White Paper to the MIT Energy Research Council
Submitted by the MIT Energy Club

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Key Recommendations

The MIT Energy Club is honored to present this paper to the Energy Research Council outlining some actions that we believe will enable MIT to maximize its impact on global challenges in energy and the environment. Our key recommendations are summarized below.

- **Form a virtual energy center** that will serve as a resource for current MIT students, faculty, and affiliates, and will increase the visibility of energy activities at MIT.
- **Form a physical energy center** that will serve as a community center for energy students, faculty, and staff.
- **Establish an energy community** at MIT through interdisciplinary projects, regular colloquia, outreach to alumni, and energy events at the energy center.
- **Encourage energy entrepreneurship** to assist the commercialization of novel and important breakthroughs in energy technology developed at MIT.
- **Provide practice-based education** opportunities to students through internships, competitions, and on-campus projects to better prepare them for practical careers in energy.
- **Lead by example** by implementing innovative energy technologies and energy-efficient practices on campus.
- **Incorporate energy concepts into the core curriculum** through a GIR or throughout core courses to teach MIT graduates to incorporate energy considerations into their decisions as professionals.
- **Organize currently available classes** by creating a complete and updated list of existing energy classes at MIT, and making this list available from the virtual energy center, the MIT bulletin, and the MIT course listings.
- **Organize currently available degree programs** by creating a list of all degree programs that contain an energy degree, or that allow students to create an energy degree curriculum. Make this list available from the virtual energy center, the MIT bulletin, and the MIT course listings.
- **Develop energy courses** by evaluating the complete list of courses, student demand, and faculty availability and interest.
- **Develop energy concentrations and degrees** for students who want to formally specialize in energy.
- **Organize current energy research** by creating and maintaining an updated web resource listing all energy research being performed at MIT, and providing links to these projects, faculty, and labs.
- **Create energy fellowships** to support interdisciplinary student research that may not be supported by any single department.
- **Instate large-scale interdisciplinary research projects** to address the complexity of challenges in energy and the environment.

TABLE OF CONTENTS:

1. Introduction

The MIT Energy Club is an active student-based organization consisting of 260 MIT students and affiliates, holding weekly events focused on community building and co-education in the MIT Energy Community. As members of the MIT Energy Club, we are honored to submit this white paper to the ERC presenting our views on how MIT can best meet the goal set out by President Hockfield to address the challenges of energy and the environment.

In this paper we present our vision of an institution on the leading edge of environmentally and socially sustainable energy technology, policy, entrepreneurship, understanding, and practice. This vision is based on four central actions for MIT to pursue.

- **Organize** energy activities and research
- **Educate** students to be energy leaders
- **Innovate** by supporting diverse energy research and its implementation
- **Lead** by making the MIT campus a model for innovation, efficiency, and implementation of new ideas

At the heart of this vision is a prominent MIT Energy Center that builds community, synergy, and organization between the plentiful and diverse energy activities on campus and leverages these efforts to have a strong impact on the global community. This vision also includes an Institute-wide academic environment that instills energy awareness in students throughout the Institute as well as presents the opportunity for students to become specialists and experts in energy. Finally, the vision includes an energy efficient Institute that is a showcase for innovative energy technologies and efficient energy practices.

The following sections outline the Energy Club's vision. We provide our suggestions for improving institute energy efforts through academics, research, and initiatives beyond the classroom or lab. In the appendix, we also include an extensive list of our ideas for an Energy Web Resource, a list of existing energy organizations at MIT, a summary of existing energy classes and recommendations for additional classes expressed in the survey, and a summary of the results of our online energy survey of nearly 20% of the student body.

2. Energy Center

A comprehensive look at the activities within the Institute show that the MIT community is already teeming with the key ingredients necessary to make it the world's flagship in energy research, education, entrepreneurship, and leadership. MIT has classes in many energy topics, excellent energy focused faculty and research, some energy oriented student organizations, and a handful of active alumni energy organizations. While these individual ingredients are quite strong, many of them are also dispersed and uncoordinated. This lack of cohesion decreases the impact MIT activities have on the global energy crisis.

Key Recommendations

- **Form a virtual Energy Center.** Create a web resource including updated information on classes, degrees, research, events, people, activities, and opportunities involved in energy at MIT. (See Appendix A for detailed recommendations)
- **Form a physical Energy Center.** Create a space for energy events and activities, interdisciplinary studies, display of energy research, and energy coordination offices. Such a center should have dedicated staff that helps organize and plan activities.

The creation of an Energy Center and its affiliated resources will unify MIT's energy goals, and optimize individual energy efforts to have the greatest possible impact.

Benefits of an Energy Center include:

- Visibility to Global Community
- Visibility and accessibility to current and prospective students
- Synergy between individual projects
- Community amongst MIT energy researchers and students, and between MIT and its affiliates
- Continuity between faculty turnover
- Increased impact in Global Community

We would like to stress that the Energy Center would not take over all energy activities, but would serve as a resource and a coordinating body for energy activities throughout the institute. Some of MIT's strength come from its expertise in specific domain areas, and it would be counterproductive to change this structure.

