DRAFT RESEARCH FRAMEWORK

Sustainable and Healthy Communities Research Program

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SUSTAINABLE AND HEALTHY COMMUNITIES RESEARCH PROGRAM DRAFT RESEARCH FRAMEWORK

Executive Summary

> "Around the country, communities are looking for ways to grow that: use less land and energy; provide safe, affordable housing options for people of all incomes and at all stages of life; make it easier for people to get to their destinations on foot, by bike, or by public transit; and, direct growth to developed areas with existing infrastructure. Together, these development strategies emphasize environmental, economic, cultural, and social sustainability. Our collective implementation of those policies at state, local, and tribal levels will assure that we accommodate our nation's anticipated growth in smarter, more sustainable ways."
>
> *Administrator Lisa Jackson, June, 2009.*

Current trends in population and the way we use energy, food, and materials have eroded critical ecosystem services and compromised the ability of the environment to tolerate increasing levels of pollution. Not only are human health and ecosystem services negatively affected by cumulative exposures to multiple toxic pollutants and a changing physical environment - these effects also have economic and social costs, in terms of health care, technologies to replace lost ecosystem services (those that can be replaced), and social injustice, at scales ranging from local to international.

To become sustainable, future approaches to protecting human health and the environment must:

- consider the inextricable link between the natural environment and human well-being;
- focus on preventative strategies or strategies that optimize management of multiple chemical , material and energy streams in order to achieve the most environmentally beneficial, cost-effective and socially acceptable outcome; and
- employ systems thinking in order to avoid unintended consequences and maximize valuable co-benefits.

Many sustainability problems are global, national and regional in scope, and national regulations and international treaties, together with State, Tribal and Federal authorities, are required to solve them. However, local governments can use their authorities, together with their more intimate connection with local residents, businesses and other actors, to make decisions in the context of these rules and regulations to change behavior in a way that makes them more sustainable.

At the same time EPA's Program Offices are seeking more cost-effective means of accomplishing EPA's mission --means that utilize synergies between programs, maximize co-benefits with coordinated approaches to environmental protection, recognize synergies in the protection of human and ecosystem health, and reduce the possibility of unintended negative consequences of regulatory decisions. The Sustainable and Healthy Communities Research Program (SHC) set as its goal to inform and empower decision-makers to equitably weigh and integrate human health, socio-economic, environmental, and ecological factors to foster community sustainability. SHC will use, as a functional definition of "sustainability," the ability to meet present needs without compromising the ability of society and the environment to meet the economic, social and environmental needs of future generations.

To achieve this goal SHC will conduct integrated, transdisciplinary research to provide information, approaches, and tools that will help decision-makers at various scales –in communities, but also in federal, state and tribal regulatory programs - to more effectively and transparently assess current conditions in the built and natural environments, to evaluate the implications of alternative policies and management actions, and to identify indicators to measure results of the programs and policies that they select.

Transdiciplinarity is a critical tenet of the SHC work. It connotes work that is not only interdisciplinary but also actively engages stakeholders and partners. SHC held a series of meetings with internal Program and Regional Office partners and listening sessions with external stakeholders – typically community sustainability directors and other staff, and NGOs concerned with sustainability to help develop the direction and format for the program. This communication strategy also will be extended to the business community and community sustainability support organizations. This stakeholder/partner coordination will continue through development and implementation of SHC in order to provide a continuous feedback loop on program needs, data availability, usability criteria, utility of outputs and the provision of program products and experience, that can feed back into SCHRP work.

Stakeholder sessions revealed that, despite variations in geography, size, and representation, the most commonly expressed need was for a way to better evaluate the full range of costs and benefits for different actions that communities were considering, so that better decisions could result. There were many circumstances identified for which this kind of "accounting" would be beneficial, especially land use planning and development decisions and "green" vs. "gray" infrastructure comparisons, but also for transportation options, building practices, waste management and cleanup and reuse of contaminated land.

The most important SHC output will be a set of tools and information that allow communities to better evaluate the comprehensive positive and negative implications of alternative management decisions, with the long-term goal of better accounting for their full costs and benefits. Such an accounting would consider the direct and indirect social, economic, and environmental costs and benefits of each alternative decision. Examples of factors that could be included in the accounting are greenhouse gas emissions, vehicle miles travelled, health benefits of walkability, urban heat island mitigation, job

creation and economic multiplier effects, waste and materials management and land use contributions to groundwater quality and quantity. Following the United Nation's International Council for Local Environmental Initiatives (ICLEI) and the International Organization for Standardization (ISO) we will call this comprehensive evaluation process "Triple-Bottom Line" (TBL) accounting, although we may not follow the exact protocols used by these organizations. For maximum utility, it would need to be adaptable to communities across the US, regardless of size, population, or economic trends. Other needs commonly expressed by stakeholders were for practical indicators and performance measures of sustainability and a better understanding of the social factors affecting behavioral change and effective communication that would help communities better engage their citizens.

The SHC also engaged its EPA partners in a series of meetings to better understand their specific needs in research areas that became part of SHC as a result of the consolidation of the ORD research programs and to see how these needs could benefit and benefit from a communities and TBL accounting perspective.

As a result of all of these discussions, it was decided to organize the SHC framework around three broad themes, with 18 associated topics (see Table E1). The research in Theme 1 is more novel in focus and stakeholders than Themes 2 and 3, and therefore will take longer to design and initiate. It also is important to note that the SHC does not intend to duplicate the work of other agencies involved in transportation, buildings and infrastructure, or to duplicate tools development by other EPA Program or Regional Offices, but to incorporate those tools into the TBL accounting. The SHC also does not intend to do original research in economics or social sciences, but again to apply such research to the TBL framework. Research and development that ORD conducts will be limited to environmental and human health areas that are the organization's main mission. Because of these considerations the resource commitments in Theme 1 will be small in FY2012, and will primarily focus on developing detailed plans for projects in Theme 1 topic areas for FY 2013 and beyond.

Notwithstanding their present preliminary form, outputs of Theme 1 are critical to the success of the SHC program and its value to communities' sustainability efforts. As such, SHC foresees that this work will focus on community pilots as the "experiments" to develop the TBL accounting methodology. These case studies are needed to delineate the totality of linkages necessary to accomplish that goal, as well as a design for further research projects to complete a community-usable and effective accounting product. The work will be flexible, and intermediate products will be useful to community decision-making as well as for underpinning subsequent SHC work. These studies will both use and inform the decision support tools in Theme 2, combining the results of the community studies with other input data the U.S. This is the long-term goal of this program.

Many projects that fall into Themes 2 and 3 already have begun under the research programs that were integrated into the SHC. These projects will be modified over the next two years to more explicitly benefit Theme 1 objectives (and benefit from the Theme 1 projects). We will look for opportunities to incorporate outputs from projects under Theme 3 into Theme 1 and Theme 2 research, as well, and to use Theme 1 projects as "laboratories" for Theme 3 projects, wherever appropriate. We will seek to be more explicitly innovative, systems-oriented and transdisciplinary in all these projects.

Framework Themes with Associated Topics

Theme 1: Working with communities to develop comprehensive approaches to become more sustainable. This theme focuses on demonstrating the Triple Bottom Line approach in real world communities to enable effective, efficient, and socially just solutions to commonly-faced community problems.

Topic 1a: System Integration – Durham Pilot
Topic 1b: Sustainable Buildings and Community Infrastructure
Topic 1c: Land Use- Sustainable Community and Regional Planning and Zoning in Natural and Built Environments
Topic 1d: Sustainable Community Transportation
Topic 1e: Sustainable Waste Management and Site Remediation and Revitalization in Communities

Theme 2: Developing decision analysis methods, tools, models, data, and metrics that support community sustainability. This theme focuses on tools to support Theme 1 efforts, but that can also support other partner needs.

Topic 2a: Decision Analysis
Topic 2b: Indicators and Indices
Topic 2c: National Atlas of Ecosystem Services
Topic 2d: Ecosystem Services and Benefits
Topic 2e: Community Public Health
Topic 2f: Technology for Sustainability

Theme 3: Targeting high-priority agency research needs. This theme focuses on high-priority, specific R&D needed to provide EPA's partner offices with scientific knowledge and expertise needed to support regulations, executive orders, special reports to Congress, programs mandated by statutory language, and other Administrator priorities. This work wills also broadly support and benefit Theme 1 and 2 research wherever possible.

Topic 3a: Contaminated Site Management and Restoration
Topic 3b: Waste and Materials Management- Support for Regulations, Policy, and Guidance
Topic 3c: Nitrogen- Support for Regulation
Topic 3d: Environmental Justice
Topic 3e: Children's Health
Topic 3f: Report on the Environment
Topic 3g: Fellowships

PROGRAM GOAL

The Sustainable and Healthy Communities Research Program (SHC) goal is to inform and empower decision-makers to equitably weigh and integrate human health, socio-economic, environmental, and ecological factors into their decisions in a way that fosters community sustainability.

To achieve this goal SHC will provide information, approaches, and tools that will help decision-makers in communities and in federal, state and tribal regulatory and community-driven programs to more effectively and transparently assess current conditions in the built and natural environments, to evaluate the implications of alternative policies and management actions, and to identify indicators to measure results. An important outcome of the program will be the development of tools and information to improve the ability of decision makers at all levels to make better policy and management choices, with the long-term goal of a comprehensive accounting of the costs, benefits and tradeoffs among social, economic and ecological outcomes .

WHAT IS THE ENVIRONMENTAL PROBLEM?

> SHC will use, as a functional definition of "sustainability," the ability to meet present needs without compromising the ability of society and the environment to meet the economic, social and environmental needs of future generations.

Current trends in population and the way we use of energy, food, and materials have created environmental threats to sustainability that include the erosion of critical ecosystem services and the compromised ability of the environment to tolerate increasing levels of pollution. While technological breakthroughs will likely continue to slow some negative environmental trends, we still face many challenging problems. Not only are human health and ecosystem services negatively affected by cumulative exposures to multiple toxic pollutants and a changing physical environment, these effects also have economic and social implications, such as resultant costs for health care, cost for technologies to replace some ecosystem services, and costs to enhance social justice, at scales ranging from local to international.

Because of the increasing pressures on the environment, it is clear that future approaches to protecting human health and the environment will not support sustainability over the long term if they:

- Fail to adequately consider the inextricable link between our natural environment and human well-being, including economic and social aspects;
- Focus on regulating one energy or materials stream or chemical at a time, rather than on preventative strategies or strategies that optimize management of multiple chemical and energy streams in order to achieve the most environmentally beneficial, cost-effective and socially acceptable outcome; or
- Lead to unintended consequences, or fail to produce valuable co-benefits, because of a lack of systems thinking.

While many sustainability problems are global, national and regional in scope, the impacts of these problems are experienced primarily in communities (whether urban, suburban, or rural) Communities are challenged to sustain the well-being of their residents, and the ecosystem services on which they depend, in the face of changing demographics; urbanization; competition for food, materials, and energy in a global economy; growing waste streams; changing climate; tighter budgets; and

environmental injustice. Communities are finding that simply adding up single-purpose, single media approaches to complex interconnected problems is often environmentally insufficient, economically inefficient, and socially unjust or unacceptable. As one recipient of an EPA Sustainability Partnership grant put it, "*Communities need better tools to help them make more pro-active and strategic land conservation, land development, and investment decisions."*

WHAT IS THIS RESEARCH PROGRAM ABOUT AND HOW WILL IT ADDRESS THE PRIORITIES IN EPA'S STRATEGIC PLAN?

The primary focus of the SHC will be on developing tools and approaches to help decision-makers understand the environmental, social and economic effects of alternative policies and actions on communities. These tools should empower community-driven decisions that increase community sustainability. "Community", for the purpose of this program, will be defined as "a group of people living in a particular local area that falls within the jurisdiction of one or more local governments" -- from small villages to large metropolitan areas. There are also ecological "communities" of interacting plants and animals, and "communities" of people with particular interests (e.g., "baby boomers" or citizens concerned about environmental justice) within these geographic areas of common local governance, and these are of significant interest as they affect local decisions. However, the primary focus in communities is on the decision-makers, who are usually elected or appointed members of county and municipal government (and their technical staffs), and on the stakeholders who influence their behavior. Information and tools that will support community sustainability efforts by other relevant parties, such as EPA program offices, State and Tribal governments, non-governmental coalitions, businesses, or even community action groups, are also critically important to informing SHC efforts. SCHRP also will address and integrate the short-term, high -priority regulatory needs of EPA Program Offices that impact sustainability, such as, waste and materials management, contaminated site remediation, children's health, environmental justice and nitrogen impacts on ecosystem services.

The focus on the "human" aspects of communities is not intended to exclude ecological systems. In fact, they are a critical component of community sustainability. The SHC will directly assess the ecosystem services that ecological systems provide to the human community, as well as how these services can be positively or negatively affected by choices communities make about planning, infrastructure, transportation, and other issues. Ecosystem services can include not only functional services such as air cleansing, water supply, and recreation, but also the contribution of ecosystems to "quality of life." While the SHC program will focus on sustainability at the community level, we recognize that community sustainability both contributes to, and is affected by, the sustainability of regional, national, and global ecological, economic, and social systems. Our research will consider these issues and scales to the extent possible.

The question often is raised as to whether communities can be truly sustainable if their consumption of energy and materials or their exports of waste products to other communities create any negative externalities. In practical terms, communities usually set achievable sustainability goals for themselves and their immediate neighbors. But since Federal regulations do govern the export of pollutants to

other communities (e.g., downstream or downwind), SHC will assume that, to pursue sustainability, a community must at least meet the federal and state regulatory requirements in place to protect other communities. As noted elsewhere, SHC will also work with partner program offices to explore ways in which regulations could be modified to make compliance more cost-effective.

The SHC goal is to conduct research and development activities that inform and empower decision-makers to equitably weigh and integrate human health, socio-economic, environmental, and ecological factors to foster sustainability in the built and natural environments of communities. The program will engage stakeholders in order to identify, develop, and provide needed information, approaches, and tools that will help decision-makers more effectively and transparently assess current conditions, evaluate the outcomes of alternative policies and management actions, and identify indicators to measure results.

EPA has, in place, a strategic plan[1] to set priorities for Agency actions. Goal 3 of that plan has as an objective to:

> Clean up communities, advance sustainable development, and protect disproportionately impacted low-income, minority and tribal communities. Prevent releases of harmful substances and clean up and restore contaminated areas.

Both the SHC and EPA Strategic Goal 3 are grounded in recognition that effective and sustainable environmental protection is inextricably linked to long-term human health and quality-of-life outcomes, economic opportunity, and community vitality. SHC also addresses four cross-cutting fundamental strategies outlined in the EPA Strategic Plan:

- Expanding the Conversation on Environmentalism
- Working for Environmental Justice and Children's Health, and
- Advancing Science, Research, and Technological Innovation
- Strengthening State, Tribal and International Partnerships

All of these high priority directions will be evident in the research conducted within the SHC, and as benefits accrue and lessons spread, more and more sustainable communities will add up to a more sustainable nation.

WHAT IS THE REGULATORY AND POLICY CONTEXT FOR SHC RESEARCH?

For decades, EPA has worked closely with communities across the U.S. to protect human health and improve community welfare; to reduce exposures to environmental hazards; and to prevent environmental degradation resulting from human activities. In this time, ORD has coordinated with

[1] EPA, 2011. FY 2011–2015 EPA Strategic Plan – Achieving Our Vision. U.S. EPA: Washington, DC.

EPA's Program Offices and Regions on developing and implementing science-based guidance, regulations, and policies that have led to dramatic improvements in environmental condition and human well-being at the community, state, regional, and national level. Despite these improvements, EPA's Report on the Environment[2] still shows that we need to make more progress to achieve the goals of those regulations. We are also coming to know that approaches that worked well in the 20th century are insufficient to address the complex environmental challenges of the 21st century. Communities are finding that targeted, linear, single-media and single-purpose approaches to environmental protection, while reducing risks, do not necessarily drive communities toward sustainable outcomes.

At the same time, EPA's Program Offices are seeking more cost-effective means of accomplishing EPA's mission --means that will maximize co-benefits of multiple approaches to environmental protection, recognize synergies between the protection of human and ecosystem health, utilize synergies between programs, and reduce the possibility of unintended negative consequences of regulatory decisions. The plethora of voluntary and innovative programs attests to this approach. The SHC is based on the premise that the best way ORD can help to meet the long term goals of EPA's regulatory Offices is to complement traditional regulatory action by helping communities find ways to comply with regulations that are less expensive and more socially just and acceptable, as well as to avoid decisions that will make it even harder to achieve environmental goals and standards. The ultimate success of EPA's mission depends on the Agency's ability to recognize that community concerns have multiple contributing causes and to develop appropriately responsive systems-oriented approaches to environmental protection. The SHC proposes that the lessons learned by solving community-level problems will assist program offices in two ways: first, by informing the next generation of EPA regulations, ensuring that those regulations most effectively and efficiently address the critical environmental challenges the Nation faces in the 21st century and, second, by providing innovative, integrated and effective non-regulatory approaches for complex problems and legislative mandates. As local benefits accrue and lessons are shared, more and more sustainable communities will lead toward a more sustainable nation.

This future vision for EPA is expressed clearly in Administrator Jackson's call to "incorporate sustainability into the way the Agency approaches environmental protection." While all of ORD's National Research Programs have adopted this vision, the SHC pursues an explicit, community-focused approach that fully embraces the complex interplay of environmental, economic, and social factors contributing to sustainability.

EPA and the States and Tribes promulgate regulations and policies to protect human health and the environment. However, communities have authorities that can complement EPA and State authorities to address problems with multiple contributing causes. Indeed, community decisions can make it harder to meet regulatory goals and standards. The SHC will conduct research and development activities that can help communities to assess their current level of sustainability relative to their goals and to identify and evaluate options that best use available authorities and result in more sustainable outcomes. SHC will also identify strategies that meet requirements and deliver cumulative co-benefits that increase ecosystem services, decrease community health risks, reduce net costs, and avoid unintended

[2] http://www.epa.gov/roe/

consequences. Ideally, SHC will identify the important trade-offs among ecological, social and economic values for multiple decision options so that decision makers at all levels can have the information needed to make the best decisions for community sustainability.

As an important component of SHC , we also will address targeted research needed by EPA's Program Offices that support critical regulatory and policy needs of the Agency that relate to waste and materials management, contaminated site remediation, and regulatory and policy measures that rely on the quantification of ecosystem services. We also will support, in coordination with efforts in all ORD programs, work on EPA's cross-cutting strategic goals of protecting children's health, insuring environmental justice (decreasing environmental and health disparities) and providing essential information and insights for EPA's Report on the Environment. In doing so, SHC will take an integrated, systems approach in research to address these problems.

Transdisciplinarity is a critical tenet of SHC work – it connotes work that is not only interdisciplinary, but that actively engages stakeholders and partners. It was for this reason that SHC reached out to internal Program and Regional Office partners, and external stakeholders to help develop the direction and format for this program. This coordination will continue thorough development and implementation of SHC in order to provide a continuous feedback loop on program needs, data availability, usability criteria, utility of outputs and the provision of program products and experience, that can feed back into SCHRP work.

