Environmental Education and Research Working Group Report

To Establish an Environmental Education and Research Institute

EERI@WUSTL

April 2006

Washington University in St. Louis

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Washington University in St. Louis

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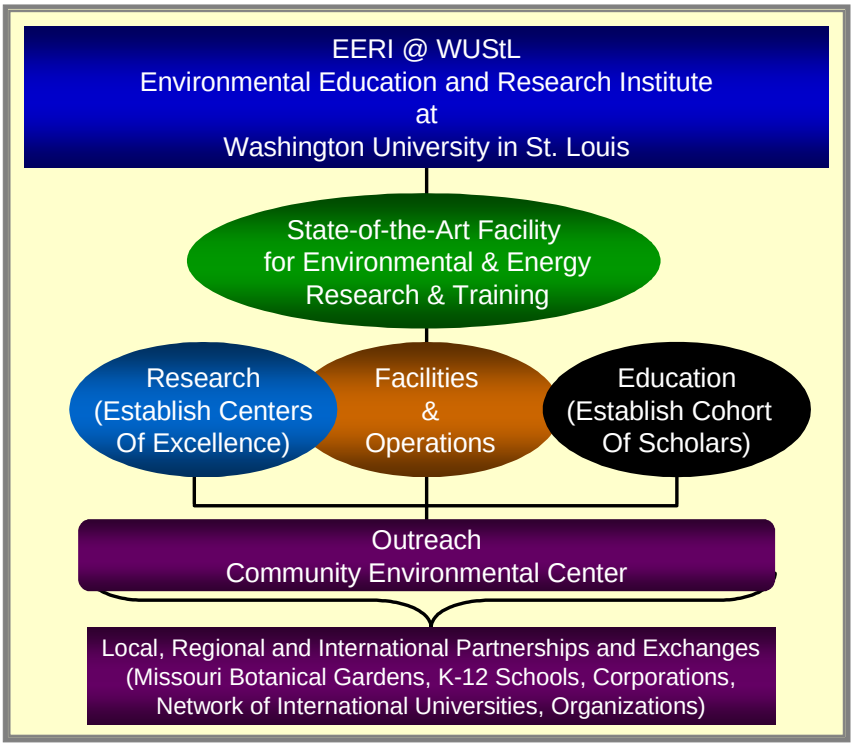
Section 1
EXECUTIVE SUMMARY

The Sesquicentennial Environmental Initiative brought in a set of distinguished invited speakers to the campus in 2003-04, and an objective was to learn the efforts of leading scientists and universities in environmental related activities. The Environmental Education and Research Working Group (EERWG) was formed and tasked by the chancellor in summer 2005 to discuss and develop a plan for future activities related to the environment at Washington University in St. Louis. EERWG consisted of 17 faculty members and staff across various schools and units of the University.

The vision is to establish Washington University in St. Louis (WUSTL) as a node for activities related to energy and environment by creating a world-renowned Institute. Creating partnerships with organizations such as the Missouri Botanical Garden, St. Louis Science Center, Academy of Science of St. Louis, corporations and other organizations—the goal is to make St. Louis a hub for environmental research, education, innovation and action. Washington University in St. Louis will educate the next generation of world leaders of the environment.

The mission of the Institute will be achieved by activities in: **Education, Research, Facilities and Operations, and Outreach.** The uniqueness is in the holistic approach that will be undertaken related to the environment, with interactions and transfer of knowledge across the four areas. The goals would be to build on existing strengths at WUSTL to create and enhance the intellectual opportunities for undergraduate, graduate, post-doctoral fellows, and faculty in areas related to energy and the environment. The focal point of the Institute would be a state-of-the-art research building that will bring together faculty and students to promote interdisciplinary activities, and allow for



partnerships to be created for the demonstration of newer environmental, energy generation, and conservation technologies.

We propose the creation of five centers of excellence in research: **Sustainable River Systems, Aerosols and Air Quality, Energy, Sustainable Ecosystems, and Environmental Health.** Along with independent research that is performed within each center, each of these areas will have overlap with the others that will increase their impact. Several of the current faculty members have expertise and interest in promoting collaborative research in each of these areas of research that have regional and global importance. With seed funds and appropriate organization, these areas would not only mushroom into self-sufficient centers, but also provide significant leadership in the worldwide community. While independent research would be performed at these centers, there would synergistic activities in law, policy, economics, and ethics through existing departments and centers of excellence at the University, thus providing for a holistic study of the scientific and technical issues. There will be significant interactions related to education, facilities and operations, and outreach activities. Finally, the creation of an administrative framework will allow for other groups of faculty researchers to propose and develop new focal areas of research in the future.

The proposed activities in education will enhance the University's undergraduate and graduate centers for learning in energy and the environment. Novel curricular changes are proposed at the undergraduate level. A mechanism to create a cohort of scholars at the graduate and post-graduate level will enhance WUSTL's position in environment-related education. These scholars will work in interdisciplinary teams—aided by multiple mentors from different disciplines, and working in a physical facility that houses a diverse group of environmental researchers and educators, and practitioners responsible for day to day operations.

The Institute will be a world leader by developing a renowned sustainability program related to its facilities and operations. The synergy with education and the centers for research will allow for transfer of cutting-edge "know-how" related to operations, for example, in energy usage and conservation in buildings. The new state-of-the-art building will be a beacon for the WUSTL campus and other university campuses in the demonstration of sustainability. Communication tools will be developed that track and articulate our efforts at enhancing and improving sustainability of all campus operations.

Outreach will be an integral component that will build a network of partners for the Institute among industry, educators, universities and other organizations, the media, and regional partners, including the Missouri Botanical Garden and St. Louis Science Center. This will be facilitated by an enhanced Community Environmental Center (CEC). Outreach activities would facilitate the dissemination of research results to these partners, and bring the ideas and needs for environmentally related research to WUSTL. Workshops will be conducted to generate white papers on important subjects and to lay the national and international agenda for activities in specific areas. An international network of universities, corporate partners and other agencies will also be created to examine focal areas related to energy and the environment.

An important outreach activity of the Institute would be to award a "*WUSTL Environmental Innovation Prize"* to recognize excellent stewardship related to the environment. This prize, the equivalent of an environmental Nobel Prize, would be presented to a researcher, educator, corporation, or agency for pioneering efforts that have made a

significant impact on improving the environment.

The report also presents an administrative structure that will facilitate the implementation of the proposed plan. It is recommended that an administrator reporting directly to the chancellor coordinate all efforts related to the environment at WUSTL. This senior administrator would work with other administrators, center directors, faculty, and staff to make the vision a reality. Resources needed to achieve the proposed vision of making Washington University and Saint Louis a world-renowned hub for environmental activities include $68 million in seed funds over the next five years. Approximately $100 million in endowment support would be required to sustain the proposed environmental Institute. After five years, it is anticipated that the Institute will have 50 affiliated faculty and staff members, 150 undergraduate students, 50 graduate students, and 20 post-doctoral fellows. Along with research and outreach activities, additional resources would be generated for supporting its operation. Careful planning and prioritization will have to be done to develop an implementation plan.

Environmental Education and Research Working Group
EERWG Members

Jan Amend

Bruce Backus

Pratim Biswas, Chair

Jonathan Chase

Bradley Evanoff

Steven Givens

T.R. Kidder

Maxine Lipeles

Jonathan Losos

William Lowry

Peter MacKeith

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Henry Schwartz

Thomas Simmoms

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Section 2
INTRODUCTION AND PREAMBLE

A committee was formed in 2003 to prepare and plan a series of seminars related to the environment during the sesquicentennial year. A goal was to evaluate the key areas of research related to the environment *vis a vis* strengths of WUSTL and to learn what some of the other leading universities were doing in this area. A list of seminar and colloquium speakers is provided in Appendix A. The series of talks brought together faculty from a variety of disciplines and helped promote interdisciplinary discussions at WUSTL. The success of the seminar series provided sufficient impetus that a University-wide effort related to the environment should be undertaken. It was quite apparent that there was significant synergy among the various schools on campus that have faculty working in areas related to energy and the environment. To this effect, Chancellor Mark Wrighton formed the current Environmental Education and Research Working Group (EERWG) to develop a plan related to environmental education, research, facilities and operations, and outreach. The overall goal was to develop a roadmap for environment-related activities at the University. The objective was to propose recommendations that would build on our current strengths, result in unique activities, and position WUSTL as a global leader in the arena of environmental education, research, and operations.

The list of members of the working group is provided in Appendix G. The committee was chaired by Dr. Pratim Biswas, the Stifel and Quinette Jens Professor of Environmental Engineering Science. As the areas to be covered were vast, the group decided to break into three subgroups to facilitate discussion and development of a plan. The Education Subgroup was coordinated by Dr. Jan Amend, Earth and Planetary Sciences; the Research Subgroup was coordinated by Dr. Pratim Biswas, Environmental Engineering Science Program; and the Facilities and Operation Subgroup was coordinated by Mr. Bruce Backus, director, Environmental Health and Safety. The subgroups met independently to develop plans, which were then followed by working group meetings to discuss the findings of each of the subgroups. The deliberations took place from September 2005 to April 2006.

This report is organized into sections, with the first describing the mission of the proposed Institute, followed by detailed plans for education, research, facilities and operations, and outreach. A structure is proposed for an environmental institute to implement the proposed plans. This is followed by a summary of resource needs and potential partners in the proposed efforts.

The working group is of the opinion that WUSTL is uniquely positioned to be a global leader in activities related to energy and the environment by building on its existing strengths. It is important, however, that the proposed plan be implemented as early as possible to build on the synergies that have been created and to use the momentum generated to guide us on a path to becoming a world leader in this arena.

Section 3
VISION AND GOALS

The vision is to establish Washington University in St. Louis (WUSTL) as a node for activities related to energy and environment by creating a world-renowned Institute. Creating partnerships with organizations such as the Missouri Botanical Garden, St. Louis Science Center, Academy of Science of St. Louis, corporations, and other organizations—the goal is to make St. Louis a hub for environmental research, education, innovation, and action. Washington University in St. Louis will educate the next generation of world leaders of the environment.

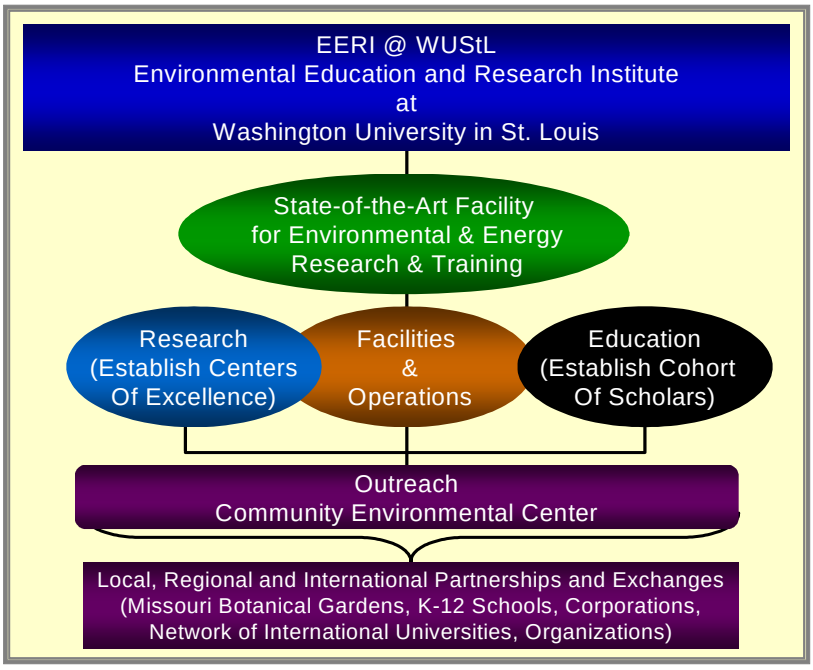
The Environmental Education and Research Institute (EERI @ WUSTL) will be created and consist of a group of scholars and administrators to conduct educational, research, and operational activities related to the environment. The goals of the Institute are:

1. To build on the existing strengths and capitalize on the synergy of activities related to the environment at WUSTL.
2. To enhance the intellectual and research opportunities for undergraduate, graduate, and post-doctoral fellows related to energy and the environment.
3. To promote interdisciplinary programs in energy and the environment involving faculty from a multitude of disciplines and the various schools at the University.
4. To facilitate such activities by having a state-of-the-art building to conduct interdisciplinary environmental research; this landmark building would demonstrate newer technologies and energy conservation and have a benign environmental footprint. The facility would be used to help create bridges between disciplines and promote collaborative work among faculty members.
5. To use the state-of-the-art facility as a model for the entire campus in terms of sustainable facilities. To work towards making sustainability a fundamental aspect and the very fiber of all University operations.
6. To become a global leader in selected areas of research, education, and operations related to the environment.
7. To create a network of partners involving industry, universities, and other outreach partners such as Missouri Botanical Garden, corporations, and other organizations to address global environmental issues that impact the world.
8. To provide leadership and coordination via EERI @ WUSTL to establish St. Louis as a world-renowned hub for activities related to the environment.

Section 4
PROPOSED PLANS

The overall structure of the Institute is illustrated in the figure below. The anchor for the Institute is a centralized facility that will house all researchers and educators and be the nerve center for facilities and operational activities related to energy and the environment. The proposed plans are presented in four sections:

1. Education,
2. Research,
3. Facilities and Operations, and
4. Outreach.



Though the plans are presented sequentially, there is significant overlap among the four areas, and this synergy will be tapped to make the efforts at WUSTL unique. Each section starts with a proposed vision, followed by a description that outlines the current status and proposed recommendations, followed by resource needs.

4.1 Education

4.1.1 Vision

Washington University has highly acclaimed programs in environmental studies at the undergraduate level and environmental engineering at the graduate level. We propose several innovative ideas that will, if implemented, build on existing strengths and greatly improve the University's position as a more complete center for learning. In addition to outlining novel programs, we also highlight several of the University's current commitments to environmental studies education that should be protected and/or enhanced. We argue that a leading university must demonstrate excellence starting with the undergraduate curriculum, through graduate programs, post-doctoral researchers, and visiting scholars, and culminating with the various levels of teaching and research faculty and administrators. In line with this view, our report is divided into two main parts: the undergraduate curriculum and post-baccalaureate programs. We conclude with a list of resource needs and specific recommendations.

4.1.2 Undergraduate Programs

The undergraduate Environmental Studies Program (EnSt) in the School of Arts & Sciences and the undergraduate endeavors in the School of Engineering & Applied Science and the College of Architecture are strong and offer a well-knit set of classes (see Appendix B). EnSt arose about 10 years ago out of a grass-roots effort by students and faculty. The numbers of majors has been steady at 60-90 (80 as of 3/2/06), with students following one of several specific tracks depending on their interests in the social or natural sciences. EnSt now counts 36 participating faculty members from anthropology, architecture, biology, chemistry, earth and planetary sciences, economics, environmental engineering, law, philosophy, physics, and political science. The Environmental Engineering Science Program, an interdisciplinary program with faculty from the Departments of Civil, Chemical, and Mechanical and Aerospace Engineering, offers an undergraduate minor. We recommend that these programs be strengthened by developing 1) topical freshman-level courses for non-majors, 2) upper-level courses for majors on specific environmental issues, 3) a track in the engineering sciences, and 4) courses with extensive field and laboratory components.

100-Level Courses for Non-Majors: High school students in the United States have far more opportunities to learn the fundamentals of biology, chemistry, physics, social studies, and history than they do the basics of environmental science. Consequently, many students who would be interested in environmental studies are unaware of opportunities at WUSTL and similar institutions. To remedy this situation and to broaden the educational platform, freshmen arriving at the University should be exposed to the diverse and exciting field of environmental studies. The current curriculum in Arts & Sciences offers very few 100-level courses on environmental topics. We propose that these broad, lecture-style courses be complemented with a set of comprehensive topical courses, each focusing on a specific issue from several different points of view. As examples, a team-taught course on global warming might cover aspects of geology, atmospheric chemistry, biology, and economics; a course on population might include lessons from evolution, anthropology, ecology, and mathematical modeling. These offerings would be inherently flexible to respond to changes in issues, student interests, and faculty expertise.

Upper-Level Courses for Majors: Most courses on environmental issues are under the direction of the departments or programs other than EnSt or environmental engineering. To advance undergraduate studies in environmental majors and minors, required courses must be developed specifically for these students and by our EnSt faculty, it is no longer sufficient to rely on courses designed in other departments and effectively borrowed by EnSt. The undergraduate curriculum would benefit from innovative 200 to 400, team-taught courses on interdisciplinary and frequently rotating topics. These courses may be integrated with the new 100-level courses mentioned above. To permit flexibility and quick response to changing interests, the courses must be under the direction of EnSt and generally taught by faculty with a specified teaching load in EnSt. The curriculum of the environmental engineering minor is in a different situation; the minor is composed of courses that are primarily elements of the curriculum of the three contributing engineering departments, and students can pursue the minor through the selection of their electives for their major degree.

Engineering Science Track: Preliminary discussions have been under way to include a set of courses that would be available to students to obtain a track in engineering science, similar to the natural sciences and social science tracks. The Environmental

Engineering Science Program offers a minor (Appendix B) that is available to students in both arts & sciences and engineering. It is proposed that a series of classes be offered that allow a student in EnSt to follow an engineering science track. This will promote cross-disciplinary interactions and allow students in both engineering and arts & sciences to take advantage of several class offerings related to the environment.

Field and Lab Courses: How can students study the environment without going outside—and by extension, without going into the lab? Currently, EnSt majors receive a predominantly classroom education, with no field or lab requirements and few appropriate opportunities. Environmental engineering offers a laboratory course and several of the courses in the minor contain substantial laboratory components; however, the enrollment of undergraduates in the laboratory-focused courses should be increased. In contrast, most chemistry, biology, and physics students have laboratory requirements, and geoscience students generally enroll in a 4 to 6 week summer field camp. A shortage of environmental field-based and lab-based courses currently prevents us from requiring this component in our curriculum. This situation must be remedied. Indeed, field-trip opportunities abound in the greater St. Louis area (*e.g.*, Tyson Research Center, Missouri Botanical Garden, confluence of three great rivers, lead smelters in southeast Missouri), and a number of our new and remodeled buildings offer exceptional lab classrooms (*e.g.*, Lab Sciences Building, Earth and Planetary Sciences Building). The incorporation of laboratory and field components into the curriculum should be accomplished by (1) developing new laboratory and field courses and (2) creating laboratory sections and field trips for existing lecture-based courses. Field/lab courses offer experiential, hands-on learning; they demonstrate the complexities of natural systems; and they can bridge the gap between classroom education and original research. Undergraduate students could become immersed in hands-on educational activities such as an energy club guided by a faculty member that exercises the creation and implementation of current energy technology. Such interdisciplinary clubs would make continual progress from senior design projects and help from interested students of all years (modeled after the areospace club, Project Aria). A benefit to a student hands-on club is that it educates young students about environmental related issues, which needs significant improvement on campus.

