPA research programs towards sustainability, a call to action was given within ORD to develop an inventory of peer reviewed sustainability indicators and link them to emerging EPA programs. The primary goals of the effort was to assist the ORD national research programs in the selection of appropriate sustainability indicators for programs such that a single taxonomy system is used and to make recommendations for candidate indicators which would be developed for the Report on the Environment. The project team engaged in an intensive search to understand the current "state of play" in sustainability indicators work and identify peer-reviewed indicators at various scales (e.g., national and regional). Further, they developed a taxonomy to help classify these indicators into a searchable database. The taxonomy itself is comprised of the classification schemes described in Section 3 (see Table 2) and includes linkages to national ORD programs. The database is intended to serve as a tool to aid in selecting indicators pertinent to EPA programs and incorporates information on relevant supporting resources. Outputs of the activity included draft versions of the indicator database cross-walked according to the taxonomies defined and a guidance document on the selection of sustainability indicators for EPA programs.

Table 2 - Taxonomy for Sustainability Indicators: Classification Schemes

Scale	Country/Org	Pillar	ROE Topic	Program	3V	Dimension
Global	US	ECO	Air	ACE	AOI	1D
National	UNEP	ENV	Ecological Condition	CSS	RFI	2D
Regional	Europe	SOC	Human Health	HHRA	SCI	3D
Community	etc.		Land	HSR	VCI	
Industrial			Water	SHC		
				SSWR		

This activity has since been developed into a SHC task (1.2.2.1) supporting the effort to provide indicators and indices to assess, track and inform community sustainability (i.e., sub-regional, local, city). Sustainability is recognized as a major factor influencing the long-term success of communities and an untapped reserve for ecological and human health-related research. However, finding the appropriate indicators to assess and/or inform community sustainability needs is daunting. The Database of Sustainability Indicators and Indices (**DOSII**) provides a searchable inventory of peer reviewed sustainability Indicators classified into a single taxonomy system designed to assist EPA's research and management in identifying candidate sustainability indicators and indices relevant to specific sustainability interests. Specifically, the task involves the development of (1) **DOSII**, a searchable database for selecting indicators, which may be used to assess sustainability and (2) a corresponding guidance document on the selection of sustainability indicators. Further, an interactive web-based tool will be developed to extend the indicator and indices database search capabilities to communities. Communities interested in exploring issues related to sustainability will be afforded a mechanism to develop a "customized" list of indicators and indices to support community-based decision-making, such as cost-benefit analysis, monitoring and assessment, and community outreach, based on the community's specific sustainability priorities. Other uses of the results generated from the tool are potentially limitless in the integrated sustainability program envisioned within the Agency. The suite of indicators generated could supply the basis for, description of, or feedback for any number of modeling efforts, engagement tools, and analytic processes. Further, there is a plan for future export and connection to EPA-based tools that will use the results. While **DOSII** provides the foundation for the web-based tool, it is a standalone tool in its own right. Although this effort is housed within the SHC program, this research task is an integrated transdisciplinary and cross-laboratory effort aimed at providing critical information that will aid in the development and selection of sustainability indicators for EPA programs. Hence, the database will afford the ability to access indicators for various topics and scales (e.g., national, regional and community) of implementation to include measures for evaluating the sustainability of programs, projects and activities related to air, water, energy, products, communities, human health risks, and national security. This work is intended to serve as both a source and "sink" for many other activities across the Agency as it is naturally linked to advancing science in such areas as decision analysis, regional assessments, technology evaluations and ecosystem services. Hence, a high level of collaboration is desired and expected as it will be connected to activities including (but not limited to) the Sustainability Metrics project, Sustainable Supply Chains, the Durham project, CSS Dashboards, Decision Analysis for Sustainable Environmental, Economy and Society (DASEES), chemical sustainability, Human Wellbeing Index, Environmental Quality Index and New and Emerging Media. The first iteration of the DOSII will be available October 1, 2012 (with annual updates) and the web tool is expected to roll out October 1, 2014. A draft of the proposed architecture for the web-based tool is provided in the Appendix.

4.2 Survey Results and Database Development

There is a plethora of activity related to sustainability indicators throughout the world. The International Institute of Sustainable Development lists nearly 900 sustainability initiatives worldwide, including almost 200 indicator development activities (IISD, 2011). Indicator evaluation and development projects often last for several years and involve task groups containing many experts who typically engage in a high level of review of existing sources and provide comprehensive information and synthesis reports detailing their efforts.

For this project, a number of well known resources (e.g., World Bank, UN Commission on Sustainable Development (UNCSD), Organization for Economic Co-operation and Development (OECD)) were initially reviewed to begin compiling the list of sustainability indicators. As the mining effort has continued, the lists of resources and indicators have progressively grown. To date, more than 50 resources (e.g., databases, reports, websites, workgroup studies and journal articles) were reviewed and over 6000 indicators have been identified and compiled. After eliminating obvious duplication and indicators from resources with no supporting description or metrics, compiling similar indicators (on-going), the list was reduced to 1411. Note: It is expected that the size of list change through subsequent iterations. These indicators have been organized according to the classification scheme (Table 2) and stored in a Microsoft Excel database; thereby, providing a "lay of the land" of existing indicators of varying spatial scale, scope and topic. Additional indicators will be synthesized, classified and incorporated during subsequent updates of the database.

As of this iteration, nearly half (48.5%) of the indicators analyzed are multi-dimensional (i.e., 2-D or 3-D) and most are deemed usable at multiple scales (e.g., national, regional, etc.). While the majority of the indicators can be linked to Sustainable and Healthy Communities (SHC), nearly 30% of them relate to the Air, Climate and Energy. The remaining programs (i.e., SSWR, CSS, HHRA and HSR) are linked to between 7.65% and 13.75% of the indicators.

The database is stored in a Microsoft Excel 2007 workbook ('DOSII.v1.xlsx') with tabs named [Indicators], [Sources] and [Summary]. The [Indicators] tab contains an inventory of the indicators and other pertinent details including the Source (shorthand for the reference (e.g., article, site, database) where the indicator was gathered), Scale, Pillar, Source theme (relates to the topic/theme as identified in the source), ROE topic, EPA Program, triple value (3V) classification, Dimension (e.g., two dimensional (2-D)) and Description (and/or metric). The [Sources] tab provides resource information including the Name, Acronym, Purpose or description of the study, the primary sustainability Pillar (i.e., economic, social and/or environmental) covered in the source, source themes, affiliated organization, scale (e.g., national), reference access information and date of last update. The [Summary] tab is a compilation of the summary statistics as provided in Table A3. A sample of the indicator database (Table A1) and resource list (Table A2) are provided in the Appendix.

4.3. Searching, Sorting and Filtering in the Database

The structured database can be used as a tool for selecting indicators relevant to particular programs or projects. This section provides instructions on **how to extract sustainability indicators** from the database by searching, sorting, and filtering according to specified criteria.

Simple techniques such as the Find command (Ctrl+F) and alphabetical sorting may be used to navigate in Microsoft Excel. For example, an alphabetical sort was used to coarsely sift through and remove duplicate indicators from the database. While these are effective methods for simple searches, efficiently maneuvering through the database typically requires more complex actions. By leveraging the advanced features of Microsoft Excel, users are able to input specific criteria to filter, sort and search the database as needed.

Suppose a user seeks a list of environmental indicators. One approach is as follows (see Figure 5):

1. Click on the filter pull down in the 'Pillar' column of the database.
2. Unclick the 'Select All' check box and then select the checkbox next to 'ENV'. This filters the list to include only indicators classified as "environmental".
3. The number of records meeting the criteria is listed on the status bar below the workbook tabs.

In this case, 537 records are returned denoting the number of indicators in the database that are classified as environmental indicators.

Another approach to generating a list from these criteria is to use the [Text Filter] provided in the [Pillar] pull down heading. By setting the text qualifier [Equals] and entering [ENV], the same results are returned. An alternative method is to use the text filter [Contains] and enter [ENV] in the Pillar column and then select [1D] in the Dimension column. Note that with any of the filtering actions, the indicators not meeting the specified criteria are not lost, but are hidden. The database may be restored in full by clicking on each of the filtered columns and checking the box next to [Select All].

A different result is obtained when only using the [Contains] ENV text filter and leaving the dimension column unaltered. The 955 indicators returned contains indicators that are classified as environmental, but may also relate to social and economic impacts. Thus, the resulting list contains multiple categories of indicators including ENV, ENV-SOC, ECO-ENV and ECO-ENV-SOC.

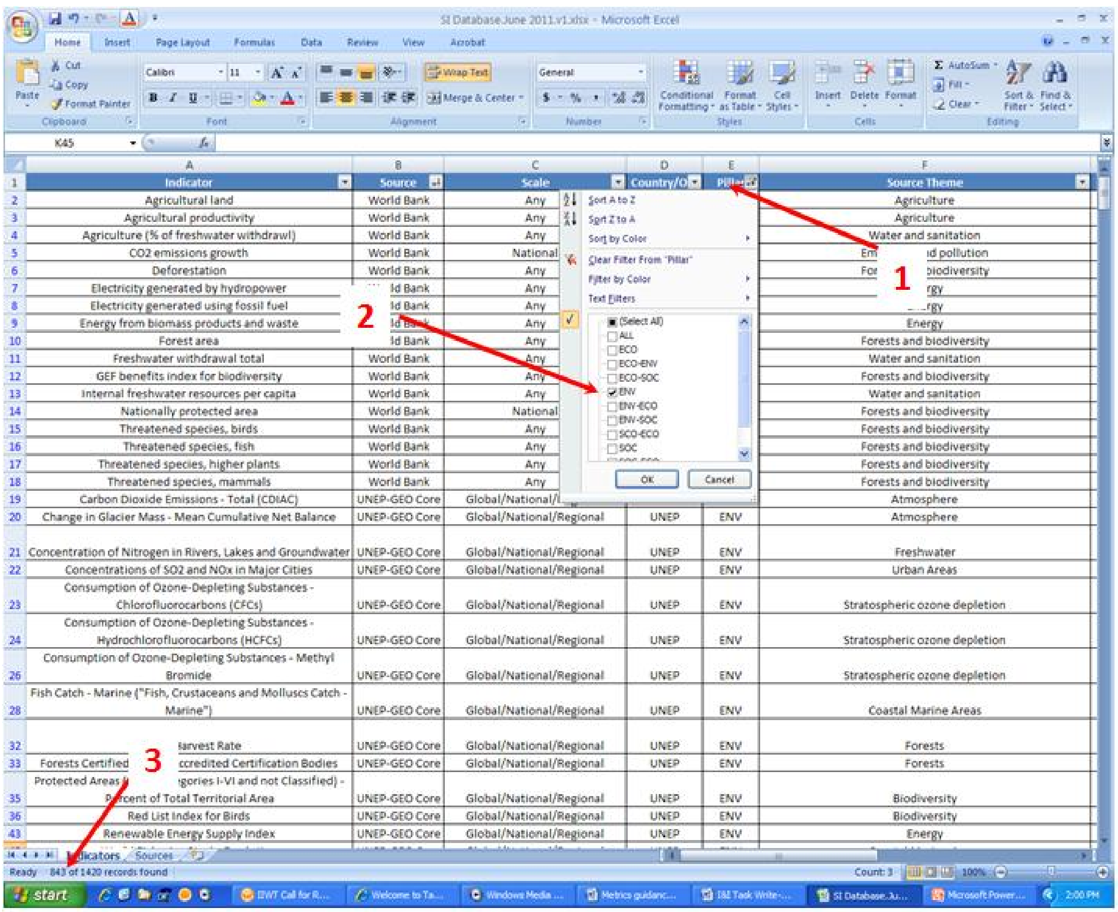

Figure 4 – Basic Steps for Filtering the Database

Building from the search for environmental indicators, the criteria may be refined to find environmental indicators related the SSWR program by keeping the filter set to [ENV] in [Pillar] column (e.g., select [ENV] only, step A in Figure 6) and checking every box in the Program column that contains the text