HOW WILL THIS PROGRAM BUILD ON AND EVOLVE FROM ORD'S EXISTING RESEARCH PROGRAM

The SHC program is one of six realigned research programs for ORD:

- Sustainable and Healthy Communities (SHC)
- Air, Climate and Energy (ACE);
- Safe and Sustainable Water (SSW),
- Chemical Safety for Sustainability (CSS),
- Human Health Risk Assessment (HHRS),

Homeland Security (HS), while all of the programs have some aspects of overlap – air pollutants deposit into water bodies and risk assessments are needed for chemical exposures, for example – SHC is the only one that integrates aspects of each of the other five programs. This is because the adverse and beneficial aspects of these diverse drivers and influences are experienced in an inextricably interconnected way at the local level. In addition, it is often the needs, decisions, purchases and life styles of individuals and communities that drive the activities creating problems.

As mentioned earlier, an innovative and holistic way of addressing problems is needed to address those problems that remain after regulatory approaches reach their effective limits. As such, SHC will *require* systems thinking and transdisciplinary research. The Program's research will not only integrate building and infrastructure; land use; transportation, and; waste management and site revitalization. In addition, it will integrate research outputs from ORD's other National Research Programs that are relevant to community sustainability. This should result in increased efficiency, both in terms of research and development, but also of EPA's regulations.

To conduct this new type of work, ORD will use its extensive research expertise and experience in the areas of landscape ecology; human health effects; environmental engineering; assessment and decision science; and materials and waste management as well as many others to accomplish SHC goals. The ecosystem services research will be extended into the new program[3] with enhancements to its economic component and additions of other existing relevant social science. Examples of notable contributions from past research areas include:

- A recent study demonstrating that the value of ecosystem service co-benefits (such as hunting, greenhouse gas mitigation, and floodwater storage) can reduce the net costs of meeting nutrient and sediment reduction targets – this work is being considered by EPA in the formulation of water quality trading policy in the Chesapeake Bay and elsewhere.
- A decades-long effort to develop cost-effective indicators and sampling frameworks has led to data and performance metrics used to guide EPA's water quality protection in collaboration with States as required by the Clean Water Act. The program also led technical development for the indicator-based EPA Report on the Environment.

[3] http://www.epa.gov/ecology/

- Multiple projects on waste treatment and cleanup technologies have saved millions of dollars in costs. For example, as alternatives to conventional pump-and-treat, technical support to Region 7 resulted in selection of in-situ chemical oxidation to clean up VOCs in contaminated ground water that saved approximately $70 million, and a partnership with Region 6 and Air Force staff resulted in application of a permeable reactive barrier at Altus AFB to treat TCE at an estimated cost saving of $8 million.
- The Community-Focused Exposure and Risk Screening Tool (C-FERST), a GIS and resource access internet tool to support community-based cumulative human exposure and risk screening assessments, became available to outside users as a beta test version in late 2010; Community Action for a Renewed Environment (CARE) projects in Regions 1, 2, and 5, are conducting pilots using the tool.
- ORD STAR grantees in collaboration with New York City housing authorities have demonstrated that integrated pest management practices not only reduce exposure of public housing residents to pesticides, but also improve general health by reducing the burden of asthma, and decreasing city costs on fumigation. Now HUD, in partnership with EPA, is recommending widespread use of these practices in its Healthy Homes initiative.

Developing the SHC Research Plan

APPROACH TO DEFINING PROGRAM DIRECTION

The charge to the SHC from the ORD Assistant Administrator was to create a program that would advance community sustainability by providing research products that are relevant and actionable for decision makers, and based on integrated and transdisciplinary approaches. This novel charge introduces a new audience to ORD's research products and demands a new way of approaching research for ORD. To insure both relevance and utility, the SHC turned to its existing partners and to new stakeholders to help develop the direction and format for the program.

Turning first to Agency partners, ORD held workshops with EPA Program and Regional office representatives to discuss how they envision their community sustainability research needs. Together, staff from EPA Program Offices, Regions and ORD agreed on a problem statement

> *Communities face social, economic, and environmental trade-offs in a resource-constrained world. These trade-offs are often not well-characterized in terms of the implications and interactions between human health, ecosystem services, economic vitality, and social equity. Conventional decision-making often does not adequately characterize these complex interactions.*

Furthermore, all concurred with the solution statement that *communities need holistic, integrated, and functional science and practical technical tools and support to find solutions that are sustainable: that is, solutions that are equitable, efficient, and effective.*

The SHC also recognized the critical importance of stakeholder (outside EPA) participation in identifying problems and finding solutions. The program will only be successful if we develop tools and information

that help communities solve the problems as they see them with tools that are relevant, useful, and practical, and that can be readily adapted for communities' particular situations. Solutions will also need to be economically and socially acceptable if they are to create community policies that can be sustained.

To learn more about stakeholders' needs for information to advance community sustainability actions, the SHC conducted extensive outreach. Seven regional listening sessions were held with a range of communities, each with a variety of governmental, NGO, university, and community participants. Three community webinars and one tribal webinar enabled input from a wider geographic area, and focused especially on attendance by local sustainability directors. A 1 ½ day workshop was held with leading local sustainability directors, academics, and NGO participants such as ICLEI-Local Governments for Sustainability, the League of Cities, and the Congress for the New Urbanism. Finally, input sessions were held in selected pilot communities in Durham NC and the Gulf of Mexico region. At all these sessions, ORD staff explained the SHC program and solicited ideas about barriers to sustainability actions and information needs that would be relevant and effective to overcoming those barriers and advancing their local efforts. Approximately 300 community representatives provided input in these forums. More detailed descriptions of outreach efforts are provided in Appendix B. Additional input will be obtained from various Agency programs that conduct community outreach, e.g. OSWER's Community Engagement Initiative (http://www.epa.gov/oswer/engagementinitiative/index.htm).

Despite variations in format, geography, size and representation, the input from these listening events was strikingly similar. The most common need expressed was for a way to evaluate the full costs and benefits of different actions that communities were considering, so that better decisions could result. Of the different circumstances for which such "full-cost" accounting would be beneficial, the most often mentioned was land use planning and development decisions, and "green" vs. "gray" infrastructure comparisons. Other important local issues were transportation options, building and infrastructure practices, and waste management. If SHC is successful, the foremost output will be the development of tools and information for improved ability to evaluate comprehensive positive and negative implications of alternative scenarios, with the long-term goal of better accounting for their full costs and benefits. Such an evaluation would consider the direct and indirect social, economic and environmental costs and benefits. Examples of such accounting include greenhouse gas emissions, vehicle miles travelled, health benefits of walkability, urban heat island mitigation, job creation and economic multiplier effects, waste and materials management and aquifer recharge, but it would be adaptable so as to address whatever issues come forward for decision. We are calling this comprehensive evaluation process Triple-Bottom Line (TBL) Accounting. For maximum utility, it would need to be adaptable to communities across the US, regardless of size, population, or economic trends.

Other commonly expressed needs were for practical indicators and performance measures for sustainability, and a better understanding of the psychology of behavioral change and effective communication. These needs will be integrated into the TBL accounting methods development, and will help to target and measure the parameters that are most important for decision making.

Because this kind of research is new to ORD, methodologies for designing and implementing it are not obvious. As such, the design of this program has, and will continue to be, an iterative process. Adaptive management principles will be used to develop a successful program that routinely incorporates stakeholder consultation to assure relevance and utility. It also is important to note that ORD does not intend to conduct research that is more the purview of sister agencies such as DOT or HUD, or to redevelop tools already developed by EPA's Program or Regional Office partners, or to conduct original research in economics or sociology. Instead, the goal will be to apply tools already developed to the TBL accounting, and to work with the sister agencies to fill the most critical gaps. Research and development that ORD conducts will be limited to environmental and human health areas that are the organization's main mission. Because there is significant relevant work and research going on elsewhere in the Agency, as well as by other federal agencies like Housing and Urban Development, Department of Transportation, and Department of Agriculture, we will continue to conduct intra- and interagency partner consultation to assure that SHC work provides added value and is complementary, not duplicative. Collaborating with pilot communities will be critical to the development and evaluation of these products. In addition, given the sustainability efforts by relevant non-governmental stakeholders, e.g. businesses and community sustainability support organizations, important early steps should include investigation, evaluation and, where relevant, coordination on their efforts, as well.

Following stakeholder discussions and further meeting with ORD's Program and Regional Office partners, the SHC was organized around three broad themes which are meant to address the decision-support needs that both groups expressed. The three themes and 18 associated topics are shown in Table 1. An interim version of this plan was reviewed at EPA's Science Advisory Board Budget review in March and it received much interest and favorable oral comments. The three themes are described in more detail later in this document.

FURTHER REFINEMENT OF THE PROGRAM

Of the three themes, the first offers the greatest opportunity to develop innovative approaches to support community decision-making. Theme 1 projects will respond directly to needs expressed by communities and the organizations that work with them. However, knowing what we want to accomplish and knowing how to accomplish it are different aspects of the same goal. To succeed in both aspects will require continuing consultation among SHC, our program and regional partners, stakeholders and ORD scientists.

Using input from the communities and the partners (described above), we consolidated a lengthier list of concerns into five basic focal areas for Theme 1 research:

- system integration;
- buildings and infrastructure;
- land use in the natural and built environments;
- transportation; and
- waste and materials management and site remediation/reuse.

Table 1. Framework Themes with Associated Topics

Theme 1: Working with communities to develop comprehensive approaches to become more sustainable. This theme focuses on demonstrating the Triple Bottom Line approach in real world communities to enable effective, efficient, and socially just solutions to commonly-faced community problems.

Topic 1a: System Integration – Durham Pilot
Topic 1b: Sustainable Buildings and Community Infrastructure
Topic 1c: Land Use- Sustainable Community and Regional Planning and Zoning in Natural and Built Environments
Topic 1d: Sustainable Community Transportation
Topic 1e: Sustainable Waste Management and Site Remediation and Revitalization in Communities

Theme 2: Developing decision analysis methods, tools, models, data, and metrics that support community sustainability. This theme focuses on tools to support Theme 1 efforts, but that can also support other partner needs.

Topic 2a: Decision Analysis
Topic 2b: Indicators and Indices
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Topic 2e: Community Public Health
Topic 2f: Technology for Sustainability- Greener Economy, Systems Thinking, Innovative Technology

Theme 3: Targeting high-priority agency research needs. This theme focuses on high-priority, specific R&D needed to provide EPA's partner offices with scientific knowledge and expertise needed to support regulations, executive orders, special reports to Congress, programs mandated by statutory language, and other Administrator priorities. This work wills also broadly support and benefit Theme 1 and 2 research wherever possible.

Topic 3a: Contaminated Site Management and Restoration
Topic 3b: Waste and Materials Management- Support for Regulations, Policy, and Guidance
Topic 3c: Nitrogen- Support for Regulation
Topic 3d: Environmental Justice
Topic 3e: Children's Health
Topic 3f: Report on the Environment
Topic 3g: Fellowships

Under Topic 1a system integration, a pilot project will provide a context for which we can construct and test the TBL accounting methodology. The latter four topic areas represent: a) common community decisions within their purview, b) decisions that can have significant environmental impacts in communities and so can provide significant opportunities for positive change, and; c) areas for which for which ORD scientists can build upon existing or readily-available expertise and information for early successes.

At an ORD Scientist-to-Scientist planning meeting on May 4-5, breakout groups met to brainstorm appropriate science questions and associated outputs for each of the latter 4 topic areas. The results of these meetings led to the Science Questions, Topics, and Outputs in Themes 1 and 2. Theme 1 topics directly support community planning and decision-making, while Theme 2 topics provide decision support systems, models, data, and other information needed to meet the Theme 1 topics. Theme 2 topics may also support other agency needs (described later). ORD has begun to get feedback to prioritize these questions and topics from our partners and stakeholders.

Theme 3 topics represent Agency commitments to research to support mission-critical regulations and policies related to several SHC themes, specifically, waste and materials management; site remediation (Superfund and Leaking Underground Storage Tank appropriations); nitrogen (Clean Air Act and Clean Water Act Regulations); Children's health (ensures that children are adequately protected under EPA regulations and polices): Environmental Justice (ensures that regulations and polices do not disproportionately impact minorities and low income populations); the EPA Administrator's Report on the Environment; and fellowship programs designed to provide practical training for the next generation of environmental scientists and engineers. Decisions about Theme 3 projects were made based on discussions with the appropriate SHC partner offices.

There has been some concern that placing the program-specific research in Theme 3 will lead to isolation of these projects from the work of Themes 1 and 2. However, we do *not* intend a disconnected approach to these efforts; rather we intend to look at each problem with full appreciation of the connections among the problems, the information needed and the possible solutions between and among them. We also will use science and tools from the other National Research Programs, as appropriate, and communicate to the regional and program offices the issues within their purview that arose in the community listening sessions.

The three Themes will be discussed in more detail below "Next Steps".

Next Steps

The next functional steps for SHC are very different for the three themes. Many projects that fall into Themes 2 and 3 already have begun under the research programs that were integrated into the SHC. These projects will be modified over the next two years to more explicitly benefit Theme 1 topics (and benefit from the Theme 1 projects). We will look for opportunities to incorporate outputs from projects under Theme 3 into Theme 1 and Theme 2 research, as well, and to use Theme 1 projects as "laboratories" for Theme 3 projects, wherever appropriate. We will seek to be more explicitly

innovative, systems-oriented and transdisciplinary in all these projects. By October 2011, Theme 2 projects will define how their goals and products will be modified in FY12 to support the Durham Pilot and other Theme 1 activities. Theme 3 projects will continue to support program offices objectives through FY 12, as they have been doing, and will begin in FY13 to determine how their outputs can more directly contribute to Theme 1 or Theme 2. A major focus for FY 12 is to have discussions among scientists in all Themes to identify synergies, efficiencies, and mutually useful outputs and to refine research plans.

Due to its innovative topic areas and its emphasis on stakeholder collaboration, Theme 1 will take longer to design and initiate than Themes 2 and 3. It is important to note that SHC does not intend to duplicate the work of other agencies involved in transportation, buildings and infrastructure, but rather to incorporate existing tools into a systems approach for TBL accounting. The SHC also does not intend to do original research in economics or social sciences, but to apply existing research to the TBL framework. Accordingly, resource commitments in Theme 1 will be small in FY12 and will primarily focus on developing detailed plans for research in FY 13 and beyond.

Theme 1 outputs are critical to SHC's value to communities' sustainability efforts. As such, SHC will use the community pilot work as an "experiment" to determine how to best realize a TBL accounting methodology in a real world setting. This will require developing systems analyses for each topic area and determining the most influential linkages among them. The intention is to create intermediate products of immediate value to communities which also will establish a solid underpinning for subsequent SHC work in the other topics.

In FY12, SHC will also begin to expand its capacity to accomplish the longer range goals of the program. We will begin development of the decision support platform. We will continue our research on indicators and metrics, focusing in particular on community sustainability. We will look to our human health, environmental justice and ecosystem services research to determine how it can best contribute to community sustainability decisions. SHC will integrate the components of this program with the other national research programs so that they are effectively synergistic and to integrate its efforts with EPA's Office of Sustainable Communities in the Office of Policy.

Program Issues/Research Themes

RESEARCH THEME 1. WORKING WITH COMMUNITIES TO DEVELOP COMPREHENSIVE APPROACHES TO BECOME MORE SUSTAINABLE

Overview:

The Program's primary aim is to help communities make decisions that move them toward a more sustainable status. As discussed earlier, the discussions with communities across the country have clearly indicated that the most effective contribution ORD can make toward achieving this goal is to

provide information and tools that support TBL accounting for important decisions that communities regularly face. Such accounting requires systematic understanding of the comprehensive and interacting environmental, human health, economic, and social consequences of community decisions, and weighing the likely outcomes and tradeoffs with community actions. For example, decisions made to improve human health and well-being are usually made in isolation from decisions made to protect ecosystem integrity, not considering the ways that ecosystems affect human health and well being. This stove-piped approach frequently leads to decisions that are counterproductive, ineffective, inefficient, or unjust.

The intended outputs of SHC Theme 1 are system integration reports which document and assess the critical interacting components, methods, models, and data needed to do TBL accounting based on real community pilot projects and Theme 2 efforts. Theme 1 outputs will also serve as input for Theme 2 (decision analysis) and will target the needs of community decision-makers at multiple levels of governance, across communities of different types and at different spatial scales. The intended ultimate outcome of this work is that communities will be empowered to move toward sustainable states through more informed decision-making.

We recognize that this represents a novel approach for ORD and for EPA. In fact, of all the research themes throughout ORD's new National Research Programs, we believe that SHC Theme 1 represents the most radical departure from "business as usual." It is through SHC Theme 1 that ORD will develop the understanding and information necessary to help communities to best leverage EPA guidance to improve community health and well-being and to protect the integrity of ecosystems and their associated services. Without consideration of the complexities explored in Theme 1—the full TBL benefits and costs of management and planning options and the systemic relationships between decisions made in different domains—communities will continue to take (at best) only incremental steps toward sustainability, regardless of EPA's efforts. Successful implementation of Theme 1 research will thus signify a paradigm shift in EPA's capacity to effectively and efficiently achieve its mission. Further, unless the TBL methods work of Theme 1 and the tool development work of Theme 2 consistently provide mutual feedback that science will ultimately fail to achieve its full potential. The SHC thus holds that attainment of Theme 1 goals is a crucially important step toward maximizing the effectiveness of ORD's ongoing research efforts.

Given the importance and novelty of Theme 1 research, SHC will evaluate existing relevant science and sequence further exploratory research before attempting to fully implement its Theme 1 Research Action Plan. This decision is based on the extensive conversations with community stakeholders, which helped the program to identify a number of broad questions that must be answered before it is possible to begin identifying the specific science questions that will define Theme 1 research:

- What are the most important decisions and crucial barriers influencing the ability of communities to achieve more sustainable states?
- What are the most important interconnections among community planning and management decisions that would best allow decision-makers to recognize possibilities for co-benefits and unintended consequences?

- What are the most important planning and management considerations needed to maximize resilience in the face of changing contexts including climate change, demographic shifts, and declining economic base?
- What are the most important factors guiding community decision-making, and how can understanding of these factors allow us to better engage communities, invoke change, and more effectively assist them in achieving their sustainability goals?

The questions above will be answered through the implementation of pilot projects designed to better understand systematic "whole community" approaches to increasing sustainability. Durham, NC will serve as the first local pilot, the system integration "experiment" in TBL accounting methods.
We also envision addressing problems common across multiple communities, as defined in the second bullet-question above. Additional pilots will be implemented with and through the regional and program offices. Criteria for selecting additional pilot locations will be developed in the near future. One location where ORD will begin collecting regional scale information is in the Gulf of Mexico , where we will work with three communities that are also working on sustainability planning for critical decision-supported needs for coastal communities.

The early "contributing" outputs from the Durham pilot, in conjunction with the immediate lessons from Theme 2 science (e.g. development of sustainability metrics and indices, completion of ecosystem services mapping tools, etc.), will help identify which aspects of the TBL accounting picture are most critical, as well as whether and how this information is used in community decisions. This knowledge will prepare SHC to directly pursue more strategically targeted Theme 1 research beginning in 2013.

The intended outputs of this initial phase (FY 2012) of Theme 1 work are:

- A catalog of the most important decisions influencing the ability of communities to achieve more sustainable states and a thorough understanding of the interconnections between those decisions
- A critical analysis of TBL accounting methodologies (or equivalent approaches) applicable at the community level
- Identification of the types of information that communities will need to evaluate the triple-bottom line costs and benefits of their options (in terms of human health and welfare, ecosystem services, and economic vitality) and to assess progress toward desired states
- A complete set of science questions that, if answered, will provide communities with accessible decision support and communication tools that will aid them in making and implementing critical decisions with significant impacts on community sustainability
- Demonstration of TBL accounting for interdependent community decisions involving land use planning, building and infrastructure, transportation, and waste and materials management.