The College of Architecture can offer the use of design studios to study campus design employing sustainable principles of design; using designs for the research center itself, a "model" of sustainable design; using design seminars and lectures to engage national practitioners and students from across the campus in discussions of sustainable issues; and using architecture's contacts to develop a short list of architects and an invited competition for the design of the research institute.

4.1.3 Post-Baccalaureate Programs

The School of Arts & Sciences has no graduate program in environmental studies, but the School of Engineering offers both master's and doctorate degrees through its Environmental Engineering Science Program (see Appendix C). The Environmental Engineering Science Program currently has 35 doctoral students, who participate in cutting-edge environmental engineering science research. There are also several research groups that are spread across campus and housed in many different buildings, departments, and schools. Here, we lay out a plan to bridge the gap between strong undergraduate environmental programs and the successful

undergraduate—but dispersed—research programs of several dozen faculty members in arts & sciences, engineering, architecture, and medicine. We propose, as an initial and immediate step, the development of graduate fellowships, post-doctoral fellowships, and opportunities for visiting scholars. Clearly, the objective is to foster the existing research programs in areas related to the environment and to build on the strengths of the existing doctoral programs in environmental engineering science.

Graduate Fellows (Donor-named); As many as 10 full-time graduate fellowships should be awarded annually in the broad area of environmental studies. These are envisioned to be along the lines of McDonnell and Danforth graduate scholars already in existence at WUSTL. Each year, all participating graduate and professional programs could nominate up to three of their incoming graduate students for these prestigious fellowships, with recipients to be selected by a faculty committee. The awardees would receive an internationally competitive financial support package that includes full tuition for study, an annual 12-month living stipend, travel allowance, and where appropriate and necessary, substantial funds for research expenses. The selection process would favor those applicants with an interest in conducting graduate research that crosses departmental and disciplinary boundaries, and awardees would be required to have a secondary advisor in a different department from his/her primary advisor. This group of graduate fellows (spanning multiple years) would form a cohort that would convene monthly to participate in a "master class" led by current faculty, affiliated post-doctoral fellows, and visiting scholars. These master classes will promote the frequent exchange of ideas and findings among environmental scholars on campus, strengthen the feeling of camaraderie and community among the scholars, and provide a forum for public outreach and national and international visibility for WUSTL. Mentoring will also be an important component of this program. The graduate fellows will mentor undergraduate environmental students and will themselves be mentored by a faculty advisor and by post-doctoral fellows or visiting scholars (perhaps along the lines of the "ambassadors" in the McDonnell Academy).

Post-Doctoral Fellows (Donor-named): Successful research programs rely not only on quality graduate students, but quality post-doctoral fellows. We propose that about five post-doctoral positions (2 to 3 years in length) be advertised and awarded annually. A committee will select the awardees from an international pool of applicants. The post-doctoral fellows will receive a competitive financial support and resource package, including 12-month salary, travel allowance, discretionary funds for research expenses, and office and lab space. It is desirable that these post-doctoral fellows be financially independent but intellectually connected to one or more research groups and to the greater community of environmental students and scholars at WUSTL. Their role in master classes and as mentors of graduate student fellows was noted above. In addition, these post-docs would deliver annual presentations on their research findings, perhaps in a symposium with the graduate fellows and visiting scholars.

Visiting Scholars (Donor named): Attracting internationally renowned, visiting scholars would be a very visible and effective demonstration that WUSTL's education and research programs in environmental studies are growing in stature. In addition to the more traditional faculty visitors (*e.g.*, sabbaticals), we also envision that public servants, policy makers, lobbyists, writers, journalists, industrialists, and corporate executives might

take residence on our campus for 6 to 12 month stays. These visitors would a) be tremendous assets to our students in building networks beyond academia, b) link the often disconnected arenas of academia, business, and government, c) provide real-world input to our research programs, and d) serve as a means for high-level public outreach.

4.1.4 Resource Needs

Launching these new initiatives and ensuring their successes in the short and long term requires a considerable commitment of new and reallocated funds. While the needs for dedicated space in a new building for environmental-related activities are discussed in detail elsewhere (section 5.4), the educational components would benefit from a new space for conducting laboratory courses, providing a central location for high-impact courses and activities (e.g., the master classes) on the environment. Here, we focus on ways to implement the development of new courses and summarize the funds needed to offer the various opportunities for environmental scholars.

Designing new courses requires time. Interested faculty should be released from their required teaching loads for a full semester for every new course developed. Faculty must then be able to substitute these new courses for a course in their home department easily and without repercussions. This will, of course, place greater strain on home departments. Lab and field courses, in particular, require time to develop, perhaps twice as long as a typical classroom offering. Reconnaissance of appropriate field sites is essential, dry runs of exercises have to be carried out, and lab experiments have to be tested and retested. Additional support for teaching staff would be particularly helpful for developing new laboratory and field-based courses. Ideally, a full-time staff position of environmental studies laboratory coordinator would be created; additional resources should also be made available for graduate teaching assistantships for these new courses.

Scholarships and visitors' stipends should be supported by a generous endowment. Prestigious graduate fellowships (per student, per year) require a tuition waver plus approximately $25K for a stipend, $1-2K for travel to conferences and field sites, and $2-5K for research expenses. In addition to office and lab space, post-doctoral fellowships require (per person, per year) $35-45K for a stipend, $2-5K for travel to conferences, field sites, and other laboratories, and $5-20K for general research funds to be spent on analyses, technical support, minor equipment, and related costs. Funds required for visitors are likely to vary widely, depending on the particular field of the scholar, their stature, their role while at WUSTL, and their length of stay.

4.1.5 Summary of Recommendations

1. Strengthen the undergraduate offerings at WUSTL and strengthen laboratory and field classes.
2. Promote graduate education by creating a cohort of scholars consisting of 10 doctoral students and five post-doctoral fellows.
3. Have a new building that is home for several of the proposed educational initiatives.

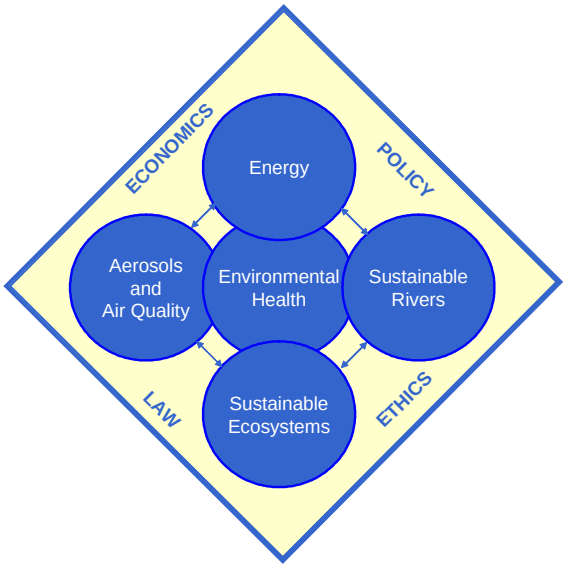
4.2 Research

4.2.1 Vision

The goal is to build on the strengths of the existing programs and promote synergistic developments in energy and environmental programs across campus so that WUSTL becomes a global leader in the selected areas of research.

The figure outlines a set of interrelated areas with significant existing strengths at WUSTL: **Sustainable River Systems,**

Aerosols and Air Quality, Energy, Sustainable Ecosystems and Environmental Health. In addition, there are common elements of Ethics, Economics, Law, Policy and Geospatial Information Science and Technology that will be cross cutting themes for the five research centers. Existing centers of excellence such as the Center for Ethics and Human Values and the Environmental Law Clinic will be active partners in the efforts. Geospatial information science and technology contributes methods and tools for finding,



accessing, integrating, analyzing and presenting environmental data. Included are geographic information systems (GIS), global position systems (GPS), satellite remote sensing, spatio-temporal data analysis, and web geospatial information systems. Geospatial science and technologies have application across the EERI Centers, and WUSTL's expertise in these areas would be most effectively used as a shared, common resource. WUSTL is currently considering a campus-wide geospatial initiative. Coordination among the EERI and the geospatial effort will be complementary and will strengthen the University's capabilities in both areas.

The five Centers are proposed as initial focal areas to build synergy and promote interdisciplinary efforts. To allow newer areas to be developed, and to phase out areas that have met their goals, a framework will be developed. Groups of faculty can propose new areas of research that can be fostered by the Institute.

4.2.2 Center for Sustainable River Systems

River systems, including watersheds and surface and ground waters, are an integral part of the universal hydrologic cycle. Humans have become part of this cycle, both in our need for water and our effects on the quality and distribution of water. Increasingly, humans are influencing the global hydrological cycle. Human populations have grown exponentially from the beginning of time to reach a billion persons in 1800 A.D., and within the last 200 years increased to 6.5 billion, with projections to nearly 12 billion in the next 100 years. Clean water for drinking, agriculture, and industry is a critical resource that is increasingly endangered. Recent natural and human-created disasters, including tsunamis, earthquakes, hurricanes, industrial accidents, and aquifer depletion, demonstrate the vulnerability of water resources. Humans cannot continue to exist in our present state without becoming more in harmony with our environment—developing sustainable river systems is an integral and critical element of promoting a better future for people throughout the world.

Washington University in St. Louis, located within the Mississippi River watershed, at the confluence of some of the world's largest rivers, has an opportunity to use its many talents to help develop a holistic interdisciplinary approach toward the development of sustainable river systems. Covering about 3.2 million km^2 the Mississippi River watershed is the third largest in the world.

Every human living within this basin, indeed everyone in the United States, is affected by the environmental, historical, economic, and political events that take place here. One only has to look at the financial, political, and human dimensions of the 1993 flood to see how broad the effects are. More recently, Hurricane Katrina and its aftermath amply demonstrate the consequences of environmental impacts on human and nonhuman populations alike. From economic losses associated with interrupted shipping to significant damage to fish stocks in the Mississippi River delta and estuary, environmental and ecological problems in the Mississippi and its tributaries affect our entire economy, society, and culture. Indeed, rivers are the lifeblood of most societies. Events in China, for example, where 100 tons of benzene were released into a tributary of the Amur River, demonstrate the direct effects of environmental issues on humans living along rivers or in their watersheds. As demonstrated by this most recent environmental catastrophe, environmental effects on river systems do not respect national boundaries and the consequences affect people from headwaters to the mouth and in nearby bays, estuaries, and coasts.

With its research and educational leadership in medicine, engineering, and the arts and sciences, WUSTL can, campus-wide, provide resources to integrate medicine, anthropology, earth sciences, engineering, business, economic, political science, and law to create a unique research and educational experience for its students and be an asset for the community. Focusing on environmental and ecological issues associated with promoting sustainable river systems is a logical opportunity for WUSTL. Our location near the confluence of two of America's greatest rivers provides an ideal context for studying rivers as interrelated ecosystems and allows researchers from multiple fields and disciplines an opportunity to come together to share ideas and to create solutions for many of the problems that face the world's populations.

Many of the issues facing populations living within river watersheds will require interdisciplinary analysis if they are to be effectively studied. For example, while major progress has been made on many river systems in the United States, 33 years after the passage of the Clean Water Act, many rivers, including the Missouri and Mississippi, are still not fishable or swimmable. On a global basis, rivers and river systems are under increasing threat. Washington University scholars are already leading research in areas related to sustainable river systems. Work in the School of Engineering is exploring the effects of land-use changes on lakes as well as natural biogeochemical processes within river systems. Recent research by J. Chase on disease vectors among birds identifies river system habitat issues as an important contributor to increased disease spread. Habitat loss or alteration within watersheds is specifically related to geological and geomorphic issues studied by Criss et al. in EPSc; their findings play a direct role in policy studies of how recent floodplain construction is negatively affecting downstream habitats as well as threatening greater flooding in the future. These issues directly and indirectly play into the ongoing contentious disputes about the spring rise on the Missouri and how water rights are shared among the states along this river. The Interdisciplinary Environmental Clinic is part of a national collaborative of advocacy groups and legal and technical support organizations working collectively to improve water quality in the Mississippi River. Clearly, the issues are interrelated and require a holistic approach if they are to be understood beyond the confines of specific disciplines or even specific governmental agencies and advocacy groups.

Key issues:

- *Water quality.* This theme permeates virtually all other concerns and relates directly to the issue of developing sustainable river systems. Water quality encompasses problems such as health effects of water contamination, how water supplies are polluted (point vs. non-point sources), how we treat, distribute, use, and reuse water, how different organisms respond to water-quality issues, who is responsible for and who pays for potable water, and how we remediate affected river systems, to name only a few of the major problems.
- *Floodplain development/habitat impact.* At home and throughout the world, humans are increasingly populating and altering floodplains and floodplain habitats. What are the ecological and environmental effects and how can they be mitigated; what are the economic and political processes and consequences?
- *Human alteration of rivers* (e.g., levee construction, dams and locks, cutoffs, habitat loss, wetlands reclamation/restoration). What happens when you levee a river or alter its course? How does development affect river and watershed habitats? What are the best policies for encouraging habitat preservation? What are the real economic and political costs and benefits of engineered river facilities?
- *Ecosystem biology.* Rivers and watersheds are not well understood as a connected ecosystem. Basic research on ecosystem biology is required to better understand at micro- and macro-levels the effects of altering watersheds and rivers.
- *Health and ecosystem effects of water contamination.* Human-introduced fertilizers, herbicides, and insecticides (even caffeine and drug metabolites) are being transported within local watersheds and are entering the water supplies of downstream consumers. Urban runoff and sewer overflows are increasingly common problems within river systems. How can we control regulated and unregulated discharge of pollutants from point and non-point sources? What is the fate of emerging contaminants (e.g., pharmaceuticals) in natural systems and in water and wastewater treatment plants? What policies and regulations can be implemented to minimize system-wide impacts, and how can these policies be effectively and economically implemented?
- *Effects of watershed clearing* (e.g., sediment transport, pollution transport, mobilization of heavy metals, urban runoff, sewage discharge). What happens when watersheds are cleared of trees, intensively farmed, or covered with asphalt? How does this affect river water quality, groundwater recharge, and geological/geomorphic thresholds? What are the impacts on the overall nutrient cycle or on the movement of sediments or pollutants? How do these issues affect downstream populations?
- *Industrial/residential pollution and their environmental impact* (air, water, groundwater, health effects, law, policy). As populations grow, how do we understand and cope with increasing human waste, greater pollution, development, noise, health impacts, increased density, and delivery of social/governmental services?
- *Drinking water issues,* distribution networks, new treatment technologies, terrorism, and homeland security.
- *Sustainable watershed development.* Is it possible to attain a sustainable level of land/water use? What would be required and how could it be implemented? What are the economic and business costs and opportunities? What are social costs and

benefits of alternative land-use initiatives (e.g., greenways, bike paths, less dense housing, brownfield reclamation)?

Interactions: Because watershed/river issues are place-based, they touch on or can be incorporated into many other environmental research issues. There is obviously a great deal of overlap with health-related issues. Furthermore, watershed/river systems are potential contexts for exploring and studying ecology and biodiversity. Because of the human dimension of watershed/river systems, they are also obvious locations for some studies of energy development/sustainable use and aerosols. For example, there are important issues surrounding the use of river water for the production of energy. This concern is evident in the use of hydroelectric facilities, but it also encompasses problems such as water intake for cooling power plants and subsequent thermal pollution when warm water is discharged. Another example is river system contamination by mercury—the largest source of which is anthropogenic combustion of coal. An example of the coupling of air quality/aerosol issues and water quality is the gasoline additive MTBE. This product was added to gasoline to address an air-quality issue but ended up impacting groundwater quality across the country. Similarly, the contribution of NO_x (e.g., from automobile exhaust, power plants) as a source of nutrients to surface waters in some parts of the United States is an area where there is overlap between those interested in air quality and river systems. Watersheds/rivers are also important contexts for understanding, developing, and implementing laws, regulations, and policies that integrate environmental issues with those related to economic, political, and social/cultural factors.

Scholarship at the center will also integrate with existing WUSTL entities, such as the program in nanotechnology, the McDonnell Scholars Academy, the program in International and Area Studies, the Center for Urban Research and Policy, the Center for Ethics and Human Values, The Center for Materials Innovation, the Gephardt Institute, and the Weidenbaum Center.

WUSTL Strengths:

- *Location at the confluence of Missouri and Mississippi.* In addition, Tyson Research Center is situated near the Meramec River, one of the largest undammed rivers in the upper Mississippi River watershed. Our unique location provides faculty and students ready access to research and teaching opportunities.
- *Existing campus facilities.* The Medical School, Danforth Campus, and Tyson Research Center represent distinctive locations where faculty and students can conduct experiments in different physical settings.
- Existing/ongoing research and teaching in engineering, arts & sciences, architecture, and law
- Interaction with advocacy groups/governments/industry
- Solid research infrastructure and multiple opportunities for outreach and interaction with existing academic/research/governmental/policy entities.

Key Players: EPSc (Amend, Criss, J. Smith); Anthropology (Kelly, Kidder, Stone); Architecture (Wolff, Hoal); History (Kastor); AmCS (Fields); Biology (Chase, Knight); Political Science (Lowry); Philosophy (Palmer, Evans); Law (Lipeles); Engineering (Wrenn, Buescher, Schwartz, Giammar, Angenent, Falke, Biswas, EPRI); Economics (Peterson, Pollard).

Areas that need further development:

- Cutting-edge teaching opportunities in areas related to sustainable river systems development. Initial focus would be on existing courses but should expand to

include new courses, especially interdisciplinary, team-taught courses that incorporate scholarship from different schools and colleges.
- More ecosystem scientists/ecologists
- Resources for geospatial information systems (GIS) for research and teaching
- Integration of research among engineering and science disciplines; inclusion of economics and business
- Development/expansion of Tyson as a research facility
- Strong outreach to local, regional, national, and international governments, communities, and interested parties. Expanded efforts to work with local businesses and activist groups
- Coordinated and focused efforts to better communicate WUSTL research findings through improved interaction with media. Educate media personnel on Sustainable River issues
- Development and promotion of intellectual and research interaction among and between faculty, researchers, graduate students, undergraduate students, and members of the community
- Financial (seed money) and academic incentives to foster interdisciplinary scholarship
- Creation of a coordinated research infrastructure for environmental analyses housed, ideally, in a central facility. The objective of this facility would be to better coordinate the use of analytical equipment, to provide improved facilities to house existing equipment, and to present opportunities for acquisition of new equipment (e.g., LC-MS and GC-MS, state-of-the-art sedimentation lab).