[SSWR] (step B in Figure 6). This customized filtering method returns 115 records. A less cumbersome approach is to select [ENV] in the Pillar column and use the text filter [Contains] [SSWR] in the Program column. By drilling down a bit further and setting the [Scale] custom filter to [Contains] [Regional] or

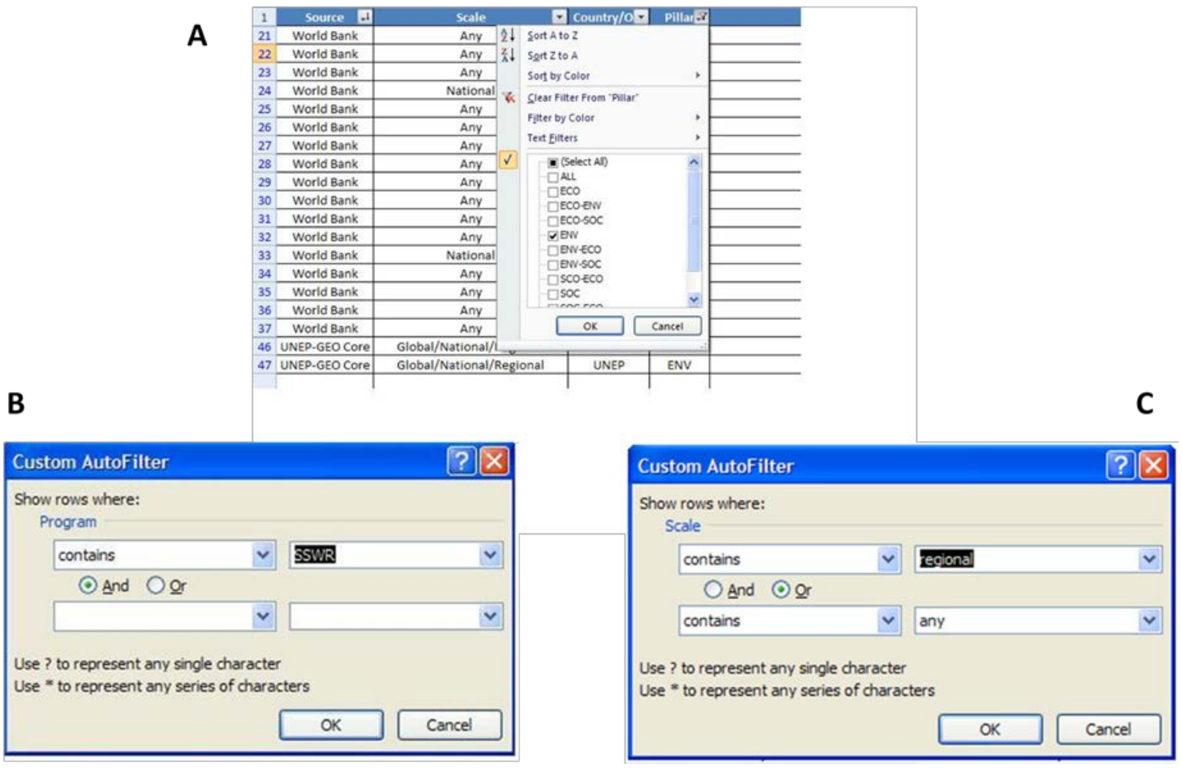

Figure 5 – Sample Custom Filter Search: Regional environmental indicators related to SSWR

[Contains] [Any] (Step C in Figure 6), 80 regional environmental indicators related to the SSWR program are returned.

4.4. Future work

The preliminary database and guidance document were initially used to a gain sense of the "world" of sustainability indicators, its subsequent linkages to EPA programs and recommend candidate sustainability indicators for the inclusion of the 2012 online, interactive EPA Report on the Environment. These products were made available to various researchers within ORD research programs (i.e., CSS, SHC, and SSWR) as well as others within program offices (e.g., OSWER) and Regional Offices (e.g., Region 1) who had an interest in investigating and identifying sustainability indicators.

Since **DOSII** is intended to be a repository of indicators for EPA programs, through multiple iterations, it will be honed and expanded in subsequent updates of the database and guidance document. Additional indicators and indices from other sources (including internal Agency projects) may be incorporated during this period, as well. Further, as previously mentioned, the continuation of the SHC task involves the development of the web-tool to enhance database access and extend **DOSII**'s search capabilities to communities through a user-friendly web interface. The first iteration of **DOSII** will be available October 1, 2012 (with annual updates) and the web tool is expected to roll out October 1, 2014.

As we have set our sights and efforts on moving in conjunction with the Path Forward, many have identified and championed the importance of sustainability indicators and indices. This work is an effort to compile, logically organize (in line with developed taxonomies) and synthesize information on the abundance of sustainability measures used around the world. In order to further increase the impact of the work, we propose a few recommendations to enhance consistency foster a collaborative spirit and capitalize on our transdisciplinary expertise:

- Due to the many terms and themes used and outlined in each source, it is necessary to undergo an iterative update and revision process to provide a succinct list and most accurately group similar indicators. However, much like typical sustainability indicator projects, it may be prudent to assemble an "expert" review panel in this effort. While we don't want to limit the amount of information available to researchers, program and regional offices or communities, a transdisciplinary approach will provide key understanding of systems, supporting indicators and corresponding metrics to streamline the database along the taxonomy. The goal of such an effort is to develop the most rational set of indicators for assessment, planning and analysis.
- An additional recommendation is the development of a core set of Agency sustainability themes to layer over the ORD research programs as an additional mapping mechanism that provides grouping themes that are source independent (e.g., World Bank, OECD). The Office of Science Information and Management's (OSIM) managed vocabulary work may provide some key insight and guidance toward this endeavor.

5. Selecting Sustainability Indicators

"Indicators arise from values (we measure what we care about), and they create values (we care about what we measure)" (Meadows, 1998). Whether in the context of government policy making or business decision making, indicators are essential for characterizing current conditions, evaluating management options that may be proposed, tracking the outcomes of actions taken, and assessing progress towards overall goals. The selection of indicators effectively determines the "lens" through which one views the system, and is therefore extremely important in influencing human decisions and judgments.

As discussed in Section 4, there are a wide variety of sustainability indicators used by different organizations in the U.S. and around the world. Depending upon the perspectives of various stakeholder groups and interested parties, the preferred indicators may be quite different. In addition, different indicators are needed at different spatial scales—from national-level reporting and tracking of progress to local, place-based or program-based investigation. This section addresses the selection of indicators in connection with two major EPA needs—the Report on the Environment, and focused planning or decision making.

5.1. Indicators for National Reporting

One objective of the Sustainability Indicators project was to select a small number of sustainability indicators for EPA's 2012 ROE. The ROE has strict guidelines for the choice of indicators, and requires a careful statement of rationale as well as supporting data and methodology. The ROE defines an indicator is defined as a numerical value derived from **actual measurements** of a pressure, state or ambient condition, exposure, or human health or ecological condition, over a specified geographic domain, whose trends over time represent or draw attention to underlying trends in the condition of the environment or human health (USEPA, 2008). The major categories of indicators reported in the 2008 ROE are discussed in Section 4.

Consistent with the Green Book recommendations, it is possible to augment the current ROE indicators to represent fundamental trends in sustainability. The simplest way to achieve this is to build upon existing indicators of pressures on the environment and human health that are already included in ROE. For example, one important goal for moving toward sustainability in a developed economy is to avoid adverse health and ecological impacts by reducing emissions of pollutants in the face of population and economic growth. To capture this trend, airborne emissions can be normalized by population size or annual economic output to create a 2-D indicator. An example of such an indicator is "greenhouse gas emissions per capita" or "greenhouse gas emissions per $ of gross domestic product". The normalizing factors are readily available from demographic and economic statistics maintained by other agencies. Rather than measuring an absolute condition, these indicators are measures of **intensity**, and reflect the rate at which pollutants are being generated in order to support the needs of the U.S. economy.

Airborne emission rates may be seen as an indirect measure of resource consumption, since they generally correlate with the rate of energy consumption and industrial activity. However, it is possible to reduce emission rates simply by pollution prevention and control technology, which does not necessarily lower the rate at which scarce resources are depleted or degraded. Another desirable option is to increase energy efficiency, thereby reducing the amount of energy (and corresponding impacts) required to deliver the same output (e.g., goods, services, electricity and transportation). Additional important goals for moving toward global sustainability are to reduce the rate at which non-renewable resources are consumed and to assure that consumption of renewable resources does not exceed their rates of natural regeneration (OECD, 2001). Accordingly, this project has investigated several additional indicators for national-scale reporting, reflecting the resource intensity for water, energy and materials.

- **Fresh water** is a critical, finite resource, and both the quality and availability of U.S. water sources are being stressed due to agricultural, urban, and industrial uses. An informative choice of sustainability indicator for water resources would be the use of water with respect to economic output (e.g., gross domestic product (GDP): **water use per unit of GDP**. Water use measures the amount of water withdrawn from the environment minus the amount discharged back into water bodies. This is an important consideration because some industrial sectors (e.g., electric power generation) return large quantities of treated water to the environment, while other sectors (e.g., agriculture) do not. Additionally, this water intensity indicator could be interpreted in the context of water scarcity to enable an assessment of sustainability. However, data to support this indicator as described above are currently not available. Every 5 years the US Geological Survey reports data on total water withdrawals compiled at the county level for industrial sectors. While current data constrains us to total water withdrawal intensities and limits interpretations with respect to sustainability, trends in water withdrawals per capita and per GDP can provide useful information on water withdrawal efficiencies by industrial sector or geographic region.
- **Energy** is a critical resource for economic growth and human well-being. However, there is growing concern over shrinking fossil resources, rising energy costs, and adverse impacts of certain energy generation technologies. The U.S. has achieved significant advances in energy efficiency and more opportunities exist to reduce energy demand and shift to renewable sources. Therefore, a useful sustainability indicator is the following measure of energy intensity: **energy use per unit of GDP**. Again, energy intensity can be measured on a national level and can be disaggregated across different energy use sectors.
- **Material** flow is an important aspect of sustainability because increasing material consumption requires a greater demand on resources (water, energy, minerals, land, etc.) and larger quantities of pollutants and wastes. In the U.S., over 90% of the materials that are extracted from the environment, transported, and processed are eventually discharged as waste or atmospheric emissions. To achieve sustainability it is necessary to break this pattern by "decoupling" material consumption from value creation. A suitable indicator of progress in material use reduction is material intensity, but it is difficult to gather reliable data on a national scale regarding actual material consumption over the life cycles of all products and services. Instead, a surrogate indicator for which reliable data are available is waste intensity, which can be measured as follows: **solid waste per unit of GDP**. Conservation of mass implies that the lower the amount of waste generated, the lower the overall material flow through the economy. This approach is consistent with the "sustainable materials management" initiative being conducted by EPA's Office of Resource Conservation and Recovery.