The SHC thinks it is premature to define specific Theme 1 science questions, pending these 2021 outputs. However, as described earlier, considerable time and effort went into conversations with our partners and stakeholders, through which we identified the four broad research topics to feed into, and out of, the Durham TBL accounting pilot:

- Sustainable Buildings and Community Infrastructure
- Sustainable Land Use –Sustainable Community and Regional Planning and Zoning in the natural and built environment
- Sustainable Community Transportation and
- Sustainable Waste Disposal, Materials Management, and Site Remediation

These broad areas address common and important issues affecting community sustainability across the nation and represent the most likely targets for expenditure of ORD resources under Theme 1. The outreach discussions also led to the collaborative development of illustrative science questions that represent the type of research that will ultimately be conducted under Theme 1. These illustrative questions are described below for each of the topics. Theme 1 research will be used to assist communities with actual decisions they face (initially for Durham and by its example), and will also serve as input for the development of strategic science questions for 2013 and beyond.

RESEARCH TOPICS

Topic 1a. System Integration Pilot – Durham, NC

The overall goal of Theme 1 is to create a TBL accounting tool that fully integrates the many-faceted decisions faced by communities, rather than considering these decisions in isolation. For example, transportation planning that is based on a future scenario that accepts expected growth patterns as constraint is less sustainable then planning that simultaneously considers land use planning and zoning, building and infrastructure, waste and materials management, and possibly other decisions such as related to energy sources and climate adaptation. As Topics 1b-1e develop tools suitable for those topics, there is a need to understand how all four topics (and potentially others) interact and can be incorporated into a truly integrated decision support model that can be used by communities.

Durham, NC will serve as the pilot laboratory to develop and answer the science questions that are most critical to developing the integrated TBL accounting method. Durham has the advantage of having municipal sustainability goals in place, ongoing sustainability initiatives, and a proximate location to EPA's largest ORD facility, located in Research Triangle Park. These conditions will allow convenient access to the community and to ongoing programs that will provide background and data, evaluation of existing efforts and critique of the utility, and feasibility of interim decision support tools.

A key focus of the pilot will be to identify and understand those comprehensive and interconnected TBL impacts linked to common management decisions. That system integration product will help us evaluate how well the method will work, how well it translates to other locations and other decision making circumstances, and what gaps remain for subsequent SHC research to address.

In addition, there is significant social science work going on regarding the human dimensions of sustainability decision making, which can be explored to help identify those issues or aspects of

sustainability that are the most critical levers for decisions and behavior changes. This kind of information can help focus data collection, target where TBL assessment needs more detail, and help craft communication and delivery mechanisms for community or program users.

Illustrative Science Questions:

1. What are the TBL interactions that are relevant to community decisions and what construct will best support defining and, where possible, quantifying those interactions?
2. What aspects of community decisions are the most relevant for decision makers and persuasive in creating changed behavior, and how can that information help shape data collection and metrics/indicator development?
3. What are the most significant TBL interactions with respect to environmental or health impacts, opportunities for cumulative benefits, and frequency of effect from decision making?
4. Where and how can TBL interactions be quantified, or if only qualitative, how can scale of influence be represented?
5. How can the TBL accounting methodology be packaged into a user-friendly and relevant tool for communities and others making community-driven decisions?

Topic 1b. Sustainable Buildings and Community Infrastructure

Communities make frequent decisions that affect local building, housing and infrastructure and these decisions have significant financial, environmental, health and social impacts for the community. Some local governments provide affordable housing, as well as enable and encourage different types and arrangements of housing. Some set building safety and health standards. All make infrastructure decisions to provide services, like sewage collection, or prevent problems, like stormwater flooding. These are all costly decisions which would benefit from better information. This topic is also significantly interconnected to the Theme 1 land use and transportation topics described later.

Housing is a pivotal consideration for communities. Housing shortages (such as for work force housing) have some communities focused on building more homes or mixed use developments to attract new members to the community and to meet existing residents' needs. Other communities are driven by a economics to expand their tax base by renovating existing building stock, do energy retrofits or deal with abandoned buildings as their economy shrinks and people move away.

One positive trend is that communities are increasingly developing land use plans and zoning decisions with sustainability goals in mind. However, these can be undone easily by *ad hoc* rezoning or variances for specific buildings or developments the municipality determines, on the basis of limited cost/benefit information, are economically justified or desired. Such decisions have long-term implications and can be made without the community participatory process that usually accompanies planning efforts. Roads will replace greenfield acreage, with accompanying impacts on ecosystem services. Buildings and other non-road infrastructure will similarly displace vegetation, create impervious surfaces and impose long-term costs and constrain future options. Buildings may be considered more expendable, and so not as permanent a decision, but rarely does built property revert to green space. And unless a building is designed for flexibility of future use, unproductive buildings are often torn down, and the embodied

energy in buildings and materials is wasted. All of these decisions have important environmental components.

Due to these economic cost and environmental implications, community decisions that affect new development and infrastructure are best made with well-informed foresight and TBL insights. In addition, there is significant new experience in retrofitting sprawl, dead malls and other underperforming sites into denser, mixed use, transit-oriented development, yet evaluations of comprehensive TBL implications of these measures do not yet exist. Accurate TBL accounting methods to compare the implications of existing development, redevelopment and green field development alternatives would significantly benefit common community decision-making and might highlight significant economic opportunities.

Evaluations of alternative infrastructure options also need TBL information. Anecdotal evidence is calling into question many assumptions about infrastructure design and suggests that acting on those assumptions might result in counterproductive decisions. For example, narrower streets in neighborhoods will better support walking, biking and a more protected feel, but wider streets are sometimes required by code to allow faster response time with larger fire trucks. An unforeseen consequence of the wider streets is that more firefighters are being killed in traffic accidents en route to fires than fighting fires. Such anecdotes highlight the need to evaluate the assumptions which underpin costly infrastructure decisions.

Two more examples of community infrastructure decisions that would benefit from comprehensive TBL evaluation include green infrastructure and leaking underground storage tanks. Communities that want to transition from “grey” to “green” infrastructure are having difficulty justifying costly retrofits without suitable evidence of the net benefits, even though common repair decisions could provide significant opportunities for multipurpose green infrastructure. Aging underground storage tanks for fuels can create significant problems as ethanol expands the benzene plumes generated from leaking tanks, endangering groundwater supplies and causing vapor intrusion in buildings. A recent ORD analysis has shown that populations surrounding urban cores have a higher vulnerability due to the co-location of gas stations and water supply wells. TBL assessments for options can empower decisions that minimize impacts.

Illustrative Science Questions:

1. What are the effects of the design, condition and maintenance practices of housing and other built environments (e.g. schools, office spaces, retail spaces, etc.) on human health and well-being? What are the best practices and products that communities can employ to minimize health risks (or promote wellness) from indoor exposures?
2. What are the cumulative TBL implications of green infrastructure compared to grey and who is most affected by those?

3. What type and mix of housing best promote the well-being of individuals and communities?
4. How does the distribution and type of built infrastructure affect the delivery of ecosystem services?
5. How can safe, affordable and healthful housing be distributed such that communities are better integrated and individuals have equitable access to the benefits associated with such housing (including community benefits such as access to transportation, education, healthy food, medical services and cultural amenities)?
6. How can building and infrastructure choices affect a community's ability to adapt to climate change?
7. What are the cumulative benefits of green practices implemented at the individual level (e.g. rain barrels, roof gardens, compact fluorescent bulbs, low VOC paint) in terms of improved health and well-being and increased delivery of ecosystem services? Which green practices contribute most to these benefits?

Topic: 1c: Land Use – Sustainable Community and Regional Planning and Zoning in Natural and Built Environments

Community outreach participants reported that many communities have developed "sustainability" plans, but that these are often driven by more traditional long-standing planning practices that have mixed results. In addition, planning can take place without inclusive, well-informed discussions with community members and key stakeholders like local businesses and neighborhood associations. Rural communities are interested in ways to conduct planning that maintains their individual identities and the land uses that sustain the rural economy (from agriculture to nature-based tourism on protected lands). Communities are also interested in integrating land uses that promote healthy and safe lifestyles (e.g., greenways, trails, parks), however they are unclear about the benefits compared to impacts of their choices. Given the array of issues that must be considered (e.g., buildings, greenways, infrastructure), communities are challenged to know which sustainability practices and projects will serve them best.

Again, a holistic, cumulative TBL assessment of local decisions will better empower policy makers to make good decisions. For example, in attempts to increase their property tax base and create jobs, communities often permit big box stores on city fringes, sometimes contrary to existing plans. However, a recent case study on tax values for different kinds of properties showed that infrastructure costs for big box stores would not be paid back by the expected revenue for decades, while payback for urban midrise mixed-use development was nearly 100 times greater per acre. A decision to permit a big box store may not have been made were these real costs and payback known. At the same time, there are unintended impacts and long term costs imposed by sprawl development that are not quantified, and so, not considered in such decisions, e.g. stormwater runoff pollution, heat island exacerbation, spreading of associated sprawl because of extended infrastructure, increased vehicle miles travelled (VMT) and mobile emissions, loss of green space or farmland and traffic problems.

Just as there are unaccounted costs in typical community decision making, there are also cumulative benefits for sustainable urbanism actions that are usually unrecognized or unquantified for decision making. For example, green space within a streetscape can treat stormwater, create walkable places for more healthy lifestyles, feed biophilia and a feeling of well-being, increase social interactions and social capital, increase adjacent land values, support wildlife and pollinators, create activity-related jobs and increase customer traffic at adjacent businesses.

Besides the obvious parameters, planning and zoning decisions will affect traffic volume, viability of transit, feasibility of transportation alternatives like walkability and bikeability, proximity of services, proximity of green space, etc. These parameters of urban form affect health by affecting, for example, the amount of air pollution, the ability to incorporate exercise into daily living, safety (e.g. traffic accidents and crime) and the psychological benefits of increased social capital and freedom of mobility without a car. Communities are especially interested in the TBL assessment of sprawl forms of growth compared to smart growth options. It is important that this be done with appropriate metrics for effective comparison. For example, GHG emissions per acre show a much different picture than GHG per capita, which demonstrates the energy efficiency of cities. Similarly, quantifying impervious surfaces in a dense, mixed use scenario may seem worse than in a diffuse suburban scenario, but comparing these scenarios on a common denominator of capacity basis (such as, “per 100,000 people” or “per 100 acres”) will give a more realistic comparison of the ecosystem services impacts.

Community decision-making is often confounded by things that happen outside their boundaries and ability to control. Understanding what these processes are and how they factor into community problem solving is crucial for communities to move towards sustainable futures. For example, many communities in the Southeast share a common water supply and recent droughts have created “water wars” among communities. Communities also often export problems, e.g. the state of South Carolina’s most impaired water body is located just downstream of Charlotte, NC.

Illustrative Science Questions:

1. How do building density, mix (e.g., residential versus commercial/industrial), and location affect the environmental, economic, and social health of a community?
2. What are the impacts of non-urban land use management (e.g., local versus distant agriculture, chemical use, crops and rotations, timber harvest), on the environmental, economic, and social health of a community?
3. How do a variety of land uses (e.g., community agriculture, parks, and urban services) contribute to community health and well-being and economic vitality?
4. What social and judicial levers or emerging information technology will best compel behavior change related to land use at the individual and community levels?
5. How can we quantify the values of ecosystem services provided by a landscape and integrate those values with other social and economic parameters for improved decision making?

6. How do regional-scale processes (e.g. development outside community boundaries, air pollution transport, and shared water supplies) affect community-scale sustainability and how can these processes be factored into community decision-making?

Topic: 1d – Sustainable Community Transportation

Many communities find themselves in a transportation construct imposed by past generations' priorities, which doesn't easily fit more sustainable transportation models , imposes a high demand on fossil fuels and imposes economic burdens on individuals and communities. In order to support transition to new transportation forms, decision makers must fully understand the full and long-term implications of new and transitional options. For example, many people think of mass transit alternatives only in terms of traffic benefits and economic costs to build and operate. However, there are many indirect economic and health benefits of mass transit that are relevant for decisions. It encourages better health by increasing walking, raises adjacent property values, lessens need for more destructive road building, decreases road congestion and so emissions, increases social capital and psychological health by enabling more incidental social interactions, and makes more jobs accessible to people who cannot afford cars. Also, adequate comparisons of transportation issues need to be placed in the proper context of alternatives. For example, two options for meeting commuting demand could be building a new highway lane or buying 50 buses for critical routes and creating incentives for ridership. The type and extent of economic, environmental and social costs for these two alternatives are quite different, so tradeoffs should be clear for such a decision.

Transportation issues also vary between rural and urban communities, especially for economic and social reasons. Large, urban centers are usually growing, with increasing need for transportation capacity. However, they are usually striving to decrease traffic and vehicles miles traveled (VMT) in cars by facilitating public transportation, walking and bicycling. Alternatively, rural residents are highly dependent on cars to access job centers and services. Most rural communities have a very limited public transportation infrastructure. While they recognize the value of public transportation from a sustainability perspective, it is more difficult for them because of cost, limited ridership, and the complexity of setting up regional partnerships with neighboring counties/cities.

Illustrative Science Questions:

1. How can we comprehensively assess environmental, economic and social effects of alternative transportation modes and fuels decisions on the sustainability and resilience of communities?
2. What new and existing community, state, and national policy options, incentives, interventions, or communication strategies can be used to improve transportation effects on community sustainability and resilience?
3. What suite of transportation options improves community sustainability and resilience most effectively and economically?
4. What associated land use and development designs can increase the use of public transportation systems?

5. How do transportation choices made in suburban and exurban areas affect overall community sustainability and resilience and the distribution of costs and benefits?
6. How can transportation design and choices affect a community's ability to adapt to climate change?
7. How can we communicate the full costs and benefits of transportation choices in a way that effectively informs decisions and changes behavior?

Topic: 1e – Sustainable Waste Management and Site Remediation and Revitalization in Communities

All communities are faced with managing a steady stream of municipal solid waste (MSW), the majority of which is managed in landfills. The per capita generation rates grew from 1960 to 1990 and remained in the range of 4.3 to 4.7 lb/person/day through 2009, when there was an apparent slight decline. Less than two-thirds of yard waste, aluminum cans and tires are recycled and less than a third of glass containers. Almost two-thirds of the entire MSW stream is organic materials that emit greenhouse gases as they decay and contain energy values, which are lost if the waste is disposed in a conventional landfill. Communities need to be able to evaluate the full costs and benefits of MSW recycling and management options in order to build the right infrastructure and set disposal fees and incentives in ways that meet costs and provide for future sustainable management. But even well-founded initiatives can fail if compliance by residents is easily circumvented. Bans on certain objects in landfills have been known to result in more of those objects thrown onto the roadside. Understanding motivations for non-compliance and incentives for compliance will assist communities to design and implement successful programs.

In addition to routine wastes, many communities periodically have to manage high volumes of debris from natural disasters, such as earthquakes, tornadoes, and flooding, often when infrastructure and communications are already strained. As an example, after a tornado ravaged Joplin, MO, the community needed support in managing the large volumes of debris that were generated. ORD was asked about comparative trade-offs in considering various risk management options, including landfilling and combustion. A decision support tool that identified the life cycle impacts of potential human health and ecosystem services of the various reuse/treatment/disposal options could have provided support in the recovery of the community. Additionally, these events (likely more frequent with climate change) create significant surges in materials that are sometimes contaminated and have the potential to create long-term environmental and/or human health impacts. TBL accounting for the technological and planning options would allow communities to implement the options that have the least impact on land resources, ecological resources, and human populations, particularly populations that are more susceptible or already disproportionally exposed to environmental stressors. Other man-made debris, such as building and demolition discards and roadbuilding and maintenance wastes, could also be recycled and disposed of more sustainably with information identifying the best technologies, plans, ordinances, and pricing schedules.

Communities have more blighted properties following the recent economic recession and some of these, particularly defunct commercial and industrial properties, are suspected of being contaminated by hazardous materials. Brownfields grants and other voluntary programs can help communities assess and redevelop properties. Added focus on the full costs and benefits of redevelopment alternatives (parks, green space, urban agriculture, business parks, small business, residential, green energy) could maximize sustainability gains. Such redevelopment also offers opportunities to rectify conditions faced by disadvantaged populations.

ORD will work with the Office of Solid Waste and Emergency Response (OSWER) in developing TBL tools to assist individuals and communities in managing MSW, brownfields, site remediation and land revitalization. Note that this topic is complemented by research in Topics 3a and 3b. Whereas Topic 1e research focuses on community decision-making, the focus of the Theme 3 topics is more on the R&D to ensure that environmental regulations involving waste and materials management and site remediation are based on sound science and engineering.

Research for this topic is already at a stage that SHRCP can begin significant research in 2012 that will feed into the TBL method development. One early product would be a web-based, updated version of a decision support tool for MSW management, a previous version of which has already been tried in communities. Also, work is underway with the OSWER, EPA regions and the US Geological Survey which will allow assessments of the impacts from such contaminant sources as gas stations and dry cleaners, with GIS analysis to integrate with work in Theme 2. SHC could also fill in science gaps related to, for example, alternatives to MSW landfills, construction/demolition materials management, or urban agriculture on brownfields.

Illustrative Science Questions:

- What data, technologies, and tools are needed to help communities reduce, recycle, reuse, repurpose, and dispose of municipal solid waste with minimal burden to ecosystems and natural resources, the economy, and human health and wellbeing?
- What information and incentives are effective in reducing consumption without reducing economic, social, and personal wellbeing?
- What are the social, economic, and environmental implications of options and incentives for recycling, reusing, and repurposing materials in community waste streams?
- What new methods can be developed to encourage extending the life of materials destined for the municipal waste stream?
- How can municipal solid waste be managed to conserve land, minimize emissions to air and water, produce co-benefits, and protect nearby communities, including low income and sensitive populations?
- What tool(s) will allow community decision-makers to evaluate the full set of benefits, risks, and costs from landfilling, composting, recycling, and incinerating sub-streams of municipal solid waste?

- How can local/regional networks and incentives be designed to conserve resources in manufacturing, construction/demolition, and consumer products to reduce waste volume and toxicity while meeting community needs and enhancing the local economy?
- What industrial waste streams can be substituted for virgin materials to produce net benefits to communities in terms of life-cycle costs, human health and well-being, ecological?
- What innovative processes/tools can be developed to better manage contaminated sites and enhance land revitalization for short- and long-term protection of ground water and land resources and reduce exposures?

RESEARCH THEME 2: DEVELOPING DECISION ANALYSIS METHODS, TOOLS, MODELS, DATA AND METRICS THAT SUPPORT COMMUNITY SUSTAINABILITY

The goal of this theme is to provide communities with data, methods, indicators, and models that they can use to develop efficient, effective, and equitable approaches to increase their sustainability and resiliency by maximizing co-benefits and minimizing unintended consequences.

We intend to provide community-driven decision-makers with a process for decision analysis that helps them deal with the complexity inherent in sustainability issues where multiple scales interact, feedbacks and synergies occur, values differ, and factors outside scientific understanding influence how policies and management actions are implemented. We also intend to help identify and/or develop indicators that can be used to quantify current state, diagnose problems, and track the performance of approaches. We will develop decision support tools appropriate to analysis needs (see details below), and develop data bases and modeling platforms that communities can use to think through problems systematically. Decision support tools will focus on identifying specific, measurable outcomes that are desired by local communities and managers, and then analyzing the expected impact on those outcomes of alternative policies and approaches. We also will use science and tools from the other NRPs, as appropriate. Theme 2 tools will be deployed in support of the Theme 1 projects described above and to the broader Agency mission. Some research and development may anticipate applications to future community projects undertaken by the SHC.

