ENERGY TASK FORCE

A report on education and research on energy
INTRODUCTION:

Energy, its generation, transmission, storage and consumption are some of the major challenges that our society is increasingly facing. Energy is the main driver in almost all economic activities including transportation and manufacturing. In addition, energy generation and consumption is closely related to other challenges and becomes a controlling factor in environmental pollution, atmospheric warming, and mobility of populations.

Two important drivers for energy consumption come from the continuous rise in human population, the steady increase in industrial output, and the world-wide changing lifestyles of consumer economies as a result of rapid industrialization.

Much data is available on population growth and projections for our future. Several websites present instantaneous population clocks and other pertinent information. These include:

http://opr.princeton.edu/popclock/

www.worldometers.info/

In addition to the overall increase in world population, changing people demographics, caused by non-uniform growth rates, continue to shift balances and introduce new pressure points to the world.

Long-term prediction of energy consumption is a difficult task given the political shifts and dynamics in energy-related technologies. Much information and speculative data is available in the literature. However, one thing for certain is that problems related to energy, ranging from its generation to consumption and consequential impacts, will continue to be a major challenge and will also continue to play an ever increasing role as an instrument in world politics.
Increase in individual energy consumption levels in already populous countries such as China compound the problem both from an energy viewpoint as well as in its environmental consequences. In the United States, the annual CO$_2$ release to the atmosphere per capita already exceeds 30 tons per year. Considering that combustion of only one gallon of gasoline releases 18+ pounds of CO$_2$ into the atmosphere, the link between population growth, equalizing of lifestyles, energy consumption, and the environment become quite clear.

In the United States, energy inventory shows that energy consumption was at 94.6 Quads ($10^{15}$ Btu) in 2009 and it is predicted to reach 133 Quads by 2025; an increase of 40% in 16 years. Oil is likely to continue to be the major source of energy. Hydroelectric generation has its own natural limitations in terms of availability and although some progress can be expected from advances in renewable energy sources, they are not likely to make significant progress in meeting the growing needs.

Global energy consumption follows a similar pattern with increases expected in every form of energy generation. Nuclear energy, even though controversial in several countries including the United States, is gaining importance as a viable means for long-term energy generation in light of the steady depletion of fossil fuels. Improvements in nuclear fuel management and safety are likely to make nuclear energy more acceptable in the future since the alternative energy sources will be limited to meet the demand.
ENERGY TASK FORCE

Since issues surrounding energy are not only a topic of current interest, but also a growing global concern, WPI has established an Energy Task Force to determine an action plan to help our students be better prepared as professionals and become informed world citizens. Another task is to identify potential research areas for new discoveries that will produce positive impact on areas related to energy.

The Energy Task Force Committee was appointed by the Provost and had the following membership:

- Selçuk Güçeri, Dean of Engineering – Chairman
- David Cyganski, Electrical & Computer Engineering
- John Orr, Electrical & Computer Engineering
- Diran Apelian, Mechanical Engineering and Director—MPI
- Rick Sisson, Mechanical Engineering and Dean of Graduate Studies
- Pamela Weathers, Biology & Biotechnology
- Robert Thompson, Chemical Engineering
- Germano Iannocchione, Physics – Department Head
- Stephen Flavin, Vice President, Academic & Corporate Development
- Sharon Johnson, School of Business
- Robert Kruger, Political Science
Four subcommittees were formed to focus on the following topical areas:

- Inventory of existing activities both within WPI and outside
- Education at Undergraduate and Graduate levels
- Exploration and research
- Outreach and globalization

DELIBERATIONS

Many options were considered within the framework on energy studies. It is noted that the subject field is so broad that it is impossible to develop a comprehensive approach to address the large number of issues related to this important field. A study of energy-related research across the United States revealed a large number of institutions varying in size and focus area. Their areas of concentration ranged from renewable energy to consumption and storage. Many of these activities were carried out in a Center format also ranging in size greatly. Federal and state funding were the principal drivers for their existence as well as size and focus areas.

At WPI, 25 faculty responded to a survey as being active in energy-related activities. Their time commitment to energy studies ranged from 5% to 100% and included work on new generation of batteries to wind energy, smart-grid systems, and algae-based renewable energy as well as energy conservation. The average time commitment for these 25 faculty members was 24%.