Although it appears that these intensity indicators only account for environmental and economic aspects, it is clear that core resources (e.g., energy, material and water) have a significant and measurable impact on people (hence, the social pillar), both individually and collectively. The goal of developing and recommending sustainability indicators for the ROE was to enhance the coverage past its core focus on the environment. Ongoing work on the ROE includes investigating the feasibility and relevance of these indicators and possibly expanding the use of intensity indicators by developing per capita measures (e.g., municipal solid waste per capita) to augment the view of sustainability and further highlight the impact of human activity. Subsequent editions of the ROE intend to increase the development, tracking and use of sustainability indicators.

5.2. Indicators for Focused Investigation

To accelerate successful adoption of the Sustainability Framework, the Green Book (NRC, 2011) recommends that EPA pursue a set of place-based and program-based pilot projects to develop sustainability expertise, encourage cultural change, and demonstrate value for stakeholders. Such projects will typically involve collaborations both within and outside EPA, making it critical to select a comprehensive set of goals and indicators that reflect stakeholder aspirations for shared value.

Generally speaking, in the context of decision making, a portfolio of indicators will be needed to represent the breadth of environmental and socioeconomic issues associated with sustainability. Typical categories of sustainability indicators that may be relevant to various stakeholder groups are illustrated in Figure 7. Note that in order to fully capture the dimensions of sustainability, environmental footprint reduction indicators need to be accompanied by stakeholder value creation. Table 3 further illustrates various categories of sustainability indicators that have been used by international organizations to characterize conditions in different countries and cities around the world.

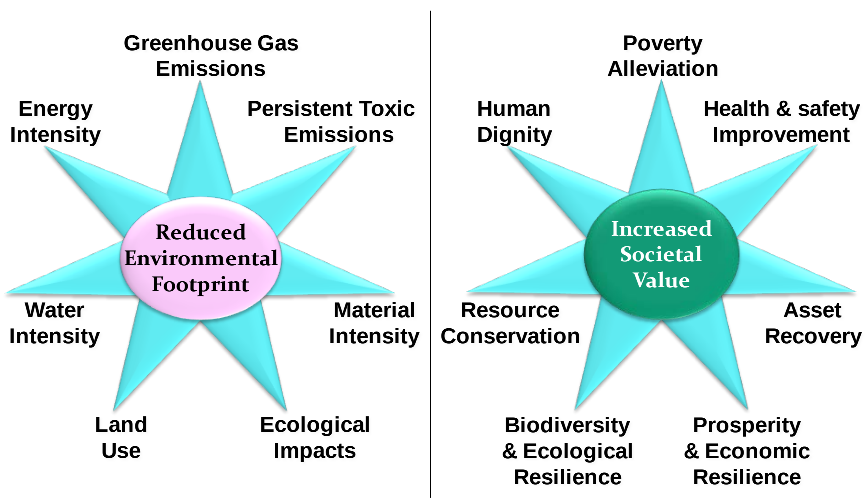

Figure 6 – Typical categories of sustainability indicators

Based on generally accepted performance measurement principles, an overarching criterion in the selection of indicators is "materiality," i.e., their relevance to the problem or issue under consideration. The following is a list of selection criteria that can be used to choose sustainability performance indicators (Fiksel, 2009). The set of indicators should be:

- **Relevant** to the interests of the intended audiences, reflecting important opportunities for enhancement of social and environmental conditions as well as economic prosperity.
- **Meaningful** to the intended audiences in terms of clarity, comprehensibility and transparency.
- **Objective** in terms of measurement techniques and verifiability, while allowing for regional, cultural and socio-economic differences.
- **Effective** for supporting benchmarking and monitoring over time, as well as decision-making about how to improve performance.
- **Comprehensive** in providing an overall evaluation of progress with respect to sustainability goals.
- **Consistent** across different sites or communities, using appropriate normalization and other methods to account for their inherent diversity.
- **Practical** in allowing cost-effective, non-burdensome implementation and building on existing data collection where possible.

In addition, the Green Book (NRC, 2011) states that indicators should have the following attributes:

- **Actionable**, so that practical steps can be taken to address contributing factors.
- **Transferable** and **scalable**, so that they are adaptable at regional, state, or local levels.
- **Intergenerational**, reflecting fair distribution of costs and benefits among different generations.
- **Durable**, so that they have long-term relevance.

While every indicator need not satisfy all of these criteria, a credible portfolio of sustainability indicators should have the above characteristics. The most effective performance measurement programs are those that focus upon a small number of quantifiable key performance indicators (KPIs) covering the most important aspects of sustainability for the specific problem at hand.

Table 3 – Examples of Sustainability Indicators Used Worldwide

Poverty
- Unemployment rate
- Poverty index
- Population living below poverty line

Population Stability
- Population growth rate trend
- Population density

Human Health
- Average life expectancy
- Access to safe drinking water
- Access to basic Sanitation
- Infant mortality rate

Living Conditions
- Urban population growth rate
- Floor area per capita
- Housing cost

Coastal Protection
- Population growth
- Fisheries yield
- Algae index

Agricultural Conditions
- Pesticide use rate
- Fertilizer use rate
- Arable land per capita
- Irrigation % of arable land

Ecosystem Stability
- Threatened species
- Annual rainfall

Atmospheric Impacts
- Greenhouse gas emissions
- Sulfur oxide emissions
- Nitrogen oxides emissions
- Ozone depleting emissions

Generation
- Municipal waste
- Hazardous waste
- Radioactive waste
- Land occupied by waste

Consumption
- Forest area change
- Annual energy consumption
- Mineral reserves
- Fossil fuel reserves
- Material intensity
- Groundwater reserves

Economic Growth
- GNP
- National debt/GNP
- Average income
- Capital imports
- Foreign investment

Accessibility
- Telephone lines per capita
- Information access

Sources:
United Nations, *Indicators of Sustainable Development*
World Bank, *World Development Indicators*

5.3. Integrated Indicator: Index

Many organizations have developed integrated indicators that combine multiple indicators into a single index as a common "currency". Examples include the Human Development Index used by the U.N., the Environmental Quality Index and the Genuine Savings Index mentioned earlier. While an index is convenient for purposes of communication and tracking, it reduces transparency by collapsing a variety of substantive information into a single index. Thus, it is difficult for a user or stakeholder to interpret the value of increasing the index or its underlying indicators by a certain amount. While reporting such aggregate indices, it is generally advisable to also present the information that comprises the index, and to make it available to interested parties. Many researchers have performed sustainability studies using multiple indices (e.g., Wilson et al., 2007; Nourry, 2008; Pulselli et al., 2008; Tiezzi and Bastianoni, 2008; Hopton et al., 2010). Such data can be presented as a spider diagram for visual inspection, but further aggregating these composite into a single overall index invites similar transparency concerns. Researchers around the world, including within ORD are wrestling with methods of identifying underlying drivers of behavior reflected in indices. Methods under investigation include principal components analysis (PCA), system dynamics models and correlation tests (Vyas and Kumaranayake, 2006; USEPA, 2010; Primpas et al., 2010; Eason and Cabezas, 2012; Gonzalez-Mejia et al., 2012).

Further, scientists are studying and testing methods based on fundamental properties of systems (e.g., thermodynamic and information-theoretic approaches) to develop a new generation of sustainability indices. Examples of these approaches include Fisher Information (Mayer et al., 2007), exergy (Dincer and Rosen, 2007; Baral and Bakshi, 2010), and emergy (Odum, 1994). These composite indicators can be used alone or in combination with other indicators. Emerging indices offer powerful scientific tools for sustainability assessment and are the subject of ongoing research. However, since the focus of this document is on the selection and implementation of commonly used, transparent, and meaningful sustainability indicators, a detailed review of indices is not included in this report.

6. Implementing the Use of Sustainability Indicators

Following the guidance of the Green Book (NRC, 2011), it is assumed that EPA will begin to implement a Sustainability Assessment and Management (SAM) process as depicted in Figure 8. The important features of the process include the following:

- **Comprehensive and systems-based**: Analysis of alternative options should include an integrated evaluation of the social, environmental, and economic consequences.
- **Selective application**: The level and depth of analysis should match with the scale and magnitude of potential consequences for the decision at hand.
- **Intergenerational**: The long-term consequences of alternatives should be evaluated in addition to the more immediate consequences.
- **Stakeholder collaboration**: Stakeholders should be involved throughout the process.

Sustainability indicators play a critical role in the SAM process, from the initial establishment of goals to the ultimate evaluation of outcomes. Ideally, the indicators used in the EPA sustainability assessment and management process will be consistent with the indicators in the Report on the Environment, thus providing linkages between broad national indicators (e.g., GHG emissions per capita) and focused local or regional assessments (e.g., annual energy use per urban household).

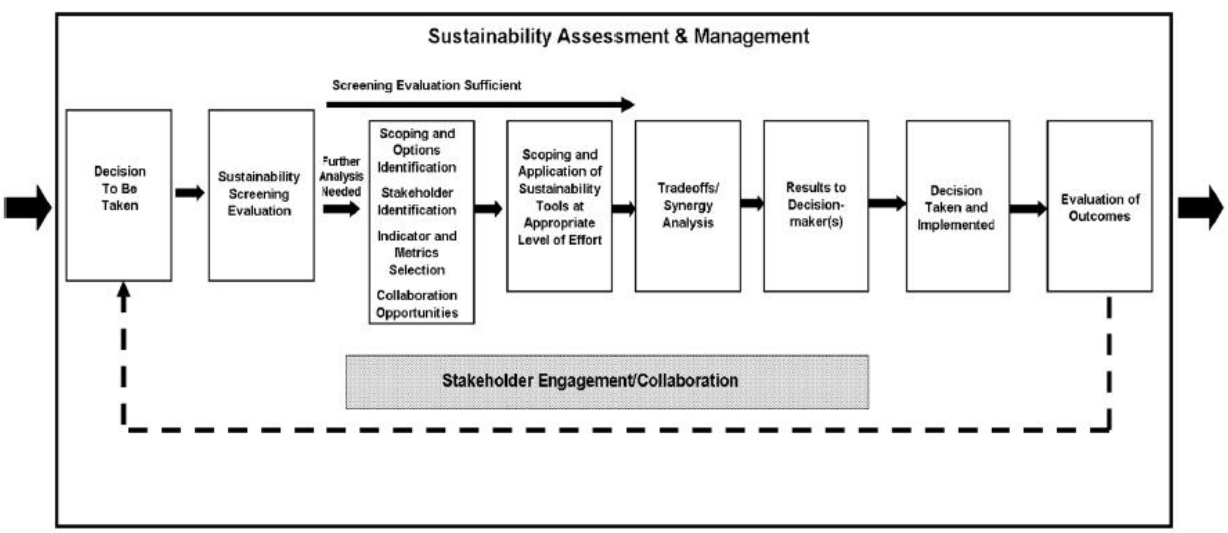

Figure 7 – The Sustainability Assessment and Management Process

Similar to SAM, the following is a five-step guideline for implementing the use of sustainability indicators in the context of applied research projects that are intended to support policy or decision-making. These steps are illustrated using a pilot project that is currently being conducted by ORD on mitigation of excessive nutrients (i.e., nitrogen and phosphorus compounds) in New England waterways, in collaboration with EPA Region 1. This is a place-based study focused on the Narragansett Bay and its watershed, with a broad scope that includes social, economic, and environmental issues.