Several existing research efforts can provide metrics, decision support, and understanding of cause effect relationships to move this theme forward immediately. Work will continue in these areas with a refocusing towards providing the means for TBL accounting. These existing efforts include the National Atlas of Ecosystem Services and related research on Community Public Health, Ecosystem Services and Benefits, and Sustainable Technology.

Topic 2a: Decision Analysis

Output: Information, tools, processes, and communication and engagement activities that provide input to the communities' full cost accounting framework being developed under Theme 1.

Decision analysis is, in itself, a complex process and is often not done effectively, or at all, due to a lack of information, inadequate representation of all the factors that contribute to desired goals, and the absence of a transparent process for structuring and assessing the decision objectives. Communities' decision processes vary by specific decision, community culture, the individual decision-maker, the ability to synthesize available information that could be used to inform the decision, and the degree of understanding of the linkages between actions and changes in community health and well-being. The SHC intends to improve access to information, tools, and decision frameworks that allow community decision-makers to understand how specific actions affect community well-being, weigh the full consequences of alternative management actions, track progress towards goals, and allow the creation of innovative solutions to community problems. It is also our goal to empower communities to effectively advocate for improving social equity and access to the full benefits of a sustainable future.

Decision analysis is needed to: 1) identify and understand issues or problems; 2) assess sustainability; 3) enable future visioning and goal setting; 4) evaluate alternatives to enhance sustainability; 5) track progress towards goals, and; 6) develop adaptive responses. (As examples, see the ICLEI STAR Community Index program (http://www.icleiusa.org/programs/sustainability/star-community-index/star-goals-and-guiding-principles) and the FIRST framework[4]. In addition, tools should be: interoperable and use common data to the degree possible; make use of emerging technologies in areas of information technology, visualization, and modeling, and; resonate with users such that changes in behavior and new business-as-usual approaches result. New metrics and indicators are needed to reflect and communicate the linkages between human well-being and environmental changes and to measure progress. Communication and engagement of communities throughout the development of SHC decision support is crucial – it is needed to ensure we are meeting communities' needs, to effectively communicate the results of our research, and to ensure ongoing use of our tools.

Improved Data Infrastructure to Support Decision Analysis:

SHC initiatives require better data infrastructure in order to link and synthesize currently available data on multiple factors that impact communities. Private and public sectors are scrambling to transition data into streaming web services to provide online data management tools and interfaces. Data infrastructure is not strictly a technologist's or scientist's problem, but rather a mixture requiring interdisciplinary communication. There is no single solution, so we plan to combine several approaches, including: working with the Office of Sustainable Communities (OSC) and the Census' DataWeb initiative

[4] (J. Fiksel et al. The triple value model: a systems approach to sustainable solutions. Submitted to *Clean Technology and Environmental Policy,* April 16, 2011)

to access socio-economic data; partnering with OEI and their emerging partnership with ESRI services; exploring partnerships with NSF's DataNet and Data.gov/Socrata, and; developing new workflow and governance models to make sure data from communities can be used efficiently and effectively.

Information technology is moving more quickly than ever – where capability builds upon itself – requiring more agile approaches to doing business. This is especially true for communities, where emerging IT could be harnessed to have tremendous impact on real-time, in-situ sustainability planning. We plan to creatively extend our outreach efforts and engage in online social networking culture to achieve our ends as efficiently as possible. For data needs and integration of our existing and future tools, we plan to transition to a modular and interoperable IT business model (with consultation from OEI), similar to the building block model involved in creating a Blackberry. For example, one block controls the camera, another converts pictures to .mpeg files, and another manages how such files are sent to other smart phones. The "block" analogy shares commonalities with several other business models – for example, those of Drupal.org and WordPress.org. Drupal programmers create building "blocks" that are interoperable – referred to as "modules." Website developers then use those blocks to build their website (e.g., the Whitehouse site). One block includes the code for a "log-in" page, whereas another is a tool for viewing a gallery of images. Just as millions of people publish and peer review Wikipedia articles, millions of programmers from around the world now publish and peer review Drupal modules for free. We plan to extend that analogy to the development and maintenance of sustainability tools, and other tools that build on one another. This approach is aimed at using software that is already publicly available (open source) and harnessing a virtual workforce of programmers to help us develop and maintain the code necessary to help communities solve problems and achieve sustainability (however they may define it).

Communication to Support Decision Analysis

One of the proposed Program Tenets for the Sustainable and Healthy Communities (SHC) Research Program is "*Research is planned and conducted with the active participation of stakeholders, partners, decision-makers, and other ORD/EPA programs that would use the research products*." In other words, the SHC will work with communities to identify and develop products that empower communities towards sustainable outcomes. To meet this tenet, ORD will work with the Program Offices and Regions, in particular the Sustainable Community Liaisons, to develop a plan that will identify ways to improve the knowledge, skills and resources that support the application of scientific information and tools to issues of importance in communities. In addition, ORD will leverage existing relationships (in particular the EPA/HUD/DOT Partnership for Sustainable Communities) and internal activities (in particular the EPA's Cross-Agency Community-Based Workgroup) in developing these solutions. ORD also will seek partners, e.g., universities and relevant non-governmental organizations, to create synergy by bringing to bear our collective knowledge and relationships to reach communities across the nation.

Finally, the SHC will identify a few communities as demonstration pilots to work with EPA in exploring and developing these products and processes that serve as a model and replication to other communities. When EPA conducted the Regional Listening Sessions described in the introduction, communities identified many common issues, which are reflected in Theme 1. Of these, three issues

especially relate to how we can assist communities through this topic: (1) Communicating, Educating, and Framing the sustainability discussion with the public; (2) Resources (financial, time, technical expertise) to support sustainable projects are limited; and (3) Practical sustainable practices are lacking and/or hard to implement.

We cannot physically meet with every community that needs our help. Therefore, we plan to work across the Agency and set up an online integrated framework (or platform) by which communities and stakeholders can virtually gather and participate in the problem-solving process (in essence, an online version of our ongoing community pilot studies and listening sessions). Several existing social media websites, such as Facebook and LinkedIn, offer examples that can inform our ability to virtually engage stakeholders in environmental problem solving and sustainability planning. We plan to partner with universities, non-profits, and the private sector to develop an external-facing online site (.org) that allows stakeholders to, for example, create communities, state problems, define goals and sustainability objectives, develop their own metrics, play out scenario-based games, and conduct analyses (using streaming data from communities and from elsewhere, see above). Functionality would be extendable, modular, and contributed by EPA and external organizations and programmers. The site would subscribe to – and act as an interface for – the business model described above (data infrastructure).

Science Questions for Decision Tools:

- How can we modify and link existing tools, including use of a common platform and data, to make them more effective and to provide useful interim products?
- What data are needed to aid assessment, modeling, and decision support, and how can we best synthesize environmental and human health data in a way appropriate for different types of decision-makers?
- What empirical relationships can be extracted from existing data to allow communities across the nation to explore a series of "what-if" questions that illustrate the implications of alternative decisions?
- How do we create tools with different levels of complexity to make information accessible to multiple levels of decision-makers and stakeholders?
- What visualizations are the most effective for achieving a broader understanding of analysis results?
- What decision analysis approaches are most appropriate for assessment, future visioning, evaluating alternatives, and tracking progress towards sustainability?
- How can we improve decision processes through analysis of how tools are used?

Science Questions for Data Infrastructure:

- What are the most appropriate mechanisms for utilizing streaming data (web services), and incoming, outgoing governance/moderation data flow models?
- What reliable/innovative methods can be used to elicit community goals/concerns?

- How can we help communities self-organize to seek and implement solutions to promote sustainability (i.e., reduce resource use, reduce pollution, improve health?)

Science Questions for Communication:

- How can we more effectively communicate, educate and frame scientific information and tools to improve understanding and application by communities?
- How can we more effectively engage decision-makers and stakeholders in the SHC research and development process to focus on solving the decision priorities in communities across the nation?
- How can we partner with other agencies, organizations, and universities to provide the resources (e.g., financial, time, and technical expertise) needed to support decision-making in communities?

Decision Analysis Contributing Outputs:

- An interoperable, user-friendly platform that links tools and provides for a common database to support community decision needs
- Ability and mechanisms in place to incorporate data directly from communities (via web services, where possible) into SHC tools. An intuitive, external, extendable online site or platform that allows communities and scientists to use tools and data, to ask for tools and data they need, and to contribute tools, data, and information.
- Tools that use appropriate synthesis methods for different data limitations and assessment needs
- Tools that create a compelling picture of the implications and trade-offs of alternative management actions and individual choices
- User-profiles for the full suite of decision-makers SHC hopes to inform including specific information needs, ability to understand complex information, etc.
- Tools that allow community decision-makers to quickly understand the results of analysis
- Guidance on the appropriateness of different decision analysis approaches for specific needs

Topic 2b: Indicators and Indices

Output: A suite of indicators and indices that effectively communicate environmental and human health changes for decision alternatives and progress towards community sustainability.

In the complex arena of sustainability, where the costs of failure can be high and stakeholders have multiple and sometimes conflicting interests, communities need measurement tools to characterize their current state, develop meaningful goals and quantifiable objectives for the future, understand the consequences of alternative investment strategies, track their progress, and confirm that their investments are yielding the intended results.

This component of the SHC will identify and develop indicators that go beyond those developed elsewhere in the program and that: signal when current environmental, economic, and social trends are becoming less sustainable; identify to the extent possible the thresholds of sustainability for such indicators; and identify performance metrics that signal if approaches to increasing sustainability are working as intended (including indicators of any unintended consequences). This component also will develop indices that combine indicators in a way that can capture trends in the overall sustainability of a community as well as boil down large amounts of data to provide useful information.

Achieving sustainability at the community-scale requires information on the economic, social, and health benefits produced from ecosystems in the vicinity of the community, and information on the condition of those ecosystems relative to their potential to deliver those benefits. Communities need to know how various decisions are likely to affect the production of ecosystem goods and services which in many cases provide the very essence of livability (e.g. clean air and clean water) for human health and well being. The proposed research will develop a suite of methods to measure (i.e., metrics) the potential of terrestrial and aquatic ecosystems to produce the goods and services that directly benefit people, and a corresponding suite of indicators that gauge the capacity of ecosystems to deliver those benefits as a consequence of their condition. It is important that this be done with appropriate metrics for effective and relevant comparison of decision alternatives.

Because we know that not all metrics are indicators and not all indicators will aggregate into a suitable index, a key aspect of this research is to develop appropriate approaches for selecting those indicators and metrics that are most practical and most meaningful to community sustainability goals and objectives. The accuracy and variability of the metrics and indicators in time and space need to be determined and evaluated along with their sensitivity to various environmental parameters. Sampling methods also must be devised that allow extrapolation from sites where metrics can be measured to the entire community.

Research Questions:

- What indicators/indices are most relevant, effective, and feasible for assessing the sustainability of a community? A region? The nation?
- What indicators are most useful for setting environmental goals and communicating these goals to community stakeholders?
- What metrics and indicators best characterize a community's use of ecosystem services (including economic, health, social and non-market benefits) and the condition of those services under alternative management actions?
- With what accuracy can metrics or indicators be extrapolated to unmonitored sites or across landscapes?
- What indicators/indices are of most utility in diagnosing the causes of sustainability problems and identifying potential solutions?
- What are the thresholds for indicators/indices of community sustainability?

- What are the most useful indicators for tracking the performance of projects intended to increase environmental sustainability of communities?

Contributing Outputs:

- Inventory of available community sustainability indicators/indices
- Guidance document for selection of community sustainability indicators.
- Guidance document for selection of available community sustainability performance measures.
- Guidance on threshold values for community sustainability indicators.
- Methods for extrapolating metrics to unvisited sites and across landscapes, with an assessment of the accuracy of the resulting predictions of environmental, social, and economic conditions.

Topic 2c: National Atlas of Ecosystem Services

Output: An online decision support tool that will allow users to view and analyze the geographical distribution of ecosystem services supply, demand, and drivers of change at multiple scales and for communities across the country. Explicit relationships between human health and well-being and the provision of services will communicate a full accounting of how decisions affect communities' progress towards sustainability under different scenarios.

Communities, EPA Program and Regional Offices, and other decision-making bodies do not have adequate access to spatially explicit information crucial to making decisions while allowing them to consider a TBL accounting of alternative decisions. Decisions made at multiple scales (ranging from communities to regions to nationally) impact the quality of life at the community scale. Information is needed to support decision analysis at all of these scales -- information that characterizes: the variations in biophysical characteristics that predispose communities towards a particular response to changes in conditions; the distribution of stressors that affect community sustainability; the distribution of both vulnerable resources and populations, and; the opportunities for multiple benefits or unintended consequences associated with management actions.

The National Atlas of Ecosystem Services (Atlas) represents a comprehensive approach to quantifying the current and future provision of valued ecosystem services needed by communities to sustain human life and well-being. As an interactive, publicly available web tool, the Atlas will also present the distribution of drivers of change (population, multiple stressors, climate changes, etc.) and forecast future trends for each of these drivers with associated changes in the supply of, and demand for ecosystem services and implications for human health and well-being. Where feasible, the Atlas will provide information about the social and economic costs of various decisions, such as the trade-offs between grey and green infrastructure. Data and model results will be available at multiple scales, i.e. coast to coast information at a relatively coarse scale (approximately 83,000 spatial units) for the conterminous U.S., the underlying national data layers at a much finer scale (30 m^2) and then very fine-scaled analyses for selected communities across the country. The multiple scales of information can be used in combination which will allow decision-maker insights into issue context (e.g. clarifying the role of upstream watersheds for protection of community water quality and regional pollutant sources for

community air quality) as well as information relevant to regional and national policy alternatives.

The urban component of the Atlas will provide information linking human health and well-being to environmental conditions such as urban heat islands, near-road pollution, wise use of resources, access to recreation, drinking water quality and other quality of life factors. In addition, the urban Atlas will facilitate the analysis of who pays and who benefits through characterization of populations that are disproportionately impacted due to limited access, low levels of opportunity, and lack of community empowerment to effect positive changes. The urban atlas will facilitate site-specific problem-solving and provide support to individual communities by allowing identification of places that are further along towards finding innovative solutions to sustainability challenges. The urban Atlas will rely heavily on foundational land cover data that will be characterized from aerial imagery at a 1 to 3 meter pixel resolution.

The Atlas will serve as a foundation for SHC decision support and sustainability assessment, providing both the basic landscape information (e.g. soils, land cover) as well as modeled output that represents the distribution of specific ecosystem services (e.g. water supply, air quality, agricultural yields, biodiversity) and human populations served . These data, both static and modeled, will inform analyses of what-if questions that are reflective of decision-maker needs at the individual, community, regional, and national scales. This will be accomplished through the development of empirical relationships that build on the vast information available from the Atlas and the spatial and temporal linkages among those factors that influence changes in environmental condition and human well-being. In addition, this research will be interfaced with research in other federal agencies including the US Geological Survey, National Oceanographic and Atmospheric Administration, and the National Aeronautics and Space Administration.

The Atlas will also provide the foundational data layers for answering many of the research questions described in Theme 1. Reciprocally, the research results from Theme 1 will be used to inform the Atlas, as successful research products performed at the community scale can provide the methodology to calculate information over larger geographic areas, which can then be incorporated. The fine-scaled urban land cover data, for example, can be used to answer science questions about building density and impervious cover. Cropland data and soils information contained within the Atlas can be used to answer questions about local and potential local food supplies.

It is also important to note that while the Atlas is within the SHC, the information will be of equal value to the other ORD programs, especially Air, Climate and Energy, and Safe and Sustainable Water.

Science Questions:

- How can landscape composition and pattern combined with additional data and model results (e.g. CMAQ) be used to quantify and map production, demand, and drivers of ecosystem services for communities, regions, and the nation?
- What scales are most appropriate, given available data and model resolution, to reflect the distribution of various ecosystem services and then communicate how these services relate to

human health and well-being at various levels of decision-making ranging from communities to the nation?

- How can cause-effect response surfaces be developed using spatial data and model output to communicate the trade-offs associated with future land use and other management choices as they relate to ecosystem services and their impact on human health and well-being?
- How can the information presented in the Atlas be used for screening land/waterways to provide more effective investments in protection, restoration, conservation, or use, of ecosystem services? What are the opportunities for developing innovative solutions to problems faced by communities using information from the Atlas?
- How does the distribution of ecosystem services vary among populations, and are there specific populations who are underserved or subject to disproportionate human health impacts?
- How can finer-scale data at a community level be integrated with coarse national scale data to reflect supply and demand of ecosystem services that encompass a broader service district in a way that informs community-scale decisions?
- How can proximity analyses of socio-economic data be used to identify human population vulnerabilities to urban heat islands, traffic pollution, lack of access to green space, etc.?

Contributing Outputs:

- High resolution land use/land cover for up to 250 communities across the country
- National synthetic (dasymetric) population maps, which use US Census data combined with biophysical characteristics to estimate where people are located at a much finer resolution than US Census data can provide, such that analysis of exposures, demand for services, and disproportionate impacts can be facilitated.
- Map representing water recharge capacity to provide insights into analyses of water supply
- Map representing national scale recreation demand and available supply
- Identification of urban heat island effecting up to 250 communities across the country
- Detailed land use/land cover map that augments NLCD data with USDA's Cropland Data Layers to provide refined estimates of land management including chemical inputs
- Refined estimates of changes in ammonia flux associated with agricultural inputs that affect concentrations of criteria pollutants
- National maps of nitrogen sources
- National maps of soils attributes
- National maps of clean water demand
- Beta versions of online Atlas web tool

Topic 2d: Ecosystem Services and Benefits -

Output: Production functions that quantify the value of ecosystem services and changes in the level of services associated with decision alternatives.

Ecosystem services are the many life-sustaining benefits we receive from nature--clean air and water, fertile soil for crop production, pollination, and flood control. These ecosystem services are important to our health and well-being, yet they are limited, vulnerable and often taken for granted as being free. The ecosystem services research topic is aimed at transforming how communities and regions account for the type, quality, and magnitude of nature's goods and services, so that that their benefits can be considered in environmental management decisions.

The research is providing the data, methods, models, and tools needed by states, communities, and tribes to understand the TBL costs and benefits of using ecosystem services. The current ecosystem services projects focus on particular regions or communities (for example, Willamette Valley, OR, the upper Midwest, and Tampa Bay, FL) and on ecosystem services associated with wetlands, floodplains and riparian zones in general. We expect to refocus the ecosystem services research to new transdisciplinary community and regional pilots in the out-years. The development of ecosystem production functions (quantitatively relating environmental changes to the services delivered and valuation of those benefits) serves as a critical input to decision support, Topic 2a.