The overall outcome suggested that WPI should focus on our existing and current strengths and to develop more organizational improvements/approaches to increase the efficiency and breadth of operations. Along those lines, offering new degree programs both as a stand-alone degree or even a “Minor” in engineering were eliminated as options. For undergraduate studies, WPI is known for its project-based learning. As such, the committee strongly recommends the formation of a WPI
Sustainability Energy Project Center to achieve the goal of educating our students in this very timely topic, covering the consequential issues such as sustainability, environment as well as policy and business components. At the graduate level, it is recommended that energy related research should follow our current strengths and benefit from the dynamics in federal programs both in support of individual research activities as well as the establishment of large-scale and comprehensive research centers. The following sections further elaborate on these two categories of undergraduate and graduate based activities.

WPI SUSTAINABLE ENERGY PROJECT CENTER

The WPI Sustainable Energy Project Center will be co-located on the premises of a National Energy Laboratory. It will act as a comprehensive WPI project center hosting IQP, MQP, and graduate projects related to renewable energy production, energy conservation, and sustainability with substantial elements of entrepreneurship and commercialization. Similar to WPI’s other project centers, students will have the opportunity to solve real-world problems working in small teams in close collaboration with faculty who supply supervision and mentorship. At this Center, students will also have access to Department of Energy laboratories, test facilities, and research personnel to work on cutting-edge pressing problems in this strategically important domain.

The Sustainable Energy Project Center represents a new exemplar for WPI project centers. This Center couples the Global Perspectives, Great Problems, MQP/IQP, and graduate project programs at WPI by providing access to resources and facilities that address one of the great challenges of the world in the context of both of WPI’s project-based degree requirements. It will be the first center that can host a project in virtually any disciplinary area as well as and in conjunction with societally important IQP projects. It will allow the faculty to explore the possibility of super-projects that involve cross-
communicating teams from many disciplines and IQP areas working together to explore technical solutions while concurrently examining societal impacts and commercial viability. The National Energy Laboratory will benefit in many congruent and overlapping areas of national importance, among these are: education of a strategically important workforce nationally, development of talent immediately relevant to the Lab, and outreach activity with societal impact promoting the mission of the Lab. This is by no means an exhaustive list.

Because of the disciplinary breadth of the Department of Energy’s activities and the resources available at the National Laboratories to address these diverse aspects, a great span of academic majors can be served at the new Center. For example, the major thrusts of the DOE can be aligned with WPI supported disciplines as shown here:

**Energy Research and Development**
- Aerospace Engineering
- Chemical Engineering
- Electrical & Computer Engineering
- Computer Science
- Mechanical Engineering
- Robotics Engineering
- Physics

**Energy Policy**
- Economics
- Social Science
- Society, Technology and Policy
- Sociology
- System Dynamics

**Biomass and other fuel development**
- Biochemistry
- Biology & Biotechnology
- Bioinformatics & Computational Biology
- Chemistry

**Environmental Impact and Conservation**
- Environmental Studies
- Mathematical Sciences
- Civil & Environmental Engineering
- Architectural Engineering
- Environmental Engineering

**Education**
- Interactive Media & Game Development
- Liberal Arts & Engineering
The opportunities for collaboration and access to facilities created by the special center will allow WPI faculty to participate in their own disciplinary research as visiting researchers while participating as mentors in the MQP/IQP programs. Furthermore, research begun by an undergraduate can lead to on-site thesis work and graduate internships, extending the scope of project education at WPI by creating new durable tracks for continued pursuit of passions.

To apply for the Sustainable Energy Project Center, prospective IQP and MQP students will have to be enrolled in the Energy or Sustainability minors at WPI and have completed at least two courses that belong to the special energy sector interdisciplinary or disciplinary courses. This will guarantee proper preparation for rapid on-site productivity. Benefits of this Center for WPI can be summarized as follows:

- Provides another venue for students seeking the unique benefits of the WPI educational program with a tight connection to a national strategic initiative and alignment with academic and career opportunities that span nearly every major available at WPI.
- Promotes careers in energy research, commercialization, policy and business.
- Attracts students to WPI with an interest in the future of energy by highlighting what WPI has to offer and the “WPI Difference.”
- Creates a pathway into a nearly incomparable number of collaborative research and funding opportunities for WPI faculty with the Department of Energy, which can grow organically from connections and familiarity that arise during faculty project advising visits.
- Connects WPI projects and faculty with DOE funding opportunities, and possible opportunities for graduate internships and fellowships.
- A well populated WPI remote campus offering IQP K-12 outreach projects to the surrounding school districts will enhance WPI’s visibility in the western states.