Step 1 - Problem Definition, Scoping and Planning

Problem definition is a critical activity in the SAM process because it determines the scope and boundaries of the system to be considered, and explicitly identifies the relevant stakeholder interests. Systems thinking is needed because an overly narrow problem formulation may omit important unintended consequences. Therefore, definition of sustainability goals should address all the important environmental, economic, and social aspects that might be affected by a system intervention. In the Narragansett example, the overall goal is to reduce nutrient impairment while supporting regional economic growth and community well being.

Step 2 - Identification and Selection of Relevant Indicators

As discussed in Section 5.2, a portfolio of sustainability indicators should be chosen to address the goals of the research as well as the interests of different stakeholder groups. For the nutrient study, the triple value framework (see Section 3.4) was selected to represent the overall system, and ten primary “key” indicators were chosen covering each of the three major subsystems—industries, communities, and environmental resources. As shown in Figure 9, the Narragansett Bay project involved identifying and modeling the causal linkages among these indicators. During the course of the project, a variety of additional indicators were identified for purposes of modeling the system behavior.

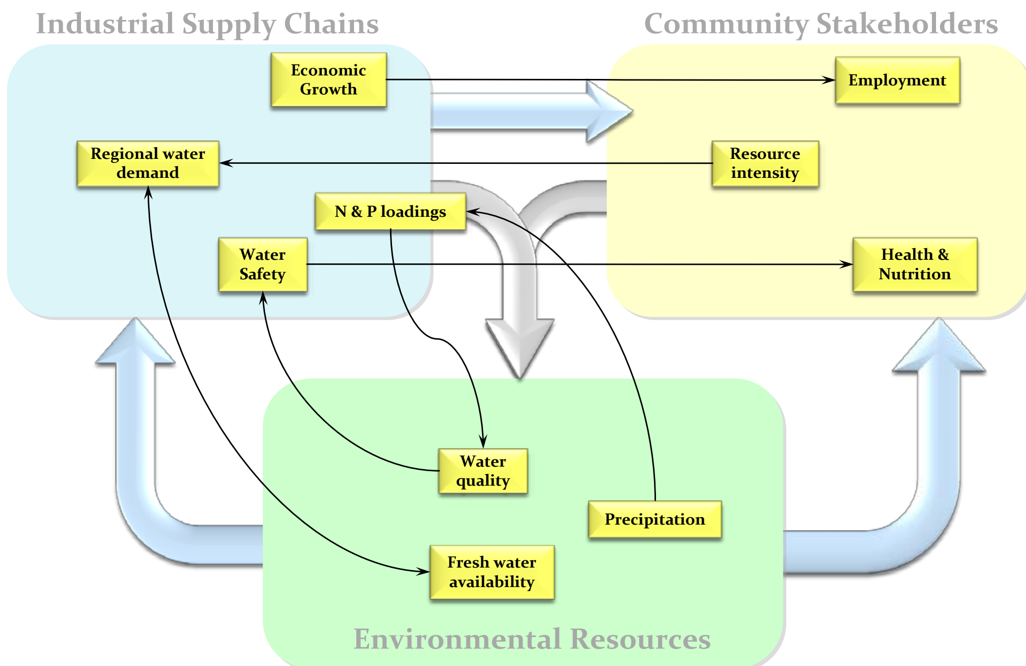

Figure 8 – Selected Key indicators for Mitigation of Nutrient Impairment

Step 3 - Specification of appropriate spatial scale and units of measure

To implement the use of an indicator, it is necessary to define the scope or scale of measurement (e.g., single water body vs. watershed-scale vs. regional or national scale) as well as the physical or monetary units (i.e., metrics) to be utilized. For example, "water demand" can be quantified in terms of the following specific metric: millions of gallons of water consumed annually within the watershed. It is important to distinguish between **absolute** measures and **relative** metrics, which are normalized with respect to another quantity. Examples of relative metrics are time-based indicators, e.g., percent increase in water demand from 2010 to 2020, and "intensity" measures, e.g., water demand per capita" (see Section 5.1). Although stakeholder groups often advocate the use of absolute measures, these may lead to inappropriate comparisons whereas relative indicators are generally less biased by differences in system characteristics. For example, the largest facilities in a region will typically be the largest consumers of water, even though their water intensity may be significantly lower than others.

Step 4 - Data collection and quality assurance procedures

Once the indicators and measurement approaches have been determined, data must be collected from primary or secondary sources. Typically a baseline set of data will be established in a given year for purposes of future comparison. As in any research effort, care must be taken to assure the quality, accuracy, reliability, comparability of the data. It is also useful, where possible, to identify the sources of uncertainty and to establish uncertainty bounds. Since indicators will typically be tracked over a long period of time, provisions must be made for data archiving, maintenance and retrieval.

Step 5 - Communication and reporting

Indicators are valuable tools for purposes of problem analysis, reporting of progress, evaluation of outcomes and assessment of performance. Through successive iterations of the SAM process, sustainability indicators can be used repeatedly to support decision-making and stakeholder communication. The availability of quantitative measures lends credibility to any type of communication exercise. However, care must be used to assure that indicators are used appropriately, bias is avoided, uncertainty is communicated and transparency is emphasized. If an aggregated index is used, the components and weighting factors that comprise the index should be available and understandable.

Implementing the above process across EPA's multiple activities will pose challenges in terms of coordination and consistency of interpretation. Establishing uniform guidelines, procedures, and tools for the use of sustainability indicators will not only facilitate coordination, but will also enhance EPA's long-run credibility and provide leadership to stakeholders in the business community and civil society.

7. Conclusions

Incorporation of sustainability concepts into the EPA policy and decision making process will require the adoption of sustainability indicators for purposes of problem definition, goal setting, measurement of progress, evaluation of performance, communication with stakeholders, and public reporting. In particular, to effectively support sustainability initiatives in Program and Regional offices, coordination of ORD research programs will be facilitated by the adoption of a common framework for sustainability indicators. This document provides guidelines for the definition, selection, and implementation of sustainability indicators that are consistent with EPA's mission. The approach presented here is an effort to provide a comprehensive and flexible toolkit for tracking of sustainability progress at multiple scales across the full spectrum of EPA activities.

Sustainability indicators are a powerful tool for focusing attention on important environmental, economic, and social trends that provide signals of change. However, indicators can potentially be manipulated to convey biased messages, and therefore the selection of indicators for public policy purposes should be approached with the utmost effort to assure objectivity, transparency, and stakeholder consensus. It is in EPA's interest to develop an ongoing repository of sustainability indicators that are meaningful, verifiable, defensible, and relevant to stakeholder audiences. The database developed under this project can provide a starting point for such a repository.

The guidelines and tools provided through this work should be helpful as EPA moves forward with implementation of the Green Book recommendations. Selection and implementation of sustainability indicators should be coordinated across various Agency activities, including high-level, national-scale reporting through the Report on the Environment, programmatic activities including policy development and rule-making, and focused, place-based projects involving collaboration and decision-making.

Acronyms

CALCAS	Co-ordination Action for innovation in Life-Cycle Analysis for Sustainability
SHCRP or SHC	EPA Sustainable and Healthy Communities Research Program
EEA	European Environment Agency
FAO	Food and Agricultural Organization of the United Nations
GRI	Global Reporting Initiative
IWGSDI	Interagency Working Group on Sustainable Development Indicators
IISD	International Institute for Sustainable Development
ISO	International Organization for Standardization
NRC	National Research Council
NRMRL	National Risk Management Research Laboratory
ORD	Office of Research and Development
OECD	Organisation for Economic Co-operation and Development
SEDAC	Socio Economic Data and Applications Center
SAM	Sustainability Assessment and Management
SDI Group	Sustainable Development Indicator
DOSII	The Database of Sustainability Indicators and Indices
PCSD	The President's Council on Sustainable Development
ROE	The USEPA Report on the Environment
UN	United Nations
UNCSD	United Nations Commission for Sustainable Development
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UN-HABITAT	United Nations Human Settlements Programme
USEPA or EPA	US Environmental Protection Agency
WBCSD	World Business Council on Sustainable Development

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Appendix A

This appendix provides a sample of the sustainability indicator database, resource list and summary statistics on the classified indicators.

Table A. 1 – Sample of DOSII

Name	Source	Scale	Pillar	Source Theme	ROE Topic	Program	3V	Dimension	Units/Description
18- to 24-year-olds without a school leaving certificate	GRM	National/Regional/Community	ECO-SOC	Intergeneration equity		SHC	SCI/VCI	2D	Share of 18- to 24-year olds (of all 18- to 24-year olds) who currently do not attend any school or institution of higher education and are not in training and hold no qualifications from post-16 education or from the dual system of vocational training.
25-year-old university graduates	GRM	National/Regional/Community	ECO-SOC	Intergeneration equity		SHC	SCI/VCI	2D	Percentage of 25-year-olds (of all 25-year-olds) who have completed a university degree.
Abundance and distribution of selected species: butterflies	EURO SI/EEA	National/Regional/Community	ENV	Biodiversity	Ecological Condition	SHC	RFI/SCI	1D	Population trend indicator, based on aggregated data for a number of species. Measure: Number of species
Abundance of invasive alien species	EURO SI/CSD	National/Regional/Community	ENV	Biodiversity/Species	Ecological Condition	SHC	AOI/SCI	1D	This aim of this indicator is to monitor trends in invasive alien species (IAS) at the national scale. An additional component could be to measure the cost of invasions of such species. Measure: Number of invasive alien species in a given country or region
Abundance of selected key species	EURO SI/CSD	National/Regional/Community	ENV	Biodiversity/Species	Ecological Condition	SHC	RFI/SCI	1D	This indicator uses estimates of population trends in selected species to represent changes in biodiversity, and the relative effectiveness of measures to maintain biodiversity. The indicator can be applied to individual species groups (e.g. birds, butterflies), or can be aggregated to incorporate a number of taxa (e.g. in a fashion similar to the Living Planet Index), according to data availability and indicator applicability. Measure: Number of mature individuals or other relevant indicator of abundance within a given area or population
Access of population to mobility	AUS	National/Regional/Community	ECO-SOC	Mobility	Human Health/Land	SHC	SCI	2D	A person is considered to have local access to public transport from their place of residence if • the individual lives within a radius of 1500 m of a stop providing at least • one connection to the nearest appropriate centre (regional centre, work, school, etc.) • within a specified interval of departure and arrival with • no more than two changeovers are required. This data gives information about access to public transport. However, neither the quality of the offer (travelling times, frequency of connections) nor the quality of the location (How important are the objectives that can be achieved?) are illustrated by this indicator.
Access to improved sanitation (% of total population, rural, and urban)	UN Hab/World Bank	National/Regional/Community	ECO-ENV-SOC	Shelter/Water and sanitation	Human Health/Land/Water	HHRA/SHC/SSWR	SCI/VCI	3D	Proportion of the population with access to improved sanitation or percentage of the population with access to facilities that hygienically separate human excreta from human, animal and insect contact. Facilities such as sewers or septic tanks, poor-flush latrines and ventilated improved pit latrines are assumed to be improved, provided that they are not public. To be effective, facilities must be correctly constructed and properly maintained, and not shared by more than two households. Metric: % of total population, rural, and urban
Access to improved water source (% of total population, rural, and urban); Access to safe water	World Bank	National/Regional/Community	ENV-SOC	Water and sanitation	Water	SHC/SSWR	SCI/VCI	2D	Percentage of the population with reasonable access to an adequate amount of water from an improved source, such as piped water into a dwelling, plot, or yard; public tap or standpipe; tubewell or borehole; protected dug well or spring; or rainwater collection. Unimproved sources include an unprotected dug well or spring, cart with small tank or drum, bottled water, and tanker trucks. Reasonable access to an adequate amount means the availability of at least 20 liters a person a day from a source within 1 kilometer of the dwelling. % of total population, rural, and urban