Science Questions

- How can we quantify the value of ecosystem services across different environmental settings?
- What models can be applied or developed to estimate ecosystem services associated with land management and conservation practices?
- What land-use configurations in managed landscapes afford the best combinations of ecosystem services given different community values?
- How does human health and well-being change with changes in the provision of ecosystem services? How do these changes vary among different population sectors?
- What changes in ecosystem services occur at scales broader than communities, yet impact communities' abilities to progress towards a sustainable future?
- How can information on the value (including social and cultural values) of ecosystem services facilitate innovative approaches to promote protection, conservation, and restoration of ecosystem services?
- How can the benefits and services provided by wetlands, floodplains, groundwater and riparian zones be quantified, including carbon sequestration, wildlife habitat, flood control and storm surge protection, fisheries support, the maintenance and improvement of water quality and quantity, and human well-being?
- How can wetlands, both existing and constructed, be used to mitigate environmental damages associated with intensive land use?
- What configuration of wetlands, floodplains and riparian zones on the landscape provides an optimal level of ecosystem services for communities across the country?

- How can markets for environmental services reduce communities' costs of becoming sustainable?
- How do alternative transportation, infrastructure, land use, and waste and materials options affect the supply and demand of ecosystem services and communities' overall resilience?

Contributing Outputs:

- Models relating land use and management to the provision of a variety of ecosystem services (e.g., crop production, clean water provision, settings for nature recreation) in both rural and urban settings.
- Interactive decision support tools that illustrate watershed to regional trade-offs associated with alternative future scenarios reflecting different land use choices or policies
- Models that estimate spatial variation of a variety of ecosystem services (e.g., clean water provision, settings for nature recreation)
- Partnerships with communities to demonstrate case studies of application to specific decision opportunities
- Guidance and ecological production functions for quantifying the benefits and services provided by wetlands, including carbon sequestration, wildlife habitat, flood control and storm surge protection, fisheries support, the maintenance and improvement of water quality and quantity, and human well being.
- Guidance on how markets for environmental services can reduce communities' costs of becoming sustainable.

Topic 2e: Community Public Health

Output: Communities will have comprehensive, user-friendly tools to access and integrate all available data and guidance related to environmental contaminants and public health indicators for incorporation into their decision support analyses and decisions

As essential component of achieving sustainability at the community level is to assure that all members of the community have access to an environment that protects and promotes good health. Poor health places heavy personal and economic burdens on families and, therefore, on communities. It results in lost wages and diverts both personal and public resources to heath care that could otherwise be applied to programs that remediate harmful exposures, enhance sustainable development and protect ecosystem services. Therefore, progress towards sustainability must include provisions for preventing exposures and adverse health impacts of environmental contaminants and making community development decisions that foster public health and healthy lifestyles for all residents.

Research in other EPA programs, particularly Chemical Safety and Sustainability Program will help EPA insure that products manufactured and used by society do no harm. However, EPA regulates emissions, often of single chemicals, not based upon the combinations of exposures that converge in communities. Nor do we, at present, fully appreciate the combined impacts and risks of such complex exposures. In

addition to possible health risks associated with pollutants exposures, social and economic stressors add to the total burden of environmental contributions to public health. Furthermore, people are variably vulnerable to chemical and non-chemical stressors depending upon inherent factors, such as their life stage, genetics and pre-existing disease, and so-called voluntary factors associated with their life styles choices and behaviors.

EPA's mission includes protecting all citizens and ensuring that certain groups are not placed at disproportionate risk of exposures or adverse impacts. Therefore, preventing risks to vulnerable populations and fostering public health for all community residents is integral to achieving sustainability. The consequence of not doing so are particularly dire for children because impacts early in life, such as birth defects and chronic childhood diseases and conditions, can stress the social fabric of families and the resources of communities for years to come. Indeed, EPA's Strategic Plan includes a cross-cutting goal of "Working for environmental justice and children's health" which articulates the Agency's commitment to these ends.

In order for communities to assess their current state with respect to complex environmental stressors, public health status, and environmental equity, as well as the interrelationships among these factors, they need reliable and interpretable public health data linked to information about specific and diverse exposures and their associated risks. To meet this need, SHC is developing and evaluating a tool that will bring available data together in a user-friendly web-based tool called the Community-Focused Exposure and Risk Screening Tool (C-FERST). Designed in active collaboration with community-based research projects in the CARE (Community Action for a Renewed Environment) and RARE (Regional Applied Research Effort) programs, C-FERST is assisting communities with the challenge of identifying and prioritizing issues, and making informed decisions about integrated exposures and risks. Work is underway to link to and build upon other community-focused tools and data such as CDC's public health tracking program and to integrate these tools with the National and Urban Atlas and the TBL accounting described above.

T-FERST, a tribal-focused module of C-FERST, will serve as the research framework and developmental platform to empower tribes with an environmental decision support tool incorporating best available human health and ecological science. EPA (ORD, Regions, Program Offices, National Tribal Science Council, AEIO), Tribes, and other partners (e.g., Tribal Colleges, USGS, HUD, BIA, NOAA) will collaborate to develop, populate, and pilot T-FERST, a web-based geospatial and information access decision support tool incorporating best available information and science, for building sustainable and healthy tribes. T-FERST will help tribes to conduct tribal assessments, incorporating a sustainability framework to prioritize environmental issues within a given tribe and compare information across locations; inform risk management decisions based on a sustainability framework; and assess tribal well-being, impact of sustainable solutions, and adaptive management strategies.

A related tool called EJ-Wizard is being developed by SHC in collaboration with EPA's Cumulative Risk Assessment Technical Panel. It will be an alternative step-by-step process within C-FERST, but will focus on cumulative risk assessment and environmental justice. The EJ-Wizard will use data sources currently

in, and planned for, C-FERST, but will also include other factors often considered in environmental justice analyses, such as community assets.

In order to evaluate the impacts on public health of various risk reduction and sustainability decisions, communities also need reliable indicators of public health, including data on the incidence and severity of the chronic diseases and conditions that are related to our environment and impacted by the design of our communities. Many of these such as asthma, obesity, hypertension, and cardiovascular disease disproportionately affect children and/or the elderly, as well as minorities in disadvantaged communities. Data and tools are needed so that communities and public health officials can track trends in these diseases and monitor changes, particularly in relationship to the features of the built environment that are modifiable, as articulated in Theme 1. Research that helps communities understand the complex interactions among the built environment, the natural environment, and public health outcomes is essential for validating the best indicators for this purpose.

Science Questions:

- How can we quantify, track and reduce cumulative human health risks at the community level, related to both chemical and non-chemical stressors? Which stressors are most important to reduce to insure protection of vulnerable groups such as pregnant women, children and the elderly?
- How can we systematically identify and prioritize key chemical stressors among the complexity of exposures within a given community, using best available science?
- How can we assess community-level distributions of human exposure to environmental stressors for the development and evaluation of effective, sustainable risk reduction strategies?
- What tools can be developed to characterize community-level distributions of human exposure to environmental stressors for the development and evaluation of effective, sustainable risk reduction strategies? How can we measure and evaluate stressors that may be unique to certain groups of people with distinct life style and cultural practices such as tribal communities and other culturally distinct communities?
- What environmental factors related to the built environment and community development can be modified to decrease the incidence and severity of chronic diseases, and promote healthy lifestyles, particularly in the most vulnerable groups?

Contributing Outputs:

- Community-Focused Exposure and Risk Screening Tool (C-FERST) - a GIS and resource access Web tool to support cumulative human exposure and risk screening assessments.
- Tribal-Focused Exposure and Risk Screening Tool (T-FERST) - a GIS and resource access Web tool to support cumulative human exposure and risk screening assessments geared to Tribal communities.
- EJ-Wizard tool for characterizing communities at risk of disproportionate exposures and health outcomes and taking action to reduce those disparities.

- Reliable public health indicators and tracking systems to monitor the impacts of changes in community structures and practices and measure improvements in public health, particularly for diseases and conditions most closely associated with environmental quality.

Topic 2f: Technology for sustainability – greener economy, systems thinking, innovative technology

Output: Communities have better access to technology that supports sustainability efforts.

The technology explosion over the last century has led to vast human benefits in terms of standard of living, health care, education, communication, mobility, and many other measures. Because most technologies were designed with a specific benefit in mind, they produced such side effects as resource depletion, ecosystem degradation, hazardous waste, and disproportionate human exposures to toxics. While the private sector is the major developer of new technologies, the federal government can accelerate the development and diffusion of beneficial new technology.

To that end, SHC will continue the P3 (people, prosperity, planet) Awards program, which is designed to stimulate innovation by awarding student grants and bringing public recognition to designs for technologies leading to greater sustainability. The Small Business Innovation Research program will provide funding for technology development relatively early in the commercialization process in categories such as Green Building, Innovation in Manufacturing, and Waste Monitoring and Management. The program also will support a new Regional Technology Innovation Cluster, designed as a hub for innovation to advance a technology-driven economy and to develop innovative technologies that solve environmental challenges and in the process spur sustainable economic development.

Science Questions

- How can technology be developed and deployed to protect and restore community health and the environment, and does this approach foster a greener economy?
- What tools and incentives/disincentives can promote development and purchase of technologies that have lower environmental impacts and move toward sustainability?
- Can regional assets be leveraged in a technology cluster to develop and implement innovative environmental technologies while producing green jobs and other economic benefits?

Contributing Outputs

- Produce a model module that compares technology options from a full life cycle perspective
- Complete a supply chain analysis case study to illustrate opportunities to identify technology gaps and design/production alternatives that are more sustainable

RESEARCH THEME 3. TARGETING HIGH-PRIORITY AGENCY RESEARCH NEEDS

As noted in the introduction, EPA's Program and Regional Offices have continuing high-priority needs for R&D and expertise in these areas to respond to development and technical support for regulations, This theme focuses on high-priority, R&D needed to provide EPA's partner offices with scientific knowledge and expertise needed to support regulations, executive orders, special reports to Congress, programs mandated by statutory language, and other Administrator priorities. Outputs for Theme 3 topics will fulfill these important Programmatic needs. Although some outputs may be less-directly related to the integrated community focus of the SHC, they can nevertheless provide valuable information for communities.

In accordance with the Path Forward principles, we intend to integrate the results of Theme 3 research with Themes 1 and 2, wherever appropriate. In addition, this work will support other EPA programs and address EPA's cross-cutting themes of working for environmental justice and children's health, and building state, tribal and international partnerships.

RESEARCH TOPICS

Topic 3a: Contaminated Site Management and Restoration

Output: Tools and technologies for improved assessment and remediation of contaminated sites more cost effectively and at an accelerated pace.

Reports in the 1980s estimated the number of potentially contaminated sites in the U.S. to be in the hundreds of thousands[5]. Many of these sites contain toxic levels of chemicals at concentrations that affect human and ecological health, or concentrations that impair environmental media, including ground water, surface water, and land. These properties, ranging in size from a commercial lot to tens of square miles, impair development, redevelopment, economic activity, and provisioning of ecosystem services. All occur in someone's community.

EPA expends more than $1 billion annually to assess and clean up Superfund sites alone; substantially higher annual expenditures are applied to federal facilities, RCRA Corrective Actions, State, brownfields, and voluntary programs. Over $260 million was allocated to States and Tribes in 2010 to clean up underground storage tanks. Research is needed to provide innovative approaches to site characterization and remediation that improve effectiveness, cost, and timeliness of moving sites to construction complete and ready-for-reuse. New methods, models, and technologies are needed as new exposure pathways are identified (e.g., vapor intrusion) and as toxic properties of previously non-regulated chemicals raise concerns for human and ecological health (e.g., perchlorate and endocrine-disrupting compounds). Scientific and engineering support is needed to improve the tools and techniques available for cost-effective management of contaminated sites. Research contributes to

[5] GAO/RCED-88-44; GAO/RCED-85-75; OTA-ITE-252.

guidance development at the federal and state level to ensure that the basis for site-specific decision-making is sound.

All of these problems are issues that affect any study associated with Theme 1 and can be better integrated as the Program proceeds.

Science Questions:

- How can contaminated groundwater best be detected, characterized, and modeled, and treated to prevent human exposure via drinking water or vapor intrusion and to prevent deterioration of water quality?
- What methods can be developed or applied to assess contaminated sediments and to measure the short-and long-term effectiveness of remediation?
- What existing and new approaches can be used to clean up contaminated sediments and manage dredged material?
- What contaminants and exposure pathways pose unacceptable risks to human health and ecological receptors, considering bioavailability and other factors?
- What concentrations of amphibole asbestos affect different organs and systems leading to impairment or disease? How can human exposures be estimated when asbestos fiber concentrations in contaminated media do not correlate with breathing zone measurements?
- How can environmental releases from oil spills and leaking underground storage tanks be managed to minimize environmental damage and human exposures?

Contributing Outputs:

- Develop and test treatments for contaminated ground water that increase the percentage of Superfund decisions that utilize in situ treatment from the 43% baseline in FY2005-2008 (Superfund Remedy Report 13th edition 2010).
- Provide data that gets incorporated in revised program guidance on assessing the potential for vapor intrusion in order to reduce the frequency of false negative and positive results in thousands of buildings overlying shallow ground water contamination.
- Develop a predictive method that links sediment contamination levels reliably with concentrations in food fish so that the proper cleanup level can be specified to reduce fish consumption advisories in a reasonable period of time (5-10 years) after remediation.
- Develop innovative contaminated sediment remedies with documented performance or cost advantages compared to dredging and sand capping that are selected in Records of Decision for Superfund sites by 2014.
- Assess the toxicity of amphibole asbestos to various organs and systems in time for the results to be considered in the site-specific risk assessment for the Libby, MT site, where the Regional Office intends to revisit past decisions and make decisions on other operable units to ensure they are protective of multiple modes of toxicity.
- Technical support for 75 Superfund sites annually across three technical support centers.

Topic 3b: Waste and Materials Management – support for regulations, policy, and guidance

Output: Scientific support for management of solid and hazardous waste streams to prevent exposure to toxic constituents while conserving resources.

OSWER programs, including those delegated to the states, are responsible for management of solid and hazardous wastes. Municipal solid waste is produced at a rate of 4.3 lb/person/day, with more than half the volume managed in landfills. That can pose long-term risks to human health, ecological receptors, and water resources, as well as produce potent greenhouse gas emissions. Commercial and industrial waste streams, both hazardous and non-hazardous, also must be disposed of in ways that prevent unacceptable releases and exposures. To conserve natural resources and reduce disposal volumes, EPA, state regulatory agencies, and waste generators attempt to find beneficial uses for these materials in applications ranging from residential drywall to road building and construction materials. Research is needed to evaluate toxic constituents in all of these waste materials, potential for release from disposal or use practices, and subsequent exposure to human and ecological receptors. Some waste streams change over time, such as the electronics content in residential waste, the pharmaceutical content of wastewater treatment residues, and the composition of solid residues from air pollution control devices as emission limits are reduced. The effects of these changing characteristics need to be evaluated to ensure that management and reuse options continue to be safe. Research is also needed to develop alternative waste minimization, disposal and use options that protect human health and the environment, while minimizing economic burdens and consumption of natural resources.

Science Questions

- How can landfills be designed and managed to: prevent air, water, and land emissions; maximize lifespan; and recover energy?
- What management and use scenarios for waste streams result in low emissions to all media and low human and ecological exposure, at acceptable cost while conserving natural resources?

Contributing Outputs

- Source terms and fate and transport models that can be used to estimate contaminant movement and potential exposures.
- Design and operations manuals for waste management units.

Topic 3c: Nitrogen– support for regulation

Output: An assessment of the impact of reactive nitrogen on ecosystem services and human health and the benefits and costs of alternative reduction strategies in both air and water.

Human activities have increased the formation of reactive nitrogen (N) more than 2-fold at the global scale and approximately 5-fold within the US during the last century. This trend is an almost inevitable result of the requirement for food (especially livestock) and energy production to support the growing global population. This increase in reactive nitrogen, with cascading impacts on air quality, water quality and ecosystem structure and function, is among the most significant impacts of human activities on the environment and public health.

Management of this increase in reactive nitrogen has become a substantial challenge for regulatory agencies. Nitrogen is a fertilizer at certain levels and places, but it generates multiple air and water pollutants (ozone and PM; nitrate and ammonia, respectively) as well as nitrous oxide, a significant greenhouse gas and ozone-depleting chemical. It also causes hypoxia, eutrophication and shifts in ecosystem function in many of our nation's valued ecosystems. Current air regulatory processes center around setting appropriate levels of the direct (NO_x) and indirect (PM, ozone) impacts of nitrogen on human health and public welfare. The problem is perhaps more challenging in water where non-point source pollution dominates the inputs and impacts. For water, states and regions are working on determining appropriate criteria and then implementing an integrated process in order to reduce these inputs and achieve the criteria and designated use. In addition, increases in reactive nitrogen are impinging upon safe drinking water in many areas, either directly by exceeding the human health nitrate standard or by creating eutrophication products which require treatment, adding expense and the potential for creating disinfection byproducts. More efficient integrated management of excess reactive nitrogen would address this cascade of environmental and human health problems. Given the multi-media and multi-sector nature of nitrogen pollution, and given the importance of this issue for the EPA mission, integration across the traditional regulatory and research silos of air and water is needed in order to achieve solutions, and integration with non-traditional TBL approaches might introduce innovative solutions.

This research will coordinate extensively with research in the ACE, SSWR and SHC programs to develop an integrated transdisciplinary approach for solutions related to nitrogen pollution. At the national scale, agriculture is the largest source of reactive nitrogen, and thus improvements to agricultural management, including production of biofuels and feedstocks and life cycle analysis of products, are key to reducing nitrogen effects. Nitrogen also has strong climate ties both as a regulator of ecosystem production and carbon cycling, and by having direct impacts on the greenhouse gases methane and nitrous oxide. Fundamental research pieces to this approach are mapping of N sources, monitoring of N levels and effects, decision support and economic valuation of ecosystem services effects.

Science Questions:

- How can complex media-specific models be loosely coupled to support a combined policy assessment capability for air and water quality issues that allows exploration of many policies, provides inputs for calculation of human health and ecosystem services impacts, and illuminates cross-media interactions and unintended consequences to allow development of more sustainable policies?

- What are the critical inputs needed to reliably characterize impacts of Nitrogen/Ammonia atmospheric deposition including the use of critical loads to assess and restore ecosystem health? What are the key indicators of human and ecosystem health used to evaluate efficacy of NAAQS? How can ORD and partners (e.g. Centers for Disease Control) take advantage of the national initiative for e-records to track changes in health outcomes and disease associated with air pollution?
- What are the identifiable scientific, policies, and socioeconomic structural characteristics of existing successful N and P (phosphate) reduction tools, models or other innovative approaches?

Contributing Outputs:

- An integrated modeling set of complex and reduced form models to support strategic policy analysis and development, including maps of nitrogen sources over space.
- Assessment metrics and indicators for connecting nitrogen with human and ecological systems.
- One or more tools that include models and metrics to quantify and communicate human health and ecosystem service outcomes based on various N and P management options.

Topic 3d: Environmental Justice

Output: ***The Agency and communities will have user-friendly and accessible tools and technical guidance for conducting disproportionate risk analysis needed to ensure environmental equity.***

Multiple aspects of the physical environment in which we live, learn, work, and play can put certain groups of people "at higher risk." Also, individuals and groups may experience disadvantages related to their gender, life stage, socioeconomic status, race, ethnicity, disability, education, geographic location, and/or other characteristics historically linked to discrimination or exclusion. This complex interaction between the physical environment and other conditions of social disadvantage contributes to known social disparities in environmental health outcomes.

