Communication

The Sustainable and Healthy Communities Research Program: The Environmental Protection Agency's Research Approach to Assisting Community Decision-Making

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Abstract: A sustainable world is one in which human needs are met equitably and without sacrificing the ability of future generations to meet their needs on environmental, economic, and social fronts. The United States (U.S.) Environmental Protection Agency's Sustainable and Healthy Communities Research Program aims to assist communities (large and small) to make decisions for their long term sustainability with respect to the three pillars of human well-being—environmental, economic and social—and are tempered in a way that ensures social equity, environmental justice and intergenerational equity. The primary tool being developed by the Sustainable and Healthy Communities (SHC) research program to enhance sustainable decision making is called TRIO (Total Resources Impacts and Outcomes). The conceptual development of this tool and the SHC program attributes are discussed.

1. Introduction

John Muir, "When we try to pick out anything by itself, we find it hitched to everything else in the Universe" [1].

Hundreds, perhaps, thousands, of times a day, communities throughout the United States (U.S.) make decisions on infrastructure, schools, roads, facilities, and a host of other issues. In most of these cases, the decisions are clearly made in good faith and with an outcome in mind—often a single short-term outcome targeted at the primary basis for the decision [2]. By this statement, we are not intending to be condescending to local decision makers (indeed similar arguments could be forwarded for decision making at the state and federal levels) but rather are simply stating an observation that many decisions result in unintended consequences. These consequences are often due to lack of holistic consideration of the myriad of interacting issues associated in the original decision making process. Because of this single-mindedness, the resultant outcomes are often inefficient and develop unintended consequences (good and bad) associated with issues not considered when the decision is made. As John Muir's insights allude, decisions have ripple effects. For example, siting a new school in a particular location because it is the least expensive (sole criterion is economic) might miss the unintended consequences of higher fuel costs for longer bus routes, children's air pollutant exposures due to long bus rides or proximity to an interstate highway, or the social consequences of moving disadvantaged populations long distances out of their neighborhoods. Hence, the decision to place the school at a particular location based solely on short term economic criteria might not yield the best long term outcome for either the community's school budget or the children's welfare [3].

"Sustainability", the increasingly-discussed paradigm, does not refer to the current "sustainababble" frequenting many political and social discussions [4] rampant in the development of sustainable products, ideas and concepts—from "green" cleaning supplies to sustainable music, candy or sidewalks. Rather, the basic concept of sustainability is that put forward by the Brundtland Commission [5] which states that sustainable development is, "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." This mirrors the policy of the Federal Government stated in the 1969 National Environmental Protection Act, which is "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"—the definition that the President used in Executive Order 13514 on sustainability and the federal government. In 2010, EPA provided an operational definition of sustainability: "Sustainability is the continued protection of human health and the environment while fostering economic prosperity and societal well being" [6].

In its report to the U.S. Environmental Protection Agency (EPA), the National Research Council recommended that "EPA formally adopt as its sustainability paradigm the widely used "three pillars" approach, which means considering the environmental, social, and economic impacts of an action or decision" [7] and furthermore that "EPA should also articulate its vision for sustainability and
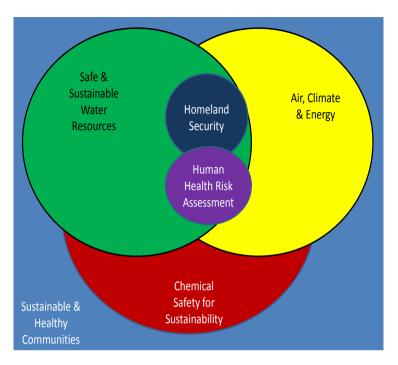
develop a set of sustainability principles that would underlie all agency policies and programs" [7]. EPA's Office of Research and Development (ORD) has developed research programs to support this sustainability paradigm [8], one of which is the Sustainable and Healthy Communities (SHC) Research Program. The SHC program fully embraces the "three pillars" approach described by the National Research Council and is developing tools, methods and approaches to support decisions that will foster community sustainability. Alternatively, there is a recent view [9–12] that, rather than examining sustainability simply as trade-offs among the three pillars, incorporates a broad range of criteria and objectives, drawing from the socio-ecological resilience literature and highlighting the importance of things like adaptive capacity and precaution in decision-making. These alternative approaches tend to emphasize the importance of taking paths that maximize gains (or avoid losses) in relation to the full range of sustainability criteria and have explicit rules for dealing with trade-offs.