The exact nature of this proposed MIT Energy Center will depend upon financial and organizational constraints. We can envision three different types of Energy Centers depending on the level of funding and integration with MIT's existing structure. As a minimum, a virtual Energy Center should be created and maintained by a small core staff devoted entirely to the coordination of energy activity at MIT. We describe the different characteristics of the three types of Centers below:

1) <u>Minimally Funded, Highly Leveraged Virtual Energy Center</u>
   - Create a Central Web Resource
   - Form a core staff to maintain the web resource and coordinate and organize MIT energy activities

2) <u>Moderately Funded, Institute-Core Energy Center</u>
   - Appoint a few core (~5) interdisciplinary energy faculty to positions in the Energy Center
   - Form a core staff to coordinate and organize MIT Energy Activities
   - Allot a small physical space to the energy community
   - Formulate an Energy Technology & Policy Degree Program
   - Create Central Web Resource

3) <u>Highly Funded, Institute-Wide Energy Center</u>
   - All MIT energy activities coordinated within single organization
   - Large physical space with joint professor appointments to the Energy Center
   - Director & Staff to coordinate and organize energy activities
   - Energy Technology & Policy PhD/Masters Programs
   - Central Funding Pool for Energy Faculty within the Center
   - Central Web Presence to enhance MIT energy visibility and provide a common resource for MIT Energy Community

At all levels of funding, an Energy Center will also have a role in energy academics and research at MIT, and in energy activities beyond the classroom and the lab.

3. Beyond the Classroom, Beyond the Lab

Perhaps the most important actions that MIT can take to address global energy challenges will be those that extend beyond the classroom and the lab. These actions will unite the MIT energy community around a set of common goals, increase synergy between projects and learning across projects, and demonstrate the benefits of implementing energy-efficient and innovative practices.

Key Recommendations

- **Build an Energy Community at MIT.** The establishment and nurturing of an energy community will build synergy between projects, increase awareness of existing MIT energy activities, and stimulate cross-disciplinary learning. This objective will be one of the primary functions of the Energy Center. This center would host and sponsor energy events, connect with alumni in the energy field, and publicize energy research being done at MIT and in the greater community.
- **Encourage Energy Entrepreneurship.** For MIT to truly impact global energy challenges, it is not enough to research and develop innovative technology. MIT should also assist the commercialization of the innovations made within its walls. This should be done by establishing a clean energy business incubator and providing seed funding for new energy technologies in the early stages of commercialization.
- **Provide Practice-Based Education.** Practice-based education such as internships, competitions, and on-campus energy-efficiency projects will expand on students' strong academic education and provide them with application-based experience.
- **Lead by Example**. Implement efficient and innovative energy technologies and practices wherever possible on campus.

Community

One of the easiest and most critical ways that the Energy Research Council could advance energy related efforts at MIT is by helping to develop a more cohesive energy community. MIT affiliates already do a great deal of energy work and have deep personal and professional interests in this topic. However, this community has not been developed to its full potential. Many energy-related research groups and degree programs operate independently of others, there are few forums where students can connect to one another, and alumni who are energy professionals are often unsure how to identify and interact with students who have energy related career goals. The promotion of community will be a main role of the Energy Center. In addition to developing a virtual and physical energy center, community can be fostered by the following actions:

- **Sponsor energy-related events.** A physical center could sponsor energy related events like an energy research colloquium for MIT affiliates to share their current work and a regularly scheduled social event.

- **Connect with Alumni Community.** The Energy Center should be charged with maintaining relationships with key players in the energy field through the MIT alumni network.
- **Publicize Research more broadly.** The Energy Center could be used as a vehicle for more actively communicating the findings of important research, and for promoting energy related research and for developing cross-cutting interdisciplinary research opportunities that may have broader appeal.

Entrepreneurship

MIT is uniquely suited to advance energy innovations through entrepreneurship. One of the reasons MIT has become a world class institution is due to the innovations created by commercial enterprises founded by MIT's graduates. Beyond the numerous and substantial contributions to society, these successes have resulted in MIT having greater ability to build its endowment and to attract the best and brightest students to become the new generation of innovators. Given MIT's commitment to help solve the world's energy problems, it only stands to reason that MIT should do everything in its power as an institution to support the creation and success of clean energy enterprises by MIT students and alumni. Some ways MIT can do so are listed below:

- **Create or invest in a fund to help seed clean energy businesses founded by MIT affiliates.** MIT can support the efforts of MIT students and affiliates by helping to provide relatively small investments for these companies that will enable them to prove their concept and access more traditional forms of financing.
- **Create a program to validate and demonstrate commercial clean energy technologies on campus.** Support the development of markets for clean energy innovations by demonstrating the viability of novel clean energy technologies.
- **Facilitate the licensing of clean energy technologies developed at MIT.** Designate a member of the Technology Licensing Office to focus on the development and licensing of clean energy technology intellectual property.
- **Partner with a clean energy business incubator in the vicinity of the Cambridge campus.** Many universities have affiliated with business incubators, but none are focused on clean energy technologies, and no others have access to the creativity and entrepreneurial spirit of MIT students and alumni. This incubator could be used to improve the critically important interface between MIT's research laboratories and society at large. It will be a proving ground to determine which clean energy technologies will have the greatest impact on the marketplace.

Practice-based Education

Energy issues are broad-based, interdisciplinary, and ultimately practical. While theoretical foundations are important, to address energy challenges one must understand how to engineer and implement change in the world. As part of MIT's energy efforts, we need to support practice-based, extra-curricular educational opportunities. We have identified three areas where those efforts could be particularly fruitful.