Since 1994, under Executive Order 12898, all federal agencies, including EPA, are required to identify and address disproportionately high and adverse human health or environmental effects on minority and low income populations that may result from their programs, policies, and activities. The concept of disproportionate environmental health impacts and burdens refers to the finding that some populations systematically experience higher levels of risks and impacts than the general population. This perspective recognizes that multiple factors, including social, psychosocial, economic, physical, chemical and biological determinants may contribute to disproportionately high and adverse human health or environmental impacts.

The importance of science in environmental decision-making at the EPA always emphasizes the need for data and information that is sound and defensible, reproducible, and informative. But for

environmental justice stakeholders, it is even more important that the science underlying EPA's decisions appropriately accounts for the multiple exposures to chemical stressors and cumulative impacts from such multiple exposures that they experience in their communities. Further, the social/real world context in which exposures to environmental contaminants occur also needs to be explicitly considered and reflected in EPA's scientific research and analysis as emerging evidence demonstrates that social context may enhance the toxic effects of both single and multiple environmental contaminant exposures. Such considerations require new models for assessing the toxicity of environmental hazards, advanced methods for analyzing complex interactions between multiple stressors, and enhanced access to community level wisdom and resources.

In response to these needs, under Plan EJ 2014, EPA has committed to building a strong scientific foundation for supporting environmental justice (EJ) and conducting disproportionate impact analysis, particularly methods to appropriately characterize and assess cumulative impacts. The Science Implementation Plan discusses overarching goals, strategies, and activities, including a science and research agenda for the Agency, from which we are deriving science questions and outputs for this research topic. The science and research activities described in Plan EJ 2014 build upon discussions and recommendations from EPA's Science of Disproportionate Impacts Analysis Symposium (March 17-19, 2010) and an EJ regulatory analysis technical workshop (June 9-10, 2010). The March 2010 Symposium has helped the Agency to identify how to address these impacts in governmental decision-making and commit to adopting new ways of conducting scientific inquiry to inform environmental decision-making. In response to this challenge, ORD will work to build capacity in community-based participatory research, both within EPA and in over-burdened communities. The SHC will establish Centers of Excellence in Environmental and Health Disparities Research in cooperation with NIH/National Institute of Minority Health, We also will collaborate with HUD, researching the effects of the built environment on community health, and with the EPA-HUD partnership, studying healthy homes. ORD will also participate in action plans being proposed by an Interagency Children's Environmental Health Taskforce such as a plan to reduce asthma disparities in disproportionately impacted communities. STAR grants will explore the interactions between pollution exposures and social stressors often encountered in low income communities (e.g., asthma and nervous system function) and provide innovative approaches for assessing risk in urban populations where pollution and poverty converge.

Science Questions:

- What are the complex interactions between social, natural and built environmental systems, conditions and policies that result in unequal environmental health conditions or disproportionate impacts among (diverse) disadvantaged population groups, communities, neighborhoods and individuals?
- How can these complex interactions be described quantitatively and qualitatively?
- How do current systems of environmental governance create, maintain or exacerbate disproportionate environmental burdens experienced by socially disadvantaged populations/communities?

- Who and what drives current and changing patterns of social inequalities in environmental health?
- What are new strategies for alleviating systemic drivers of racial and socio-economic disparities in environmentally mediated health outcomes (environmental health) and access to healthy environments?
- How do the following processes contribute to and create environmental inequalities among certain populations and communities: suburbanization, land use planning, residential segregation, exclusionary zoning, banking systems (mortgage guarantees), transportation policies, housing policies, property speculation?
- What is the role of systemic economic inequalities, and uneven regional development in creating and or maintaining inequalities in environmental health and the distribution of environmental hazards and environmental quality?

Contributing Outputs:

- Research conducted by the Centers of Excellence in Environmental and Health Disparities research, in collaboration with the NIH's National Institute of Minority Health and Disparities will build capacity for EPA to work for environmental justice.
- ORD will acquire capacity to identify communities and groups at disproportionate risk and to work with communities using participatory approaches to reduce health and environmental disparities in these communities.
- ORD will develop programs to build capacity in community groups so they can become competitive for community development funding grants.
- Technical guidance will be issued to help the Agency conduct uniform EJ evaluations and progress to the goal that all Americans will be equally protected under the law.

Topic 3e: Children's Health

Output: The Agency and communities will have comprehensive tools with which to evaluate and integrate exposure, health, and social/demographic data to ensure that rules, actions, policies and decisions protect and foster sustainable children's health in community contexts.

The Agency has a longstanding commitment to, and is placing increased emphasis upon, ensuring the health and well-being of children. This is due to the increasing recognition that children are not small adults. Rather they breathe more air, drink more fluids, and eat more food than adults on a body weight basis. Additionally, the hand-to-mouth route of exposure is much more significant in children. Therefore, risk assessors need to consider age-specific factors based on phase of development. To fully understand and address children's environmental health, systems thinking and new statistical tools are needed in order to analyze the total impacts of the multiple and diverse stresses which converge on children in specific community settings, i.e. those which vary by exposure sources, climate (dampness, temperature), adequate housing, etc. Furthermore, these stressors need to be considered and analyzed in light of ongoing, continuous or intermittent exposures and in relationship to the child's age and development, which determine the child's behavior and vulnerability. In addition, children need safe

places to play and learn, free from contaminants and safe from other physical and social hazards. Thus, children's health and development is a function of many factors, including the quality of the built environment as depicted in Theme 1, life style and dietary factors, exposures to various contaminants some of which are based upon age-dependent behaviors and vulnerabilities, and the social/family structure which dictate almost all aspects of a child's early life.

Policies and associated decisions made by EPA, other Agencies and local governments related to child care centers and school building and management practices, recreational facilities, and community structure (e.g. transportation/walkability) need to be informed by systems thinking. SHC will continue to address emerging and ongoing children's environmental health issues in community settings (rural and urban) through the inter-disciplinary Children's Environmental Health Center Program (co-funded with NIEHS). The next phase of this program will encourage systems approaches (as opposed to individual exposures or disease foci), community-based participatory research and outreach, and translation to medical and environmental public health practice. In response to the needs and priorities of EPA's Office of Children's Health Protection, extramural and in-house research in SHC will explore how to optimize built environments and cleaning/custodial practices for buildings where children live, play and learn. Research will expand our knowledge of age-specific exposure factors to inform rulemakings and risk assessment, and develop improved metrics for evaluating children's exposures in homes, schools and community settings. Also, research will develop improved biomarkers for child specific exposures and verify the optimal public health indicators for childhood diseases and conditions related to environmental factors. Community-based Tribal grants in the STAR program will also provide added emphasis on children's vulnerability and health in unique environmental and cultural contexts.

Science Questions:

- What chemicals and combinations of chemicals, such as those occurring together in products that children use or are exposed to, pose the greatest risk to children's health and how does this risk vary across EPA's child-specific age groupings?
- Does exposure to complex environmental exposures and stress during fetal development and early life contribute to the epidemic increases in childhood and adult obesity, diabetes and asthma? What community-level metrics and models are most useful for characterizing children's exposures to multiple contaminants over the range of exposure routes and what suite of indicators is the best metric for community interventions?
- How do child care and school environments, defined broadly to include both physical characteristics (e.g. lighting, ventilation), and potential chemical exposures (e.g. cleaning products, indoor pollutants), impact learning and performance of children and their teachers?
- How can community planners best consider children's health in community development or re-development practices and in community-specific public health messaging for parents.

Contributing Outputs:

- Guidelines for schools and child care centers to insure healthy buildings for children

- A suite of indicators for communities to use to identify community-specific children's health problems and inform decisions such as school permitting/siting and community development that present harmful exposures, while promoting healthy lifestyles.
- Guidance for parents regarding child-specific product use and safety
- Intervention strategies in homes and schools for preventing childhood diseases such as asthma and exposure to potentially dangerous chemicals/products.

Topic 3f: Report on the Environment-

Output: Future versions of the ROE that contain more or better indicators (including those specifically targeted at sustainability) and improved electronic access to the data and contents

The Report on the Environment (ROE) presents the best available indicators of information on national conditions and trends in air, water, land, human health, and ecological systems that address questions EPA considers mission critical to protecting our environment and human health. Many of the indicators covered in the ROE relate directly to the sustainability of communities.

The ROE can be accessed electronically (www.epa.gov/roe). The user can review the underlying data, the genesis of the indicator, and the way the indicator addresses issues of concern for protecting human health and the environment. The electronic ROE is updated semi-annually and the user will soon be able to manipulate the indictor graphics to meet their own requirements. A new set of sustainability indicators will be added in 2012 that will enable us to track the continued assurance of human health and well being, environmental resource protection, and economic prosperity.

Science Questions:

- What are the best indicators for trends in national conditions and trends in air, water, land, human health, and ecological systems?
- What are the best indicators for sustainability that could be incorporated into future versions of the Report?
- How can technology be used to make the information in the Report more useful and accessible to EPA's partners and stakeholders?

Topic 3g: Fellowships

Output: A well trained scientific workforce that can address tomorrow's complex environmental issues.

One of EPA's highest priorities is ensuring that we have an adequate and well-trained scientific workforce that can address tomorrow's complex environmental issues. To respond to this need, ORD supports several fellowship programs focusing on current and future environmental professionals. Each year, ORD awards 125 graduate STAR (Science to Achieve Results) fellowships based on a competitive RFA. In addition to STAR fellowships, ORD operates the Greater Research Opportunities (GRO) program

which offers Graduate Fellowships for master's and doctoral level students and undergraduate fellowships in environmentally related fields of study.

Science Questions: N/A

Appendices

APPENDIX A: SUSTAINABLE AND HEALTHY COMMUNITIES RESEARCH PROGRAM (SHC) FRAMEWORK ACRONYMS

ACE: Air, Climate and Energy Program
Atlas: National Atlas of Ecosystem Services
BTU: British Thermal Unit
CAA: Clean Air Act
CARE: Community Action for Renewed Environment
CDC: Center for Disease Control
C-FERST: Community-Focused Exposure and Risk Screening Tool
CMAQ: Community Multiscale Air Quality Modeling System
CRA: Cumulative Risk Assessment
CSS: Chemical Safety for Sustainability
CWA: Clean Water Act
EJ: Environmental Justice
EO: Executive Order
ES: Ecosystem Services
FML: Future Midwest Landscapes
GDP: Gross Domestic Product
GHG: Greenhouse Gasses
GIS: Geographic Information Systems
GRO: Greater Research Opportunities
HDI: Human Development Index
HHRA: Human Health Risk Assessment
HS: Homeland Security
HUD: US Department of Housing and Urban Development
ICLEI: Local Governments for Sustainability
MT: Million Tones
N: Nitrogen
NAAQS: National Ambient Air Quality Standards
NGO: Non-Governmental Organization
NIEHS: National Institute of Environmental Health Sciences
NIH: National Institute of Health
ORD: EPA Office of Research and Development
OSWER: EPA Office of Solid Waste and Emergency Response
OW: EPA Office of Water

P: Phosphorus
P3 Awards: People, Prosperity and Planet (EPA Awards Program)
PACE-EH: Protocol for Assessing Community Excellence in Environmental Health
PM: Particulate Matter
POTW: Publicly Owned Treatment Works
R&D: Research and Development
RARE: Regional Applied Research Effort
RCRA: Resource Conservation and Recovery Act
ROE: EPA Report on the Environment
RONA: Return on Net Assets
SBIR: Small Business Innovation Research
SHC: Sustainable and Healthy Communities Research Program
SSW: Safe and Sustainable Water
STAR: Science to Achieve Results
T-FERST: Tribal-Focused Exposure and Risk Screening Tool
TBL: Triple Bottom Line
US EPA PO: United States Environmental Protection Agency's Program Office(s)
US EPA: United States Environmental Protection Agency
VOC: Volatile Organic Compound

APPENDIX B: COMMUNITY OUTREACH ACTIVITIES FOR SHC PLANNING

Regional stakeholder listening sessions – Between March 9 and April 7, ORD collaborated with Region 7 to conduct several Community Listening Sessions across the country to gain insight into how communities are facing and implementing sustainable practices. Communities were selected to (1) provide a range of community sizes, including small rural communities and urban centers, (2) address a broad range of issues including environmental justice, and (3) focus on those that had a track record of addressing sustainability issues. In coordination with the Regional Sustainable Community Coordinators, the Regions chose the following communities: Asheville, NC; Boston, MA and neighboring communities; Milwaukee, WI; Ogden, IA; Spokane, WA; Woodbine, IA; and Wyandanch, NY.

These communities represent a mix of rural and urban communities with different economic livelihoods and local/regional issues. Participants included elected officials, local and state government personnel, non-profit organizations, utilities, universities and other members of the community as well as EPA staff from the Regions and ORD (laboratories and headquarters). Approximately 103 community representatives attended the meetings. Summary reports were developed for each community. Although the challenges they face and approaches to addressing these issues were vastly different, many issues emerged as common themes during these conversations.

Fourteen issues were identified as common issues In order of priority from highest to lowest, they are: *Economics* (the strongest driver for sustainability decisions in communities, yet communities do not have a good understanding of the linkages between jobs, economic development and sustainability;); *Communicating, Educating and Framing* (framing the sustainability discussion with the public so that its importance is understood and acknowledged); *Performance measures/metrics* (clearly defined and credible accountability metrics for measuring or predicting the economic, environmental, and social effects of a sustainable action in a community)**;** planning; schools; housing; natural resources; practical sustainable practices; adapting to climate change; transportation; local food systems; stormwater management; and health and healthy lifestyles. While listed separately, the issues are recognized to be interconnected, but communities often lack the tools to quantify much of the interconnectivity.

Webinars - SHC conducted 4 webinars between March 17 and April 11 to provide input from people who could not attend one of the listening sessions. Three were aimed at local government sustainability staff and one at tribal environmental staff. For the local government audience we sent broad invitations through ICLEI – Local Governments for Sustainability, the Urban Sustainability Directors Network, and the American Planning Association Sustainability and Community Research groups - 299 people registered and 129 attended. For the tribal webinar, we reached out through the Institute of Tribal Environmental Professionals, EPA and HUD tribal contacts, and the National Indian Energy NGO - 78 people registered and 28 attended.

Community needs focused especially on information needed to be able to compare options, especially for costs – long term, cumulative, costs to benefits, costs of smart growth vs sprawl, costs of grey vs green infrastructure, values for ecosystem services and the intersection of environmental challenges and opportunities in the form of economic co-benefits and jobs. Metrics was another focus, especially

for a standardized approach and metrics to assess sustainability progress. Tribal needs focused on food sovereignty, waste, the precautionary principle as a guiding goal, and the relationship between sustainability, sovereignty, and stewardship for future security in Indian Country. Their programs may benefit more from program office assistance than research - half of the respondents felt that process information would be more important than better data (20%), or characterizing the values of natural resources, metrics or performance measures.

Community Leaders Meeting – A workshop was held on April 13-14 to give a more limited number of attendees a longer time to discuss issues. Twenty non-EPA attendees represented six national NGOs, three Universities, six communities and a state sustainability coordinator gathered to exchange ideas and identify needs. Also participating were about a dozen EPA scientists, an EPA green jobs expert, an EPA sustainable community toolkit developer and two public health expert from NIEHS.

Much discussion focused on the information needed to change individual and decision-maker behavior – how to provide better information on the holistic implications of decisions, what are the metrics that will be most effective to measure sustainability progress and quality of life and how can these things be effectively communicated to community audiences and decision makers so as to compel better decisions? Costs and the fiscal realities of community work were important - jobs are of paramount importance in local decisions, costs can be barriers to getting sustainability actions in place, and community leaders need to demonstrate the financial and human health benefits of sustainability actions. Local capacity is very limited, meaning that communities would like easy ways to get information and process information, with plug and play tools, rather than just a greater "barrage of information."

Problems that would benefit from holistic cost/benefit or metrics information included land use and development, infrastructure, waste, food security, climate resilience, and water issues. Because community focus shifts, they needed a way to capture the impact of the sustainability objectives in whatever the issue of the day is, because sustainability links all aspects of community decisions and must focus on long term community quality. Social and psychological issues must be addressed to be able to move decision making toward a better quality of life/well-being goal.

City of Durham, NC – Since Durham will be the focus for the Topic 1a projectthat will serve as a demonstration site for a "whole community" TBL accounting approach to increasing sustainability, a listening meeting was held on April 20, 2011. The meeting was attended by 27 Durham representatives, including an elected official, and two local NGOs, as well as a representative for ICLEI and around a dozen EPA representatives.

A recurring theme was the need to be able to better evaluate a broader array of impacts, especially for development and transportation, to know where problems really are and the corresponding lifecycle costs. Jobs and costs are critical and the city needs to better understand and integrate cumulative social and health impacts of food islands, transit islands, brownfields redevelopment, waste management, and other problems. They would like to better assess water use, urban gardens, and energy use, to be able to better assess and integrate environmental needs with economic ones, and to be able to learn how to

communicate in a compelling way the holistic implications of action so as to create incentives for behavior change. Equity issues are very important, since Durham is has a very high minority population.

Gulf of Mexico Communities - Conference calls were held with three coastal community partners including the South Florida Planning Council, the Gulf Regional Planning Commission, and the Houston-Galveston Area Council. These conference calls included staff representatives of these agencies, as well as members of their consortium on their HUD Regional Sustainability Planning grant. The focus of discussion in these calls was how science-based research could deepen the scope of the existing sustainability planning efforts these groups are undertaking. Out of these calls, each partner community submitted ideas for how EPA could assist in supporting greater sustainability in their community.

The communities noted: 1) a need to quantify and communicate the economic value of natural resources to policymakers, including a tool to perform full and benefit cost accounting that would allow the value of natural resources to be factored into decision-making processes (e.g., a tool would be an accepted method to quantify the carbon sequestration associated with planting trees and preserving natural environments, such as wetlands). 2) A need to create an opportunity index that would explore how low-income groups and racial and ethnic populations are situated within a region's geography of opportunity (e.g., indicators in the index could include economic health, mobility, education, environmental health, housing, public health, crime, etc.). 3) A need for a comprehensive health vulnerability assessment focusing on climate impacts to community residents, including sea level rise, increased incidence of extreme heat days, and vector-borne diseases.

APPENDIX C: EXAMPLES OF HOW THEME 1 PROJECTS MIGHT BE PUT TOGETHER.

Example 1 – Waste and Materials Management

Communities across the nation are having a difficult time siting new landfills. Some potential solutions to the problem include waste reduction and diversion to lengthen the life of the facility: aggressive curbside recycling; banning certain materials from the landfill; waste-to-energy; pay-to-throw-away pricing. Other solutions may involve ways to reduce community resistance to a new landfill, including alternate sites, transfer stations, reduction of environmental justice issues, co-benefits like methane capture (offsets might be used to pay nearby residents' electric bills), etc. Any solution should consider the impacts of alternative solutions on air quality (due to operations at the site and hauling trash), water quality (including groundwater contamination); the potential for re-using sites; health implications; energy and greenhouse gas implications (should a cap-and-trade system be mandated in the future); human health implications; effects on important ecosystem services; public attitudes; environmental justice; and economics (including impacts on the attractiveness of the area for future potential residents and businesses). The project also should consider whether options for controlling or reversing other environmental problems would reduce or increase wastes to be landfilled.

Output – An approach that would allow community decision-makers to look at all reasonable alternatives to deal with an upcoming data for the end of a landfill lifetime, to identify which approaches are most cost-effective under their particular circumstances, and to quantify the most important co-benefits as well as negative impacts on air, water, ecosystem services, human health, etc. The tool also would identify which solutions were most likely to result in social acceptance versus opposition.