2. Program History

Increasingly, reports appear on the unintended, usually negative, consequences of a legislative, policy or programmatic action, at neighborhood, community, city, county, state and national scales. For example, actions intended to increase energy supplies can have huge ramifications in the economic, environmental and social spheres and a decision targeted only at increased production can have significant unintended environmental or social consequences [13,14]. Similarly, a decision to site a waste management facility at a particular location solely based on economic criteria can result in major environmental justice issues, as these are often areas with disadvantaged populations [15,16]. Lacking a framework for decision making that includes consideration of the three pillars of sustainability—economics, environment, and social drivers—in an integrated and holistic fashion creates a high likelihood of unintended consequences.

In 2010, the Environmental Protection Agency's Office of Research and Development condensed its 13 topic-oriented research programs to focus on problems of broad national interest under principles of sustainability and solution-orientation. To that end, the AA realigned ORD into six programs focused on sustainability with regard to water, air (and climate/energy), chemicals, communities, human health risk assessment and homeland security (Figure 1). The Sustainable and Healthy Communities Research Program (SHC) is shown in the figure as encompassing the entire research program because in order to assist communities holistically, SHC must avail itself of the results of the other five research programs. Of the six programs, the Sustainable and Healthy Communities Research Program (SHC) is arguably the most novel, adding a relatively new topic to, and audience for, ORD's research portfolio, and integrating the previous research programs (from the 13 topic-oriented) addressing ecosystem services, human health, geographic information systems, waste management, decision support and community engagement.

ORD had conducted community research in the past, but such work addressed specific issues in specific places. For SHC to address the new problems of broad national interest, simply "ramping up" site-specific research (more sites, more issues) was neither adequate nor feasible. Instead, EPA needed to define how to support the community decision-making process to advance their sustainability goals.

Figure 1. Relationships among Six Office of Research and Development (ORD) Sustainability Research Programs.

As such, the SHC Research Program is expressly focused on the growing interest of U.S. communities in sustainable practices [17]. In many ways, local communities are ahead of the sustainability curve, evidenced by participation in organizations that support communities' sustainability action. ICLEI (Local Governments for Sustainability) has 450 U.S. members, the U.S. Mayors Climate Action Agreement has 1060 signatories, and the Urban Sustainability Directors Network has over 100 actively-participatory members, while the American Planning Association has a Sustainability Division, the Center for Neighborhood Technology works on solutions and the Urban Land Institute provides economic perspectives for sustainability-related land use issues. What these organizations lack is the science for better evaluating problems and potential solutions, especially for aspects of human health, ecosystem services and environmental justice; SHC is designed to help provide this science basis.

While each community is unique, they have problems and decision issues in common, and as such, SHC needs to provide information and approaches that can be both flexible (*i.e.*, can address different problems) and accessible to communities of varying size and scope (*i.e.*, applicable at multiple spatial scales). In order to organize this "new approach", SHC engaged in a significant amount of outreach targeting new audiences (e.g., state and federal transportation agencies and regional planning groups) and a multiplicity of community types (e.g., small and large, rural, suburban and urban, agriculturally-based and manufacturing based) to ensure that SHC research projects would generate products that would be both useful and useable. The primary intent of this outreach effort—primarily listening sessions conducted in selected communities throughout the United States—was to determine what our "customers" needed, how they could use the information, and how this information could be used to overcome obstacles to decisions that advance sustainability goals. The most common needs expressed across communities was to create tools, methods and approaches to allow the holistic evaluation of community decision alternatives, and for metrics, indicators and indices to set sustainability

goals and evaluate their progress. These priorities provided the architectural context of the Sustainable and Healthy Communities program.