Benefits for DOE

- Increases visibility of National Laboratory and DOE programs
- Access to pre-qualified future workforce
- Address public education mission
- Access to WPI faculty with expertise in special disciplinary fields
**Proposed Project Site:** The Department of Energy supports 16 National Laboratories many of which have facilities and research programs that intersect with WPI’s programs and strategic interest in sustainable energy development. However, a review of these entities indicates that the most suitable site for the new project center would be the National Renewable Energy Laboratory (NREL). NREL is located on a 327-acre campus in Golden, Colorado (with an additional nearby wind technology center campus of 305 acres) and was funded in FY10 at the level of $536M. It is the only national laboratory solely dedicated to renewable energy and energy efficient technology development and commercialization. The activities at NREL include: development of renewable fuels (biomass, hydrogen, and fuel cells), renewable electricity (solar, wind, water, geothermal, smart-grid), architectural conservation (green building technology), energy science (chemical, bioscience, computational methods, and materials), business, policy and economic analysis (including market analysis and commercialization), and deployment (community education, information and analysis tools). The NREL appears to provide the full spectrum of opportunities for collaborative projects desirable for the WPI Sustainable Energy Project Center.

An appropriate strategy for initiating the undertaking of creating such a center would be engage in preliminary discussions at three levels: contact with the WPI alumni at NREL, discussion with leadership at the NREL and a visit with leadership at the DOE. We believe that WPI can present a compelling argument for the benefits of creating this center based on WPI’s pronounced success with project centers throughout the world. Potentially attractive to the DOE is that WPI could seek assistance from its congressional representatives as NREL is among the national laboratories that have recently come under budget cutting pressure.

**Types of Projects:** Energy is a topic for both IQPs and MQPs, but the learning goals of those projects are very different. WPI’s substantial experience with off-campus IQPs indicates that significant preparation focuses mostly on social science research methods, writing, and project management as well as on-site advising is required for success. This would engage elements of WPI outside the Engineering and Sciences area. MQPs will primarily draw upon the Sciences and Engineering disciplines and should have an ease of finding appropriate mentors/advisors who understand the educational objectives.
An MQP Center can still, of course, be highly multidisciplinary (and can still benefit from on-site advising -- more below).

The IQP component would require (a) enough projects/students (about 4 - 16) to justify a section of ID2050 to prepare them, and (b) to have an on-site WPI faculty advisor overseeing them.

**Faculty Director:** The success of any project center depends upon leadership from faculty champions and in this proposal, each faculty champion should have a clearly defined role with appropriate course release. The overall Center Director will play the most important role in building relationships, identifying projects and liaisons, negotiating on-site arrangements, etc., but also must be active here on campus to promote the program, recruit and select students.

**Faculty Advisors:** For MQPs and graduate projects, each student must have a project advisor in his/her own major. However, the envisioned scale of this Center would necessitate an advisor on-site to work with all the teams, keeping them on target. This requires a faculty advisor who is comfortable advising students outside their particular area. Obviously, this should be part of that person's teaching assignment and may require other incentives, as is done for the MIT-LL and other MQP programs.

**Budget:** There are two categories of costs to consider -- costs to WPI, and costs to students. Costs to WPI are dominated by faculty time and faculty travel/housing. Thus they will depend greatly on the advising model, and how much time WPI faculty members spend in Colorado. This can range from $50k to $100k/yr.

Costs to students are increasingly a barrier to participation, especially for off-campus MQPs. There should be strong consideration to subsidizing the cost for students. For example, two months at a site like Colorado, assuming modest student housing, might cost each student about $6,000. Revenues: Many of our successful IQP/MQP centers generate revenue that covers WPI's costs plus a portion of the students' costs. At centers such as Silicon Valley and Wall Street, fees of $20k to $25k per project are enough to cover all program costs plus subsidize part of the student experience. Sponsors usually pay this fee. Support for costs should also be sought from DOE education, internship and visiting faculty programs and/or a specific program initiated to support this new model for project education in the energy sector.