Table A. 2 - Sample of the Resource List for DOSII

#	Source	Acronym	Type	#	Purpose/Description	Pillar	Source Themes	Org (Scale)	Access	Last Update	Notes
1	**Biodiversity Indicators Partnership**	**2010 BIP**	Report	29	Includes 17 headline line indicators from seven focal areas for assessing progress towards, and communicating the 2010 target at a global level	ENV	Components of biodiversity, sustainable use, threats to biodiversity, ecosystem integrity, goods and services, status of knowledge, innovations and practices, access and benefits sharing and resource transfers	Global/National (UNEP)	http://www.bipindicators.net/indicators	2010	
2	**2003 Report on the Environment**	**ROE 03**	Report	151	Study trends in the condition of the air, water, land, and human health of the United States	ENV and a few SOC-ENV	Air, Human Health, Water, Ecological Condition, Land	US (National/Regional)	http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=56830	to 2008 report	
3	**2008 Report on the Environment**	**ROE 08**	Report	85	Study trends in the condition of the air, water, land, and human health of the United States	ENV and a few SOC-ENV	Air, Human Health, Water, Ecological Condition, Land	US (National/Regional)	http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=190806	2010 (some)	
4	**Environmental Pressure Indicators**	**EPI**	Report and EURO SI DB	60	Aims to give a comprehensive description of the most important human activities that have a negative impact on the environment.	ENV	Air Pollution, Climate Change, Loss of Biodiversity, Marine Environment & Coastal Zones, Ozone Layer Depletion, Resource Depletion, Dispersion of Toxic Substances, Urban Environmental Problems, Waste, Water Pollution & Water Resources	Europe (National)	http://esl.jrc.it/envind/tepi99rp.pdf	1999	Based on DPSIR; Considering condensing these indicators into ten indices, File: epi99rp.pdf
5	**European Environment Agency(EEA) Indicators**	**used EEA Core Set and EURO SI**	Reports and databases	[illegible]	European sustainability	ALL	Agriculture, Air pollution, Biodiversity, Chemicals, Climate change, Coasts and seas, Energy, Environment and health, Environmental scenarios, Environmental technology, Fisheries, Household consumption, Industry, Land use, Natural resources, Noise, Policy instruments, Population and economy, Soil, Specific regions, Tourism, Transport, Urban environment, Various other issues, Waste and material resources and Water	Europe (National)	http://www.eea.europa.eu/data-and-maps/indicators/#c7=all&c5=&c0=10&b_start=0	2010	
6	**Eurostat Set of Sustainability Indicators**	**EUROSTAT**	Report	144	European sustainability	ALL	Socio-economic development, Sustainable consumption and production, Social inclusion, Demographic changes, Public health, Climate change and energy, Sustainable transport Natural resources, Global partnership and Good governance	Europe (National)	http://epp.eurostat.ec.europa.eu/portal/page/portal/sdi/indicators	2007	

Table A. 3 –Distribution of DOSII within the Classification Schemes

Program*	**#**	**%**
SHC	1267	89.79%
SSWR	194	13.75%
CSS	192	13.61%
ACE	413	29.27%
HHRA	182	12.90%
HSR	108	7.65%

3V*	**#**	**%**
VCI	262	18.57%
SCI	1328	94.12%
AOI	308	21.83%
RFI	583	41.32%

ROE Topic*	**#**	**%**
Air	395	27.99%
Ecological Condition	769	54.50%
Human Health	323	22.89%
Land	352	24.95%
Water	276	19.56%

Pillar*	**#**	**%**
ENV	994	70.45%
SOC	531	37.63%
ECO	629	44.58%

Dimension	**#**	**%**
1D	727	51.52%
2D	586	41.53%
3D	98	6.95%

Scale*	**#**	**%**
Global	253	17.93%
National	1075	76.19%
Regional	764	54.15%
Community	573	40.61%
Industrial	460	32.60%

Total	1411

This table provides summary statistics on the indicators in this iteration of the database. Note that * indicates that the categories within classification schemes are not mutually exclusive, i.e., many of the indicators are linked to multiple categories within each classification scheme (e.g., Pillar: ECO and SOC or Program: ACE and SHC). Due to the overlap, the total number of indicators will not add up to 1411, nor will the sum of the percentages equal 100%.

Appendix B

This appendix provides a draft of the web-tool architecture. This is a milestone of SHC task 1.2.2.1.

SHC Theme 1: Developing Information and Tools to Support Community Sustainability (Betsy Smith, Lead) • Topic 1.2: Assessing Community Sustainability (Kevin Summers, Lead) • Project 1.2.2: Provide Indicators and Indices to Assess, Track, and Inform Community Sustainability (Lisa Smith, Lead) • Task 1.2.2.1: Inventory of sustainability indicators (Tarsha Eason, Lead)

Architecture for an Interactive Web-Tool for the Inventory of Sustainability Indicators

(Draft Version 1.0)

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September 27, 2012

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Contents

Figures and Tables

Acronym List and Definitions

Broader Term (BT)—A term representing a concept that encompasses the concept represented by another term (i.e., the narrower term). For example, "body part" is the broader term for the term "arm".

DOSII — Database of Sustainability Indicators and Indices

Holistic — A term that describes a whole system, rather than analysis or treatment of parts.

Index (calculated) — A number or symbol, developed from a series of observations or measure and used to indicate or describe a subject of interest.

Index (search) — The data resulting from the collection and parsing of content to facilitate fast and accurate information retrieval. The purpose of storing an index is to optimize speed and performance in finding relevant content for a search query.

Indicator — A measure used to describe a particular state or relationship, which may, or may not, be a direct measure of that state or relationship.

Indices — Plural of index.

Keyword — A term extracted from the ORD Managed Vocabulary and mapped to one or more Themes.

Mapping — The act of semantically linking the concepts in one vocabulary to the concepts in another, or the actual representation of that relationship as stored in a database table or terminology management system. For example, the ORD MV keywords will be mapped to Themes.

Metric — A standardized unit of measure.

Narrower Term (NT) — A term representing a concept that is subordinate or is encompassed by to the concept represented by another term (i.e., the broader term). For example, "arm" is the narrower term to the broader term "body part".

OEI/OIC/DSB — EPA's Office of Environmental Information, Office of Information Collection, Data Standards Branch.

ORD MV — ORD Managed Vocabulary; a file of selected terms, relationships and definitions that represent the broad interests of the EPA Office of Research & Development.

Pillar — One of three elements in a common framework used for the selection of indicators: environment, society and economy.

Related Term (RT) — Terms that are conceptually associated with one another. For example, the term "pitching" is related to the term "arm".

SHCRP — Sustainable and Healthy Communities Research Program

SII — Sustainability Indicators Inventory

Synaptica — The commercial terminology management tool hosted by the OEI/OCI/DSB as Terminology Services. This commercial tool is used for the ORD Managed Vocabulary, and is proposed as the tool for managing the mappings of pillars, themes and ORD Managed Vocabulary keywords in support of the SII Tool.

Theme (or Source Theme) — One of a series of 22 categories assigned to the indicators in the SII database based on the context of the source (e.g., World Bank, UNEP, etc.). Themes are assigned to one or more Pillars.

Vocabulary — A group of terms collected for a common purpose, domain, or audience that are stored as a single file with a unique name in the Synaptica terminology management tool.

1.0 Purpose

The purpose of this document is to lay the foundation and provide a framework for the development of the Sustainable Community Indicators web-based discovery tool. It includes descriptions of the architectural components, the data and processes, and the technology options needed to provide quality data to support the proposed user experience. Finally, suggestions for next steps are provided. The Sustainability Indicators Inventory database discovery tool supports the SHC Research Action Plan (RAP) project as outlined under Theme 1: Data and Tools to Support Sustainable Community Decisions, Topic 1.2: Assessing Community Sustainability, Project 1.2.2: Provide Indicators and Indices to Assess, Track, and Inform Community Sustainability, Task 1.2.2.1: Inventory of sustainability indicators otherwise known as the Database of Sustainability Indicators and Indices (DOSII).

2.0 Scope & Background

In the Sustainable and Healthy Communities Strategic Research Action Plan (US EPA 2012a), sustainability is defined as the ability "to create and maintain conditions under which humans and nature can exist in productive harmony, [and] that permit fulfilling the social, economic, and other requirements of present and future generations."(NEPA 1969). It is recognized as a major factor influencing the long-term success of communities. Nonetheless, the assessment of the environmental conditions of a community, its ability to sustain those conditions under various challenges, and to improve in a particular area or overall is a complex undertaking. It is made more difficult by the interaction and complexity of the environmental, social, economic and political structures involved; the fact that there are a number of indicators available; and that the application of these indicators must be relevant in a local context.

In order to begin to address these issues, a task was initiated within the US Environmental Protection Agency's (EPA) Office of Research and Development's (ORD) National Risk Management Research Laboratory (NRMRL) to develop an inventory of sustainability indicators using a subject taxonomy system initially designed to assist EPA's research communities in identifying trusted sources of sustainability related data. ORD's Sustainable and Healthy Communities (SHC) National Research Program has recognized the value of this type of effort, particularly as it relates to providing communities, both internal and external to EPA, with a holistic suite of "… indicators and indices to assess, track, and inform community sustainability." (QAPP 2012). To that end, the scope of the DOSII project has expanded to include the development of an interactive web-based tool for searching its repository of vetted indicators and related source information. This document provides a high-level conceptual architecture that describes the strategy for building a synergistic community-centric discovery tool pairing concepts of controlled-vocabulary and information science with the indicators inventory.

3.0 Objectives

It is anticipated that this web tool will enhance the utility of DOSII by extending access to these data in a manner that is both informative and relevant to communities. By using prompts to solicit user input, customized list(s) of suggested indicators can be built based on user specified sustainability priorities (e.g., cost-benefit analysis, monitoring and assessment, education). The existing database will be assimilated into an information science-based framework to create the basis for a keyword-driven data mining engine and lay the foundation for integrating additional indicators stemming from ORD's sustainability science portfolio. The resulting interface system, the Sustainability Indicators Inventory (SII) Discovery Tool, will leverage multi-platform web-based technology to create a stylized approach for disseminating indicator information.

A major consideration in the development of the web-tool for community use is the negotiation of language and meaning (semantics). The indicators that have been created are based on field and laboratory science, at various levels of "indicative granularity" and by diverse groups, both national and international. They may be expressed in terms which may or may not be understood by the users looking to select and use the indicators. Therefore, a primary feature of the tool development, and a critical component of this architecture, is the integration of the ORD Managed Vocabulary to provide support for improving the search and navigation of the indicators through improved semantics.