Funding opportunities: We expect that the members of the center would be able to pursue a variety of funding opportunities from international, federal, state, local, and private sources. The most obvious possibilities are federal funds from entities such as National Science Foundation, Environmental Protection Agency, and Corps of Engineers. It is also likely we could pursue funds from U.S. Geological Survey, U.S. Fish and Wildlife Service, Natural Resources Conservation Service, Department of Energy, and Department of Defense. State funds could be pursued from Departments of Environmental Protection/Conservation (or similarly functioning state-level organizations). Local funds may be available from counties and municipalities. These funds may be more readily obtained if the center embarks on policy and implementation research and even consultation. Private funds may be available from corporations (e.g., Peabody Coal, American Water, etc.). Corporate funds are likely to be limited to very specific research interests. We may be able to tap into public/private entities such as ORSANCO (Ohio River Valley Water Sanitation Commission) as well as privately funded advocacy groups. International funds may be available through entities such as the UN Environment Programme, World Health Organization, World Wildlife Fund, etc.

Summary: The Center for Sustainable River Systems Research is distinctive because there is no such comprehensive entity in the United States or elsewhere. Many academic institutions have interests in water resources, but none are built around an interdisciplinary conceptualization of rivers as systems integrating atmospheric, surface, and ground water. The center will be positioned to undertake research in any location around the globe and to explore issues without regard to conventional disciplinary boundaries. By focusing on sustainable river systems research, center researchers can engage in scholarship at all levels, from the micro to the macro and from ground water to surface water. The topic can be engaged by researchers in engineering,

sciences, humanities, and social sciences, and can encompass basic research as well as applied policy. By capitalizing on our location at the confluence of two of the world's great rivers and by leveraging our outstanding faculty and building on our existing strength, we have an opportunity to be a global leader in sustainable river research and the development and implementation of effective science and policies that will benefit the huge numbers of humans that are sustained by rivers and their water.

The center is also distinctive because it will provide a unique opportunity to integrate academic research with undergraduate and graduate education. By using our location as a classroom and by specifically developing our physical facilities as research and teaching locations for studies of sustainable river systems, we can position ourselves at the cutting edge of university teaching and research. Students at WUSTL will be able to take their education out of the classroom and apply it in the field. By providing practical and exciting research opportunities, we will make our students better scholars, decision makers, and leaders.

4.2.3 Center for Aerosols and Air Quality

Washington University has had a tradition of research in the area of aerosols and air quality since the 1960s (Macias, White, Husar), and this remains an area of topical priority for the St. Louis region. With the rebirth of the Environmental Engineering Science Program in 2000, additional faculty (Biswas, Chen, Falke) were hired to complement the efforts of the existing faculty (Husar, Axelbaum, Turner). With interactions with colleagues in the School of Medicine (Evanoff, Stanley) and in the School of Law (Lipeles), there is significant strength in this area. Aerosol issues are of importance in the environment in outer space, as exploration will take humans to build colonies on distant planets and terrestrial bodies (Stadermann, Chen, Biswas).

Aerosol science and engineering is now referred to as an enabling science and has application in a number of areas in addition to the environment. Progress in many technical areas of importance to government and industry depends on aerosol science and technology which, for this reason, it is now referred to as *an enabling technology*. An important theme is the demand for ever faster acquisition of size distribution and particle chemical composition data. Another is dealing with aggregates, the natural state of very small solid particles. We are still wrestling with the question "where does the atmospheric aerosol come from?" (Turner) This question is of central importance to our daily life, industrial development, and climate change. Also of significance is the role of aerosol science and technology to the field of nanotechnology. Nanoparticle aerosol science and technology is the backbone for nanotechnology, as it allows for the synthesis of nanomaterials with tailored sizes and compositions (Axelbaum, Biswas, Chen). There are many applications of nanomaterials—and a new discipline of environmental nanotechnology is mushrooming. This allows the use of these materials to minimize environmental damage and to develop new technologies (such as energy technologies) that are benign. The use of catalysts is another example, and WUSTL is a partner in the Center for Environmentally Beneficial Catalysis, an NSF-funded Engineering Research Center (Dudukovic, associate director). At the same time, prior to wide-scale adoption of nanotechnology, one must ensure that it is a benign technology. Research is ongoing at understanding the fundamental biological effects of nanoparticles, which will allow understanding the negative impacts (to human health) and the

design of processes for delivery of drugs to treat diseases (Biswas, Chen, Lanza, Stanley, Wickline). WUSTL researchers (Sureshkumar, Khomami) have expertise in flow modeling and additives rheology that can contribute to studying phase behavior of lung surfactants (phoshplipids) and nanoparticles at fluid-fluid interfaces. Bioaerosol research is underway to evaluate capture and inactivation technologies (Biswas, Angenent).

Aerosol-related problems have attracted talented scientists of many backgrounds (various Nobel laureates CTR Wilson, Einstein, Millikan, and recently Richard Smalley). Much of modern aerosol science and technology is based on the work of scientists who did not consider themselves aerosol specialists or experts. This has now changed—and aerosol scientists are contributing in a very big way. It is anticipated that aerosol scientists are going to play a major role in the advancement of science in many disciplines, specifically those related to air quality, energy, and other important environmental issues facing us today.

Key Issues:

- *Atmospheric air quality.* There is evidence that fine particles in the atmosphere may have enhanced deleterious health effects. Studies need to continue to unravel the source of the ultrafine particles, and understand their health impacts.
- *Indoor air quality.* Individuals spend significant portions of their time indoors. Furthermore, with homeland security issues, protecting indoor air quality is of prime importance, especially in sensitive buildings and public places (malls, transportation systems). Residential, office, and occupational environments are of interest. Work has to proceed on real-time detection and control.
- *Combustion systems.* Energy needs will be supplied by combustion processes for the next 30 years. These processes have to be environmentally benign to ensure minimal impact on the environment. Technology has to be used to the fullest extent to control the release of pollutants.
- *Global climatology.* The role of aerosols in global climate issues is significant, and a better understanding has to be developed to eventually control climate change that is being observed.
- *Global air quality issues.* Measurements provided by satellites are providing large data sets that need to be understood to elucidate global air quality impacts. Satellite data need to be harvested and integrated with ground-based station data to make them more robust and useful.
- *Analysis of air quality data* over various spatial and temporal scales will also help improve our understanding of causal factors and their impact. The use of geospatial information sciences and technology, including GIS-based approaches, should enhance our ability to better share and interpret the data; models can be used to better explain trends.
- *Web information systems*. Web technologies are revolutionizing the way air quality data are shared and how government agencies, universities, and industry collaborate in collecting, analyzing, and applying environmental information.
- *Near real time analysis* as measurement instrumentation and information technology advance, near real time assessment of the state of the environmental are becoming feasible. Research and development are needed to support real-time air quality analysis and modeling systems for applications such as homeland security.
- *Particle control technology.* More developments are needed to protect individuals in workplaces, homes, and the outdoors. As space exploration proceeds, novel methods need to be developed for

protection of pioneers who reach out to conquer space.

- *Nanoparticle aerosol science and technology*—a mushrooming area that can contribute to advancement of basic science (understanding the unique properties of materials at the nanoscale), applications in medicine (nanomedicine), environmental remediation, and control. Understanding of fundamental phenomena such as nucleation in a variety of systems is critical to many disciplines.
- *Particle Instrumentation.* Developments in instrumentation are critical to make advances in all the above areas. Instruments need to be miniaturized for personal sampling and made robust enough for use in industrial processes.

Interactions: The Center for Aerosols and Air Quality will have members from the Schools of Engineering, Arts & Sciences, Law, and Medicine. While some of these ties are already in place, more collaborative efforts need to be promoted with the School of Business and the social sciences. The centers to be established will promote these collaborations. Overlap with the Center for Energy is manyfold—and the synergy developed could lead to significant improvements. Global climate issues and the hydrologic cycle, and transfer of pollutants from the atmosphere to water bodies (such as mercury) have a direct tie to the Center for Sustainable Rivers. Linkages to the Center for Environmental Health are several-fold—with both ambient air quality and indoor air quality studies.

WUSTL Strengths: This has been elucidated in the introductory statements. The School of Engineering & Applied Sciences has a world-renowned aerosol program in place. There are 20 graduate students working with four faculty members in the Environmental Engineering Science Program. Significant strengths are in understanding particle formation and growth, instrumentation and measurement, ambient air quality, satellite mapping, and geospatial analysis. Ties to researchers with expertise in the biological and medical sciences is strong—toxicologists at the University of Rochester, and University of Cincinnati; epidemiologists at Saint Louis University, and the University of Cincinnati, and Harvard University; and medical scientists at WUSTL and elsewhere. There is a strong relationship with corporate partners, national laboratories, and international partners—thus providing a network of players.

Key Players: Engineering (Angenent, Axelbaum, Biswas, Chen, Dudukovic, Husar, Falke, Khomami, Sureshkumar, Turner), EPSc (Arvidson, Fegley), Medicine (Evanoff, Lanza, Stanley, Sweet, Wickline), Arts & Sciences (Bender, Castro, Macias, Smith, Stadermann), Architecture (Donnelly), and Law (Lipeles).

Areas that need further development:

- Researchers in the areas of global climatology and atmospheric sciences.
- Improved interactions with colleagues in the biological sciences—especially at WUSTL, to tap the synergies that are present.
- Coordinated efforts in this field with experimental and computational researchers to take the group to the next level.
- Organize Workshop to set National Agenda—invite individuals from Federal Agencies (NSF, DOE, EPA, DOD, NIH, others) and other universities.
- Hire faculty in selected areas—global climate, atmospheric sciences, computational modeling, pulmonary aerobiology.
- Improve outreach efforts, both in education and partnership with the St. Louis Science Center and other centers.
- Create and promote a network of corporate and international university partners.

Funding opportunities: There is significant funding already in place. This is an area of

research that has many programs at the national level and will grow in the next few years. There is also interest in corporate sectors and foundations—which needs to be tapped.

Summary: The elements for the Center for Aerosols and Air Quality are in place at WUSTL. The significant potential should be realized by further promoting research and educational developments.

4.2.4 Center for Energy Research

Energy-related issues are becoming increasingly vital in the 21st century for numerous reasons. It is an obvious fact that the rate of production of fossil fuels occurs at a rate (geological time scales) much slower than the rate at which we consume energy (rate of consumption to further increase with the developing economies). While demand for energy increases, traditional fossil fuel sources (oil and coal and natural gas) are becoming more difficult to develop, are more expensive, and may not meet the demands in the future. An important aspect is the impact of energy production on the environment. Controversies and disputes regarding extraction and use of these fossil fuels are intensifying. Alternative ways of meeting energy needs, usually with renewable sources such as wind and solar, are being proposed, but these proposals rarely come with thorough interdisciplinary review and systematic study. A center for the study of energy at WUSTL would have many attributes that could foster timely ideas and compelling analyses as the world transitions to new energy systems. This report provides some brief examples of those attributes in the contexts of immediate challenges, intermediate solutions, and future possibilities and then discusses education and outreach potential.

Key Issues: Energy issues span several time scales: from the present, to a period of transition, and eventually to the future. For the present and immediate future (transition period), the world will necessarily continue to rely on fossil fuels. The consequences of such reliance, especially air pollution and global warming, are well-known, but WUSTL researchers are already working on projects that can minimize and mitigate damaging effects. Consider the following examples. Environmental engineers (Axelbaum, Biswas, Giammar, and others) are working on nanoparticles and other innovative technologies to pursue carbon dioxide mitigation and the reduction of pollutants. A group of researchers in physics, chemistry, biology, and engineering (Kelton, Gelb, Biswas, Angenent, Agarwal, Al-Dahhan) are involved in research related to alternate energy generation, usage, and application. Scientists in earth and planetary sciences (Arvidson, Smith) have produced computer simulations of climate-related activity on this and other planets. Other scholars (such as Smith and Stone in anthropology) are doing research that could contribute to conservation efforts in agriculture and other energy-usage areas. The Environmental Clinic (Lipeles and Martin) has pursued several cases that involve energy-related impacts and consequences. Some of these current programs, notably the clinic, already use the interdisciplinary synergy available at this University to address these issues, but a center would greatly facilitate such collaborations in the future.

Washington University personnel are already working on programs that could provide intermediate solutions to energy needs over the next several decades. Some in environmental engineering (Biswas, Holten, Khomami) are researching the possible use of alternate energy sources such as photo splitting of water to produce hydrogen using nanomaterials and solar energy. Other Arts & Sciences faculty (Kelton, Gelb) are researching methods for storage of hydrogen in novel materials. Scholars who study river systems (Criss in earth and planetary sciences, Kidder in anthropology, and Lowry in political

science) can offer expertise on issues related to the continuing interest in greater use of hydropower. Social scientists also have a role to play in better understanding of the scenarios of energy generation and usage: Will we be moving away from a centralized generation scheme to a more distributed method in the future? Current work on waste-to-energy conversion (Angenent) and direct conversion of solar energy (Holten, Biswas, Pakrasi) provide the technological backing for such studies. Scientists in physics (Carlsson and Dickhoff) are working on other innovative approaches to energy. Many people in facilities (Barry, Thaman, Rackers) are planning to make buildings less energy intensive. Again, these intermediate efforts to reduce dependence on fossil fuels will require collaboration for realistic analyses. For example, consider the renewed interest in developing nuclear power. Any study that does not address economic and political factors as well as scientific, technological, and safety issues involving this approach will be incomplete. A center for studying energy would foster such interdisciplinary cooperation.

The greatest need for systematic, interdisciplinary work involves long-term future solutions to energy demands. Are renewable sources the answer? Scholars will need to study patterns of generation and distribution, technological barriers to hydrogen production, storage, and usage. Can solar-based systems, such as the photo splitting of water, overcome storage and distribution problems? Some WUSTL researchers are already addressing these questions, but compelling answers will need long-term, cross-discipline cooperation and review.

As the preceding paragraphs suggest, the potential for high-quality work in this field is very high at this University. A center for the study of energy would not only nurture that potential but would generate significant educational and outreach possibilities.

Interactions: The study of energy issues has clearly ties to the centers that will study aerosols and air quality, rivers, health, and ecosystems. One of the direct impacts of energy production sources is on air and water quality. The issues of public health are related both directly and indirectly.

In terms of education, several departments (Earth and Planetary Sciences, Economics, Environmental Engineering, Mechanical Engineering, and Political Science) already offer courses that include energy issues. However, those courses remain within the jurisdiction of individual departments, and rarely if ever focus solely on energy. For instance, Lowry's course on environmental issues devotes only three weeks to energy and climate change. This is a major gap in the curriculum. Several years ago, Professor Wysession of Earth and Planetary Science (EPSC) attempted to develop a course that would provide an interdisciplinary introduction to energy issues. He tried to recruit faculty from other disciplines to contribute but ultimately concluded that, without greater institutional support, the complications and difficulties of engaging and compensating other participants to teach such a course were too much to overcome. A center could provide the institutional resources needed for such classes. Graduate students studying energy issues could form committees of different disciplines that would then offer unique perspectives on the same subject matter. At the current time, dissertations rarely utilize perspectives from other disciplines that are so crucial for understanding complex issues such as those involving energy demand and supply.

Significant interactions with facilities and operations are expected. The proposed new building will be a test bed for new technologies. Furthermore, an energy audit system will be displayed—for this building, and the entire campus—that will serve as an "educational awareness" tool, and suggest ways for

improvement. The facility will provide for interaction with commercial partners and scale-up of innovations related to the energy sector.

The outreach potential for such a center is high. Potential collaborators include the other centers proposed in a possible environmental institute as well as for entities outside the university. As the preceding discussion hints, a center on energy would have natural ties to centers on aerosols and air quality (impacts of fossil fuels), rivers (hydropower), health (consequences of different energy sources), and ecosystems (extraction of fuels). Beyond the campus, collaborations are possible with current energy providers (for example, Lowry has worked with people at AmerenUE on hydropower issues), intermediate sources (Biswas and others in Environmental Engineering are already working with developers of other energy sources), and even start-up companies pursuing new technologies. Finally, nonprofit groups interested in environmental and energy issues are eager to welcome participation by the university in their endeavors. At the 2004 Earth Day symposium in St. Louis, Lowry presented a paper suggesting that WUSTL was considering a greater role in environmental and energy issues (with an emphasis on rivers and waterways). The various environmental groups and state and local agencies in attendance were extremely receptive and supportive.

Key Players: Engineering (Agarwal, Al-Dahhan, Angenent, Axelbaum, Biswas, Ehrhard, Giammar, Gleaves, Khomami, Sureshkumar), Arts & Sciences (Arvidson, Bender, Carlsson, Dickhoff, Gelb, Holten, Kelton, Lowry, Pakrasi, Smith, Smith, Wysession), Facilities (Backus, Barry, Rackers, Simons, Thaman), and Law (Lipeles, Martin).

Areas that need further development: A coordinated study of energy-related problems needs to happen. After a group is established, certain focal areas have to be identified and pursued. Seed monies to support such activities that make a holistic impact will have to be provided to further the growth of this center.

Funding opportunities: Washington University researchers have significant funding already in the study of energy-related problems (see Appendix F). A consortium of energy companies in the region could be created to support some of the activities. For example, a consortium of AmerenUE, Peabody, Arch Coal, and others could be formed to support study of existing energy sources. Other industry foundations such as those of Shell, Exxon Mobil, BP, and others could be tapped for support. Federal Government Agencies such as DOE, EPA, USDA, and NSF have made energy a priority issue and one of the topical areas.

Summary: A center for the study of energy would be a valuable addition to Washington University. It would build on, and facilitate cooperation between, existing strengths on campus. It would foster programs and efforts and that could fill existing gaps in curriculum and student training. Finally, such a center would directly involve the University in efforts, both on and off campus, to address these increasingly important issues in coming years. Due to the breadth of involvement of researchers, and an impact on facilities and operations on campus, aspects of energy generation and usage will be addressed over a variety of time scales: from the recent (to ensure that current fossil fuels are environmentally benign), to the transition technologies, and to the renewable alternates for the future.

4.2.5 Center for Sustainable Ecosystems

March 2005 marked the conclusion of the Millennium Ecosystem Assessment (http://www.millenniumassessment.org/en/about.overview.aspx) sponsored by the United

Nations to assess the health of the Earth's ecosystems in terms of biodiversity, services provided to humans, and future sustainability and restoration. Over 1,400 scientists from 95 countries around the world contributed to this program. The results from this program provide a somber overview of the size of the human footprint on the earth. However, for scientists and educators, it also provides a "call to arms" to provide new insights and innovative solutions to curb these effects, and to train the next generation of educators and scientists in this increasingly important issue.