3. Program Goals and Objectives

From its inception in 1970, EPA's mission has been to "protect human health and safeguard the environment—air, water and land—upon which life depends," and ORD's pioneering environmental research has provided a sound science foundation for EPA's work. However, despite the successes of U.S. environmental legislation, and EPA policies and regulation, current trends in population, as well as in the production and use of energy, food, and materials, have strained our natural resource base and compromised the resilience of the environment. There are too many examples where human health and essential ecosystem functions have been negatively affected by cumulative exposures to multiple toxic pollutants and a changing physical environment. These impacts have economic costs (e.g., increased heating and cooling loads, costly burdens in infrastructure and municipal services, contamination of fisheries, and diminished access to clean drinking water) and societal costs (e.g., health impacts, disparities in health risks, and loss of natural areas for healthful recreation).

Community decisions that do not take into account the ripple effects end up with social, economic, and environmental trade-offs that are often not recognized, much less understood and considered. SHC, through its research and application of that research, will inform and empower those decision-makers affecting communities (including at federal, state and tribal levels) to effectively and equitably weigh and integrate human health, socio-economic, environmental, and ecological factors into their decisions in a way that those decisions better foster community sustainability. In particular, SHC seeks to provide information that will assist decision-makers in implementing innovative actions within communities and tribal programs that can complement EPA, state and tribal authorities and achieve shared sustainability goals in more flexible, economically beneficial and effectively synergistic ways. To put it in economic terms, we want to help communities make decisions that maximize positive externalities, while minimizing or eliminating negative externalities.

4. Program Design

Each of ORD's programs has specific focal areas while maintaining close interrelationship with relevant parts of the other programs. Figure 1 illustrates the relationships among ORD's six sustainability research programs. These programs are using their expertise and experience to conduct transdisciplinary research which focuses on solving complex, real-world issues. They are seizing collaborative opportunities such that the relationships between them—safer chemicals and safer water supplies, less energy use, less air pollution and less waste—have implications for communities.

SHC is the focal point for ORD research on community sustainability, using systems-thinking, integrating perspectives from all realms (*i.e.*, private, public and civil). Furthermore, the program emphasizes collaboration in order to transcend narrow boundaries of traditional disciplines and create new knowledge and new theory, fostering new practical applications that yield advantages for multiple beneficiaries. Functionally, this breadth means that SHC is also the focal point for research to support cross-cutting topics on children's health, community, health, and environmental justice, and will be

developing ways to integrate research findings from all ORD programs. In Figure 1, this role is illustrated by SHC's location as the program that frames and encompasses the other five programs.

In order to accomplish this, SHC is organized into four themes. First, there is work on data and tools to support decision making. Second is research to characterize health and ecosystem linkages and impacts, to feed into decision support tools. Third is work that meets short term needs in communities with respect to legacy waste issues, like contaminated sites. However, this short term work also yields knowledge of processes that also feeds community decision support tools. Lastly, all these efforts are integrated into approaches for communities to use to evaluate decisions and find optimal solutions, including TRIO (Total Resources Impacts and Outcomes). The work of these four themes is described below.

5. Data and Tools to Support Sustainable Community Decisions

SHC is using decision science, interactive social media and sustainability assessment methods to assist communities in framing their sustainability goals and to develop new tools, indicators and spatial analyses for community use. In order to accomplish these activities, SHC scientists are working collaboratively with communities to develop ways to make data, information, and tools more interactive and more accessible to local audiences. Similarly, these scientists are compiling assessment indicators and tools and critiquing them for their applicability to community issues. This allows the creation of consistent metrics to characterize and communicate linkages among human health, well-being and environmental changes and measure progress toward sustainability goals. Three examples of research activities in SHC help to illustrate these approaches: (1) a classification of U.S. community types; (2) a national atlas for sustainability; and (3) an index of human well-being, described below.