4.0 Architecture Components

At the most basic level, the components of this system include data sources, various vocabulary resources, a database and user interface. The components are integrated using a service-oriented architecture, but this may be conceptual rather than physical since web services may not be used in the initial development of the system.

Figure 4-1 depicts a general overview of the SII and its components. The interfaces, which may be tailored to particular communities, provide access to resources through an access layer that synthesizes metadata from indicator resources such as the DOSII and terminology from various terminology services such as the ORD Managed Vocabulary (ORD MV).

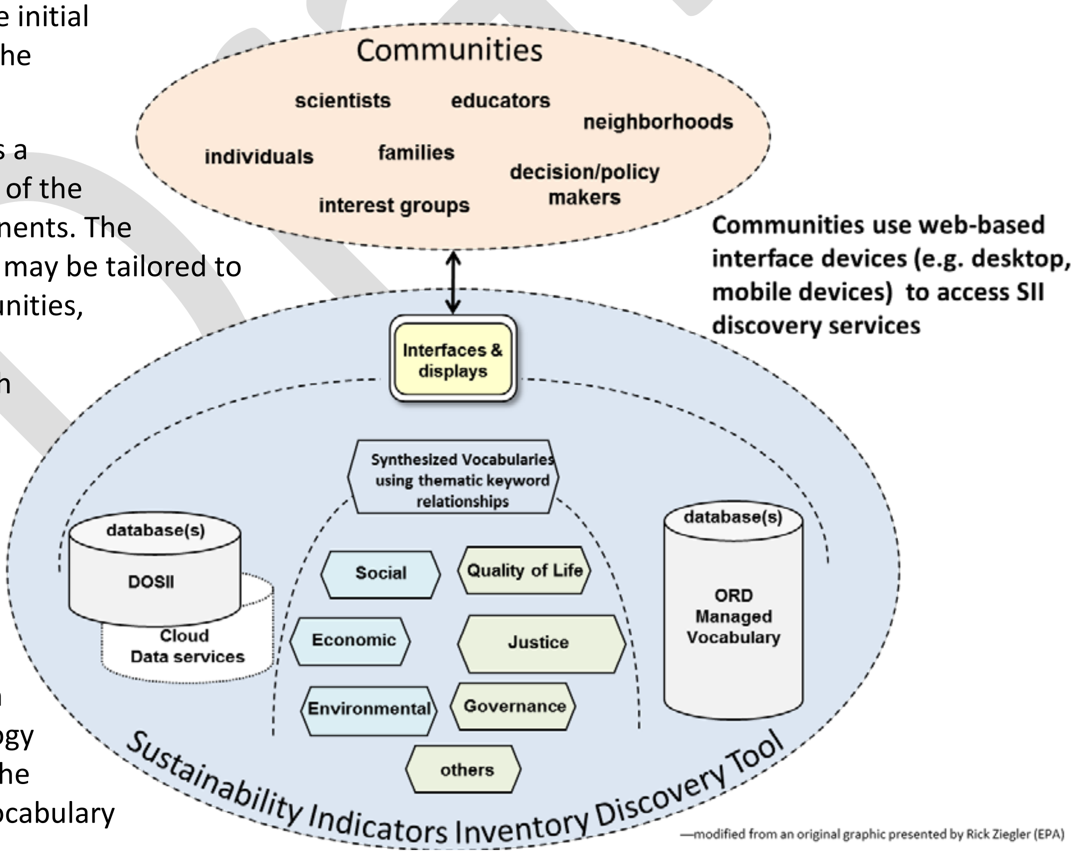

Figure 4-1: Conceptual Architectural Overview for Sustainability Indicators Inventory Discovery Tool

Each of the major components of the Discovery Tool is described below.

4.1 Communities

Communities are individuals, groups, or services that focus on specific uses or aspects of the data contained in the SII. These may include scientists, neighborhood groups and local governments, interest groups, etc. Communities use web-based interfaces via desktops or mobile devices to access SII services. The specific look-and-feel of the interface and the features and services included can vary by community by virtue of the interface design or by profiling capabilities in the hands of the users.

4.2 Database of Sustainability Indicators and Indices

The DOSII contains an inventory of indicators and indices relevant to sustainability in the context of community-based assessments. ORD's new sustainability-focused research areas as well as mature programs, such as the Report on the Environment (ROE), lacked an easily navigable repository containing reviewed and vetted sustainability indicator summary information to assist research teams in identifying data gaps, available sources, and collaboration opportunities. The DOSII database was designed using a subject-oriented taxonomy to help database users build lists of subject relevant candidate indicators. A pool of 1600+ peer reviewed indicators spanning multiple geographic scales (national, regional, etc.) were selected for inclusion in the initial database by a cross-organizational workgroup using worldwide benchmarking. The taxonomy was developed to provide intra-Agency organizations with clearly defined subject groupings that were cross-referenced to existing and planned research. Additionally, a guidance document was developed to assist EPA programmatic, administrative and research communities with accessing the DOSII information (US EPA 2012b).

The indicator database is stored in MS Excel. It includes key metadata including the indicator/index name, acronym of the source name, scale (e.g., national, community), pillar of sustainability, source theme (e.g., forests and biodiversity), Report on the Environment topic, EPA program, Triple Value Designation (e.g., system condition), dimensionality (e.g., 2D) and computational units. In the initial implementation of the SII tool, the pillars and themes will be the major organizing factors.

At the highest level, pillars represent a common framework for identifying, describing and selecting indicators. The three pillars are:

- Environment—assurance of continued integrity of natural resources
- Society—assurance of continued human health and well being
- Economy—assurance of continued economic prosperity

Most important for this process are the Source Themes, of which there are 22 unique assignments. The structure allows for a single indicator to be associated with multiple themes. In addition, a theme can be assigned to more than one pillar. Some examples of assignments are provided below (Table 4.2-1), using a partial extract example from the SII database (version 1) showing indicators from different sources and assigned to different themes.

Indicator	Source	Scale	Country	Pillar	Source Theme	ROE Topic	Progra m
GDP	World Bank	National	WB	ECO	Economic		SHC
Population	World Bank	Any (less industrial)	WB	SOC	Demographic		SHC
Population growth	World Bank	Any (less industrial)	WB	SOC	Demographic		SHC
Carbon Dioxide Emissions - per Capita (CDIAC)	UNEP-GEO Core	Global/National/Regiona l	UNEP	ENV-ECO	Atmosphere	Air	ACE

Table 4.2-1: Example of SII Database Theme Assignments

As a test, the pillars and themes are stored in EPA's Terminology Services (provided by OEI/OIC/DSB) using the Synaptica terminology management software. The pillars are treated as the names of specific vocabularies while the themes associated with them in the SII database are stored as descriptors or terms within those vocabularies. The same theme can occur in more than one vocabulary. Following is an example of the themes under the Economic Pillar Vocabulary.

Vocabulary Name - Economic Pillar

Built capital
Commercial
Demographic Changes
Economic
Economic development
Financial
Financial Instruments
Global economic partnership
Global Partnership
Governance
Human and social capital
Intergeneration equity
International Justice
International responsibility
National accounting aggregates
Product
Quality of life
Social Performance: Product Responsibility
Social Performance: Society

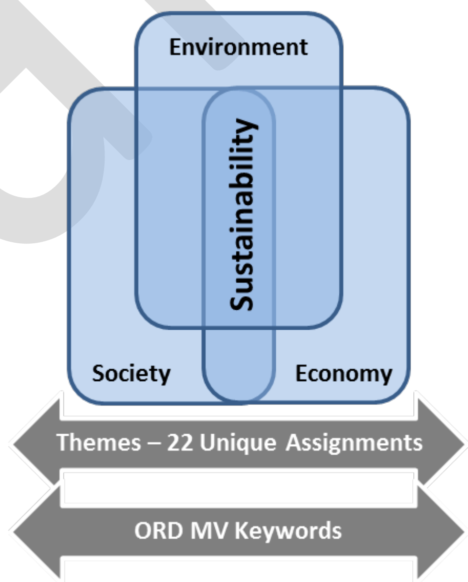

Figure 4-2: ORD MV Keywords are Mapped to Themes and Pillars

There are other possible approaches to storing the mappings, which are covered under Next Steps.

4.3 ORD Managed Vocabulary

The ORD MV is a repository of more than 10,000 scientific and technical terms of interest to ORD research. Terms have been collected in major categories such as the natural environment, chemical substances, human health, and society and economy. The ORD MV was created from a number of sources including key documents, web sites, other EPA sources such as glossaries, and other vocabularies, such as published thesauri, from other agencies such as the US Geological Survey and the National Agricultural Library.

The ORD MV also includes the hierarchical relationships, broader term (BT) and narrower term (NT). For example, Economic Analysis is a broader concept than Cost-Benefit Analysis. Therefore, economic analysis is a BT to Cost-Benefit Analysis and Cost Benefit Analysis is an NT to Economic Analysis. Other relationships may include synonyms, which include acronyms and abbreviations (AB). For example, Benefit-Cost Analysis is abbreviated by (AB) the acronym BCA.

The relationships stored in the ORD MV can help to improve the retrieval and organization of content within systems or disseminated by systems. For example, the user can enter the term cost-benefit analysis and be presented with indicators that are tagged by only the theme (or broader term) Economic Analysis.

The ORD MV and relationships it can store will be used to map commonly used terms to the DOSII themes. This will allow users of the tool to enter terms of interest and to obtain information from the system without having to understand the specifics of the terms used by the system. Because multiple indicators will be described using the same theme, it will also be possible to link indicators using this approach.

4.4 Synthesized Vocabularies

The synthesized vocabularies are built by matching the themes from the indicators database against the ORD MV and extracting the appropriate keywords from the ORD MV. The content from the Keyword extraction and the Indicator Information are linked based on the theme assigned to each indicator.

An example of the mapping is presented below. In this case, Economic Analysis is one of the Source Themes. It is found in the ORD MV with narrower terms (NT) and related terms (RT). Related terms are closely associated but they are not directly hierarchical (broader term or narrower term). Benefit-Cost Analysis is abbreviated by (AB) the acronym BCA.

<u>Economic Analysis</u>

NT Benefit-Cost Analysis
    AB BCA
NT Cost-Benefit Analysis
NT Cost-Effectiveness Analysis
NT Economic Impact
NT Green Accounting
NT Input-Output Analysis
NT Marginal Analysis
NT Risk-Benefit Analysis
NT Safe Minimum Standard
RT Decision Analysis
RT Generally Accepted Accounting Principle

In addition, the keywords from the ORD MV can be mapped to terms in the names of the indicators. For example:

Indicator Name	Related Keywords from ORD MV
Rainfall	Rainfall; Precipitation; Water Cycle; Hydrologic Cycle; Drought; Agricultural Drought; Hydrological Drought; Meteorological Drought
Total delivered domestic energy demand (electricity, other fuels)	Energy Economics; Energy Market; Energy Consumption; Energy Management; Energy Use Optimization; Carbon Dioxide Tax; Fossil Fuel; Fossil Fuel Resource; Coal; Natural Gas; Oil; Carbon-Based Resource; Energy Production

The use of mappings between the terms in the indicator names and the keywords in the ORD MV would provide more granular access. These more specific terms could also be used to extend the pillars and themes in a browse taxonomy.