- **Energy internship program.** Internships would provide a direct avenue for current students to connect with MIT alumni and help students build relationships with industry professionals while they explore career opportunities in the energy field.
- **Energy Competitions.** MIT should increase and more broadly support extra-curricular experiences that can promote collaboration and innovation around energy. The MIT Energy Center could foster student participation in such competitions by having staff members promote the competitions and facilitate the formation of teams. While existing competitions, such as the Solar Decathlon or P3 Competition, could be better supported on campus, we would also like to see MIT help develop new competitions altogether. In addition, we believe that MIT should consider sponsoring a clean energy business plan competition, either in support of or in addition to the current Ignite Clean Energy competition.
- **Sustainable House.** MIT could support the development of a student residence, Sustainable House, to push forward energy research in their lives. This house could be an on-going experiment in technology integration, energy conservation and sustainable energy production. It would also be used as a test bed for the commercialization of technologies and for competitions.

Lead By Example

MIT should set high goals for on-campus energy use, waste management, and facilities management, and then meet them. We envision the MIT campus becoming a working laboratory for renewable and efficient energy production, energy conservation, green building technologies, energy saving real estate management practices, industrial ecology and product lifecycles, and more. This initiative would provide a resource through which technology performance could be tested, and could save money for MIT. It would also raise awareness about how green energy technologies can be used and how more sustainable practices can be adopted at a community level. In reaching this goal of being a campus model, we recommend the following steps.

- **Assess on-campus energy and materials use.** MIT should carry out a rigorous consumption assessment for the campus, and actively work to determine where we can reduce energy and resource demand and how we can integrate renewable production into our new and existing buildings.
- **Implement commercial clean energy technologies on campus.** MIT can set an example, while simultaneously meeting the energy needs of the campus through clean energy technologies that, when widely commercialized, will benefit society as a whole. Technologies implemented should range from motion-detector lighting and efficient heating and cooling to renewable energy generation technologies like solar and wind power.
- **Build new campus buildings and retrofit existing buildings to Leadership in Energy and Environmental Design (LEED) certification standards.** MIT should lead our

common understanding about how to incorporate our best building ideas not just through research and teaching, but also through the development and management of the buildings on campus.

4. Academics

One of the key ways MIT can influence the global community is by educating the world's future leaders about energy. The Energy Club recommends that energy be a core component of the academic curriculum. In order to accomplish this, we recommend that the current curriculum be critically reviewed and upgraded, and specific energy degrees and formal concentrations be introduced.

Key Recommendations

- **Instill Energy Concepts in the Core Curriculum.** MIT can influence how the leading professionals regard energy by including energy material in the core curriculum. To accomplish this, MIT should encourage the incorporation of energy modules in basic design, engineering, business, policy, urban planning, and architecture courses. MIT should also consider requiring an energy course as an undergraduate General Institute Requirement (GIR).
- **Organize Currently Available Classes and Degree Programs**. Create a comprehensive list of energy classes and existing energy degree programs. Post this list on the central energy web space. This list will serve as a resource to students interested in pursuing an energy education.
- **Develop Energy Courses.** Once a comprehensive list of courses is compiled, additional course material should be developed based on student demand and faculty availability. Student demand has already been identified in energy economics, business, policy, and specific energy technologies.
- **Develop Energy Concentrations and Degree Programs.** Create formally recognized concentrations in energy topics for existing degree programs, and ultimately create specific energy degree programs.

Energy in the Core Curriculum

By emphasizing energy in the core curriculum, MIT will train future leaders in all disciplines to incorporate energy considerations into their decisions. The Energy Club recommends incorporating energy into the core curriculum with two proposals:

- **Require an Energy GIR for Undergraduates.** The inclusion of an introductory energy GIR will ensure that all undergraduates will have a basic understanding of the multidisciplinary issues associated with energy. It will also act to encourage future graduate students to pursue studies in this area.
- **Provide Widespread Energy Education.** Incorporate energy concepts and methods into existing core classes in engineering, economics, policy, urban planning, and design. This will ensure that students understand the important interactions that energy has with every field, and incorporate energy considerations into their professional decisions, regardless of their degree program.

Course Organization and Degree Development

The Institute's many energy-related course offerings suggest that much of the material required to provide an exceptional energy education already exists at MIT. According to a survey performed by the Energy Club, 77 energy-related courses are currently offered, and are scattered throughout the Institute (See the Appendix for a more extensive list). We believe that what is primarily lacking is a proper structure to help students navigate a coherent course of study in energy. To address this issue, the Energy Club recommends:

- **Organize energy-related courses currently being offered.** Compile and post an organized list of energy-related courses. Make this list available from the MIT Energy Web Resource, the MIT Bulletin, and the MIT course listings.
- **Organize energy-related degree programs currently being offered.** Compile a list of all energy degree programs at MIT. Make the list available from the MIT Energy web resource, the MIT Bulletin, and the MIT course listings under the heading of "Energy Degrees". Currently, two options exist for students to obtain formal energy-related degrees. They include any degree from Nuclear Engineering, and the Mechanical Engineering undergraduate energy conversion track. Additionally, other options exist to create an energy-specific curriculum within other programs. These options include a general institute-wide PhD, specialization within the Technology and Policy Program, and specialization within the Engineering Systems Division program. The inclusion of these degree programs within larger departments makes them hard to find. Simply listing them in an energy-specific resource will greatly increase their availability and impact.
- **Develop new courses based on curriculum gaps and student demand.** Once a full list of energy courses is compiled, it should be reviewed for gaps with respect to student demand, and new courses should be added as needed. Based on The Student Energy Survey and the Energy Club's perception of the issue, we recommend more energy courses in energy economics, business, policy, interdisciplinary subjects, and specific energy technologies like fuel cells and photovoltaics.
- **Develop energy concentrations within applicable majors.** Many courses already exist in each department that relate energy to each field of study. To recognize energy as a significant part of each field of study, and to qualify the appropriate students as knowledgeable in this field, the MIT Energy Club recommends the formation of formal energy concentrations out of these existing classes in applicable departments.
- **Develop an energy degree.** What better way to impact the world's energy future, and to announce that MIT is serious about energy than to devote an entire degree program to energy. A comprehensive energy degree should include material on policy, technology, business and economics, and environmental issues. An example of an undergraduate program would require students to take certain fundamental subjects as the core energy curriculum, then would allow students to specialize in one area. A structured curriculum for this degree can be assembled initially from courses currently available through different departments. An example of a relevant graduate energy degree program would be the formation of a Masters Program in Energy Technology & Policy that could be administered by the MIT Energy Center. This would allow students to gain a Masters level expertise in the Energy field either alone or concurrently with other MIT degree programs.

5. Research Opportunities

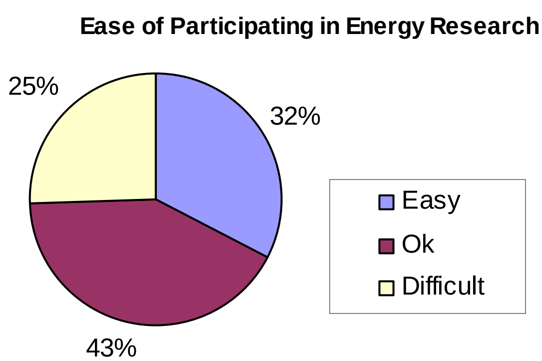
MIT consistently makes direct contributions to global challenges through its research. This research also draws prospective students, and develops and refines the education of current students. In this way, research also contributes to global challenges by better preparing MIT students to face them. However, a lack of coherence to the Institute's energy research portfolio makes MIT's research efforts less visible to the community outside of MIT, and for students interested in the energy field, makes the search for research opportunities frustrating and difficult. By making interesting research more visible and accessible, MIT will attract and focus top students towards President Hockfield's challenge.

Key Recommendations

- **Create and Maintain an Updated Resource of Institute Energy Research.** This resource should include links to research projects and labs in all departments related to energy. This list should be available through the MIT energy web resource and through the research and labs section of MIT's home page.
- **Create Energy Fellowships.** Because of the interdisciplinary nature of the most complex energy issues, we recommend that MIT create several student fellowships for students interested in energy research. These fellowships would facilitate research not supported by any single department.

Student Research

One of the major difficulties that students face when trying to locate appropriate research opportunities is the dispersed nature of energy research at MIT. Many students at all levels within the Institute (UROP, MS, PhD) reported difficulties securing energy research positions. Our informal survey of the student body indicated that 25 percent of the respondents who were seeking energy-related research had difficulty in obtaining an energy-related research position.



Survey comments reinforced this finding, and also suggested that even students that did find research positions were frustrated by a lack of options. Two of these comments are listed below:

> *“I must have looked at 40 different websites, but I still wasn’t sure of which researchers were doing what – descriptions of projects were out of date, and professors doing similar research seemed to be scattered throughout the institution, with no formal links to one another”*

> *“I couldn’t find research funding until I arrived on campus, so I decided to take a position in a field that I wasn’t as interested in – I wish I knew more about the opportunities in the energy space before I had to make a decision”*

Student’s difficulties participating in energy research activities once again demonstrate the need for organization of MIT’s energy research. An organized picture of MIT’s energy research would help draw students interested in energy work and would provide them with a clear outline of the direction, goals, and opportunities available at MIT. This organized directory of energy research would also benefit incoming students by helping them identify research opportunities, and would benefit current students by facilitating cross-disciplinary awareness and coordination. The organization and coordination of MIT research activities would prove beneficial to prospective, incoming, and current students.

The creation of interdisciplinary energy fellowships would further enable student research by facilitating interdisciplinary research that would not otherwise be supported by a specific department.

6. Institute Research Goals

Ground breaking research on many energy technologies is already beautifully conducted by individual departments at MIT. However, the complexity of global energy challenges gives rise to many cross-disciplinary research topics that fall beyond the scope of any single department. For this reason, the MIT Energy Club recommends the instatement of several cross-disciplinary research goals, and recommends their coordination by a core group of energy faculty affiliated with the MIT Energy Center.