This proposal for a comprehensive Project Center would naturally pursue third party funding opportunities. Such funding is deemed of high potential for this proposal from sources interested in societal impacts, education, engineering and science research, and commercialization. Closing the loop in this manner opens many funding opportunities from federal, state, foundation, and commercial sources with the National Lab as a full partner.
GRADUATE PROGRAMS & RESEARCH

Graduate programs typically follow the national trends, industrial demands and federal funding opportunities. The following points reflect the general consensus of the Task Force regarding WPI initiatives:

Graduate Education

Energy-specific graduate education should be limited to “Certificate” programs and should be offered in collaboration with Corporate and Professional Education (CPE). The most immediate—and developing—need appears to be in the field of Nuclear Engineering. The main national driver for this is the U.S. Navy which has a large number of vessels operating under nuclear power. There is also projected demand by select utilities with a large number of nuclear plants to maintain their operation especially in light of the shrinking number of professionals joining the work force in this area due to the reduced number of programs.

A certificate program in Nuclear Engineering has just been developed and presented for faculty approval. The next phase will focus on marketing this initiative broadly and generating resources to sustain and further enhance the program.

It is recommended that similar certificate programs be considered in other areas by following the dynamics of national trends on issues related to energy development.

Graduate Research

Any major graduate research activity requires significant funding. At this point, federal agencies such as NSF, DoE, DARPA and ARPA-E are the principal sources for federal funding. Furthermore, research in universities can be conducted by both individual investigators and/or in multidisciplinary as well as multi-institutional research teams focusing on multi-component and large-scale problems. It is the recommendation of the Task Force Committee that these two approaches are not mutually exclusive and that both forms of faculty initiatives should be supported fully.

Organized team initiatives can be built by consolidating existing strengths and focus areas. There is significant funding for large-scale projects ($>10M) that come under various names such as Engineering Research Centers (NSG), Engineering CENTERS OF Excellence (DoD) and University Affiliate Research Centers (UARC). It is recommended that large-scale initiatives should align with institutional priorities which include sustainability, manufacturing and materials/metals processing.
Of the 16 national laboratories mentioned above, Lawrence Livermore National Laboratory (LLNL) has ongoing relations with WPI at the graduate level research. LLNL is a sponsor of two of our research centers, Metals Processing Institute (MPI) and the Integrative Materials Design Center (IMDC). As part of their strategic plan, LLNL is planning to launch an open campus where by partnering institutions will conduct research in collaboration with LLNL on energy-related advanced topics. The open campus will be staffed with the faculty from affiliate institutions and will provide a research environment as well as support for students who will then receive their degrees from their respective institutions. [https://str.llnl.gov/Mar11/pdfs/3.11.4.pdf](https://str.llnl.gov/Mar11/pdfs/3.11.4.pdf)

The LLNL Open Campus is expected to produce the technical talent needed to develop long-term solutions to the energy problem through advanced research in fusion and other forms of energy generation. WPI should explore partnership opportunities in this new paradigm for conducting research in collaboration with LLNL and in becoming one of the principal founding members in this initiative/allyance.
One of the areas recognized as an important research focus is energy conservation in manufacturing. It is noted that in recognition of its importance, the Department of Energy is giving strong emphasis to their manufacturing programs where the objective is to achieve significant energy savings in this important economic activity. In particular, metals recycling energy savings can be achieved by recycling light metals such as aluminum, nickel, and magnesium. This is an important component of sustainability for an increasingly industrialized world with increasing consumerism. Critical issues still remain in the identification, purification and design/development of material properties for high value-added applications. Accordingly, we should encourage development of a Center for Energy, Manufacturing & Sustainability (CEMS) that embraces the three institutional priorities of energy, manufacturing and sustainability. Funding for such a Center may come from federal programs such as NSF-ERC (Engineering Research Center) and UARC (University Affiliate Research Center).

**SUMMARY**

The Task Force for Energy activities recognizes that energy, with its related issues of generation, storage and transmission, as well as its impact on the environment, sustainability and manufacturing will be one of the top challenges for the decades to come. Our recommendation is to build on the strengths of WPI at both the educational and research platforms by pursuing the following steps:

- Development of an Energy Project Center focusing on project based learning,
- Develop Certificate programs as needed in energy related subjects,
- Continue to strongly support individual faculty initiatives for externally funded project opportunities,
- Support an initiative for the establishment of a research center for energy, manufacturing and sustainability.