5.0 Conceptual Data Flow

Figure 5-1 shows the data flow for the SII tool at the conceptual level. This data flow is from the system perspective. Key functions needed to support this data flow include the extraction of indicators from the DOSII and eventually other sources. In the initial implementation, all records and data elements in the database may be extracted. This may change over time and may not be the case with other sources. The ORD Managed Vocabulary will be used to create a mapping of themes to keywords. These results are used to provide keywords for each indicator. This is the file which is then searched to provide the information when a user enters the name, a keyword or browses the taxonomy on the SII tool's user interface.

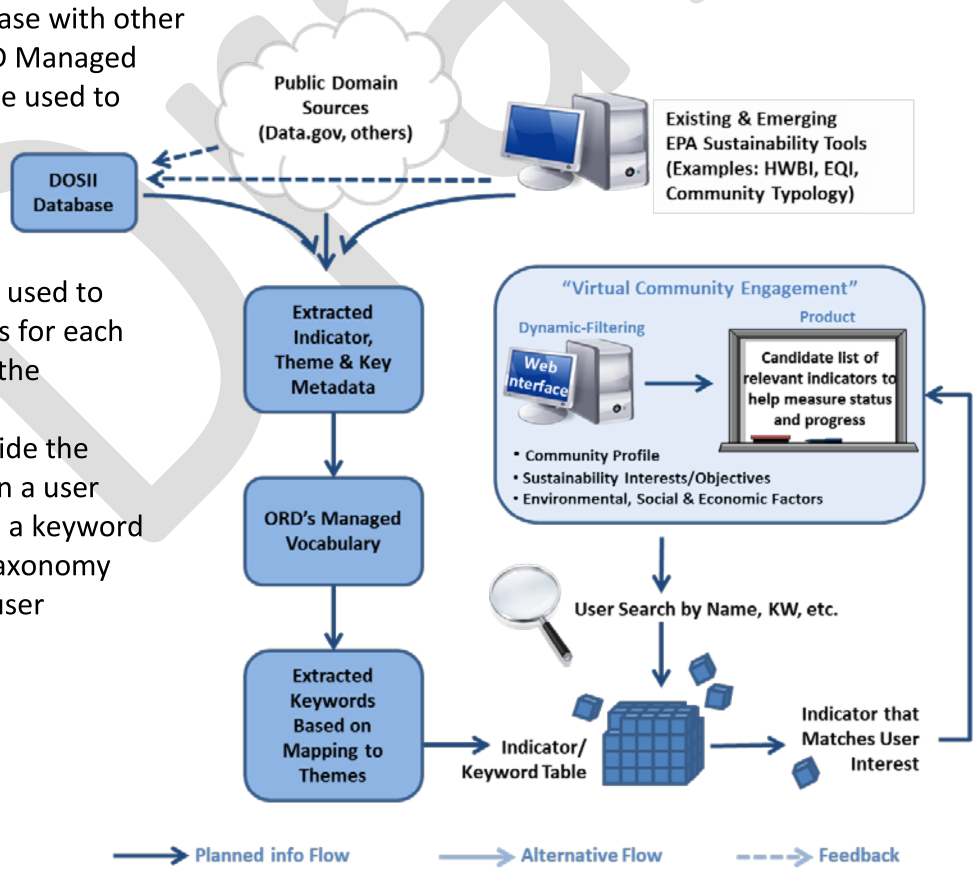

Figure 5-1: Conceptual Data Flow

6.0 Conceptual Process Flow

This section shows the conceptual process flow for the creation and maintenance of the DOSII and the process flow for the user system interaction of the SII Tool.

6.1 Building and Maintaining the SII Content

Figure 6-1 shows the process flow for building and maintaining the content in the SII. Content can be added manually to the DOSII, imported from other sources, or contributed by the user's interaction with the system. In each case, the indicators and themes are extracted from the resulting database, the themes are matched against the ORD MV and a searchable index is created from the resulting tables for use by the SII Tool.

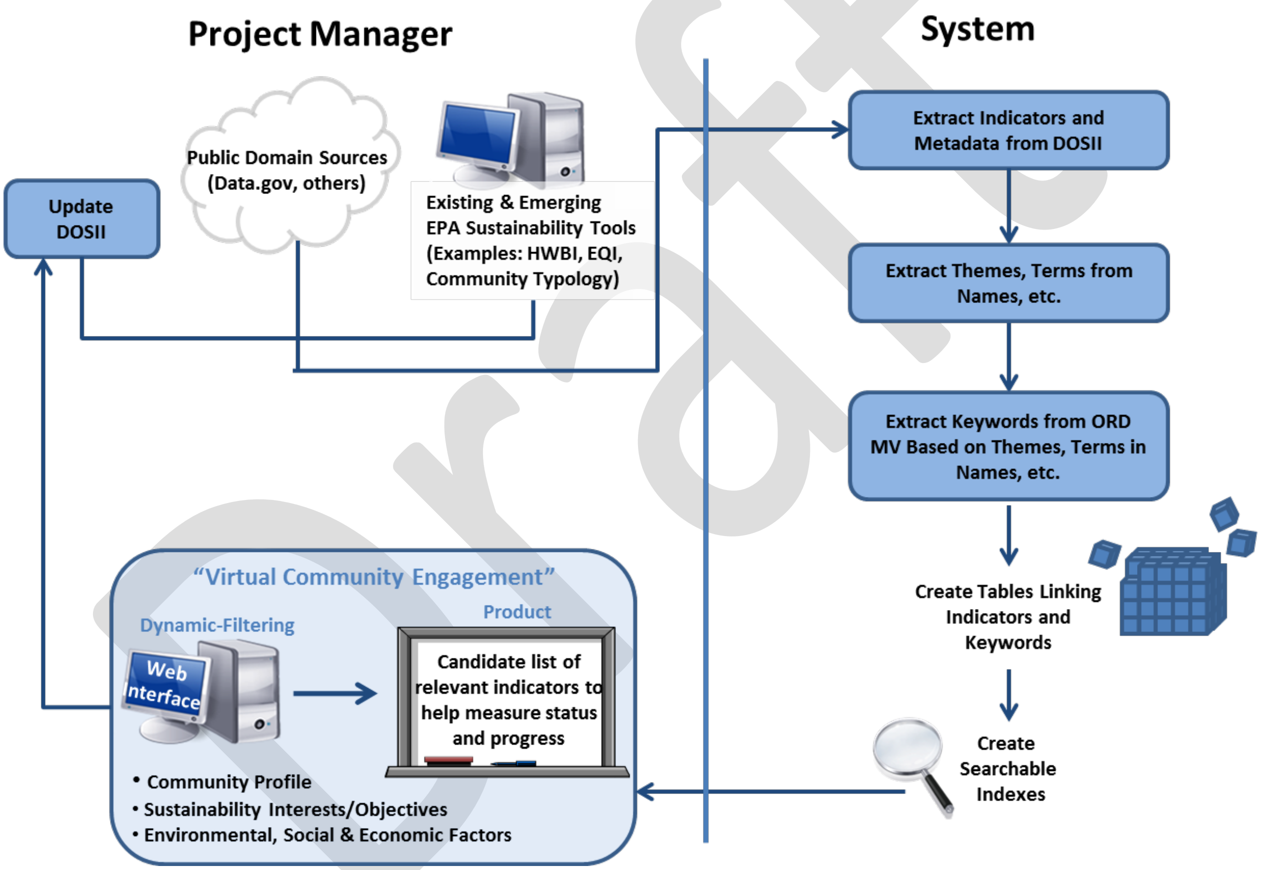

Figure 6-1: Conceptual Process Flow for Building and Maintaining the SII Content

6.2 User-System Interaction When Using the SII Tool

Figure 6-2 shows the interaction between the user and the system as the SII Tool is being used. The user accesses the system, enters a search or selects a category from the browse taxonomy (which may be based on the pillars and/or the themes), and is presented with the results from the synthesized indicators inventory. The display of the results may vary based on filters, user preferences, or user profiles. The results are evaluated by the user and may result in another request to the system or refinement of the current request.

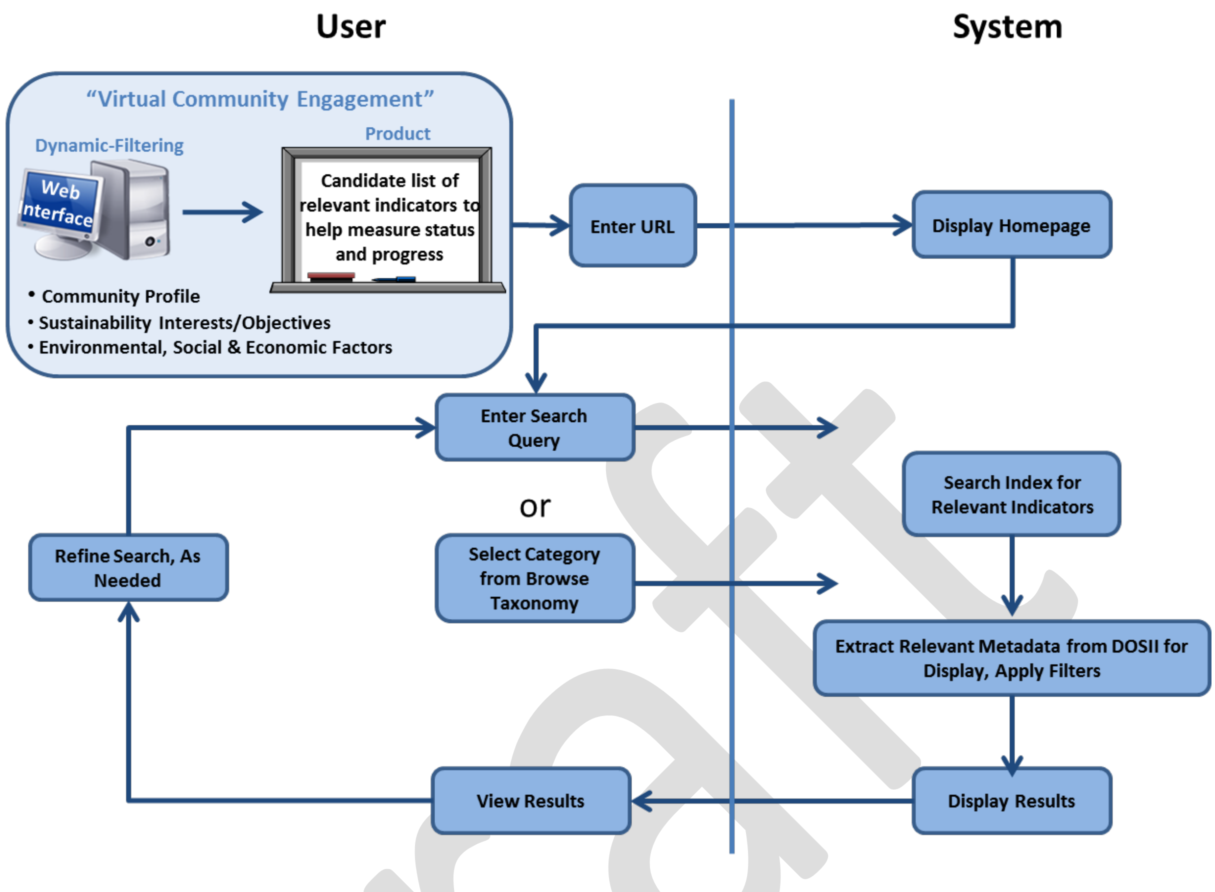

Figure 6-2: Conceptual Process Flow for Using the SI Tool

This interaction describes the most basic functionality for discovery and access. In the final system, there may be a variety of display formats or options and other functions may be available including the ability to supply indicators or comments on indicators back to the Virtual Community through social media options. It is expected that the functions will grow as the system is used and user expectations and needs are assessed and incorporated into the design.