Key Research Topics

- **Communicating Global Climate Change.** Despite significant research at MIT and other institutions, global climate change is considered poorly understood and gains little traction with the general public. While climate change science must continue to be developed, we feel strongly that there is a lot of progress to be made researching how to communicate the serious implications of climate change to the general public. Such work would require the integration of science, political science, economics, engineering, and urban studies, among others, to develop realistic and plausible scenarios to communicate the magnitude and importance of the climate change problem.
- **Conservation and Green Building Design.** The Energy Club would like to see a greater emphasis in energy conservation. Research areas could include industrial processes, residential space heating and appliances, and the design of green buildings
- **Energy and Developing Nations.** The field of sustainable development and energy in developing nations garners significant interest from students, yet it is consistently one of the most difficult fields for graduate students to secure funding in. We believe strongly that MIT should devote more resources to this area which would allow more students to participate in this area and improve the chances of developing sustainable energy practices for the developing world.
- **Pathways to Energy Demand Reduction.** Energy conservation has been technically possible for some time, yet such technologies have seen limited use in the United States due to social and cultural habits. In a country where energy conservation is rarely given much consideration, we feel that great progress could be made by researching different social, political, technical, or economic mechanisms to encourage energy conservation. This will essentially accomplish energy conservation from the demand side instead of the efficient technology side.
- **Energy Policy, Economics, and Business.** MIT has a lot of expertise in energy technologies, yet many of these technologies require fundamental developments in economics, policy, and or business fields before they may be successfully deployed. The Energy Club would like to see more research in such fields to enable the implementation of next generation energy technologies. Research into energy entrepreneurship could encourage revolutionary energy companies that would break from the traditional energy company model.
- **Grid-Scale Storage and the Orchestration of Intermittency.** We can generate energy from renewable resources like the sun and the wind. However, we can not control when

or where the wind blows or the sun shines, and hence when or where we generate power. What we can control, is what we do with the power when it is generated. A strategy must be developed utilizing grid operations and storage mechanisms to maximize the percentage of energy that can be generated from renewable, but intermittent, resources. A robust transmission and storage system will enable the widespread implementation renewable energy technologies, despite their intermittency.

Appendix A: Essential Web Resources

The MIT Energy Web Resource represents the simplest and most immediately effective tool that MIT can implement to unite and organize energy efforts at MIT. This web resource also represents the minimum action that should be undertaken. The following is a list of information that would be essential to list on this web resource. Many of these resources could be links to other offices or departments, such as the MIT Careers Office. However, the purpose is to have a central location for obtaining information about energy at MIT.

- **Energy Classes List** – A list of energy-related classes, searchable by discipline, type (e.g. survey, technical and policy), etc. This list should link to the MIT Catalog.
- **Research Directory –** A database where Professors and Research Scientists can post current energy research opportunities. It would be particularly helpful if this directory had a way to highlighted interdisciplinary projects, since they are particularly appealing and useful to students with professional aspirations as opposed to research or academic goals.
- **Laboratory Directory** – A directory of links to every MIT laboratory performing energy-related research. Perhaps this section could even take the form of a clickable campus map that identifies energy hotspots on the MIT campus.
- **Faculty Directory –** A list of faculty engaged in energy research. This would be similar to a Laboratory Directory. However, it would provide an alternative means for students and prospective students to investigate potential research advisors.
- **Club Directory –** A directory of undergraduate and graduate student clubs that concern themselves with energy.
- **Alumni Directory –** A directory of MIT alumni working in energy-related fields that are willing to act as a resource for current students and/or that offer internships.
- **Internship Directory** – A link to energy-related internship opportunities through the MIT Careers Office.
- **Fellowship Directory** – A directory of MIT, private, and federal energy-focused fellowships.
- **Degree Programs –** A list of existing degree programs that allow students to create an energy-focused degree, such as TPP or ESD, or that specialize in energy, such as the Mechanical Engineering Department's Energy Conversion undergraduate degree track.
- **Energy Events –** A calendar of energy events at MIT and within the greater Boston area. The MIT Energy Club currently provides a similar weekly email announcement to its members.
- **Energy Use at MIT –** A real time analysis of MIT's energy use, including a description of initiatives being undertaken to increase efficiency and incorporate advanced technologies.
- **Energy Footprint Calculator –** A resource that will calculate energy consumption and environmental impact of interested individuals.

Appendix B: Resource of Current Energy Groups

As a resource for building community, a list of current groups is provided below with contact information.

Student Energy Organizations

- MIT Energy Club
  - President: Dave Danielson, dtdaniel@mit.edu
  - http://web.mit.edu/mit_energy/
- Sloan Energy & Environment Club
  - President: Kerry Bowie, kbowie@mit.edu
  - http://web.mit.edu/sloaneef/
- Students for Global Sustainability
  - President: Samantha Sutton, ssutton@mit.edu
  - http://web.mit.edu/sfgs
- MIT Pugwash
  - President: Christopher J. Sequeira, csequeir@mit.edu
  - http://web.mit.edu/pugwash
- Design That Matters
  - President: Monica Lewis, ica@mit.edu
  - http://web.mit.edu/dtm/www
- Biological Energy Interest Group
  - President: Peter Weigele, weigele@mit.edu
  - http://web.mit.edu/being

Energy Entrepreneurship Alumni Groups

- MIT Enterprise Forum of Cambridge - Energy Special Interest Group
  - Chair, Jim Walker, jjwalker@alum.mit.edu
  - http://mitforumcambridge.org/EnergySIG.html
- Infinite Connection Interest Group – Clean Technology and Renewable Energy (MIT Club of Northern California, Renewable Energy and Clean Technology Program)
  - Anna Halpert-Lande, anna.halpert.lande@alum.mit.edu
  - cleantech@listserv.mit.edu
- MIT Enterprise Forum of South Texas (Houston)
  - Dave Johnston (President), dhjohnston@alum.mit.edu
  - Eric Chan (President-Elect), ekchan@inbrim.com
- MIT Club of Northern California
  - Ben Matteo (President), president@mitcnc.org
  - http://mitcnc.org