Outcomes – Communities that used the tool would find that its use led to lower cost solutions that were generally acceptable to the community; avoided unintended consequences that would likely have resulted from other solutions that they considered implementing; and delivered co-benefits that might not have resulted from other solutions they considered implementing.

Impact – More sustainable and healthy communities

Example Science Questions –

- For each potential method of reducing the volume of waste:
  - What is the cost per ton (or volume) of the technology?
  - What are the effects on the transportation of materials?
  - What are the impacts on energy use and greenhouse gas exchange?
  - What are the health risks and risks to ecosystem services of potential exposure of humans and ecosystem to pollutants (including effects of transportation of waste, etc.)?
  - To what extent would options for controlling other pollutants increase or decrease landfilled wastes (e.g., sludge)?

    - What are the positive or negative effects on ecosystem services from changes in the physical environment, hydrology, etc.?
    - Can ecosystem services be employed to actually reduce waste streams?
    - What are the economic effects, including property values, waste disposal costs (residential and commercial), attraction of new industry or other investment, potential payments for ecosystem services
    - What are the ramifications for environmental justice concerns?
    - What is the expected social response (acceptance/rejection, pressure on city or county officials from citizen organizations or industry or trade groups, lawsuits)
- For each potential method of landfilling waste elsewhere:
    - What is the cost per ton (or volume) of the technology?
    - What are the effects on the transportation of materials?
    - What are the impacts on energy use and greenhouse gas exchange?
    - What are the health risks and risks to ecosystem services of potential exposure of humans and ecosystem to pollutants (including effects of transportation of waste, etc.)?
    - What are the positive or negative effects on ecosystem services from changes in the physical environment, hydrology, etc.?
    - What are the economic effects, including property values, waste disposal costs (residential and commercial), attraction of new industry or other investment, potential payments for ecosystem services
    - What are the ramifications for environmental justice concerns?
    - What is the expected social response (acceptance/rejection, pressure on city or county officials from citizen organizations or industry or trade groups, lawsuits)
- What is the most effective design for a decision support platform to inform choices about waste reduction and disposal?
- What models and supporting data are needed that are or could be made widely available to support the decision platform?
- What are the best metrics to track the performance of the chosen solution (including any co-benefits or unavoidable consequences)?
- How are landfill siting and capacity likely to be affected by climate change and population growth over the next 25 years; is the lifetime of the solution such that a more expensive anticipatory approach might be justified?

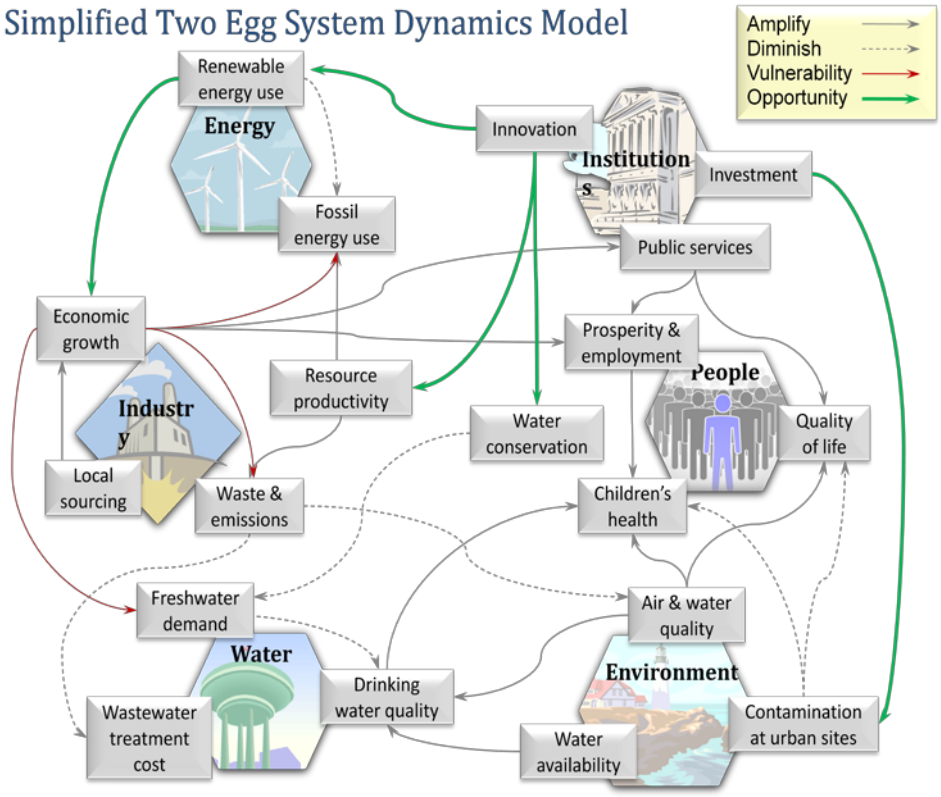
Example 2. Devising a Comprehensive Approach to Help Particular Communities Address Multiple Barriers to Sustainability in an Integrated Way

The community of Two Egg is a small city of 60,000 residents. It has been losing its economic base of agriculture (tobacco) and light manufacturing as demand has decreased and jobs have been moved offshore. The city is located just off a major interstate, and not too far from larger metro areas that have strong technical and medical economic bases. The town is served by a small watershed, with a

reservoir, and groundwater is generally of low quality and supply. Recreation is primarily hunting and fishing, hiking and canoeing (the reservoir is not large enough to support power boating) and because of the agricultural history, there is not a lot of unique physiography that would attract tourists.

- The town is concerned about its sustainability for a number of reasons, all exacerbated by a declining tax base, as agriculture and industry have declined or left the area.
- Despite the fact that there is little heavy industry in town, the proximity of the Interstate highway and some upwind power plants have caused the town to be on the verge of non-attainment for PM 2.5.
- The river on which the town depends for water and which receives both point and non-point sources of pollutant loading is under a TMDL for nitrogen and sediment. Upgrading the town POTW to remove nitrogen will be expensive; sediment loading comes primarily from poorly managed agricultural land and a housing development that was abandoned when the financial crisis struck;
- There is a contaminated site near the downtown area that was occupied by a wood treating plant, and there are a number of LUST sites at abandoned gas stations, all of which have made the downtown area less desirable to both businesses and housing.
- There is a landfill that is reaching capacity just outside of town that was located in a poor black area, and efforts to expand the landfill have been fought by the local residents as an environmental justice issue.
- The area has experienced severe hot, dry summers in two of the past five years, and the town is concerned about how it can grow or attract new industry without overtaxing its water supply.
- Two old elementary schools near the Brownfield sites also have been discovered to be contaminated by PCBs and lead. There is evidence that children in town are experiencing unacceptable levels of multiple pollutants, and also evidence that this is having an impact on the cost borne for health care by local government.

What strategies could Two Egg pursue that would solve all of these problems in a way that achieve mutually supporting co-benefits (and thus puts less strain on the tax base); that are socially acceptable to all residents; and that offer opportunities for economic growth or at least stability? The conceptual model for examining all of the concerns at once and their iterations are shown in the figure below.


Simplified Two Egg System Dynamics Model
Amplify
Diminish
Vulnerability
Opportunity
Renewable energy use
Energy
Fossil energy use
Innovation
Institutions
Investment
Public services
Economic growth
Prosperity & employment
Resource productivity
Industry
Water conservation
People
Quality of life
Local sourcing
Waste & emissions
Children's health
Freshwater demand
Air & water quality
Water
Drinking water quality
Environment
Wastewater treatment cost
Water availability
Contamination at urban sites

RESEARCH FRAMEWORK SUMMARY TABLE

EXAMPLE: SHCRP

Theme 2: Developing Decision Support Tools, Models, Data, and Metrics that Support Multiple and Future SHC Projects

Objective 2.a Provide easily-accessible and useful data and tools to decision-makers

IMPACT OF THIS RESEARCH: ORD will develop decision support tools and a

Topic	Problem	Science Questions	Research Objectives	Outputs	Outcome	Scale	Linkages
development of an interoperable decision support platform with common database and linkages among tools	Decision-makers need a systematic way to inform and make decisions and want to compare their community to others (and SHCRP has existing tools tools that can be leveraged for early outputs)	How can we modify and link existing tools, including use of a common platform and data, to enhance sustainability objectives and provide interim products?	1) develop a database framework such that tools can use common data; 2) provide a common access point and logical organization for SHCRP; and, 3) link existing tools such that they can be interoperable (i.e. use analysis capabilities from one tool after preliminary analysis in another)	An interoperable platform that links tools and provides for a common database to support community decision needs	Improved accessibility to and use of SHCRP tools (e.g. ReVA, Nat'l Atlas, C-FERST, Envision, E-DASH, DASEES)	local to national	all program areas, ICLEI, OSC, other agencies
synthesis of vast amounts of data to provide clear information	decision makers are overwhelmed with available data and need access to data synthesized in detail relevant to assessment need and technical aptitude	How can we best synthesize environmental and human health data in a way appropriate for different types of decision-makers?	1) identify best methods for data synthesis for different assessment needs and data characteristics	tools that use appropriate synthesis methods for different data limitations and assessment needs	decision-makers have access to statistically rigorous indices that facilitate comprehension of spatial patterns and overall conditions	local to national	all program areas, ICLEI, OSC, other agencies

Topic	Problem	Science Questions	Research Objectives	Outputs	Outcome	Scale	Linkages
alternative futures	Decision makers require the ability to understand the implications of alternative management decisions on future sustainability and resilience	What empirical relationships can be extracted from existing data to allow a "plug and play" modeling capability applicable to different communities across the nation?	1) identify simple relationships from broad-scale databases that can be used to generate a series of "what-if?" scenarios? 2) identify statistical processes needed to generate finer-scale alternative scenarios	tools that illustrate the implications and trade-offs of alternative management actions and individual choices	decision-makers at all levels have improved access to information to enable progress towards a sustainable and resilient community	local to national	all program areas, ICLEI, OSC, other agencies
tools with varying levels of complexity for different types of decision-makers	Decision tools need to be tailored towards different information needs	How do we create tools with different levels of complexity to make information accessible to multiple levels of decision-makers and stakeholders?	1) identify different decision makers and their specific needs; 2)design tools with varying levels of complexity and interpretation	user-profiles for the full suite of decision-makers SHCRP hopes to inform including specific information needs, ability to understand complex information, etc.	Decision-makers at all levels have improved access to information to enable progress towards a sustainable and resilient community	local to national	all program areas, ICLEI, OSC, other agencies
communication of research results using visualizations	Communication of the full implications of different actions is challenging; visualization can be an effective communication tool that evokes an emotional connection to a problem or solution	What visualizations are the most effective for achieving a broader understanding of analysis results?	1) identify and evaluate visualization technologies; 2) incorporate visualizations that effectively communicate results into decision support tools	tools that allow community decision-makers to quickly understand the results of analysis	decision-makers clearly and quickly understand decision tool analysis results	local to national	all program areas, ICLEI, OSC, other agencies

Topic	Problem	Science Questions	Research Objectives	Outputs	Outcome	Scale	Linkages
Appropriateness of different decision analysis approaches for specific needs	Individual decision analysis approaches have strengths and weaknesses for different applications and types of data input	what decision analysis approaches are most appropriate for assessment, future visioning, evaluating alternatives, and tracking progress towards sustainability?	1) link decision needs with appropriate decision science approaches	the best available science is incorporated into tools to facilitate decision analysis	increased use of tools to make informed decisions	local to national	all program areas, ICLEI, OSC, other agencies
guidance for future tool development	ad hoc development of decision support tools hampers efficient delivery of relevant outputs	what criteria should be used to guide tool development for the SHCRP?	1) identify desired characteristics of SHCRP tools	specific guidelines that govern SHCRP tool development	SHCRP tools are recognized as state of the art, reliable, and transparent decision support	local to national	all program areas, ICLEI, OSC, other agencies
understanding of decision processes used	decision support tools are developed without a full understanding of different processes used by decision-makers	How can we improve decision processes through analysis of how tools are used?	1) track use of analysis capabilities accessed in SHCRP tools; 2) refine decision processes available in tools	improved SHCRP tools that better reflect decision processes used by communities and others	increased use of SHCRP tools by decision-makers	local to national	all program areas, ICLEI, OSC, other agencies

SUSTAINABLE AND HEALTHY COMMUNITIES RESEARCH FRAMEWORK SUMMARY TABLE

Theme 2: Developing decision support tools, models, data, and metrics that support multiple and future SHC projects

Topic B: Developing and Evaluating Metrics (Indicators and Indices) That Examine and Integrate Critical Community Health, Environmental, Economic, and Social Contributors to Sustainability

Problem	Broad Science Questions	Examples of Specific Science Questions	Research Objectives	Outputs	Outcome	Comments
Metrics for assessing whether current environmental, social and economic trends are becoming less sustainable are not readily accessible to communities (i.e., not readily available or not understood)	What indicators/indices are most appropriate for assessing the overall sustainability of a community? Region? Nation?	What indicators/indices are available that address some aspect of community sustainability ?	Capture indicators of social capital (e.g., community vitality, social cohesion, walkability), environmental capital (e.g., greenways, distance to nature) and economic capital (e.g., investment, employment)	1)Inventory of available sustainability indicators/indices,	Better community choices regarding selection and use of sustainability indicators (greater probability of sustainable choices)	Coordinate with existing sustainability metrics project in NRMRL and associated with PFIT Indicators Committee as well as the NRMRL Sustainability Metrics Program
			Provide an approach for the selection of indicators of community sustainability by communities for their use	2) Guidance document for selection of available sustainability indicators for use by a specific community	Better community choices regarding selection and use of sustainability indicators (greater probability of sustainable choices)	New area but needs coordination with existing NRMRL effort at inventory and ICLEI interaction
		What indicators need to be evaluated or developed to meet partner needs?	Provide indicators of environmental sustainability for ROE	1) ROE and its adaptation to sustainability indicators	Better available information to be used in decision making	Existing project in NCEA in association with PFIT Indicators Committee
		What indicators need to be developed to meet stakeholder needs?	Provide indicators of sustainability for specific community needs	1) Indicators of specific community sustainability need	Communities can better address and achieve sustainability goals	New: Interaction with ICLEI

Problem	Broad Science Questions	Examples of Specific Science Questions	Research Objectives	Outputs	Outcome	Comments
	What indicators/indices are of most utility in diagnosing the causes of sustainability problems and identifying potential solutions?	What is the relationship between overall environmental quality indicators and human health outcomes?	Construct an Environmental Quality Index for all US counties incorporating five domains of environmental indicators and examine the relation between overall environmental quality and health outcomes	1) Environmental Quality Index,	Better understanding of the relationships of environmental quality and human health in order to improve human health outcomes	Coordinate with existing project in Human Health (NHEERL)
			Explore and test plausible associations among environmental exposure and indoor air quality and asthma	2) Environmental Exposure Indicator, Indoor Air and Asthma; Examine possibility of Indices for Indoor Air and Asthma	Better understanding of the relationships of environmental quality and human health in order to improve human health outcomes	Coordinate with exposure indicator programs in NHEERL for indoor air and asthma and NERL Air Exposure Indicators Projects
			Explore and test plausible associations among availability of ecosystem services and high-prevalence physical and mental health issues	3) Quantitative and qualitative estimates of community health effects associated with levels of local ecosystem services	Better understanding of the relationships of between ecosystem services and human health in order to improve human health outcomes	Data feed to the National Urban Atlas, C-FERST and ReVA; Research addresses Environmental Justice (EJ2014 Plan); New interaction with ICLEI STAR and collaboration with USFS
	What performance indicator/indices, at needed spatial and temporal resolutions, improve a community's decisions to prevent contamination of groundwater resources?	What indicators/indices can improve community planning through managing contaminant sources that are, or could be, impacting ground water ?		4) Indoor air indicators of potential risk to homeowners from contaminated sites		May actually be Theme 3 work

Problem	Broad Science Questions	Examples of Specific Science Questions	Research Objectives	Outputs	Outcome	Comments
		How can GIS population indicators/indices for communities using shallow groundwater be integrated with GIS data on sources of contamination to protect communities and assist with decision making?		5) Indicators of near roadway exposure, 6) Vapor intrusion indicators to determine sources of home contaminants		May actually be Theme 3 work
	How can indicators be combined in an index form that better communicates overall sustainability of a community to stakeholders?	How can overall human well-being be represented as an index and related to overall community sustainability?	Can many important indicators of individual and community well-being be combined in a few or a single index of HWB	1) Human well-being index for the US,	Use of human well-being changes as a guide for community decision making (greater probability of selection of a sustainable choice that improves well-being)	Coordinate with existing project in ESRP (NHEERL)
		How can indicators be combined to more clearly communicate interactions of human health, environmental and sustainability indicators		1) Web Tools to support cumulative exposure assessments in order to build sustainable, healthy communities	Better communication of trade-offs, risks of exposure, and impact upon sustainability for specific decision making	Coordinate with C-FERST and ReVA in NERL
		How can Children's Health be represented as an index to be communicate to totality to CH to stakeholders?		1) Index of Children's Health	Better communication of Children's Health Issues to stakeholders and easier inclusion of all CH issues in decision making	New but builds from the 2010/2011 effort to identify 80+ indicators of Children's Health
	What indicators/indices are most appropriate for assessing the sustainability of a community associated with environmental, social or economic issues?	What are the most appropriate indicators/indices of ecosystem services?		1) Indicators of specific ecosystem services	Enhanced ability to assess the economic, social and environmental tradeoffs of specific environmental decisions	Coordinate with NHEERL (WED) ecosystem indicators effort and with USDA

Problem	Broad Science Questions	Examples of Specific Science Questions	Research Objectives	Outputs	Outcome	Comments
			Test existing and new methods to quantify the production of ecosystem services and disproportionate distribution	2) Metrics and indicators of local ecosystem services in relation to community demand	Enhanced ability to assess the economic, social and environmental tradeoffs of specific environmental decisions	Data feed to the National Urban Atlas, C-FERST and ReVA; Research addresses Environmental Justice (EJ2014 Plan); New interaction with ICLEI STAR and collaboration with USFS
	What are the thresholds for indicators/indices of community sustainability?	What are the thresholds of sustainability indicators/indices that promote attributes of community sustainability (e.g., intergenerational equity, Quality of life, Social Cohesion, External responsibilities)?	Explore and test plausible associations among availability of ecosystem services and overall well-being	1) Index of Intergenerational Equity, 2) Index of Environmental Well-Being, 3) Index of Social Well-Being, and 4) Index of Economic Well-Being	Ensuring that intergenerational equity, quality of life, social cohesion and external responsibilities are part of community decision making	New but coordinated with existing Well-Being efforts in ESRP and NRMRL sustainability metrics project (e.g., measures of economic welfare and environmental justice)
			Explore and test plausible associations among availability of ecosystem services and high-prevalence physical and mental health issues	5) Quantitative and qualitative estimates of community health effects associated with levels of local ecosystem services	Better understanding of the relationships of between ecosystem services and human health in order to improve human health outcomes	Data feed to the National Urban Atlas, C-FERST and ReVA; Research addresses Environmental Justice (EJ2014 Plan); New interaction with ICLEI STAR and collaboration with USFS

Problem	Broad Science Questions	Examples of Specific Science Questions	Research Objectives	Outputs	Outcome	Comments
Metrics for assessing progress (i.e., performance) toward desired environmental, social and economic sustainability are not readily available or not understood	What performance indicators/indices are most useful for setting sustainability goals and communicating these goals to stakeholders?	What performance indicators/indices are available that address some aspect of community sustainability ?		1)Inventory of available sustainability performance indicators/indices,	Better community choices regarding selection and use of sustainability indicators (greater probability of sustainable choices)	Coordinate with existing project in NRMRL and associated with PFIT Indicators Committee as well as the NRMRL Sustainability Metrics Program; Data feed into the National Urban Atlas, C-FERST and ReVA
				2) Guidance document for selection of available sustainability performance indicators for use by a specific community	Better community choices regarding selection and use of sustainability indicators (greater probability of sustainable choices)	New area but needs coordination with existing NRMRL effort at inventory and ICLEI interaction
	What are the most useful indicators/indices for tracking the performance of projects intended to increase the sustainability of communities	What performance metrics will be used to assess the progress of individual programs/projects within SHCRP? SHCRP as a whole?		1) Performance Metrics for SCHRP	Ensuring meeting Sustainability goals of SCHCRP	Coordination with OPARM and ORD development of performance metrics
	How can performance indicators be combined into indices to better communicate progress toward sustainability goals?	What performance indices will be used to assess the progress of individual programs/projects within SHCRP? SHCRP as a whole?		1) Succinct Index of Program progress	Clear measures of programmatic success or progress toward stated goals	Coordination with OPARM and ORD development of performance metrics

RESEARCH FRAMEWORK SUMMARY TABLE for SUSTAINABLE AND HEALTHY COMMUNITIES

Theme 1: Developing comprehensive approaches to help communities become more sustainable

Theme 2: Developing decision support tools, models, data, and metrics that support multiple and future SHC projects

Topic B: Future Midwestern Landscapes Study: Providing Tools to Inform Land Use Decisions in the Midwestern U.S.