Key Issues: Human activities are continually degrading natural ecosystems. These activities include land development for housing and agriculture, energy and materials extraction, harvesting of plants and animals, and alteration of biogeochemical cycles and climate change. At the same time, these very ecosystems provide a wide variety of "services" to humankind, ranging from psychological and aesthetic to food (agriculture), sustainable energy (e.g., biofuels) and medicine products to control over important biogeochemical cycles (e.g., carbon, nitrogen) to direct human health benefits (reduction of pollutants, diluting emerging infectious diseases). Obviously, a balance must be reached. Humans need to continuously find ways to extract resources from the earth to sustain the burgeoning population and increase quality of life, but they need to do so in a more sustainable way.

Interactions: Sustainable ecosystems are at a nexus of issues and centers within EERI.
Health: Healthy ecosystems are often correlated with healthy environments in which humans live. However, the connection can be more direct. Research conducted at WUSTL and elsewhere shows a strong causal relationship between healthy ecosystems (biodiversity, ecosystem functioning) and infectious disease transmission.
Energy: Energy use directly affects ecosystems and biocomplexity through habitat destruction (e.g., fossil-fuel extraction, hydroelectric dam construction), pollution, and alteration of the C-cycle, and its consequent global climate consequences. Alternatively, sustainable ecosystems can generate energy through biofuel production and other mechanisms.
Rivers: Rivers provide a strong direct link with this center, as a "case study" of research on sustainable ecosystems.
Local institutions: Within the St. Louis area, there are strong linkages with Missouri Botanical Garden in research on the evolution and maintenance of biodiversity (director, Peter Raven, is a strong proponent for ecological research on biodiversity), the St. Louis Zoo (both locally and internationally based conservation research), the Danforth Plant Science Center (many collaborations on crop plant production), and the other local universities (SLU, UMSL). In addition to research connections, educational opportunities in sustainable ecosystems are essential for the program, and the WUSTL campus and Tyson Research Center provide urban and rural "test beds" for ways to intertwine humans with biodiversity.

WUSTL Strengths:

- *Generation and maintenance of biodiversity*. Researchers from biology (Chase, Knight, Larson, Losos, Olsen, Raven, Templeton, Schaal), anthropology (Rasmussen, Richard Smith, Sussman), earth and planetary sciences (Blank, Josh Smith) and the Medical School (Berg, Cheverud, Conroy, Phillips-Conroy, Gordon, Fay, Groisman) are world-renowned in the area of the creation of diversity through genetic/evolutionary processes as well as the maintenance of diversity through ecological processes. Research also focuses on the causes and consequences of changes in diversity to ecosystem functioning.

- *Biogeochemistry, climate reconstruction, and climate change*. Researchers from anthropology (Kidder), earth and planetary sciences (Amend, Arvidson, Blank, Jen Smith, Criss), and environmental engineering (Giammar) are active in understanding past climates and possible future climate scenarios and the role of microbes and pollutants in biogeochemical cycles.
- *Crop production and yield*. Research on crop production and yield aims towards understanding human relationships with crops, increasing yield to decrease economic and environmental costs (e.g., pesticide, more land destroyed). Researchers in biology are studying the mechanisms of creating transgenic plants (Ho, Quatrano) and in the underlying genes in crop domestication (Olsen, Schaal). In addition, WUSTL is a partner in the Danforth Center; where researchers who work on plant biology relevant to crop production are adjunct at WUSTL (e.g., Beachy, Nielson). Research in anthropology (Fritz, Stone) also considers crop production and human use of plants.
- *Human health and infectious diseases*. A wide variety of human ailments are directly a result of infectious diseases (bacterial or viral), and these diseases are intimately associated with the surrounding environment. Furthermore, some of the most important human diseases are zoonotic, requiring either animal reservoirs or vectors (e.g., malaria, avian flu, cholera, plague, ebola), and many others are derived from related animal diseases (e.g., HIV). Human alterations to ecosystems invariably alter the relationships between these reservoirs and vectors, and can lead to changes in the disease. Researchers in biology (Chase, Templeton, Thatch), anthropology (Stoner), and the medical school (Storch, Diamond, Fremont, MRCE) study emerging infectious diseases in this context.
- *A 'microcosm' for ecosystem sustainability studies*. Tyson Research Center, owned and operated by WUSTL, provides an excellent center for ecosystem sustainability studies. Research by biology (Chase, Knight, Losos, Schaal, Templeton) and earth and planetary sciences (Criss) already uses the site to study invasive species, rare species, biodiversity, and ecosystem functioning, emerging infectious diseases, and biogeochemical processes. However, an integrated research program that utilized the site more effectively could serve as a centerpiece for studies on ecosystem sustainability.
- *Strong linkages with other institutions, NGOs, and government agencies*. Washington University has strong research linkages with the St. Louis Zoo and Missouri Botanical Garden (several curators are adjunct at WUSTL). Strong conservation commitment of these organizations greatly complements our research, and biology faculty often collaborate with these groups (Knight, Olsen, Schaal, Templeton). In addition, Schaal and Templeton serve on the board of The Nature Conservancy's local chapter, Knight serves on the board of the Center for Plant Conservation, and Templeton works closely with the Missouri Department of Conservation.
- *Strong link between current research activities and outreach*. Washington University's science outreach program provides a very strong linkage between cutting-edge research and the general public, including ecosystem sustainability.

Key Players: Anthropology (Fritz, Kidder, Sussman) biology (Chase, Knight, Larson, Losos, Olsen, Templeton, Schaal) earth and planetary sciences (Amend, Criss, Jen Smith, Josh Smith) medicine (Cheverud, Gordon,

Phillips-Conroy) engineering (Giammar). Missouri Botanical Garden (Hoch, Raven, Richardson, Salick), and the Danforth Center (Jez).

Areas that need development:

- Environmental economics and putting monetary terms of ecosystem functions and sustainability in the short and long terms
- Linkages with the social and political sciences
- Landscape architecture, city planning, and the issue of "reconciliation ecology"—integrating social, economic, and ecological functions into a single ecosystem.
- Key faculty hires, including an endowed research chair for the center, ecosystem ecologists, environmental economists, ecological psychologists.

Funding Opportunities: In addition to traditional investigator driven funding from NSF, EPA, USDA, DOE, and NIH, there are several cross-cutting programs from which this center would seek money. NSF has several long-term research awards that research—in particular at Tyson Research Center—would compete for (e.g., LTER, NEON), as well as an undergraduate research program (Undergraduate Mentoring in Environmental Biology). In addition the EPA has established some new initiatives exploring interactions at the face of aquatic and terrestrial ecosystems for which this center could be strongly competitive. The Mellon and Packard Foundations often provide philanthropic contributions toward ecosystem science. Local companies such as Monsanto, Anheuser Busch, and Enterprise also often contribute to ecosystems science and conservation initiatives.

Summary: Washington University is poised to become a leader in sustainable ecosystems research and education. The Departments of Biology, Anthropology, and Earth and Planetary Science, and the School of Medicine have already established a research core on the generation and maintenance of biodiversity and the role of ecosystem processes. Furthermore, strong connections with Missouri Botanical Garden, the St. Louis Zoo, and the Danforth Center make St. Louis an ideal location to develop a center for excellence in this area. The University's Tyson Research Center will serve as a research and educational core of this group, and funding from a variety of private and public sources will make this center internationally recognized.

4.2.6 Center for Environmental Health Studies

Research efforts related to the environment should include the effects of the environment on human health. Research into human health effects can include a very broad range of measures of health and health outcomes, applicable to different environmental exposures or effects. Studies of disease and physiology are predominant among most environmental health programs. A broader conception of health will also encompass social and psychological factors.

The outcome of common concern to public health is the effect of the environment on the morbidity and mortality from diseases linked to environmental exposures. For example, mortality studies have linked air pollutants to increased rates of mortality from cardiovascular and pulmonary diseases; occupational cancer studies have linked environmental pollutants to and excess of cancer deaths. The occurrence of new cases of diseases, or the worsening of existing diseases, is also a concern. For example, air quality has been linked to increased hospitalizations for asthma among children. The critical disciplines to this type of study are epidemiology, occupational, and environ-

mental medicine, and disciplines able to quantify exposures, such as environmental engineering and environmental chemistry.

Closely linked to morbidity and mortality are studies of biomarkers or physiologic processes that result from exposure. Examples include DNA adducts, measures of bone or tooth lead, and measures of airway responsiveness following exposure to air pollutants. These markers are often detectable in people with no diagnosed disease, but are thought to predict future disease or to help understand the mechanisms of disease.

A broader view of health includes factors such as physical fitness or activity (affected by the design of streets and sidewalks), healthy diet (affected by the availability of healthy foods), and overall well-being. Income and educational disparities are often compounded by disparities in exposure to environmental pollutants and lack of access to safe physical activity or to affordable healthy foods. Broader views of health also encompass psychological health and social structures that directly affect or mediate other determinants of health.

Key issues:

- *Asthma.* The prevalence of this common disease continues to rise, particularly among African-Americans. Air pollution and indoor air quality (including mold and insects) are significant contributors to asthma in children; workplace exposures are a major contributor in young adults.
- *Lead exposure.* Pediatric lead exposure is a major concern in the urban core of St. Louis, as well as in surrounding areas (such as Herculaneum). This is a legacy of lead-based industries and of lead paint in our older housing stock.
- *Housing patterns and the effects of the environment on health behaviors.* The concentration of people in the urban core, as well as the sprawl around St. Louis, contributes to a number of health problems beyond air quality and lead exposure. The physical layout of housing and workplaces can either encourage or discourage exercise; ability to purchase healthy food nearby changes dietary habits; long commutes are stressful; etc. Existing research programs on health behaviors, diet, and exercise would aid this line of research.
- *Neurological disorders.* Chronic neurological disorders are receiving a great deal of attention now from NIEHS and other funding agencies. A research program in Parkinson's disease related to welding fume exposure is in early stages of development at the School of Medicine; the considerable strengths of the school in neuroscience could be an advantage here.
- *Cancer:* Occupational and environmental cancers are a major health concern. Though the School of Medicine has little ongoing research relevant to environmental cancers, the Siteman Cancer Center and the wealth of basic research in cancer mechanisms may be helpful here.
- *Emerging Infections.* Environmental changes promote the emergence of infections that affect humans and animals. Examples include the avian flu and the generation of antibiotic-resistant human pathogens through the use of antibiotics in livestock. The School of Medicine has significant strengths in infectious disease research; there are existing collaborations with the Danforth Campus faculty.

Interactions: Researchers in the School of Medicine are just beginning to collaborate with researchers on the Danforth Campus in the areas related to the environment. More synergies are to be realized, and establishment of the Institute will promote collaborative efforts. Environmental health has linkages to all the centers—aerosols and air quality (some work has been initiated already), rivers, ecosystems, and energy.

WUSTL Strengths:

- Very strong basic science research in many areas relevant to human health
- Access to large patient populations
- New emphasis on clinical research that could encompass environmental health (BioMed 21, proposed Division of Clinical Sciences)—these currently are planned but not actualized
- New pre-doctoral and post-doctoral training programs (K-12 and T-32) centered at the medical school offer the opportunity for non-clinicians to get training in clinical research (broadly defined).

*Key players:*WUSTL—Mario Schootman (geocoding and cancer epidemiology; health behavior research); Mario Castro (asthma research); Sam Klein (obesity, physical activity); Brad Evanoff (environmental medicine); Brad Racette (neurological disorders); Vicky Fraser (infectious diseases); Sam Stanley (emerging infections); Gary Weil (parasitic infections in developing nations); Maxine Lipeles (health policy and law); Bill Peck (health policy); Jay Turner (air pollutants); Pratim Biswas (air pollutants, nanoparticles); School of Social Work faculty. SLUSPH—Ross Brownson (physical environment and physical activity); David Sterling (lead exposure and remediation); Roger Lewis (occupational health); Mark Buller (infectious diseases).

Areas that need further development:

- *Public health.* Washington University is among the few universities with a top-ranked medical school but without a school of public health. Most schools of public health have a department of environmental health focused on research in this area.
- *Epidemiology.* Few researchers at WUSTL are studying the distribution and determinants of health in populations of people or animals.
- *Toxicology / biomarkers.* Though some existing research at the School of Medicine could be relevant to these areas, or shifts in emphasis encouraged by funding, these areas are quite underdeveloped.
- *Faculty visibility/ faculty recruiting.* Few faculty at the School of Medicine are visibly involved in environmental health related research; no faculty are primarily identified as doing research in environmental health.
- *Cooperative projects between theDanforth Campus and the School of Medicine.* Cooperative projects between WUSTL and the St. Louis University School of Public Health (SLUSPH). WUSTL could better realize complementary strengths between these different groups to encourage multidisciplinary research.

Funding Opportunities: With WUSTL's recognition in the medical sciences, we are ideally poised to grow in the area of environmental and public health. Significant funding can be readily attracted, and teams of researchers across the disciplines—medicine, engineering, business, law, and others are well-positioned to study important problems.

Summary: The center will bring together researchers in the field of environmental health. With seed funding and other resources, the potential of this field can be demonstrated, and justification for the eventual goal of having a school of public health can be provided.

4.3 Facilities and Operations

4.3.1 Vision

Washington University in St. Louis should be an environmental leader by developing a world-renowned sustainability program. Sustainability incorporates environmental stewardship objectives into all business and work decisions. It encompasses a broad range of environmental goals, from energy

conservation, building design, campus layout, people movement, and neighborhood integration, to policies and programs on recycling and purchasing, to day-to-day operations and the impact of those operations on the environment (see http://www.WUSTL.edu/university/ehs-mission-statement.html). A state-of-the-art facility that will house environmental educators and researchers should be the hallmark of the University campus in demonstration of sustainability and a beacon for other campus facilities worldwide.

4.3.2 Recommendations

Because sustainability is so broad, and because environmental goals for our institution may differ from another university's, due to geographic, social, political, and financial differences, specific operational and facilities management goals for each aspect of sustainability are not being recommended. Rather, a process and program to systematically prioritize and integrate sustainability goals into operations and facilities on an ongoing basis is proposed.

Sustainability experts from other university programs (in the area of operations and facilities) should be brought in to review WUSTL's current program(s) and provide us with guidance on how to improve or develop our sustainability program.

At the outset, at least two sustainability directors should be invited from other institutions to WUSTL to:

- Perform an external review of WUSTL's program, approximately one and one-half days in length, with final debrief and report.
- Share their insights on what is necessary for successful implementation of a sustainability program (what is needed for someone to successfully do their job at WUSTL).
- Provide a history of their own programs, mistakes made, and unique cultural impacts that may or may not be similar to WUSTL.
- Meet with critical people (for example, John Klein, Ed Macias, Barb Feiner, Alan Kuebler, Ralph Thaman, Walt Davis, etc.) to assess our program and culture, and to share insights with them on how to implement a sustainability program at WUSTL.
- Present findings to the EERWG and key leadership (chancellor).
- Present a lecture or workshop to environmental engineering and environmental studies students.

There will be natural overlaps with the education and research environmental initiatives, and to the extent possible, University facilities and operations should be used for education and/or research efforts. For example, alternative energy generation systems could be installed on new and existing University facilities, with environmental classes using on-site field trips and theory studied in the classroom to understand the principles of the various technologies. Graduate students, or new environmental research fellows, could develop and test cutting-edge energy generation systems installed in or on University facilities, as part of their thesis research work. An example is the installation of solar panels, a project initiated by a group of undergraduate students.

Washington University should recruit a leader for sustainability efforts and the sustainability program should be adequately funded.

Washington University should seriously consider recruiting a star sustainability director to lead WUSTL's program. The chancellor should use the day-long diversity retreat as a model for forwarding the sustainability initiative at WUSTL. (The recent day-long diversity retreat is an excellent model for forwarding the sustainability initiative at

WUSTL. It would pull together University Council members, key operational people necessary for the success of sustainability, and guest speakers. The retreat would educate leadership about sustainability and allow them to brainstorm on how to make it a success at WUSTL.)

In order for a sustainability program to be *sustainable* at WUSTL, it should be a separate administrative function established at a senior level. (Examples discussed ranged from special assistant to the chancellor, a vice chancellor-level position, or a director reporting to the proposed new environmental institute vice chancellor.) The program should be funded through the Central Finance Unit (CFU) and it should administer or control a loan fund sizeable enough to encourage cooperation and adoption of sustainable operations at Washington University (such as the program at Harvard University).

This recommendation does not end with the hiring of a sustainability director for WUSTL. This is a short-term first step. The program will need a budget. It will grow and will grow quickly. At a minimum, it will start with a director and a secretary.

Who this sustainability director reports to is important. It is critical that there be no conflict of interest in the reporting structure. To that end, the position should not report to operations or facilities. The head of the sustainability program will need to be a strong leader, adept in justifying sustainability initiatives in the face of potentially strong cynicism. However, the ability to administer funding for sustainability projects should build natural partnerships and support within the institution.

The sustainability director should work with appropriate administrative group(s) to define sustainability for the institution, catalog and measure current sustainability efforts, and, with facilities, operations, faculty, and student leaders, implement a sustainability program. The sustainability program should have measurable environmental improvement goals for the institution, including a continuous review cycle and establishment of new goals when existing goals are met. Sustainability education programs need to be developed and presented, along with defined responsibilities for all University personnel.

Sustainability programs and projects should receive input from students and student groups, faculty, staff, and administrators. The Committee on Environmental Quality brings together representatives from each of these groups and should be considered an important resource.

Sustainability projects should offer strong opportunities for teaching and research collaboration, and priority should be given to those sustainability projects which offer research and/or teaching opportunities. (For example, a natural tie-in may be the Olin School of Business students' investment of part of the University's endowment. Washington University could ask the business students to consider sustainability as part of the criteria by which they make their investments, asking them to research whether sustainability has any effect on the profitability of those investments. This would fulfill operational, education, and research missions.)

Sustainability will need to be woven into financial, business, capital planning, and master planning efforts, as well as day-to-day facilities and operations activities.

Sustainability will need to be integrated into operations and will require the input and buy-in of facilities and operations leaders.

Facilities and operations are critical to the success of a sustainability program at WUSTL. The executive vice chancellor for administration, associate vice chancellor for facilities planning and management, executive director of resources management (purchasing), medical school associate vice chancellor for administration and finance,

medical school assistant vice chancellor for facilities management department, and the assistant vice chancellor for environmental health and safety will need to work with the sustainability director to provide input and support in implementing sustainability programs and projects.

All capital planning projects and repair and renovation projects should add a sustainability review step (energy efficiency, recycling, waste minimization, green building, etc.) to their approval processes. The head of the sustainability program should have input in this process and possibly have limited veto authority for projects that do not meet predefined energy conservation, air quality, and recycling standards. Master plans for the campuses should also have a sustainability review phase.