Appendix C: Energy-Related Classes: Recommendations and Resources

Full List of Energy Classes at MIT

Course Name	Number	UG/G	Term	Units	Description
Advanced Special Subject in Propulsion and Energy Convers	16.598/16.599	G	Fall, IAP, Spri	anged	Organized lec
Advanced Thermal Fluids Engineering	2.41	UG	Spring	: 4-0-8	Subject exam
Aircraft Engines and Gas Turbines	16.511	G	Fall	: 3-0-9	Performance
Alternate Energy Sources	12.213	UG	IAP	: 1-4-1	Explores a nu
Alternative Energy	SP.775	UG	Spring	: 3-4-2	A project-bas
Analysis and Design of Heating, Ventilating, and Air Conditio	4.427J/2.67J	G	Fall	: 3-0-9	Explores the
Applications of Technology in Energy and the Environment	1.149/2.63/5.00/10.579/22.813/ESD.174	G	Fall	: 3-0-9	Introduces ad
Architectural Thermal and Fluid Dynamics	2.661J/4.423J	G	Spring	: 0-2-7	Application of
Building Technologies II: Building Structural Systems I	4.462	G	Spring	: 3-2-4	Introduction t
Building Technologies IV: Energy in Building Design	4.464	G	Spring	: 3-1-5	Explores asp
Building Technology Laboratory	4.411	UG	Fall	: 2-4-6	Concepts of b
Building Technology Seminar	4.481	G	Fall	: 2-0-1	Introduction t
Circuits and Electronics	6.002	UG	Fall, Spring	: 4-2-9	Fundamental
Climate Physics and Chemistry	12.842	G	Fall, IAP	: 4-0-8	Meets with gr
Compound Semiconductor and Heterostructure Devices	6.772	G	Spring	: 4-0-8	Physics, mod
Corrosion: The Environmental Degradation of Materials	3.54J/22.72J	G	Fall	: 3-0-9	Applies therm
Daylighting	4.430	G	Fall	: 3-0-6	Provides the
Ecology II: Engineering for Sustainability	1.02	UG	Spring	: 3-2-7	Use of ecolog
Economics of Marine Transportation Industries	13.661	G	Fall	: 2-0-4	Studies the e
Electric Machines	6.685	G	Fall	: 3-0-9	Treatment of
Electrical, Optical, and Magnetic Materials and Devices	3.15	UG	Fall	: 4-0-8	Explores the
Electrical, Optical, and Magnetic Properties of Materials	3.23	G	Fall	: 4-0-8	Origin of elec
Electromagnetics	6.630	G	Fall	: 3-0-9	Introduction t
Electromagnetics and Applications	6.013J	UG	Fall, Spring	: 4-0-8	Electromagne
Electronic and Mechanical Properties of Materials	3.225	G	Fall	: 4-0-8	Electrical, opt
Elements of Reactor Design, Operations, and Safety	22.39	G	Fall	: 3-2-7	Integration of
Energy Systems and Economic Development	ESD.126	G	Spring	: 3-0-6	A team-based
Engineering Mechanics II	1.060	UG	Spring	: 3-2-7	Mechanics pr
Engineering of Nuclear Reactors	22.312	G	Fall	: 3-0-9	Engineering p
Engineering of Nuclear Systems	22.06	UG	Spring	: 3-0-9	Introduces en
Entrepreneurs in Innovation: Information Technology, Energy	15.398	G	Spring	: 2-0-4	Introduction t
Environmental Law, Policy, and Economics: Pollution Preven	1.811J/11.630J/ESD.133J	G	Spring	: 3-0-9	Reviews and
Environmentally Benign Manufacturing	2.83/2.813	G	Spring	: 3-0-9	Introduction t
Fundamentals and Applications of Combustion	2.28	G	Fall	: 3-0-9	Fundamental
Fundamentals of Advanced Energy Conversion	2.60/2.62J/10.392J/22.40J	UG, G	Spring	: 4-0-8	Fundamental
Fundamentals of Energy in Buildings	1.044J/2.66J/4.42J	UG	Fall	: 3-2-7	Introduction t
Fusion Energy	22.62	G	Spring	: 3-0-9	Basic nuclear
Global Change Science	1.071J/12.300J	UG	Fall	: 3-0-9	Introduces th
Global Climate Change: Economics, Science, and Policy	15.023J	G	Spring	: 3-0-6	Introduces sc
Implementing the Cambridge Climate Protection Plan	17.918	UG	IAP	: 2-0-4	This seminar,
Intermediate Heat and Mass Transfer	2.51	UG	Fall	: 3-0-9	Analysis, mod
Internal Combustion Engines	2.61	G	Spring	: 3-1-8	Fundamental
Introduction to Building Technology	4.401	UG	Spring	: 3-0-9	Introduction t
Introduction to Electric Power Systems	6.061/6.690	UG, G	Spring	: 3-0-9	Fundamental
Introduction to Ionizing Radiation	22.01	UG	Fall	: 3-0-9	Introduction t
Introduction to Solid-State Chemistry	3.091	UG	Fall, Spring	: 5-0-7	Basic principl
Logistical and Transportation Planning Methods	1.203J/6.281J/13.665J/15.073J/16.76J/ESD.216J	G	Fall	: 3-0-9	Quantitative t
Low Power Analog VLSI	6.376	G	Fall	: 4-0-8	A comprehen
Managing Nuclear Technology	22.812J/ESD.163J	G	Spring	: 3-0-9	An examinati
Mechanics of Material Systems: An Energy Approach	1.033/1.57	UG	Fall	: 3-2-7	Introduction t
Modelling and Approximation of Thermal Processes	2.52	G	Spring	: 3-0-9	Focuses on t
Neutron Science and Reactor Physics	22.05	UG	Fall	: 3-0-9	Sources of ne
Nuclear Engineering Design	22.33	G	Fall	: 3-0-9	Group design
Nuclear Reactor Physics I	22.211	G	Spring	: 3-0-9	Reviews the
Nuclear Systems Design Project	22.033	UG	Fall	: 3-0-9	Group design
Nuclear Waste Management	22.77	G	Spring	: 3-0-9	Introduces sc
Ocean Wave Interaction with Ships and Offshore Energy Sys	2.24	G	Fall	: 4-0-8	Reviews surf
Past and Present Climate	12.301	UG	Fall	: 4-0-8	Meets with gr
Photovoltaic Solar Energy Systems	SP.769	UG	Fall	: 2-0-4	Study and ex
Policy Choice and Global Environmental Issues	17.413/17.414J/ESD.156J	UG, G	Spring	: 3-0-9	Examines the
Power Electronics	6.334	G	Spring	: 3-0-9	The applicati
Power Electronics Laboratory	6.131	UG	Fall	: 3-6-3	Introduces th
Regional Socioeconomic Impact Analyses and Modeling	1.285J/11.482J/ESD.193J	G	Fall	: 2-1-9	Reviews regi
Seminar in Electric Power Systems	6.691	G	Spring	: 3-0-9	Planning and
Seminar in Environmental Science	12.085	UG	Fall	: 3-0-6	Stresses inte
Seminar in Nuclear Science and Engineering, Seminar in Nu	22.011, 22.911	UG, G	Fall	: 2-0-4	Surveys the r
Ship Power and Propulsion	13.21	G	Fall	: 3-1-8	Examines shi
Special Problems in Energy in Buildings	4.428/4.429	G	Fall, Spring	anged	Supplementa
Strange Bedfellows: Science and Environmental Policy	12.103	UG	Fall	: 3-0-9	Explores the
Sustainable Energy	1.818J/2.65J/10.391J/11.371J/22.811J/ESD.166J	G	Spring	: 3-1-8	Assessment
Systems Analysis of the Nuclear Fuel Cycle	22.351	G	Spring	: 3-2-7	In-depth tech
Thermal Energy	16.05	UG	Spring	: 3-1-8	Thermodynar
Transportation Demand and Economics	1.222J/ESD.202J	G	Fall	: 2-0-4	A survey subj
Transportation Flow Systems	1.225J/ESD.205J	G	Fall	: 2-0-4	Design, opera
Transportation Policy, Strategy, and Management	1.223J/ESD.203J	G	Fall	: 2-0-4	A survey subj
Transportation Systems	1.221J/11.527J/ESD.201J	G	Fall	: 2-0-4	Introduces tra
Urban Transportation Planning	1.252J/11.540J/ESD.225J/1.252J	G	Fall	: 3-0-9	History, policy