(1) The statistical classification of U.S. communities will be used to guide development of decision and assessment tools that can address widely-shared sustainability issues. It will also inform transferability of tools to specific types of communities. The initial classification will be based on characteristics related to biophysical setting (e.g., climate, landform, soils, vegetation), community attributes (local governance, sustainability practices), demographic attributes (e.g., size, growth/decline, density, distribution) and ecosystem service characteristics. The classification will be updated over time to incorporate new data and relevant findings.

(2) The EnviroAtlas, a national Geographic Information System (GIS) atlas of sustainability-related parameters, will provide communities across the country with a suite of accessible, interactive maps showing indicators of production, demand and drivers of ecosystem services [18,19]. Categories of ecosystem services include: clean water for drinking; clean water for recreation and aquatic habitats; adequate water supply; food, fuel, and fiber; recreation, cultural and aesthetic amenities; contributions to climate stability; protection from hazardous weather; habitat and the maintenance of biodiversity; and clean air. A growing number of selected cities will have finer scale information with even more metrics.

(3) An index of human well-being [20–22] that would be applicable across spatial scales (national, regional, state, city, community, neighborhood) and temporal scales (intergenerational) is being developed by SHC. This index is comprised of information describing eight dimensions (health, safety and security, living standards, education, connection to nature, social cohesion,

leisure time, and spiritual and cultural fulfillment) with each dimension having multiple indicators represented by multiple specific metrics. The index is being constructed to provide communities with a tool to assess the effects of decision options on the well-being of their residents, as well as those in adjacent and even distant communities. Obviously, development of these types of indicators and indices are challenging and often dependent of the specific value systems of individual communities or sensitive population groups (e.g., children, tribes, socio-economic entities).

6. Forecasting and Assessing Ecological and Community Health

SHC scientists conducting research in this area will develop the information and methods that communities need to assess the health and well-being of their residents. To accomplish this, these researchers conduct foundational research in two major areas: (1) the science of ecosystem goods and services—those ecosystem functions that society depends upon to survive and prosper—including their production, use and benefits; and, (2) the science of human health and well-being as influenced by changes in ecosystem services as well as exposures to chemicals and other stressors in homes, schools, or neighborhoods. SHC's ecosystem-focused research will develop methods to quantify ecosystem goods and services, such as, water filtration, nutrient recycling, and mitigation of floods and storm surges. The research addresses how to estimate current production of ecosystem goods and services, given the type and condition of ecosystems; how ecosystem services contribute to human health and well-being; and the way in which the production and benefits associated with ecosystem services may be affected under alternative decision scenarios, in order to address the sustainability of those functions.

SHC's human health-focused research: will develop better methods to quantify, track, and reduce cumulative risks to public health; will develop a holistic understanding of how children's health may be linked to exposures (from before birth through adolescence) and impact their health throughout life; and will understand how differences in community setting (e.g., location of residence in relative to pollution sources, availability of safe, walkable streets, access to healthy foods) can contribute to good health and well-being or to environmental injustice and disproportionate health risks. Communities can use these types of information to develop and implement better public health policies and practices, especially for their most vulnerable residents (children, the elderly, or socio-economically disadvantaged), and to evaluate the effectiveness of interventions designed to improve public health.

Some examples of primary research in this area of SHC are: (1) Methods to Enhance Children's Health; (2) Standardized Classification of Ecosystem Goods and Services (EGS); (3) Searchable Database of Ecosystem Services; and (4) Web-based Tools for Environmental Justice, which are described below.

(1) Children's health research will contribute to EPA risk assessments, guidance documents and policies that protect overall children's health by providing metrics for age-specific chemical and non-chemical exposure and health impacts. In addition, work will examine children's health in a holistic way, looking at a wide variety of factors (e.g., children's play, psycho-social issues, their surrounding built and natural environments) and how they may interact with chemical and non-chemical exposures to impact children's health and health disparities [23,24].