(Of note, while there may be limited environmental benefits that can be gained by trying to retrofit an older, iconic structure like Brookings Hall with energy-efficient systems, or building a single new Leadership for Energy and Environmental Design (LEED)-certified green building on the Danforth Campus, the University is in the position to make a huge environmental impact if it incorporates sustainability planning into the many acres, buildings, roads, walkways, bike paths, commuter connections and green spaces it plans to develop in the future between the medical school campus and the Center for Resesarch, Technology and Entrepreneurial Exchange (CORTEX facility/ies.)

Existing environmental and sustainability programs need to be recognized and supported.

Energy conservation, recycling, and environmental protection programs are in place at the University and quietly have done well in many areas over the years with the resources provided. A sustainability program will help coordinate and promote the successes of these efforts. The institution needs to have a strong environmental compliance, environmental protection, and environmental stewardship program in place, in order to be able to speak with authority in this area; otherwise sustainability successes will be countered by adverse public reports about less-than-perfect management of hazardous materials. The institution needs to make environmental stewardship and compliance a priority. The University of Minnesota and Iowa State University spent $8.5 and $10.5 million, respectively, to purchase land and build facilities to house environmental health and safety staff, hazardous waste operations, and classrooms for environmental health and safety training. Environmental regulators now expect top-tier academic institutions to have top-tier, adequately-sized facilities to manage their various hazardous waste streams. Similarly, universities with high solid waste recycling rates devote entire buildings, and space within each classroom or laboratory building, for recycling containers, carts, sorting systems, etc. Policies about recycling, purchasing materials with recycled content, energy conservation, green buildings, and environmental compliance should be reviewed and, if needed, updated. The chancellor, executive vice chancellors, and deans need to constantly communicate that environmental stewardship, environmental compliance, and sustainability are top priorities for our institution, and they need to adequately support these ongoing programmatic efforts.

Communication tools need to be developed to help articulate and sell the importance of developing a sustainability program at WUSTL.

Funding should be provided for graduate students and an adjunct faculty member to update the information boards developed by the 2003 Sustainability Architecture class, and

to develop a 3-D computer model of an iconic University structure, such as Brookings Hall, to communicate sustainability concepts and the need for a sustainability program at WUSTL. It is estimated that this will cost approximately $16,000 and possibly could be funded through existing EERWG funds.

State-of-the-Art Facility to house environmental researchers and laboratories

A state-of-the-art, dedicated facility should house environmental researchers and their laboratories. Details are provided in Section 5.4. This facility will support all the four areas of activities related to education, research, outreach, and facilities. It would be a state-of-the-art demonstration of energy conservation and environmentally benign operations at the University. In addition, it will be a test bed for new developments, and a "role model" to promote environmental conservation principles. This building will become the centerpiece of the proposed efforts and promote collaborations among the various faculty members. Most of the individuals interested in environmental activities will be involved and associated with this building; thus, it becomes a centerpiece of the proposed efforts. The unique facility will also promote further activities and attract additional resources to further develop environmental research and education. The foyer of the building will have displays outlining progress made by WUSTL in operational activities—such as energy usage values from year to year and key indicators that illustrate our efforts at moving toward a sustainable campus. The developments and knowledge gained from the centralized facility will be a beacon to other campus facilities, and the perspectives of sustainability will be considered to be fundamental and integrated into the very fiber of the University.

4.4 Outreach

4.4.1 Vision

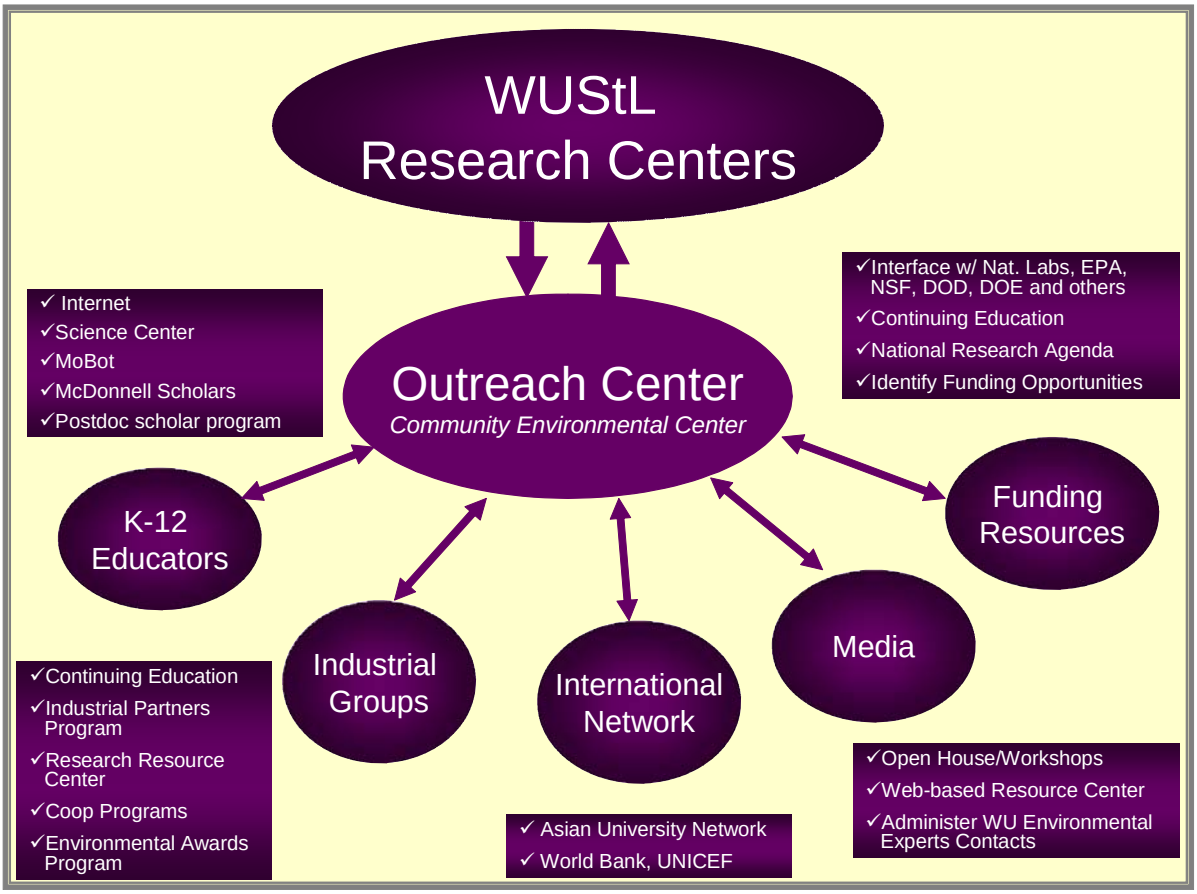
The goal of Institute outreach is to build a network of partners for the Institute among industry, educators, an international network of universities and other organizations, the media, and regional partners, including Missouri Botanical Garden, the Academy of Science of St. Louis, and St. Louis Science Center. Outreach activities would facilitate the dissemination of WUSTL research results to these partners, and bring the ideas and needs for environmentally related research to WUSTL.

4.4.2 Community Environmental Center

The function of outreach should be to inform the general public of new information, collaborate with other groups to commercialize the most promising techniques and technologies, and learn from the application of this and other research to better focus Institute-sponsored efforts. The outreach center will stimulate collaborative research between faculty groups, industry, and other partners.

This function will be fulfilled by enhancing an existing organization on campus, the Community Environmental Center (CEC). The CEC, on the WUSTL campus since 1993, has served as the collaborative focal point for a variety of research organizations and end users in the municipal water and wastewater and manufacturing industries. The CEC will be expanded to provide effective outreach to additional groups. The interactions and tools used are depicted graphically in the figure on the next page.

The Community Environmental Center can fulfill this crucial role by working with these groups to identify research topics and potential funding sources and guide the application of WUStL research results to real-world, environmental problems. Information will flow both from the specific research centers (in the form of research results) and to



the researchers to build interdisciplinary projects which meet the needs of the public and private sector and funding agencies. In this way, the outreach will be more dynamic than a repository of information; it will be used to develop collaborative, multidisciplined research projects. This mechanism will develop links to industry and other research institutions to help guide research and identify new and emerging areas of interest where WUSTL can be a major leader. By increasing the value of the research, the information can be better shared with other universities, research institutions and government agencies, leading to better recognition and, ultimately, enhanced financial support for the Institute.

<u>*Key issues:*</u>

- *Collaboration among Institute research centers.* The potential of each proposed research center within the Institute is enormous. However, many environmental problems faced by the world today require a wide array of disciplines. The CEC will assist individual research centers in building strong, multi-disciplined teams to pursue environmental research funding. Collaborative research among two or more of the research centers would make the Institute an extremely powerful and effective environmental organization.
- *Coordination of educational activities.* An environmentally literate populace is essential to success in the 21st century. Thus, outreach will focus on assisting local K-12 educators in educating future generations. Institute interactions with K-12 educators could take a variety of forms, from a real-time video linkage to the St. Louis Science Center, to integrating the proposed post-doctoral fellows program

into local high school environmental curricula, to sponsoring teacher training courses during the summer.

- *Outreach to Missouri Department of Transportation and Metro Link to understand transportation issues related to campus and the region.* The goal would be to promote car pooling, use of public transportation and work with governing bodies to enhance the quality of the environment.
- *Expansion of industrial programs.* Industries can be the biggest beneficiaries of environmental research, and often have a natural interest in environmental research agendas. The CEC can work with the engineering co-op program, The Career Center, and others to expand on current efforts to involve local industries through the Environmental Engineering Science Program and Engineering Industrial Partners Program. Members pay a small fee and receive regular updates on ongoing research and results, but they also give input into future research agendas. Further, these members often provide researchers with research opportunities and WUSTL graduates with challenging jobs. In this way, WUSTL's best and brightest have the opportunity to remain in the area and contribute to the community.
- *Interactions with the media.* The CEC will promote Institute activities through on-going press releases, maintenance of a web-based resource center, research center open houses, and similar activities. The CEC will work with local media to provide a list of experts from WUSTL available for contact when environmental issues arise. In addition, the CEC will work to establish a member of the media as a visiting professor to better advertise the Institute's activities and benefits.
- *Build international alliance of universities and agencies.* Much of the Institute's research will have applicability worldwide. Thus, a major focus of outreach will be to build liaisons with universities and international agencies, such as the World Bank and UNICEF.

WUSTL Community Environmental Center Strengths: Initially sponsored by Union Electric (now AmerenUE) and the Electric Power Research Institute, the center's collaborative nature gives it the flexibility to work with a variety of organizations. These include governmental and state agencies, private engineering firms, universities, and other private research groups.

The expertise within the Institute's research centers is very impressive; the CEC offers a ready-made way to launch outreach activities for this expertise.

4.4.3 The WUSTL Environmental Innovation Prize

To further enhance outreach and publicity for the programs under way at WUSTL, a major, international "WUSTL Environmental Innovation Prize" is proposed to be given in alternate years. This prize is envisioned as an environmental Nobel Prize. The prize, consisting of a plaque and a $250,000 award (income from an endowment), will be given to an individual, group, corporation, or organization that has made pioneering contributions to improving the quality of the environment. The award ceremony will include a day-long event on the WUSTL campus with a forum for researchers to showcase their activities.

4.4.4 Saint Louis – The Hub for Environmental Research, Education, Innovation, and Action

The goal is to help make St. Louis a hub for environmental activities, analogous to regions in California that house the Silicon Valley, or parts of the Northeast which are referred to as the "bio-belt." To assist in this, if the concept of the Institute is accepted, a

workshop will be held in fall 2006 to launch the efforts related to the environment. One activity that the group has interest in pursuing is that of eco-restoration, and in conjunction with Missouri Botanical Garden, the plan is to make St Louis a hub for ecorestoration activities. The other is the creation of a network of international universities to address environmental issues. The McDonnell Academy would be a significant partner in this endeavor. The Center for Ethics and Human Values has agreed to assist in the coordination and planning for such a workshop, along with other partner organizations and institutes.

Key Players: Ehrhard, Murphy, and other participants in EERI.

Areas that need further development:

- Development of a web-based clearinghouse of WUSTL Environmental Research, both ongoing and past
- Work with WUSTL researchers to learn about current and future research activities
- Work with student groups on environmental programs
- Strengthen Industrial Partners Program by increasing participation
- Develop Institute-sponsored continuing education program using resources of University (University College, Knight Center)
- Launch formal cooperative outreach agreements with the St. Louis Science Center, Academy of Science of St. Louis, Missouri Botanical Garden, Danforth Plant Science Center
- Launch annual Institute technical transfer conference
- Develop list of WUSTL expertise in various environmental areas for use by media outlets
- Develop formal network of international universities and agencies
- Use current Asian university network as basis
- Include World Bank, UN agencies, others where appropriate
- Develop a national environmental award program for exemplary performance by a business.

Funding opportunities: Outreach efforts would include identifying funding opportunities for the research centers. Presenting research results is essential to obtaining additional research funding, so outreach would focus on developing and promoting the Institute's results.

There are a number of promising funding opportunities. The research agendas from a variety of international organizations, including the World Bank, World Health Organization, and the UN Environment Program should be scrutinized to determine possible areas where Institute research teams can respond. Currently, federal funding is given to large, multi-disciplined research efforts that can come from the Institute from the National Science Foundation, the Department of Energy, National Labs, and the Department of Defense. In addition, the Environmental Protection Agency provides funds for a variety of environmental programs. On a regional level, the Industrial Partners program and a continuing education program are two promising funding opportunities. Several state energy agencies currently fund various energy and environmental initiatives.

Summary: The Community Environmental Center is poised to perform the outreach functions for EERI. The CEC staff is well-qualified to perform this function, with a keen understanding of University needs, environmental research issues, and industry requirements.

Section 5
PROPOSED STRUCTURE OF THE INSTITUTE

5.1 Vision

The working group envisions an Environmental Institute that leads and supports a world-class, cross-disciplinary effort in research, education, operations and outreach. Washington University will bring the world's top graduate students, post-doctoral candidates, and fellows to study at the institute. Faculty renowned in their fields, as well as new faculty showing great promise, will be recruited for the Institute. Existing, diverse environmental research, education, outreach and operation efforts will be centralized and supported to further push the excellence of their programs.

The purpose of this integration, and what makes this Institute unique from other benchmarked institutes, is the translation of University research efforts into educational, operational and outreach programs. The intent is to partner with community leaders, such as the Missouri Botanical Garden, St. Louis Science Center, Academy of Science of St. Louis, the Donald Danforth Plant Science Center, and industry, to use the University campuses and buildings as highly visible research and education field stations, and to develop practical solutions to environmental problems in developing and established economies around the world. In places like Madagascar, India, and South America, Washington University Olin School of Business, Environmental Engineering, Environmental Studies, and Social Studies, partnering with the Missouri Botanical Garden in their new reforestation initiative, could research and implement practical solutions that help revive deforested or contaminated environments while providing jobs for the local workforce. This research and outreach effort could then be expanded to China, sub-Saharan Africa, and other regions.

For developed urban and urban-sprawl regions, the University campuses, including Tyson Research Center, will be used for demonstration research and education efforts. Portions of green space will be test zones for sustainable and colorful, native plants that use less water, fertilizer, and pesticide than traditional flowering succulents and grass. Educational plaques, displays, and handouts will be used to explain to prospective students and their parents, the purpose and value gained from these research areas. Different buildings materials will be researched and used to educate students on the advantages and disadvantages of various environmental solutions, for example, solar-cell collection systems on roofs, versus reflective roofs, green roofs, and traditional roofing material. Alternative recycling and waste minimization strategies, that utilize experts from psychology, political science, business, law, and environmental studies, could be tested within the University system. Again, public displays noting industry and Institute support, could be used to educate the university community about these environmental initiatives.

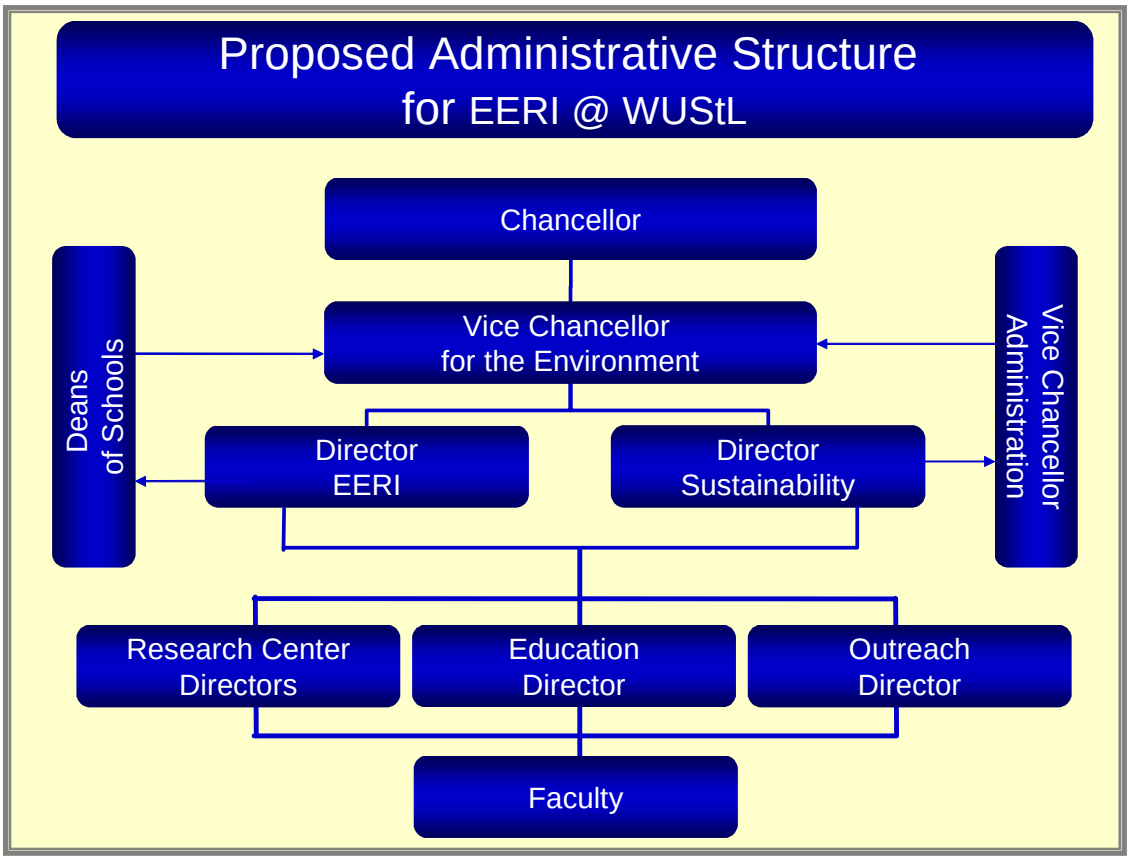
5.2 Recommendations

An Environmental Institute should be created at WUSTL. A vice chancellor-level position should lead the Institute. Environmental research, education, outreach, and

operations should be coordinated and overseen by the institute.