Energy courses by host department

77 courses related to energy are offered by MIT. With cross-listings, the 77 courses appear as 125 total offerings, and are summarized by host department in the table below.

Of the 77 energy classes, 65% are graduate, 35% are undergraduate. 60% are offered in the Fall, 45% in the Spring, and 5% during IAP (some are offered in multiple terms).

Table C.1.
Energy Classes by
Host Department

Course #	Total	%
1	17	14
2	15	12
3	5	4
4	11	9
5	1	1
6	12	10
10	3	2
11	5	4
12	9	7
13	3	2
15	3	2
16	5	4
17	3	2
22	18	14
ESD	13	10
SP	2	2
Grand Total	125	100

Table C.2.
Energy Classes Recommendations from the Survey

Classes		
Alternative Technologies	37	21%
Economics/Business	22	13%
Miscellaneous	20	11%
Policy	18	10%
Power/Electricity	10	6%
Human Behavior	9	5%
Systems	8	5%
Conventional Technologies	7	4%
Nuclear	7	4%
Buildings/Planning	6	3%
Chemistry	5	3%
Global Warming	5	3%
Survey	5	3%
Interdisciplinary	4	2%
Transportation	4	2%
Developing World	3	2%
Energy History	3	2%
Pollution	3	2%
Total =	176	100%

Summary of Survey Class Recommendations

Table C.2 above is a summary of the 176 written responses to the survey question: *What courses would you add that are not currently being offered?* In summary, three class areas stand out, requests for courses on specific alternative technologies, classes in economics and business, and more policy-oriented classes. General comments from the survey also highlight a need to both publicize and educate students on what classes are available and which they should be taking.