(2) A central scientific problem limiting the clear understanding and consistent linkage of ecosystem changes to human health and well-being is having a metric with which to compare functions across different geographic settings—e.g., an acre of wetland in one location will not contain the same kinds and amounts of natural functions as an acre of wetland elsewhere. For EGS classification, SHC will develop standardized metrics for ecosystem goods and services; thus, significantly enhancing evaluation of how policy choices affect human health and well-being conditions. In addition, it will allow "trading" of ecosystem service credits, informing more commensurate mitigation of ecosystem damages through a consistent quantification of services that were lost.

(3) SHC researchers are developing production functions for many U.S. ecosystem services and benefits, that is, a characterization of the kind and amount of services and benefits a given unit of each ecosystem will produce. This is being accomplished by developing protocols for estimating the value of ecosystem services, including methods for quantifying the uncertainty associated with these estimates, understanding how scale affects estimates, and assessing the transferability of results from one area to other areas. These production functions are being catalogued and will be easily accessible to EPA, other agencies, NGOs, and anyone interested in considering ecosystem service trade-offs associated with changes in environmental conditions or decision alternatives.

(4) SHC is developing user-friendly web-based tools to help communities assess whether disproportionate health impacts or environmental exposures exist and, if so, to develop risk mitigation strategies that advance environmental justice. With this type of process and substance assistance (e.g., defining objectives, creating partnership databases, ranking risks and developing mitigation options), communities can better locate the source of the problems and improve conditions for everyone.

7. Implementing Near-Term Approaches for Sustainable Solutions

Research in this area of SHC builds upon federal, regional and state successes and experience to improve the efficacy of methods and guidance to address existing sources of land and groundwater contamination (required under RCRA [25] and Superfund [26]). RCRA, which regulates land-based disposal of waste (and focuses on hazardous waste) has the goal of reducing waste and encouraging recycling. This is not a ban on land-based disposal, but rather a regulation thereof, which uses "manifests" and the "cradle-to-grave" tracking system. All hazardous waste must obtain an identification number, and be accompanied by a "manifest" which tracks the waste. Each time the waste changes hands, a copy is sent back, ensuring that everyone along the chain is informed, and preventing unidentified wastes from arriving at disposal facilities. Superfund is a United States federal law designed to clean up sites contaminated with hazardous substances. Superfund created the Agency for Toxic Substances and Disease Registry (ATSDR), and it provides broad federal authority to clean up releases or threatened releases of hazardous substances that may endanger public health or the environment. The law authorized the Environmental Protection Agency (EPA) to identify parties responsible for contamination of sites and compel the parties to clean up the sites. Where responsible parties cannot be found, the Agency is authorized to clean up sites itself, using a special trust fund.

SHC research builds on RCRA and Superfund policies that encourage the use of innovative approaches to reduce new sources of contamination; enable material and energy recovery from existing waste streams; and enable brownfields sites to be put to new, economically productive uses that benefit communities. SHC research to address near-term solutions includes management of contaminated sites, materials and waste management, integrated management of reactive nitrogen, EPA's Report on the Environment, and sustainable technologies. Specific examples of research in this area are (1) tools to assess, measure and monitor clean-up of contaminated sediments; (2) beneficial reuse of material and energy recovery from wastes; and (3) sustainable nitrogen management.

(1) SHC research will improve biological, chemical and geophysical procedures to assess chemicals in sediments [27–31], as well as to better predict chemical concentrations in fish, shellfish, and birds (*i.e.*, aquatic dependent wildlife) from exposure to contaminated sediments. These will allow communities to measure and document the effectiveness of sediment remediation.