A state-of-the-art facility, from a green-building perspective, should be built to house environmental education and research activities for the Institute. To symbolize the importance of operations to this initiative, environmental health and safety administrative offices should be housed within the Institute to represent the overlap and integration of facilities and operations with research and teaching.

Two directors will lead the Institute. One will be responsible for the educational and research mission, whereas the other will be responsible for facilities and operations. Two directors are envisioned due to the extended responsibilities. They will report to the deans of the schools and work with the vice chancellor to ensure smooth functioning of the Institute. There will be research center directors and a director of education and an outreach program director, who will report to the Institute and sustainability director. The



5.3 Administrative Structure

The administrative structure is illustrated in the above figure. A vice chancellor for the environment will lead the effort at Washington University on campus. This individual will be responsible for overall leadership, and developing policies for the Institute that are consistent with the goals of the different schools.

faculty will work with these groups of leaders in the research activities. While each faculty member is tenured in a home department in a traditional school, their workloads will be decided by the Institute director. All overhead will be returned to the faculty's home department and school. The Institute will be supported initially by seed funds, and later by endowment income. The teaching income

generated by the environmental degree programs will be allocated to the Institute. What does an individual faculty member have to gain? First, they are in the Institute because of their interests in areas of activities related to the environment, and their work load and productivity will be measured in terms of their performance in areas of their interest by their peers. Second, the Institute will facilitate collaborations and allow individual faculty to work in teams to attract research funding. Third, funding will be available for students and post-doctoral fellows, along with seed monies from endowment funds. Departments and schools from which these faculty come would have more actively performing faculty, and receive all the overhead generated (additional due to their being more productive).

5.4 State-of-the-Art Facility

A common facility will bring together researchers who are involved in environmental research and education, and would promote and enhance cross-disciplinary activities. The state-of-the-art facility would be a test bed and demonstration site for new technologies that minimize environmental impacts on the environment and maximize energy conservation and healthy building parameters.

Facility Advantages:

- Provide state-of-the-art facility to conduct laboratory scale research related to the environment
- Promote sustainability of environmental related efforts at WUSTL
- Promote discussion and cross-disciplinary research between departments that do not typically work together, e.g. engineering with social science, etc.
- Test location for state-of-the-art energy usage and conservation (beyond what is required by Leadership in Energy and Environmental Design (LEED))
- Provides a system for demonstration of alternate energy, e.g., solar, wind, geothermal, and waste-to-energy conversion.

Facility Features: The state-of-the-art building will house the following:

- *Research Centers*: The Institute will initially focus on five research areas: rivers, energy, aerosols and air quality, environmental health, and sustainable ecosystems. These focus areas are dynamic and will change gradually over time. Because of the changing focus over time, laboratory areas should be flexible in their design. Many researchers will be willing to house their research laboratories in this building on a permanent basis—such as those from engineering, political science, and others.
- *Environmental Law Clinic:* The Law Clinic will occupy space in this building, and the presence of scientists, engineers, facilities staff working in close proximity will help in the functioning of the clinic.
- *Education:* Offices for staff to coordinate Bachelor of Science degrees in environmental studies, environmental engineering, and related studies should be housed in the Institute, as well as offices for environmental doctoral fellows, post-doctoral fellows, visiting scholars, and doctoral candidates from other departments who are doing their environmental thesis work in the Institute's laboratories. Conference, seminar, break, and lunch-room facilities will need to be included. An atrium area with environmental education displays, particularly as related to operations on the University campuses, will be a focal point for the facility.
- *Outreach:* Administrative and staff offices for kindergarten to 12th grade (K-12), media services, clearinghouse operations, industrial partnerships, Asian University Network, Missouri Botanical Garden, St.

Louis Science Center, Donald Danforth Plant Science Center, and industry outreach will be needed.

- *Operations:* Space is needed for approximately 15 environmental health and safety staff, including the assistant vice chancellor, as well as space for emergency response equipment and regulatory files. Space is needed for the proposed new sustainability director and support staff—assume three offices are initially needed, expanding to six offices within two years.
- *Administrative Offices / Staff and Students of the Institute:* The new Institute vice chancellor and all the directors will have their offices and laboratories in this building. In addition, staff and technicians will be housed in the facility, so that they are in close proximity to the nerve center of operations.

  Office space and networked computer work space, possibly wireless, is needed for all housed in the facility. "Hotel" office space, with computer networks, phone, fax, desks, and file storage, can be used for visiting scholars. The building, while open for most activities, will need appropriate security for research laboratories and areas with regulatory files.

Implementation: The campus has a blueprint for development, and it is proposed that the facility be in conjunction with one of the future buildings that is already in the campus master plan. For example, the School of Engineering has a region earmarked for their buildings, and there may be others such as biology that will also be feasible to house EERI.

The College of Architecture will take the lead in running an international competition for the design of this building. Key criteria will be the minimization of negative environmental impacts, co-use of energy sources, foyers with educational displays and real-time statistics of environmental footprints, and state of the art in energy and environmental conservation. For example, a part of the energy could be supplied by solar panels, wind turbines, or other sources; and there are commercial firms that may help retrofit these technologies. A similar demonstration with wastewater reuse systems or toilets that are energy efficient could also be used. In short, the building will be a demonstration of several novel technologies, and a test bed for development of ideas in conjunction with commercial partners.

Section 6
RESOURCE NEEDS

Resources will be needed to implement the vision and realize the goals of the proposed Institute. Seed funding of approximately $68.75 million will be required in the first five years. This includes about $50 million for the state-of-the-art facility that will be the centerpiece of EERI. Over these five years it is also proposed that a minimum endowment of $100 million will be created to sustain environmental related activities at WUSTL. Clearly, this will help attract significant amounts of external funding to the University. Current external sponsored research funding of some of the interested faculty members is on the order of $50 million for four years (see Appendix H). It is anticipated that this will increase to $75 million of sponsored research funding over four years, once the Institute, with its support structure and endowments, is established. Potential sources for funds are outlined in Appendix F.

The Table, on the next page, gives a breakdown of the proposed budget.

Seed funding of approximately $250,000 per year for each of the centers would be necessary to coordinate and establish the various research centers. To initiate and create the cohort of environmental fellows, five will be hired starting from Year 1. These students will work with the existing graduate students conducting environmental research. In the long run, a $20 million endowment will be created to recruit and fund 10 new doctoral students each year, who will work in conjunction with 40 other doctoral students. Similarly, funds are requested for five post-doctoral fellows. About $50,000 per year is requested to support educational initiatives, and after Year 6 this will be obtained from the tuition income of students in the revamped Environmental Studies Program. A similar budget is requested for facilities and operations, and in the long term this will be supported by a $10 million endowment. Outreach activities will start with a budget of $25,000 per year and will also be supported by a $10 million endowment in the future. The income from this endowment will also provide the resources for the WUSTL Environmental Innovation Prize, to be given out in alternate years. Monies are requested to hire about 20 new faculty and staff, who will primarily play a leading role in the research centers. A permanent endowment of $30 million should be created to support the new hires. Finally, the building will be constructed with a $50 million budget—and should be one of the planned buildings on campus. An endowment of $10 million will support the laboratory and equipment purchases/maintenance for this building.

Proposed Budget

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6 onwards
Research Centers (5 areas)	1,250,000	1,000,000	750,000	500,000	250,000	self sustaining w/ research ($10M per year—if 40 faculty are involved) and additional endowment support of $10M
Environmental Fellows (10)	500,000	550,000	575,000	600,000	425,000	create endowments for doctoral students—$20M; 40 other fellows supported by research grants
Post-Doctoral and Visiting Fellows (5)	375,000	380,000	400,000	425,000	450,000	create endowments for $10M
Educational Initiatives	50,000	75,000	100,000	100,000	100,000	income generated from Tuition income to support efforts
Operations and Facilities	50,000	75,000	100,000	100,000	100,000	create endowment to seed initiatives = $10M
Outreach	25,000	50,000	75,000	50,000	25,000	income generated from collaborative initiatives with outreach partners and endowment = $10M
WUSTL Environmental Innovation Prize		250,000		250,000		given out every alternate year (income from outreach endowment)
Administrative, Staff and Faculty Hires	1,000,000	1,250,000	1,500,000	1,750,000	2,000,000	Have at least 20 Endowed Professorships of the Environment = $30M
State-of-the-Art Facility	250,000	275,000 Competition for Design	50,000,000 New Building Construction	250,000	250,000	Endowment to maintain & promote activities in facility = $10M
TOTAL	**3,500,000**	**3,905,000**	**53,500,000**	**4,025,000**	**3,800,000**	

TOTAL REQUESTED FOR 5 YEARS = $68,730,000
TOTAL ENDOWMENT SUPPORT = $100,000,000

Section 7
ENVIRONMENTAL EDUCATION AND RESEARCH INSTITUTE (EERI) IMPLEMENTATION PLAN

To build on the synergy and the enthusiasm among the faculty, it is recommended that implementation of the proposed plan begin immediately. A few implementation steps as seen important by the working group are outlined:

1. Appoint key lead personnel to implement the proposed suggestions to begin to create St. Louis and WUSTL as a hub for environmental activities. The admistrative structure is outlined in Section 5—and the working group recommends initial appointments of the vice chancellor for the environment, director of the Institute, and director of sustainability. These three individuals can then be tasked with developing the details and timeline for implementation. (by June 2006 or earlier)
2. Develop a detailed budget with staggered funding to initiate EERI (by August 2006)
3. Identify key faculty to lead the different research areas (by September 2006)
4. Organize a Workshop at WUSTL in fall 2006 to launch the Institute. This should be done in conjunction with the Missouri Botanical Garden and other stakeholders, both on campus (such as the McDonnell Academy, and Center for Ethics and Human Values) and off-campus (industrial partners) (fall 2006)
5. Vice chancellor for the environment should work with University administration and deans of schools to identify centralized facility (fall 2006 and spring 2007)
6. Fund-raising initiatives and plans for longer-term operation of EERI developed (spring 2007)
7. List of participating faculty and mechanisms for participation with the Institute should be formalized. Identify and appoint Institute fellows (spring 2007)
8. EERI should be fully function by fall 2007 and admit first cohort of students (fall 2007)

Section 8
APPENDICES

A. Sesquicentennial Seminar Series

B. Undergraduate Environmental Programs at Washington University in St. Louis (Environmental Studies Program and School of Engineering & Applied Science Minor)

C. Environmental Engineering Science Graduate Programs

D. List of Interested Faculty (from survey)

E. Reports of Visit to Other Universities

F. Potential Fund-Raising Suggestions

G. Acknowledgements

H. Current Environment Related Research Grants

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UNDERGRADUATE ENVIRONMENTAL PROGRAMS AT WASHINGTON UNIVERSITY IN ST. LOUIS

Environmental Studies Program

B.1. INTRODUCTION

The natural systems that shape the Earth's environment are dynamic and highly interactive. As an example, ash injected into the upper atmosphere during volcanic eruptions lowers atmospheric temperatures and leads to changes in weather. In addition to natural phenomena, human activities have begun to influence Earth's environmental systems in significant ways. The warming of the atmosphere by increased carbon dioxide associated with burning wood and fossil fuel—the "greenhouse effect"— and ozone destruction by the chlorofluorocarbon gases are examples of how human activities can also affect climate. The release of waste products into the Earth's rivers and oceans is another way in which human activities affect naturally dynamic systems. These and other processes profoundly affect the diversity and distribution of life on Earth and are major factors to contend with in conservation efforts. Environmental issues have also achieved a prominent position on the agenda of many political systems in many societies. Today, these issues—and their economic consequences—are shaped by political leaders, interest groups, public opinion, and international concerns that invade both the industrial and the developing worlds. The Environmental Studies Program offers students the opportunity to undertake a major or minor in environmental sciences or in societal issues associated with the environment. The program is interdisciplinary; it takes advantage of faculty expertise in anthropology, biology, economics, earth and planetary sciences, political science, and engineering.

B.2. AVAILABLE TRACKS

TRACK 1 – Social Science

The Social Science Track of Environmental Studies is designed to give students a broad understanding of the environment with regard to anthropology, economics, history, philosophy and political science. In order to ensure the breadth and depth necessary to evaluate the consequences of environmental policy decisions, the environmental social science major has been created with the following required (A) and elective (B,C) courses.

A. Required Courses:

1. One of the three following courses:
   a. ANTH 361 – Culture and Environment
   b. POL SCI 332 – Environmental and Energy Issues
   c. CIV ENG/ENST 461 – Environmental Law and Policy
2. ENST 294 – Introduction to Environmental Studies: Social Science
3. ENST 295 – Introduction to Environmental Studies: Biology
4. EPSC 201 – Earth and the Environment
5. Capstone Experience

B. Tier 1 Electives (3 of the following):

The courses in A1 not taken as a required course.

ANTH 3322 – Brave New Crops
ANTH 3612 – Population and Society
ECON 103 – Microeconomics
ECON 451 – Environmental Policy
EnSt 335/Phil 235F – Introduction to Environmental Ethics

Pathfinder 201 AND 202 (both courses necessary for one requirement)

C. Tier 2 Electives (2 of the following):

ANTH 306B – Africa: Peoples and Culture
ANTH 3091 – Peoples and Cultures of South America
ANTH 406 – Primate Ecology and Social Structure
ANTH 4253 – Researching Fertility, Mortality, and Migration (WI course)
ANTH 4282 – Political Ecology
ANTH 4622 – Anthropological Demography
CIV ENG 253 – Pollution and Environmental Impact
E LIT 424 – Topics in American Literature II
ENV ENG 262 – Introduction to Environmental Engineering
HIST 3066 – American City in 19th and 20th Centuries
HIST 424 – Tale of Two Cities
ENST/HIST 3003 – Critical Issues in American Environmental History
ENST/HIST 302 – Urban Environmental History
ENST/PHIL 3901 – Environmental Ethics Writing (WI course)
ENST/ANTH 379 – Feast or Famine: Archaeology and Climate Change
ENST/ANTH 3793 – Mississippi River Basin: Past, Present, and Future
ENST/ANTH 479 – Climate, Culture, and Human History
ENST/ARCH 455 – Metropolitan Landscapes
ENST/ARCH 464 – Hybrid Landscapes: Ecology, Infrastructure, and Cultural Expression
ENST 495 – Environmental Writing (WI course)
ENST 4980/EPSc 498 – Undergraduate Research Seminar (WI)
NOTE: Students must make sure that while completing the major, that they also complete 18 units of upper-level coursework (300 or above) within the major.

TRACK 2 – Geoscience

The Geoscience Track of Environmental Studies is for students interested in Earth surface processes, including global elemental cycling, land use, aqueous geochemistry, geobiology, paleoenvironmental processes, and climate change. Students take a number of required courses (A), complemented by electives fro two tiers (B,C).

A. Required Courses:

1. One of three of the following
   a. EnSt/Anth 361 – Culture and Environment
   b. EnSt/Pol Sci 332 – Environmental and Energy Issues
   c. EnSt 461 – Environmental Law and Policy
2. EnSt 294 – Introduction to Environmental Studies: Social Science
3. EnSt 295 – Introduction to Environmental Studies: Biology
4. EPSc 201 – Earth and the Environment
5. EPSc 323 – Biogeochemistry
6. EPSc 352 – Earth Materials
7. Math 131 AND 132 – Calculus I and II
8. Chem 111 AND 112 – General Chemistry I and II
9. Capstone

B. Tier 1 Electives (3 of the following):

EPSc 216 – Resources Of the Earth
EPSc 221 – Human Use of the Earth
EPSc 318 – Development of the North American Landscape
EPSc 401 – Earth Systems Science
EPSc 408 – Earth's Atmosphere and Global Climate
EPSc 409 – Surface Processes
EPSc 418 – Paleobiology
EPSc 422 – Sedimentary Geology
EPSc 428 – Hydrology
EPSc 430 – Environmental Mineralogy
EPSc 444 – Environmental Geochemistry
EPSc 484 – Paleoenvironmental Reconstruction

Chem Eng 443 – Environmental Chemistry
Civ Eng 262 – Introduction to Environmental Engineering
Civ Eng 424 – Environmental Spatial Data Analysis

C. Tier 2 Electives (3 courses):

TRACK 3 – Biology/Ecology

This track of the Environmental Studies major provides students with a strong background in biology and ecology, with emphasis on evolution, genetics, botany, population, and behavior. Students take a number of required courses (A), complemented by electives from two tiers (B, C).

A. Required Courses:

1. One of three of the following
   a. EnSt/Anth 361 – Culture and Environment
   b. EnSt/Pol Sci 332 – Environmental and Energy Issues
   c. EnSt 461 – Environmental Law and Policy
2. EnSt 294 – Introduction to Environmental Studies: Social Science
3. EnSt 295 – Introduction to Environmental Studies: Biology
4. EnSt 370 – Biological Conservation
5. Bio 381 – Introduction to Ecology
6. EPSc 201 – Earth and the Environment
7. Math 131 AND 132 – Calculus I and II
8. Chem 111 AND 112 – General Chemistry I and II
9. Capstone

B. Tier 1 Electives (3 of the following):

Anth 307A – Human Variation
Anth 3661 – Primate Biology
Anth 4211 – Paleothnobotany and Ethnobotany
Anth 362 – Biological Human Behavior
Bio 2960 – Principles of Biology I
Bio 343 – Plants, Environment and Civilization
Bio 349 – Microbiology
Bio 3501 – Evolution
Bio 372 – Behavioral Ecology
Bio 4170 – Population Ecology
Bio 4181 – Population Genetics
Bio 4182 – Macroevolution
Bio 4183 – Molecular Evolution
Bio 419 – Population and Community Ecology
Bio 4193 – Experimental Ecology Laboratory
Bio 4202 – Evolutionary Genetics
EPSc 323 – Biogeochemistry

C. Tier 2 Electives (4 courses from the list):

Tier 2 Electives for Tracks 2 and 3

1. Any course listed in Track II or Track III not taken to meet another EnSt major requirement.
2. Any of the following. Note that some have prerequisites not required by Environmental Studies:

ANTH 367 – Paleoanthropology
ANTH 434 – Behavioral research at the Zoo (can be used for Capstone Experience requirement or elective credit but not both)
ANTH 459 – Human Osteology
BIOL 311 – Vertebrate Structure
BIOL 347 – Darwin and Evolutionary Controversies
BIOL 4021 – Biochemistry of Plants
BIOL 4023 – How Plants Work: Physiology, Growth, and Metabolism
BIOL 4031 – Biological Clocks (WI)
BIOL 404 – Laboratory of Neurophysiology
BIOL/ENST 4193 – Experimental Ecology Laboratory
BIOL 4412 – Evolution of Animal Development
CHEM ENG 345 – Pollution Abatement & Waste Management
CHEM 251 OR CHEM 252 – Organic Chemistry I, II
CIV ENG 253/ENST 422 – Pollution and Environmental Impact
CIV ENG 352A – Water and Wastewater Treatment
EPSC 310 – Geological Field Methods
EPSC 400 – Topics in the Geosciences
EPSC 407 – Remote Sensing

EPSC 446 – Stable Isotope Geochemistry
EPSC 449/ENST 4491 – Microbes and the Environment
EPSC 454 – Exploration and Environmental Geophysics
EPSC 480 – Special Topics in Microbiology-Chemistry-Earth Science
ENST 4980/EPSC 498 – Undergraduate Research Seminar (WI)
ENST/BIO 373 Behavioral Ecology Lab
PHIL 235/ENST 335 – Introduction to Environmental Ethics
POL SCI/ENST 332 – Environment and Energy Issues
PSYCH 330 – Sensation and Perception
PSYCH 3401 – Introduction to Biological Psychology
Pathfinder 201 AND 202 (both courses necessary for one requirement)

B. 3. MINOR IN ENVIRONMENTAL STUDIES

Minors in Environmental Studies will take a minimum of six courses: (4 required and 2 electives). These must be distinct from the student's major. No double counting. Also, at least 9 units must be at the 300-level or above.