Problem	Science Questions	Research Objectives	Outputs	Outcome	Comments
The trade-offs associated with changing land uses in agricultural regions particularly in the Corn Belt, are not well understood or accounted for in national policy or regional decision-making.	What models can be applied or developed to estimate ecosystem services associated with agricultural land uses and conservation practices?		Models relating agricultural land use to each of a variety of ecosystem services (e.g., crop production, clean water provision, settings for nature recreation)	-- Trade-off evaluations of landscapes reflecting alternative future choices (ethanol production emphasis vs. service optimization) are provided to the Farm Service Agency and other users -- Watershed, conservation and environmental management	Coordinate with: --SSWR (hydrologic outcomes), --ACE (biofuel scenarios and impacts) --CSS (pesticide use associated with agricultural scenarios)
	What land-use configurations in agricultural landscapes afford the best combinations of ecosystem services?		-- Alternative future scenarios reflecting different land use choices or policies -- Ecosystem service evaluations for each scenario		
	What information and decision support systems can facilitate conservation and restoration of ecosystem services?		-- Interactive tools for visualization and evaluation of alternative landscapes -- Case studies of application to specific decision opportunities -- Dashboard for user-generation of alternative landscape scenarios		

SUSTAINABLE AND HEALTHY COMMUNITIES RESEARCH FRAMEWORK SUMMARY TABLE

Theme 3: Developing decision support tools, models, data, and metrics that are important for program office needs

Topic A. Reactive Nitrogen and Ecosystem Services

Subtopic - Cross-program modeling and decision support, cutting across ORD programs

Theme	Problem	Science Questions	Research Objectives	Outputs	Outcome	Comments
Cross-cutting modeling connecting air-land-water-social-economic systems.	Current policy analysis is typically one media at a time, omits the full suite of environmental benefits and will likely miss many unintended consequences and opportunities for sustainability	How can complex media-specific models be loosely coupled to support a combined policy assessment capability for air and water quality issues that allows exploration of many policies, provides inputs for calculation of human health and ecosystem services impacts, and illuminates cross-media interactions and unintended consequences to allow development of more sustainable policies	Develop a loosely coupled set of national multi-media models that treat the full complexity of the system and allow incorporation of reduced form models for rapid analysis	An integrated modeling set of complex and reduced form models to support strategic policy analysis and development. Also includes maps of nitrogen sources over space.	Improved potential for decision-makers to see the broad-based impacts of changes in pollution.	Author Robin Dennis, with multiple ESRP-N collaborators - Here is a rough first cut at a topic to include under Theme 2. This effort has support from OW (John Powers) and OAR/OAQPS (Brian Hubbell) and I am trying to work with them to craft a research program to develop a multi-media modeling capability starting with air and water and working at the national level, scalable to regional and local levels. John Powers is also working with Dixon Landers to develop an ecosystem services classification system to go along with this integrated modeling efforts. The modeling provides the inputs for the classification system which then feed the valuation system. John has presented this idea before, but only now do I begin to grasp what he is talking about. Nitrogen (nutrients) is a logical first pollutant to tackle.

Theme	Problem	Science Questions	Research Objectives	Outputs	Outcome	Comments
Impact of nitrogen deposition on ecosystem services	Human and ecological impacts of Nitrogen/Ammonia , and impacts of changes to NAAQS; Economic, social and human health impacts of nitrogen, using an ecosystem services perspective.	What are the critical inputs needed to reliably characterize impacts of Nitrogen/Ammonia atmospheric deposition including the use of critical loads to assess and restore ecosystem health? What are the key indicators of human and ecosystem health used to evaluate efficacy of NAAQS? How can ORD and partners (CDC) take advantage of national initiative for e-records to track changes in health outcomes and disease associated with air pollution?	This includes following: - Impacts of different forms of atmospheric deposition of N (NOx, NH4, N2O, etc.) - Impacts of atmospheric and other N sources (e.g., agriculture, waste, water, etc.) - Impacts on nutrient cycles - Impacts on ecosystem services - Impacts of other NAAQS pollutants (e.g., SOx, O3, Pb, etc.)	Development of assessment metrics and indicators for connecting nitrogen and human and ecological systems.	Although studies have been able to demonstrate the tangible health benefits of improved air quality additional approaches are needed to directly correlate the human health and ecosystem benefits attributed to the NAAQS. As linkages between pollutant exposure and impacts on health or ecosystem compromise are better identified, then the benefits of achieving reductions in NAAQS pollutants can, in turn, be included in assessments of the cost- benefits analysis for pollution control strategies and regulation.	The NAAQS addresses oxidized forms of N, but inclusion of reduced forms of N is lacking. The components that are necessary to develop a critical load provide a conceptual framework for linking atmospheric pollutants to ecological endpoints that indicate impairment. Air impacts are relatively better quantified than water impacts, so we hope to work with SSWR on this. Author Jana Compton - collaboration with NCEA, OAQPS and OAR staff

Theme	Problem	Science Questions	Research Objectives	Outputs	Outcome	Comments
Examination of policy, regulatory and voluntary tools to reduce the impacts of nutrients	Existing regulatory, non-regulatory and scientific efforts had early successes but have not kept pace with the growth of anthropogenic N and P sources, and related sediments and pathogens. Climate change has the potential to exacerbate impacts of N and P pollution. Excess N and P negatively impacts human health, plants (including valuable crops and forests) and economic prosperity. To optimize sustainable production of ecosystem services, communities	What are the identifiable scientific, policy, and socioeconomic structural characteristics of existing successful N and P reduction tools, models or other innovative approaches?	Develop a scientific foundation for an adaptable (responsive to different regions) model decision support framework that rapidly identifies the range of tools available for communities to achieve sustainable ecosystem services targets for protection and restoration based on quantifiable multiple source loads.	Models and metrics that build one or more tools to support local and regional communities in decision-making, environmental restoration, and future planning through providing the quantification and communication of human health and ecosystem services outcomes based on various N and P management choice scenarios.	Incorporation of integrated management of nutrient-related problems in air, land, surface waters and drinking water.	Authors: Jana Compton, Holly Campbell and Steve Jordan. This also contributes directly to the objectives within SSWR and potentially ACE.

SUSTAINABLE AND HEALTHY COMMUNITIES RESEARCH FRAMEWORK SUMMARY TABLE

Theme 2: Developing decision support tools, models, data, and metrics that support multiple and future SHC projects

Topic A. Developing Decision Support Platforms and Models That Integrate Critical Community Health, Environmental, Economic, and Social Contributors to the Decision Process

Subtopic - Community N modeling and decision support

Research Theme	Science Objectives	Science Questions	Research Outputs	Research Outcomes	Comments
Tool for communities to estimate and track community net reactive nitrogen flux.	Develop spatially explicit data sets, models, and user interface for NNF (community net nitrogen flux, would account for all sources, sinks, and outputs of reactive N for a community)estimation and tracking and test these models.	What data are available or needed at community scales for NNF estimation? What existing models and tools can be applied or adapted to NNF estimation? What additional modeling and development are needed? How can loading models at various scales (national/regional/watershed) be applied at community scales?	A tool for community-level, spatially explicit estimation and tracking of NNF. This would aid in community-level decisions related to groundwater nitrate contamination, air quality problems and non-attainment of aquatic use and TMDLs	Communities apply NNF as one of a suite of indicators of sustainability. NNF is reduced as the result of understanding of sources, sinks and outputs. Human and environmental well-being are improved. Downstream and down-airshed communities benefit from NNF reduction	Cuts across SHC, SSWR, and ACE research programs; Author - Steve Jordan
Nitrogen life-cycle analysis tools for multiple human activities, starting with an assessment of biofuels production and use	Communities rate the cost of transportation as one of their top concerns. Alternative fuels such as biofuels are one way to meet growing energy demands while providing much needed job growth and economic stimulus in rural communities. Current policy analyses are incomplete regarding full accounting of the costs and benefits of nitrogen budget (fate, transport, process) changes in response to policy directed biofuels production and consumption (i.e., life cycle analysis) across multiple media, multiple scales, human health, ecosystem health and services and social and economic consequences.	What are the key aspects of the nitrogen cascade that are impacted by biofuels production and consumption, and how are these aspects directly or indirectly linked to human health (e.g., respiratory disease, cardiovascular disease, asthma, allergic response, nitrate in drinking water, disease vectors, harmful algal blooms, etc), ecosystem services (e.g., clean air, clean water, food and fiber production, climate regulation), economic well being and overall local and regional community sustainability.	Develop a more complete life-cycle accounting that explicitly includes indirect as well as direct costs and benefits contributing to community sustainability of nitrogen cascade response to biofuels production and consumption.	Models and metrics that support the quantification and communication of human health effects and ecosystem health and services addressing identified gaps in current biofuels life-cycle analysis at the regional and local community scale.	Author Ellen Cooter - I told the group I would submit something dealing with biofuels. As you can see from my big science question, I think it is a good cross-cut science question under the potential cross-ITR theme of Nitrogen. I have tried to phrase then end so it is specific to communities here. Let me know if I need to come up with one for FML. That is actually a little of a stretch because we really are focusing on larger area issues or at least watershed-scale as opposed to rural agricultural communities.

Research Theme	Science Objectives	Science Questions	Research Outputs	Research Outcomes	Comments
Reactive Nitrogen in Aquatic Ecosystems - Risks to Human health and well-being: Developing decision support tools, models, data, and metrics that support decisions at National, Regional and Community Scales	Human alteration of nitrogen and phosphorus cycles through the use of fertilizers and the burning of fossils fuels has resulted in a 3-5 fold increase in the availability of these nutrients. Ultimately, excess nutrients find their way into aquatic systems leading to the cultural eutrophication of both fresh and salt waters. Some of the undesirable consequences of cultural eutrophication are reductions in ecosystem services (i.e. reduced aesthetic appeal and recreation opportunities), contamination of drinking water supplies, and an increase in the risk to human and animal populations from toxins associated with harmful algal blooms. Management decisions to help mitigate these risks are at multiple scales from national level policy (e.g. reductions in atmospheric deposition of nitrogen) to state/regional (e.g. setting state nutrient standards), and local/community (e.g. actions needed to achieve TMDLs and siting of BMPs to reduce nutrient loads to individual waterbodies).	The science questions related to this topic are transdiciplinary and span 5 major disciplines: Ecology, Toxicology, Epidemiology, Economics, and Information Mangement. The broad science questions for each are are: 1.) Ecology: How do nutrient loads, land use/land cover, and climate relate to cultural eutrophication in lakes, ponds, and reservoirs; 2. Toxicology: How does cultural eutrophication result in the production of toxins (e.g. cyanobacterial toxins) that have a deleterious impact on human health; 3. Epidemiology: What are the landscape level risks to human and animal populations associated with cultural eutrophication; 4. Economics/Policy: How do changes in ecosystem services and economic impacts relat to policy decisions targeted towards management of nutrients and control of cultural eutrohpication; 5. Information Management: What information, knowledge, and tools are most effective and useful for informing national, state, and community decisions that promote	1. A policy document that uses a decision context approach to clearly defines, the decision makers and stakeholders and their desired outcomes and management options. 2. A data and information management plan to guide the research and ensure that all outputs are reproducible and available. 3. A decision support system that includes database, analyses, and peer reviewed publications documenting each step of the process. We anticipate that this will include sets of coupled ecological, toxicological, epidemiological, and economic models that interface with a user friendly, online, decisions support system. The models will predict changes to human health and well-being that result from cultural eutrophication of aquatic ecosystems.	1. This research will advance the scientific understanding of the complex relationships between nutrient loads, management options, eutrophication of aquatic ecoystems, and risks/impacts to human health and well-being 2. Decision makers will use the outputs of our research (predictive models, decision support systems, etc.) to assess the human health risk, the impact to human well-being and economic costs/benefits of alternative management decisions at National, state, and community scales.	This research has the potential to cross-cut at least three of the research areas. Each of the different decision scales tracks closely with the different research areas. National policy impacting climate and reduction in nutrient depositions is clolsely aligned with ACE. State policies regarding nutrient criteria closely aligns with SSWR, and decisions made at local scales directly impact the communities that rely on individual water bodies for recreation or drinking water and feeds directly in SHC. Authors: Jeff Hollister, Hal Walker, Bryan Milstead,

Research Theme	Science Objectives	Science Questions	Research Outputs	Research Outcomes	Comments
Developing decision support tools, models, data, and metrics that support multiple and future SHC projects	Communities rate the cost of transportation as one of their top concerns. Alternative fuels such as biofuels are one way to meet growing energy demands while providing much needed job growth and economic stimulus in rural communities. Current policy analyses are incomplete regarding full accounting of the costs and benefits of nitrogen budget (fate, transport, process) changes in response to policy directed biofuels production and consumption (i.e., life cycle analysis) across multiple media, multiple scales, human health, ecosystem health and services and social and economic consequences.	What are the key aspects of the nitrogen cascade that are impacted by biofuels production and consumption, and how are these aspects directly or indirectly linked to human health (e.g., respiratory disease, cardiovascular disease, asthma, allergic response, nitrate in drinking water, disease vectors, harmful algal blooms, etc), ecosystem services (e.g., clean air, clean water, food and fiber production, climate regulation), economic well being and overall local and regional community sustainability.	Develop a more complete life-cycle accounting that explicitly includes indirect as well as direct costs and benefits contributing to community sustainability of nitrogen cascade response to biofuels production and consumption.	Models and metrics that support the quantification and communication of human health effects and ecosystem health and services addressing identified gaps in current biofuels life-cycle analysis at the regional and local community scale.	From Ellen Cooter - I told the group I would submit something dealing with biofuels. As you can see from my big science question, I think it is a good cross-cut science question under the potential cross-ITR theme of Nitrogen. I have tried to phrase then end so it is specific to communities here. Let me know if I need to come up with one for FML. That is actually a little of a stretch because we really are focusing on larger area issues or at least watershed-scale as opposed to rural agricultural communities.

SUSTAINABLE AND HEALTHY COMMUNITIES RESEARCH FRAMEWORK SUMMARY TABLE

Theme 2: Developing decision support tools, models, data, and metrics that support multiple and future SHC projects

Topic A. Developing Decision Support Platforms and Models That Integrate Critical Community Health, Environmental, Economic, and Social Contributors to the Decision Process

Subtopic - Restoration toolbox - Specific options available to communities for N removal. This is an example

Theme	Problem	Science Questions	Research Objectives
	Floodplains, wetlands and riparian zones are hotspots of physical and biogeochemical activity that disproporionately influence ecosystem services and are often identified as critical zones for restoration and management (e.g. riparian buffers, floodwater bypasses, and critical habitat). The critical and influential nature of these land-water interfaces has resulted in billions of dollars of restoration taking place in communities throughout the country to satisfy various regulatory and non-regulatory requirements. This includes consent decries, single environmental stressor mitigation efforts (e.g. sediment, temperature, nutrient, other pollutant or TMDL requirements), aesthetic considerations, single species habitat protection, safety (e.g. flood control and unsafe dam removal), and recreation, many of which fall under several different statutory authorities of the EPA. These restoration activities are minimally studied or evaluated for success of the primary objective and few if any are evaluated from an integrated systems perspective.	When restoration is implemented in the aquatic-terrestrial interface how does system hysteresis alter the expectations and metrics of succes. How should managers and practitioners of restoration expect scale to affect their outcomes and what is the appropriate resolution to evaluate and predict restoration outocmes. How can qualities of disproportionality be used to enhance return on restoration investment, in essence what gives the manager the most bang for the buck?. In systems where individual restoration activities have effects that are small or highly variable be evaluated from a population or distribution of activities to better understand the overal impacts of restoration on an ecosystem? Are there better ways to inform, understand, and plan for uncertainty in various restoration approaches with respect to outcomes. Can we evaluate cutting edge restoration methods to provide better information to restoration decision makers and practitioners. Can the problems of widespread nitrogen accumulation be mitigated through restoration at the aquatic-terrestrial interface? Are there unforseen water quality effects like treatment byproducts degrade drinking water when organic carbon and other naturally occurring compounds increase following restoration. How does large river floodplain restoration affect ecosystem services? How does legacy sediment or urban stream restoration affect ecosystem services?	Objectives should include guidance in the form of Reports and other material used by communities, decision makers, and practitioners on aquatic-terrestrial interface restoration. This guidance shall include perspectives on groundwater, surface water, nutrient, and be inclusive of an ecosystem services perspective.

Outputs	Outcome	Comments	
Outputs will include core competencies and experts within the agency at the ORD and regional levels to assist with technical transfer and interpretation surface water, groundwater, and terrestrial restoration. Outputs will include holistic and specifistic models that guide sustainable natural restoration of aquatic-terrestrial interface habitats. Tools for communities and decision makers to evaluate the consequences of restoration decisions a priori as well as aid them in the evaluation of restoration success. New decision tools to help communities determine likelihood of success and provide insight to possible road blocks to success. Outputs will include tools and research that help communities with floodplain and stream restoration decisions and monitoring. Outputs will include a systems based understanding of nitrogen cycling in aquatic-terrestrial interface habitats like floodplains and riparian zones.	Using an adaptive and iterative evaluation of restoration strategy ORD will develop the ability to determine whether restoration practice X will have the desired effect on factor Y as well as identify the unintended and collateral effects of the restoration practice; sufficient evidence to inform environmental policies on adoption of alternative restoration approaches; sufficient evidence to inform regulatory permitters, municipalities, and citizens of the related restoration effects to environmental health and ecosystem services of interest, ability to estimate how restoration change will affect compliance with mitigative requirements and standards of expectiations for water quality, ability to reduce/prevent unforseen ecosytem threats under various restoration scenarios	Research for this area originated in the ESRP and will continue through SHRC, SSWR, and ACE. Cross cutting groups that are central to this work are Nitrogen, Green Infrastructure, and Ecosystem Restoration. Author Ken Forshay	