7.0 Technology Options

The conceptual design provided above does not dictate any particular technology options. No matter what the initial technology set turns out to be, we want to make sure it is implementable and requires only a basic skill set. However, it is valuable to consider technology options as the project moves forward if for no other reason than to continue to ensure that the design is technology agnostic. A technology roadmap can also be advantageous when working with other stakeholders to determine where their systems will be in the near and long-term futures.

7.1 Technology Roadmap and the Interoperability Framework

A high level technology roadmap ensures that the SII tool will be in line with the principles expressed in the SCHRP interoperability architecture shown in Figure 7-1 below. The puzzle pieces representing the data, the user interface, the analytical tools, and the communication/community engagement through social media are interoperable pieces that make up the whole.

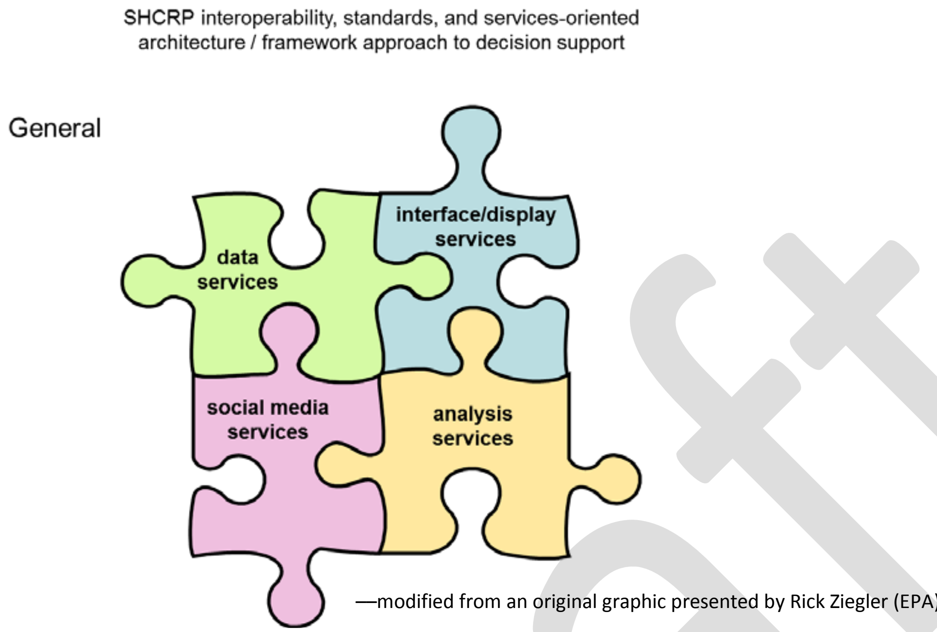

Figure 7-1: General SHCRP Interoperability Framework

Figure 7-2 uses the general framework to describe the high level components of the SII Discovery Tool.

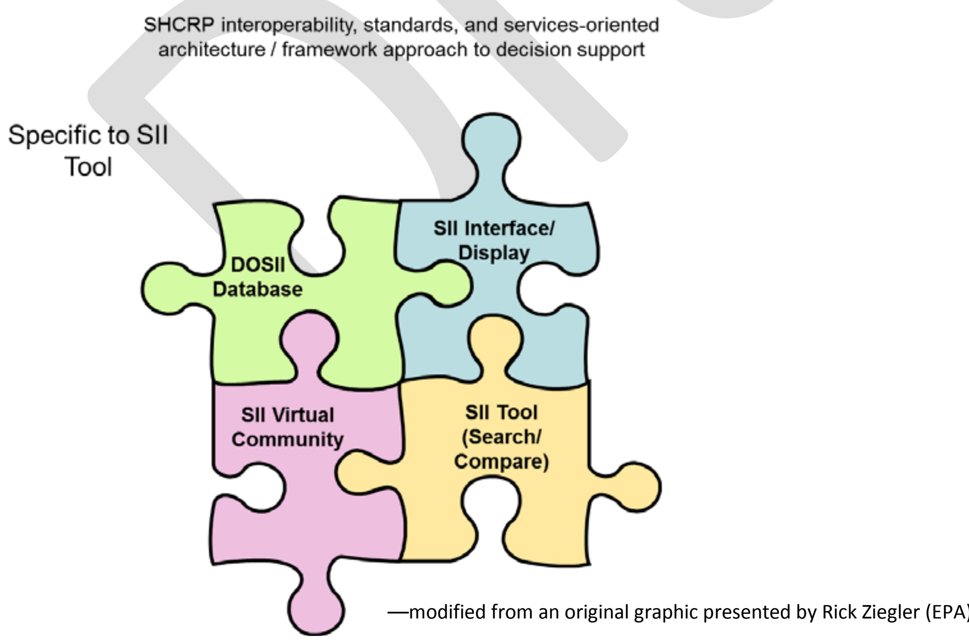

Figure 7-2: Specific SII Tool within SHCRP Interoperability Framework

Any one of these pieces can be external to the other, allowing other entities to create products and services that interoperate and enhance the SII tool.

7.2 Technology Options by Architecture Component

This section describes the various technology options that may be considered in the future for each component identified in the Architecture Components section.

Vocabulary Management

The ORD MV is currently managed in Terminology Services, one of the registries in the EPA System of Registries (SoR) provided by the OIC/Data Standards Branch. Terminology Services is run on terminology management software called Synaptica. This is actually an application over an Oracle database that manages the terms, controls and validates the entry of relationships between terms and other elements that are maintained, and provides an interface and APIs to access the terminology.

However, the functionality of terminology management can be provided by several other products. The common features of these tools include adherence to the rules around the formation of a well-formed hierarchical vocabulary (aka thesaurus or taxonomy) and the ability to extend such a structure to include other metadata about each term.

User Interface

The development of the user interface will, in the short term, use an HTML development tool such as PHP. However, we are recommending that the development move quickly or even initially consider the use of HTML-5. This approach, along with a device agnostic design approach, will allow the resulting website to be accessible via all types of mobile devices. Mobile accessibility for end user systems is being promoted by EPA and by the Administration's Digital Government Strategy (OMB 2012). In this particular case, one can readily imagine a scenario where the local resource manager is in the field when attempting to identify or coordinate the selection of sustainable community identifiers. Further, interface design considerations will include:

- Icon driven user prompts to help transcend language barriers;
- Application assisted community characterization using prompted scripts and SHC community typology efforts (SCH Task: 2.1.3.2); and
- Future development of an audio component to assist with compliance of Section (508) of the Rehabilitation Act of 1973

Social Media Tools

The Sustainable Community Indicators web site can be viewed as just the beginning of an effort to bring the community together. Figure 7-2 offers an example of virtual community engagement effort under development in SHC New and Emerging Media (Task 1.1.2.1) research. One can imagine a robust virtual community where local officials share expertise, collaborate on challenges, identify joint solutions, and recommend improvements to indicators that have been provided. This type of forum can be facilitated by social media tools.

While these types of tools are not the purview of this project, the design should be open enough to entertain the connection with tools such as Drupal and Jive. In particular, it should be open enough to be linked to or integrated with social media platforms, such as Julie's Earth collaboration tool, which has been investigated as a platform by EPA.

Key to the use of social media tools are user profiles and filters against the content that provide information that best matches the user needs. In addition, there are other social media tools such as RSS feeds to register and push targeted updates to users, bi-directional communication tools such as Twitter, community and group facilitation tools that mimic LinkedIn and Facebook, and multi-media content similar to You-Tube videos.

Web Services

As discussed above, the basic architecture takes into consideration a Service Oriented Architect (SOA) approach which links the resources and functions via web services. However, there can be issues related to the use of web services, particularly for public facing systems, that involve security issues, firewall protection, etc. For this reason, we have recommended the use of batch data exchanges between the layers rather than the use of web services. In addition, there can be performance issues and little to be gained with the use of web services, if the original content is very static.

However, ultimately, it will be beneficial to move to web services in order to open the tool's data to other systems and applications. This would also be in line with the Digital Government Strategy (OMB 2012) which calls for APIs for all publicly available data.

8.0 Next Steps

There are several next steps related to further design, development and deployment of the SII Tool, specifically related to the vocabulary support. These include data, processes and further testing of the concepts expressed above.

Most immediately, the next step is to develop a proof of concept and implementation of the tool based on this architecture. This proof of concept would limit the data to the DOSII database and the use of the ORD MV to a mapping of pillars and themes.

Further work would extend the data to include the Health and Well-being indicators (HWBI SHC Task 1.2.2.2) and the Environmental Quality Index (EQI SHC Task 1.2.2.3). Plans are already underway to take the Well-being and the EQI and build direct mappings between them. In these cases, there may be additional vocabulary work that is needed to support the indicator search and mappings. This would also extend the keywords from the ORD MV used to categorize and enhance access. Some of these terms have already been added to the ORD MV as part of its development. Increasing the number of data and vocabulary sources may raise other process issues, particularly with regard to the maintenance of the synthesized vocabularies to reflect changes made to the sources. There are also distinct characteristics of these sources that may need to be reflected in the data or in the user interface. For example, the HWBI has very distinct grouping categories for indicators/metrics. The appropriate way to incorporate these "more specific" grouping categories needs to be discussed.

In addition to the design and proof of concept development of the tool, and extension of the data, next steps should include a complete analysis of the process and data flows between the ORD MV and the tool, an analysis of the maintenance requirements for all the files, and a review of the best structure for storing the terms and the mappings. In the initial Proof of Concept, the pillars and related terms are stored in a single directory (task view) in separate vocabularies for each pillar with the terms stored within each vocabulary. With this approach the themes are not only linked to the pillars but if the same theme occurs in multiple pillars, the two occurrences can be linked. There are other approaches for storing and mapping the pillars, themes and keywords. For example, one approach would store the themes in the same vocabulary and assign the pillars as top terms. Alternatively, the themes would be stored in a single vocabulary without duplication, and one or more pillars assigned as categories to each theme. The best approach depends on the format needed when extracting terms from the vocabularies, the functionality required, and the impact of maintenance.

Additional analysis is also needed to determine whether themes containing multiple concepts or those that could be considered hierarchical should be stored as single terms, as they were in the test, or in a different way. For example, the theme, "human and social capital," includes two concepts – human capital and social capital. In this initial test, the themes were entered into Terminology Services in their combined, original form. However, they could be represented in the vocabulary as two separate but related concepts. For example:

Human capital (related term) Social Capital
Social capital (related term) Human Capital

In this way, each concept can have its own mappings to specific keywords.

Similarly, hierarchical terms such as Social Performance: Product Responsibility and Social Performance: Society were retained as joined strings. These could have been separated and stored with a hierarchical relationship as:

<u>Social Performance</u>
  Product Responsibility
  Society

The best approach to the style of the terms will depend on the proposed use cases and the tool's user interface design.

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