A. Required Courses:

1. One of the three following courses:
   a. ANTH 361 – Culture and Environment
   b. POL SCI 332 – Environmental and Energy Issues
   c. CIV ENG/ENST 461 – Environmental Law and Policy
2. ENST 294 – Introduction to Environmental Studies: Social Science
3. ENST 295 – Introduction to Environmental Studies: Biology
4. EPSC 201 – Earth and the Environment (or EPSc 200A)

B. Elective Courses:

One of the courses in A1 not taken as a requirement.
ANTH 3322 – Brave New Crops
ANTH 3612 – Population and Society
ECON 451 – Environmental Policy
ENST/HIST 3003 – Critical Issues in American Environmental History
ENST 335/PHIL 235F – Introduction to Environmental Ethics
ENST 370 – Biological Conservation
BIOL 381 – Introduction to Ecology
EPSC/ENST 323 – Biogeochemistry
EPSC 352 – Earth Materials

B.4. MINOR IN ENVIRONMENTAL ENGINEERING (http://www.env.wustl.edu/envminor.htm)

A popular minor with Environmental Studies majors is the Environmental Engineering Minor. This minor offers a good way to combine studies in the social and natural sciences with an understanding in engineering. The 6 core requirements are listed below:

1. Env 262 Intro to Environmental Engineering **–OR–** ChE 351 – Engineering Analysis of Chemical Systems **–OR–** ME 370 – Fluid Mechanics
2. Env/ChE/ME 344 – Air Pollution **– OR–** Env/CE 352A – Waste Water Treatment
3. Env/ChE 443 – Environmental Chemistry
4. Env/ChE 518 – Aerosol Science and Technology **–OR–** Env/ChE 505 – Environmental Reaction Engineering **–OR–** Env/ChE/CE 409 – Environmental Engineering Laboratory **–OR–** ME 449 – Sustainable Air Quality
5. Env/ChE 345 – Pollution Abatement and Waste Minimization **– OR–** Env/CE 482A – Design of Water Quality Treatment Facilities **–OR–** Env/ME 448A – Combustion and Environment

–OR– Env 499 – Environmental Senior Project

6. Env/ChE 438 – Environmental Risk Assessment **–OR–** Env/ChE 539 – Industrial Ecology **–OR–** Env/CE 461 – Introduction to Environmental Law & Policy

Students wishing to pursue the Environmental Engineering Minor should contact the Environmental Engineering Science Program:

Environmental Engineering Science Program
School of Engineering & Applied Science
One Brookings Drive, Campus Box 1180
Saint Louis, MO 63130-9989
Tel: 314-935-5548
fax: 314-935-5464
email: env@seas.wustl.edu
www.env.wustl.edu

B. 5. LIST OF AFFILIATED FACULTY

Chair

Jan Amend, Associate Professor (Earth and Planetary Sciences), Ph.D., University of California-Berkeley. Microbial geochemistry of shallow marine and continental hydrothermal ecosystems. Focus on geochemical constraints on the metabolism of microorganisms as well as the effects of microbes on the geochemistry of their habitat. Current field sites include the thermal vents of the Aeolian Islands in southern Italy and hot springs in Yellowstone National Park.

Professors:

Lars Angenent, Assistant Professor (Environmental Engineering), Ph.D., Iowa State University. Bioaerosols, anaerobic waste treatment, biological wastewater treatment.

Raymond E. Arvidson, James S. McDonnell Distinguished University Professor (Earth and Planetary Sciences), Ph.D., Brown University. Remote sensing and surface process studies of Venus, Mars and the Earth including lander and rover surface operations on Mars aimed at testing hypotheses related to early warm and wet conditions on the planet.

Richard Axelbaum, Associate Professor (Environmental Engineering), Ph.D., University of California, Davis. Gas-phase synthesis of advanced materials, soot formation in flames, fundamental flame studies.

Carrine Blank, Assistant Professor (Earth and Planetary Sciences), Ph.D., University of California-Berkeley. Geochemical and molecular biological approaches studying microbial populations in the boiling springs and geysers of Yellowstone National Park. Evolutionary history of microbes as a means of understanding the early evolution of life and the geochemical conditions under which early life evolved.

Pratim Biswas, Stifel and Quinette Jens Professor of Environmental Engineering, Ph.D., California Institute of Technology. Teaching and research interests include aerosol science and engineering; nanoparticle technology; air quality engineering; combustion; materials processing for environmental technologies, environmentally benign processing, environmental nanotechnology, and the thermal sciences.

Jon M. Chase, Assistant Professor (Biology), Ph.D., University of Chicago. Diversity, distribution, and abundance of animal and plant species from the population/community/ecosystem perspective and the patterns and processes that develop at the interface between local and regional spatial scales.

Geoff Childs, Assistant Professor (Anthropology), Ph.D., Indiana University. Synthesis of Anthropology and Demography in studying Tibetan societies.

Robert E. Criss, Professor (Earth and Planetary Sciences), Ph.D., California Institute of Technology. Stable isotope geochemistry, hydrothermal systems and ore deposits, river

and groundwater hydrology, granitic batholiths, and mathematical modeling.

Willem Dickhoff, Professor (Physics), Ph.D., Free University, Amsterdam. Team-teaches Physics 171/EnSt 272: Physics and Society, an introduction to physics, its goals, methods, and relevance for society. Topics include energy as a unifying principle of physics and society's use of energy; nuclear energy; global climate change; science and government; and bad and pseudo-science.

Milorad (Mike) Dudukovic, Laura and William Jens Professor of Environmental Engineering (Chemical Engineering), Ph.D., IIT, Chicago. Chemical reaction engineering involving kinetic-transport interactions in multiphase systems.

Bob Dymek, Professor (Earth and Planetary Sciences), Ph.D., California Institute of Technology. Professor Dymek utilizes field, chemical, and phase petrology in the study of igneous and metamorphic processes. More recently, he has begun to examine trace elements in sedimentary and metasedimentary rocks as recorders of crustal evolution. He has carried out extensive field studies in West Greenland investigating high-grade Archaean gneisses, and in the Grenville Province of Canada investigating Proterozoic massif anorthosites and related rocks. Dr. Dymek is especially interested in geological problems that have a fundamental bearing on Precambrian Earth history.

J. Claude Evans, Associate Professor (Philosophy), Ph.D., SUNY-Stony Brook. Teaches Phil 235 Introduction to Environmental Ethics and occasionally an advanced course on topics in the philosophy of the environment. The introduction deals with issues such as animal rights, anthropocentrism vs. biocentrism, Aldo Leopold's "land ethic," wilderness, deep ecology, biodiversity, sustainability, environmental economics, and corporate responsibility.

Bruce Fegley, Professor (Earth and Planetary Sciences), Ph.D., Massachusetts Institute of Technology. Paleo-environmental questions such as the effects of large asteroidal and cometary impact on the terrestrial biosphere at the time of the Cretaceous-Tertiary boundary and the connection between impacts on the early Earth and the origin of life. Currently teaching Thermo and Phase Equilibria, Earth System Science and Planetary Geochemistry.

Dan Giammar, Assistant Professor (Environmental Engineering), Ph.D., California Institute of Technology. Aquatic chemistry in natural and engineered systems, chemical reactions at the solid-water interface, engineering for water quality control, fate and transport of inorganic contaminants in the environment.

T. R. Kidder, Professor (Anthropology), Ph.D., Harvard University. North American archaeology, geoarchaeology, ceramic analysis, humans and climate change, plant domestication; Mississippi River, southeastern United States.

Tiffany Knight, Assistant Professor (Biology), Ph.D., University of Pittsburg. Effects of interspecific interactions, in particular herbivory and pollination, on the population dynamics of rare and invasive plants.

Maxine Lipeles, Professor (Engineering and Policy), J.D., Harvard University. Environmental policy and regulation, particularly hazardous waste and water pollution.

Jonathan B. Losos, Professor (Biology), Ph.D., University of California-Berkeley. Evolutionary adaptation of anolis lizards to different habitats on Caribbean Islands and ecology of isolated populations of Missouri lizards.

William R. Lowry, Professor (Political Science), Ph.D., Stanford University. Environmental policy, regulation, and public lands management.

Edward S. Macias, Professor (Chemistry), Ph.D., Massachusetts Institute of Technology. Problems of the polluted atmosphere with particular emphasis on the causes of haze in pristine areas of the United States such as the Grand Canyon.

F. Beth Martin, Engineering and Science Director, Interdisciplinary Environmental Clinic, (Environmental Engineering) M.S. Washington University. Environmental Policy and its interaction with science and engineering.

Ken Olsen, Assistant Professor (Biology), Ph.D., Washington University. Plant evolutionary biology, including the molecular genetic basis of adaptation, the mechanisms by which populations diverge, and the population genetics of crop domestication.

Clare Palmer, Associate Professor (Philosophy), Ph.D., Oxford University. Environmental philosophy and ethics, feminist ethics, Continental philosophy, Whitehead and process philosophy. Professor Palmer's books include Environmental Ethics and Process Thinking (Oxford, 1998) and forthcoming co-edited books Killing Animals (University of Illinois Press, 2005), and Critical Concepts in Philosophy: Environmental Philosophy (5 vols.) (Routledge, November 2004).

Jill Pasteris, Professor (Earth and Planetary Sciences), Ph.D., Yale University. Traditional mineralogic-geologic approach to non-traditional materials. Application of vibrational spectroscopy, laser scanning confocal microscopy, microthermometry, and more traditional geochemical analysis techniques to: fluid inclusions in minerals and glasses, nanocrystalline precipitates and skeletal minerals in bacteria and humans, CO_2 introduced onto the ocean floor.

Bruce Petersen, Associate Professor (Economics), Ph.D., Harvard University. Teaches EnSt/Econ 453 Environmental Economics. The course considers the reasons why economies may generate excessive levels of pollution, what economists mean by "optimal" pollution levels and "efficient" pollution abatement, and how such outcomes can be achieved. The course also examines the practice of pollution control in the United States, including water pollution and various types of local, regional, and global air pollution.

Robert Pollak, Professor (Economics), Ph.D., MIT. Teaches EnSt/Econ 453 Environmental Economics. The course considers the reasons why economies may generate excessive levels of pollution, what economists mean by "optimal" pollution levels and "efficient" pollution abatement, and how such outcomes can be achieved. The course also examines the practice of pollution control in the United States, including water pollution and various types of local, regional, and global air pollution.

D. Tab Rasmussen, Associate Professor (Anthropology), Ph.D., Duke University. Evolution of early primates; biology of living prosimian primates; changes in mammalian communities during the Cenozoic (last 60 million years); extinctions of primates and birds in Madagascar; paleontological field work in Africa and North America; courses taught include primate biology, primate evolution, paleontological laboratory methods and analysis.

Barbara A. Schaal, Professor (Biology), Ph.D., Yale University. Conservation biology of plants; studying the genetic consequence of habitat fragmentation and management practices in several native plant species.

Jennifer R. Smith, Assistant Professor (Earth and Planetary Sciences), Ph.D., University of Pennsylvania. Use of geologic and archaeological tools to study the relations between ancient humans and their environment.

Joshua B. Smith, Assistant Professor (Earth and Planetary Sciences), Ph.D., University of Pennsylvania. Vertebrate paleontology and paleoenvironment reconstruction, sedimentology.

Glenn Stone, Associate Professor (Anthropology), Ph.D., University of Arizona. Cultural and political ecology; indigenous agriculture; population; settlement patterns; ethnoarchaeology.

Robert W. Sussman, Professor (Anthropology), Ph.D., Duke University. Primate evolution and ecology; conservation strategies and policies in tropical environments, such as Madagascar, Costa Rica, Guyana, and the Indian Ocean Islands.

Alan R. Templeton, Professor (Biology), Ph.D., University of Michigan. Applies molecular genetic techniques to problems arising in conservation biology, including management of captive populations of endangered species, management of natural populations of endangered species, management of natural populations, reintroduction of endangered species to restored habitats, and inferring taxonomic status of endangered groups.

Jay R. Turner, Associate Professor (Engineering and Policy, Chemical Engineering), D.Sc., Washington University. Environmental reaction engineering with emphasis on air pollution characterization and control. Policy and technical aspects of transportation / air quality issues.

Jane Wolff, Assistant Professor (Architecture), MLA, Harvard University. Professor Wolff has practiced landscape and urban design in the Bay Area, and before her appointment at Washington University, she taught at the California College of Arts and Crafts and the Ohio State University. She is the author of **Delta Primer**, a book designed to educate diverse audiences about the contested landscape of the California Delta. Her research interests deal with the hybrid landscapes produced by natural process and cultural intervention. Her study topics have included the architecture of the Finnish railway system, the history of land reclamation in the Netherlands, and the cultural landscapes of the Tennessee Valley Authority, and her work has been supported by two Fulbright Scholarships, a Charles Eliot Traveling Fellowship, and a grant from the Graham Foundation for Advanced Study in the Visual Arts.

Brian Wrenn, Assistant Professor (Civil Engineering), Ph.D., University of Illinois. Environmental biotechnology: bioremediation processes, soil, sediment, groundwater treatment.

ENVIRONMENTAL ENGINEERING SCIENCE GRADUATE PROGRAM

HTTP://WWW.ENV.WUSTL.EDU/

C.1. INTRODUCTION

The Environmental Engineering Science Program at WUSTL is an integrated, multi-disciplinary program that provides a scientific education for individuals interested in focusing on the improvement and management of the quality of the environment.

The mission of the program is to educate future generation of engineers and scientists to tackle and solve the complex environmental issues we face today and in the future.

The mission is accomplished by:

- Inculcating a tradition of "life-long learning"
- A curriculum to provide a fundamental training coupled with application in an advanced focal area and breadth in other disciplinary areas
- Participation in cutting edge research with faculty members and industrial partners
- Access to state of the art facilities and instrumentation.

Courses and research encompass areas such as air quality and pollution control, aerosol science and engineering, biological treatment processes, contaminant transport, drinking water treatment, environmentally benign processing, nanotechnology, sustainable technology, water quality and pollution control, environmental law and policy.

A Master of Science and Doctoral Degree in environmental engineering science is awarded on completion of a course of study and research work. A joint degree program with the College of Law allows interested students to obtain both a J.D. and M.S. in Environmental Engineering Science. A minor is offered to Undergraduate Students interested in Environmental Engineering, and can be selected by any Engineering or Science student.

C.2. PROGRAM FACULTY

The program consists of about 10 affiliated faculty members:

Lars T. Angenent
Ph.D., 1998
Iowa State University
Assistant Professor, Department of Chemical Engineering.
Molecular Biology for Environmental Engineering,
Bioaerosols, Anaerobic Waste Treatment, Biological Wastewater Treatment

Richard L. Axelbaum Ph.D.,1988
University of California Associate Professor
Department of Mechanical Engineering.
Nanoparticle Synthesis, Combustion

Pratim Biswas
Ph.D., 1985
California Institute of Technology
Stiffel and Quinette Jens Professor.
Director, Environmental Engineering Science Program.
Aerosol Science and engineering, nanotechnology; air quality and pollution control

Da-Ren Chen
Ph.D., 1997
University of Minnesota
Associate Professor, Mechanical Engineering.
Particle measurement and instrumentation, particle filtration and separation, aerosol dynamics modeling, aerosol science and technology

Milorad P. Dudukovic
Ph.D., 1972
Illinois Institute of Technology
Department Chairman, Chemical Engineering.
Laura and William Jens Professor of Environmental Engineering

Daniel Giammar
Ph.D., 2001
California Institute of Technology
Assistant Professor, Civil Engineering.
Aquatic Chemistry, Water Quality Engineering, Fate and Transport of Inorganic Contaminants

Rudolf B. Husar
Ph.D., 1970
University of Minnesota
Director, Center for Air Pollution and Trends Analysis, Professor, Mechanical Engineering.
Environmental Informatics, Aerosol Pattern and Trend Analysis

Maxine Lipeles
J.D., 1979
Harvard University
Professor, College of Law
Environmental Law

Jay R. Turner
D.Sc., 1993
Washington University
Associate Professor, Chemical Engineering.
Air Quality Management

Brian A. Wrenn
Ph.D., 1994
U. of Illinois
Assistant Professor, Civil Engineering.
Bioremediation Processes, Soil, Sediment, Groundwater Treatment
Env Biotech. Lab

Charles A. Buescher
M.S., 1961
Washington University
Senior Professor
Water Quality

Stefan Falke
Ph.D., 1999
Washington University
Research Assistant Professor
Air quality data analysis, environmental information systems

Henry G. Schwartz
Ph.D.
Caltech
Member, National Academy of Engineering
Senior Professor

C.3 Focal Areas

Thre three major focal areas of the program are:

- **Aerosols and Air Quality**
  This speciality focuses on the fundamental mechanisms that control the physics and chemistry of air quality. The emphasis is on specialized study in aerosol science and engineering, ambient air quality encompasing atmospheric chemistry, combustion processes and air pollution control.
  Faculty: Pratim Biswas, Da-Ren Chen, Jay Turner, Richard Axelbaum, Rudy Husar, Stefan Falke
- **Water Quality**
  This specialty focuses on the fundamentals, design and operation of the physical, chemical and biological processes used in the treatment of water and wastewater, industrial and hazardous waste.
  Faculty: Brian Wrenn, Charlie Buescher, Dan Giammar, Lars Angenent
- **Sustainable Technology**
  This specialty focuses on the development of new environmental technologies (such as clean technologies, nanotechnologies

for the environment) and environmentally benign processing methodologies. The emphasis is on an understanding or processes at the atomistic or molecular scale. This group also focuses on the legal and policy aspects of new and existing environmental technologies.
Faculty: Mike Dudukovic, Pratim Biswas, Richard Axelbaum, Maxine Lipeles, Beth Martin, Dan Giammar, Lars Angenent

C.4 Students

The program currently consists of about 35 doctoral students who are advised on a number of projects funded by Federal and Industrial Agencies. The diverse group of students are very high quality and have won numerous national awards.