(2) Beneficial reuse research will provide data and tools to help optimize the recovery of energy from wastes and the beneficial reuse of wastes [32,33], thereby identifying opportunities to further reduce the volume of waste disposed, conserve natural materials and reduce net costs while protecting the natural environment in an economically and technically sound manner.

(3) When reactive nitrogen is released to the environment it creates a cascade of harmful effects that includes eutrophication of aquatic ecosystems, toxic algal blooms [34], hypoxia or "dead zones" [35–37], acid rain, nitrogen saturation of forests, contributions to global warming, and human health effects due to contamination of drinking water and air pollution [38]. SHC nitrogen research is part of an agency-wide effort. This work will synthesize existing and new analyses about the sources of nitrogen, its distribution in air, land and water, and its impacts on valuable ecosystem services [39], then it will identify strategic and efficient options to reduce the most damaging effects of reactive nitrogen while maintaining the benefits of nitrogen use.

8. Integrated Solutions for Sustainable Outcomes

The two primary significant barriers to effective decision making for community sustainability are the failure or inability to account for unintended impacts of actions and the failure to account for and take advantage of linkages among issues [40–43]. Regardless of the reason (oversight or lack of information), these omissions impede effective decision making. The design of policies, technologies and incentives to best foster community sustainability needs to take into account the linkages between human health and welfare and the built and natural environments, especially with respect to ecosystem services. SHC research in this area is exploring systems modeling approaches to account for the linkages among resources and assets managed by a community with special emphasis on high priority decision sectors—waste and materials management, land use, transportation, and buildings and infrastructure. Systems models that account for stocks and flows of energy, materials and water can be used by communities to identify opportunities to increase efficiencies and resource recovery with their actions.

TRIO (Total Resource Impacts and Outcomes—a term coined by SHC) research is developing methods and approaches to account for the multiple and interconnecting implications of decision alternatives, including direct and indirect costs and benefits across dimensions of human and

community well-being (economic, environmental and societal). A transdisciplinary team of health scientists, ecologists, economists and policy partners will evaluate and develop indicators that reflect the response of these sustainability dimensions to decisions made by communities. The TRIO approach will use systems models to estimate the full range of costs, benefits, impacts and outcomes for a given decision using relative weights for specific indicators to reflect community preferences and needs. TRIO is being tested in a proof-of-concept project in Durham, NC, but ultimately the TRIO tool will be available as a web-based model for more widespread application to community sustainability decisions.

9. Summary and Conclusions

Each community is unique with respect to policy context, resources, constraints and culture, but the issues of sustainability are common to all—a clean environment, a robust, resilient economy and concerns for their residents' health and well-being. The desired goal of the Sustainable and Healthy Communities research program is to provide communities the information they need to transform their expressed interest in sustainability into integrated actions that can address their short term needs, but yield greater benefits than current piecemeal approaches—a laudable goal for a program in its developmental stage. To accomplish this goal, SHC will develop and use a whole-systems approach to proactively and holistically assess the implications of community-level decisions, identify negative unintended consequences and evaluate opportunities for achieving optimized outcomes through integrated sustainability practices.

The tools and methods developed by SHC will enable EPA, regions, states, tribes and communities to implement their respective responsibilities with far greater ability to capture synergies in meeting their respective sustainability goals. The information from the SHC research program, together with communities' more intimate connections with their place, as well as with local residents, businesses and other groups, provides opportunities for communities to pursue effective, state-of-the-art actions.

There is also great interest from communities, around the country and the world, in using more sustainable practices to provide a full range of services (economic, environmental and social) [40–43]. These conditions provide both a receptive audience for SHC research products and an expansive level of information about early experiences on which to build and refine a scientific research program with immediate applicability to community needs. Supported by tools and information developed by SHC, communities, individuals and organizations can be empowered to better understand and manage how their activities can promote progress toward a sustainable future. As benefits accrue for individual communities, and as lessons spread, more and more sustainable communities will add up to a more sustainable nation and planet.

Disclaimer

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Conflicts of Interest

The authors declare no conflict of interest.

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