C.5 Selected Projects

NSF – Research Experience for Undergraduates & Educational Programs

The REU program is now in its fourth year and provides an opportunity for students to participate in cutting-edge research in environmental disciplines. The program is directed by Dr. Brian Wrenn and includes participation of all the faculty members affiliated to the program.

Drs. Axelbaum, Biswas, Chen and Giammar are members of the Center for Materials of Innovation at the University (www.cmi.wustl.edu). These faculty along with their colleagues are establishing a minor in the School of Engineering and the University that will introduce undergraduates to the exciting field of nanotechnology.

Another collaborative project on education with the University of Florida has resulted in the development of interactive Aerosol Education Modules. For a first hand experience, please access http://www.aerosols.wustl.edu/aaqrl/Courses/CYCOPCRESP/index.html

DOD- MURI Project on Nanoparticle Toxicology

Drs. Biswas and Chen along with their colleagues Dr. David Pui at the University of Minnesota and Dr. Gunter Oberdorster at the University of Rochester have embarked on a five year project to unravel the toxicological properties of nanoparticles. Researchers at WUSTL will focus on the synthesis and classification of narrow size nanoparticles (with tight control on size and composition) and also on establishing the properties as a function of size. These characterized samples will be used in biological studies to determine their effects as a function of size and composition.

NASA - Application of ESE Data and Tools to Particulate Air Quality Management

Recent research performed by Drs. Stefan Falke and Rudy Husar includes development of data structures for the transmission of environmental knowledge (geographic, animation, hypertext); the use and refinement of interactive, graphic data exploration, and analysis techniques; and application and demonstration of multimedia data delivery systems. A sizable research effort focuses on long-term air pollution trends spanning this century in the United States. Visibility trends have been compiled for North America and Europe. The CAPITA visibility trend analysis work contributed significantly to the deliberations for the Clean Air Act Amendment of 1990. Details are available at www.capita.wustl.edu

NSF Engineering Research Center Center for Environmentally Benificial Catalysis

Generating technologies that will transform the catalytic manufacture of chemicals into inherently safe and ecologically responsible processes, while retaining their economic viability. Dr. M.Dudukovic is Associate Director of the Center.

NSF-NIRT

Synthesis and Application of Magnetic Nano- and Nanocomposite Particles. PIs: Drs. D. Chen, P. Biswas, R. Indeck and R. Axelbaum. Industrial Collaborator: Stereotaxis. Magnetic nanoparticles/nano-composites have many promising industrial and biomedical applications. This project is exploring laboratory scale synthesis methods to obtain nanoparticles with tailored size, composition and morphologies; developing systems for online measurement of high concentrations in high temperature environments, and demonstrating applications in data storage, recording, and biomedical applications.

An e-survey (http://www.seas.wustl.edu/EnvironmentalEnergyCatalog/) was conducted to seek faculty input and interest in Environmental Education, Research and Operations at WUSTL. 71 individuals responded to this survey (and a summary of their entries is provided in the following pages). The survey form follows these tables.

Last name	First Name	School	Department	Research	Teaching	Operations	Rivers	Aerosols	Energy	Health	Eco Systems	Law & Policy
Agarwal	Ramesh	Engineering	Mechanical Engineering	✓	✓				✓			
Al-Dahhan	Muthanna	Engineering	Chemical Engineering	✓	✓							
Amend	Jan	Arts & Sciences	Earth & Planetary Sciences	✓	✓		✓				✓	
Angenent	Largus	Engineering	Environmental Engineering	✓	✓		✓	✓	✓			
Arvidson	Raymond	Arts & Sciences	Earth & Planetary Sciences	✓	✓			✓	✓			
Axelbaum	Richard	Engineering	Environmental Engineering	✓	✓			✓	✓	✓		
Backus	Bruce	CFU	Envr. Health & Safety			✓			✓		✓	
Barry	Ed	Facilities	Facilities			✓		✓				
Bender	Carl	Arts & Sciences	Physics		✓			✓	✓			✓
Biswas	Pratim	Engineering	Environmental Engineering	✓	✓		✓	✓	✓	✓		
Blank	Carrine	Arts & Sciences	Earth & Planetary	✓						✓		
Btowman	David	Arts & Sciences	Anthropology & Archaeology	✓	✓						✓	
Castro	Mario	Medicine	Internal Medicine	✓				✓		✓		
Chase	Jonathan	Arts & Sciences	Biology	✓	✓	✓	✓				✓	
Chen	Da-Ren	Engineering	Environmental Engineering	✓	✓			✓	✓	✓		
Childs	Geoff	Arts & Sciences	Anthropology	✓	✓	✓	✓					
Dickhoff	Willem	Arts & Sciences	Physics		✓				✓			
Ehrhard	Ray	Engineering	EPRI	✓		✓	✓		✓			
Evanoff	Bradley	Medicine	Medicine	✓	✓					✓		✓
Falke	Stefan	Engineering	Environmental Engineering	✓	✓		✓	✓				
Farber	Nuri	Medicine	Psychiatry	✓								
Fegley, Jr.	M.	Arts & Sciences	Earth & Planetary	✓	✓			✓	✓			
Gelb	Lev	Arts & Sciences	Chemistry	✓					✓			
Giammar	Daniel	Engineering	Environmental Engineering	✓	✓		✓	✓	✓			
Givens	Steven	Administration	Office of the Chancellor			✓						
Gleaves	John	Engineering	Chemical Engineering	✓	✓				✓			
Gordon	Mae	Medicine	Ophthalmology							✓		

Last name	First Name	School	Department	Research	Teaching	Operations	Rivers	Aerosols	Energy	Health	Eco Systems	Law & Policy
Gray	David	Medicine	Neurology	✓	✓						✓	✓
Gronowski	Ann	Medicine	Pathology				✓					✓
Hall	Robert	CFU	Facilities			✓		✓				
Heider	Robert	Engineering	Chemical Engineering	✓	✓							
Husar	Rudy	Engineering	Mechanical Engineering	✓	✓							
Jeffe	Donna	Medicine	Medicine	✓								
Kelton	Kenneth	Arts & Sciences	Physics	✓					✓			
Khomami	Bamin	Engineering	Chemical Engineering	✓				✓	✓			
Kidder	Tristram	Arts & Sciences	Anthropology	✓	✓		✓					
Knight	Tiffany	Arts & Sciences	Biology	✓	✓						✓	
Kodner	Ira	Medicine								✓		✓
Larson	Allan	Arts & Sciences	Biology	✓	✓							
Lipeles	Maxine	Law	Law		✓		✓	✓	✓	✓		✓
Losos	Jonathan	Arts & Sciences	Biology	✓	✓					✓	✓	
Lowry	William	Arts & Sciences	Political Science	✓	✓		✓	✓	✓			
Mackeith	Peter	Architecture			✓	✓						
Martin	Frances	Arts & Sciences	Environmental Studies		✓		✓	✓	✓	✓		✓
Morley	Robert	Engineering	Electrical Engineering		✓				✓			
Ogilvie	Michael	Arts & Sciences	Physics		✓			✓	✓			✓
Pakrasi	Himadri	Arts & Sciences	Biology	✓					✓			
Palmer	Clare	Arts & Sciences	Philosophy/Environmental Studies	✓	✓							✓
Paris	Paul	Engineering	Mechanical Engineering	✓	✓				✓			
Plax	Kathryn	Medicine	Pediatrics		✓					✓		✓
Racette	Brad	Medicine	Neurology	✓						✓		
Rackers	Steve	CFU	Facilities			✓		✓	✓			
Ramachandran	Palghat	Engineering	Chemical Engineering	✓	✓							

Last name	First Name	School	Department	Research	Teaching	Operations	Rivers	Aerosols	Energy	Health	Eco Systems	Law & Policy
Rasmussen	David	Arts & Sciences	Anthropology	✓	✓				✓		✓	
Repovich	Michael	Architecture			✓	✓						
Schaal	Barbara	Arts & Sciences	Biology	✓	✓						✓	
Schade	Janis	CFU	Facilities			✓						
Smith	Jennifer	Arts & Sciences	Earth & Planetary	✓	✓				✓			
Smith	Richard	Arts & Sciences	Anthropology		✓	✓			✓		✓	
Smith	Joshua	Arts & Sciences	Earth & Planetary		✓			✓	✓			
Stadermann	Frank	Arts & Sciences	Physics	✓				✓				
Sureshkumar	Radhakrishna	Engineering	Chemical Engineering	✓				✓	✓			
Sweet	Frederick	Medicine	Obsterics & Gynecology	✓				✓		✓		
Templeton	Alan	Arts & Sciences	Biology	✓	✓							
Thaman	Ralph	CFU	Facilities			✓		✓	✓			
Thomson	Thomas	Sam Fox	Architecture		✓							✓
Treiman	Rebecca	Arts & Sciences	Psychology			✓					✓	
Turner	Jay	Engineering	Environmental Engineering	✓	✓							
Wolff	Jane	Architecture		✓			✓					
Wrenn	Brian	Engineering	Environmental Engineering	✓	✓		✓					
Yoak	Stuart										✓	✓

Review of Arizona State University (ASU) Global Institute of Sustainability (GIOS)

ASU's GIOS provides an interesting model for the WUSTL deliberations about a center for the study of the environment. ASU's GIOS is the most recent name for what was once known as the Center for Environmental Studies. At present GIOS is largely a research organization but in the next 18 months it will emerge as a degree-granting school of sustainability (offering BA/BS, MA, and Ph.D. degrees). As such, GIOS is in flux, but there is a great deal we can learn from their successes and failures. T.R. Kidder did a site visit on February 3, meeting with the director, Charles Redman, and many staff representing different branches of GIOS (planning, education/communications, management, grants and academic programs). A good deal of information about GIOS is available on their web site (http://sustainable.asu.edu/gios/index.htm).

This review emphasizes issues that were covered by Professor Lowery in his site visit to Stanford and expands on some of the most important lessons articulated by the director and staff of GIOS.

1. GIOS results from the transformation of environmental studies, which was seen by the university president as moribund. The emphasis on sustainability is likewise a direct result of the president's interest and emphasis. Both entities (environmental studies and GIOS) were principally research-oriented centers and did not have a mission for teaching at the undergraduate level. ASU had many programs and scholars interested in environmental research, teaching, and education, and GIOS has as a core mission the support of these faculty. Because it will become a degree-granting school, it envisions an increasing role as the center for teaching environmental studies/sustainability at all levels.
2. GIOS is run by a director, Charles Redman, and supported by 8-12 full-time staff. The director and full-time staff are funded by a "hard" budget-line derived from the annual state appropriation. Everyone at GIOS emphasized that this full-time hard money support was crucial and integral to maintaining the activities of the Institute. At present GIOS reports to the vice president for research but will soon move under the provost as it becomes a degree-granting school. The mandate of GIOS is to "catalyze and advance interdisciplinary research on environmental, economic and social sustainability, especially as it relates to urban areas."
3. Besides a core staff who run research programs, education and outreach, business, strategic planning, network/technology, and grant/proposal writing, there are some faculty who are halftime on the institute budget and halftime in an academic department (currently 10-14 faculty). In addition, they have staff that run data management, GIS labs, and manage grants that are funded by "soft" money sources. In some cases staff move between soft and hard money lines depending on what role they play at any given time. There is an internal faculty oversight committee and an external committee who advise the director.

Brief Review of the Stanford Institute for the Environment

The Stanford Institute for the Environment (SIE) provides a useful example for WUSTL's deliberations regarding a possible center for the study of the environment. We can draw lessons from the things we have in common as well as the things we may do differently. Professor Lowry did a site visit to SIE on January 27, meeting with the Director (Professor Jeff Koseff) as well as other faculty members. The SIE has a very informative web page (environment.stanford.edu) with many helpful links, so I will not review all aspects of the program but rather focus on those things that may be of use to our deliberations.

1. Many parallels exist between the SIE and what we might want to do here at WUSTL. Stanford is a private, highly regarded university that, until 2004, had many disparate programs and projects dealing with environmental issues. Some of those programs were quite active and had been so for years. Their situation was thus not unlike what we currently face.
2. The history of the creation of the SIE is also somewhat similar to our own recent history. A major assessment of the university in the late 1990s identified study of the environment as a priority for the future. A faculty work group met over several years to discuss how to move the university forward in this area. In the early 2000s, their efforts gained the support of the university's president and the influx of new grant money. Thus, in April 2004, the university established the SIE under the leadership of two co-directors in different disciplines, Professor Koseff of Civil and Environmental Engineering and Professor Barton Thompson in the Law School. The mandate is to be an independent, interdisciplinary center that will serve as a hub for all environmental research and education on campus.
3. In creating the Institute, the directors and members of the faculty leadership committee realized that the SIE had to be more than just a face to the outside world. They needed a mission that emphasized certain principles. These are to:
   - enhance the environmental infrastructure of the university (through personnel and facilities)
   - facilitate collaborative transfers (inside and outside the university)
   - promote economic opportunities in environmental solutions.
4. The personnel infrastructure of SIE currently consists of the two co-directors, a staff of 10-15 people, the Faculty Leadership Committee (a dozen faculty members from different disciplines), and the fellows of the program. The staff includes a director of programs, a business manager, a communications manager, and several administrators.
5. In terms of facilities, Stanford will soon construct a high-tech, state-of-the-art building for the SIE. This building will be beyond Leed-platinum standards. One goal for the facility is to use 50 percent less energy than buildings of its kind. Over 40 faculty members will be located in the building by the fall of 2007. Faculty members will be placed in offices that cluster around research foci, such as energy or oceans, and not according to existing disciplines. Director Koseff is confident that this will facilitate interdisciplinary collaborations.

6. The SIE is not a degree-granting authority. Thus, undergraduate advisees remain in their home departments. The SIE does, however, foster teaching and training in environmental issues in important ways. At the undergraduate level, the Center invites faculty to teach interdisciplinary undergraduate courses. Many of these are taught through the Stanford Introductory Studies curriculum that all students are encouraged to take. These typically involve freshman seminars or sophomore dialogue classes. At the graduate level, the SIE supports the Interdisciplinary Graduate Program in Environment and Resources (iper.stanford.edu). Graduate students can achieve their PhD through this program or a dual (not sole) Master's degree.
7. The SIE is still developing compensation mechanisms for faculty involvement. One current mechanism involves seed money in the form of research initiation grants for collaborative proposals. Last year alone, 87 faculty members from 29 different departments (including classics, music, and chemistry) submitted 39 different proposals. Of these, 12 were fully funded. In terms of compensating faculty for co-teaching interdisciplinary courses, the current procedure is as follows. The SIE requests the cooperation of departments who contribute faculty members for teaching time. They have received a wide range of reactions, but in most cases, the SIE provides compensatory funding to the home department for a faculty member's teaching time.
8. Appointments to the SIE can take several forms. Most faculty members are appointed jointly with their home departments. For junior faculty, the tenure line is in the home department. The SIE also can appoint Senior Fellows for varying periods of time who will be housed in the institute's facility. Over 50 applications for such fellowships have already been received.
9. One of the ongoing activities in which SIE faculty participate is a weekly forum that brings in outside speakers or discusses an in-house faculty member's current research. These are quite interdisciplinary. Director Koseff and one other faculty member both called these weekly meetings the "glue" that has held the institute together.
10. One SIE faculty member also mentioned that Stanford has a green dorm. The emphasis in this housing unit is on sustainability and energy efficiency. It does not have a formal relationship to the SIE.

POTENTIAL FUND-RAISING SUGGESTIONS

There are several sources from which funds can be raised to support the activities of EERI. These include Federal Agencies, Foundations, Corporations and other partners. The Community Environmental Center that will coordinate outreach activities will provide support for fund raising efforts for EERI.

1. **Federal Agencies**: Several agencies support energy and environmental research, and have specific programs. These include NSF, EPA, DOE, DOD, USDA, NIH, NIEHS, NASA, Homeland Security and others.

2. **Foundations:** Sloan, Ford, Mott, Rockefeller Family, Dreyfus, Rasmussen, and many others. Some of them support research for the natural environment, education, environmental justice, and others are more open ended. The following website http://www.environmentalgrants.com/ has a list of foundations that support environmental activities to the tune of $ 1 billion annually.

3. **Corporate Partners:** Partnerships with corporations should be created for an annual member fee. Currently, the Environmental Engineering Science Program and the Chemical Reaction Engineering Laboratory have Industrial Partner Groups, and these should be extended to include at least 50 member companies.

   Local multinational companies: Boeing, Tyco, Malinckrodt, Sigma Aldrich, Monsanto, Emerson, Ameren UE, Doe Run
   Multinationals: DuPont, Dow Chemical, Cabot, DeGussa, BASF, 3M, Shell, BP, Exxon-Mobil
   Environmental Consulting Companies: URS, CH2MHill, Jacobs, Trinity, Variety of Small Businesses.

   Create focus groups:
   Clearinghouse for Energy Issues: Ameren UE, Arch Coal, Peabody Coal;
   Nanoparticle Technology and Safety: many companies

4. **Partnerships:** Partnerships with NGOs and other organizations – Missouri Botanical Garden, St. Louis Science Center, United Nations, World Bank, USAID, International Foundations

5. **Individual Donors:** There are several individuals who have amassed wealth, and would like to see it put to good use for supporting education and research related to energy, environment and public health. Notable examples are Bill Gates, Vinod Khosla (founder of Sun Corporation) and many other former CEOs.

Acknowledgements

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Dr. Glen Stone, Anthropology

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Current Environment Related Research Grants

A partial list of faculty research grants related to Energy and the Environment for the last three fiscal years is provided. Grants related to energy and environmental research for all faculty listed in Appendix D that could be extracted from the University research database are included. The list is not complete as there are additional faculty at the University conducting research in this area. Furthermore, several industry supported grants and contracts are not listed.

Total number of faculty with grants listed = 47

16 from Engineering
6 from Earth and Planetary Science
2 from Anthropology
8 from School of Medicine
7 from Biology, and
8 from other Arts and Sciences, Law

TOTAL RESEARCH PROJECT FUNDS LISTED = $ 54.4 million
(Current, and FY 05, 04 and 03).