Current Resources that list Energy Classes

Current resources to identify energy classes include:

- MIT course listings and online course catalogue
- Individual department websites (e.g. TPP)
- EnviroClasses page

The lists of classes returned by each of these resources are summarized below. The MIT course catalog provides many listings, but is difficult to sort through. Program websites are outdated and not comprehensive. The EnviroClasses website is better organized and updated, but is not comprehensive, and may not be an obvious resource to new or prospective students. Better organization is needed.

1. MIT online course catalog

Searched for: energy
153 courses found.
http://student.mit.edu/@8866271.26432/catalog/index.cgi

2. TPP Track Information - Working List - 11/08/00

Electric Power			
	6.334	Power Electronics	(3-0-9); H; Spring
	6.686	Advanced Power Systems	(3-0-9); H; Fall
	~~6.689~~	~~Seminar on Power System Modeling, Dynamics, and Control~~	~~(3-0-9); H; Spring~~
	6.938	Engineering Risk-Benefit Analysis	(3-0-6); H; Spring
	~~ESD.161J~~	~~Operation and Planning of Electric Power~~	~~(3-0-9); H; Fall~~
	ESD.166J	Sustainable Energy	(3-1-8); H; Spring
			Number of Items: **4**
Energy			
	~~1.141J~~ (3.563J) ~~(22.822J)~~	~~Strategic Analysis for Environmental Policy Planning, Design, and Implementation~~	~~(3-0-6); H; Spring~~
	2.280	~~Fundamentals and Modeling in Combustion~~	(3-0-9); H; Spring
	2.58J	Radiative Transfer	(2-0-4); H; Spring
	2.615	Internal Combustion Engines	(3-1-8); H; Spring
	6.938	Engineering Risk-Benefit Analysis	(3-0-6); H; Spring
	10.551	Systems Engineering	(3-0-6); H; Spring
	10.74J	Radiative Transfer	(2-0-4); H; Spring
	15.023J	Global Climate Change: Economics, Science, and Policy	(3-0-6); H; Spring
	22.77	Nuclear Waste Management (Revised Content)	(3-0-9); H; Spring
	~~22.78~~	~~Nuclear Techniques in Environmental Analysis~~	~~(2-6-4); H; Spring~~
	~~22.812J~~	~~Nuclear Energy Economics and Policy Analysis~~	~~(3-0-9); H; Spring~~
	ESD.166J	Sustainable Energy	(3-1-8); H; Spring
			Number of Items: **9**
			Total Number of Items: 11

http://tppserver.mit.edu/index.php?idnum=55
Courses crossed out are no longer offered.

3. EnviroClasses http://greenclasses.mit.edu/index.jsp

Browse: topic: energy

18 classes...
Alternate Energy Sources (12.213)
Alternative Energy (SP.775)
Analysis and Design of Heating, Ventilating, and Air Conditioning Systems (4.427J/2.67J)
Architectural Thermal and Fluid Dynamics (New) (2.661J/4.423J)
Building Technologies IV: Energy in Building Design (4.464)
Daylighting (New) (4.430)
Energy Systems and Economic Development (ESD.126)
Fundamentals and Applications of Combustion (2.28)
Fundamentals of Advanced Energy Conversion (2.60) UG
Fundamentals of Advanced Energy Conversion (2.62J/10.392J/22.40J) G
Internal Combustion Engines (2.61)
Managing Nuclear Technology (22.812J/ESD.163J)
Nuclear Systems Design Project (22.033)
Nuclear Waste Management (22.77)
Ocean Wave Interaction with Ships and Offshore Energy Systems (2.24)
Photovoltaic Solar Energy Systems (SP.769)
Seminar in Nuclear Engineering (22.011)
Sustainable Energy (1.818J/2.65J/10.391J/11.371J/22.811J/ESD.166J)

Keyword Search Results: energy

26 classes...
Alternate Energy Sources (12.213)
Alternative Energy (SP.775)
Analysis and Design of Heating, Ventilating, and Air Conditioning Systems (4.427J/2.67J)
Applications of Technology in Energy and the Environment (1.149/2.63/5.00/10.579/22.813/ESD.174)
Biological Oceanography (7.47)
Building Technologies IV: Energy in Building Design (4.464)
Building Technology Seminar (4.481)
Climate Physics and Chemistry (12.842)
Ecology I: The Earth System (1.018J/7.30J)
Ecology II: Engineering for Sustainability (New) (1.020)
Energy Systems and Economic Development (ESD.126)
Environmentally Benign Manufacturing (2.83/2.813)
Fundamentals of Advanced Energy Conversion (2.60)
Fundamentals of Advanced Energy Conversion (2.62J/10.392J/22.40J)
Fundamentals of Energy in Buildings (1.044J/2.66J/4.42J)
Global Change Science (1.071J/12.300J)
Introduction to Building Technology (4.401)
Introduction to Hydrology (1.070J/12.320J)
Introduction to Solid-State Chemistry (3.091)
Land-Atmosphere Interaction (1.713J/12.826J)
Ocean Wave Interaction with Ships and Offshore Energy Systems (2.24)
Past and Present Climate (12.301)
Photovoltaic Solar Energy Systems (SP.769)
Regional Socioeconomic Impact Analyses and Modeling (1.285J/11.482J/ESD.193J)
Seminar in Nuclear Engineering (22.011)
Sustainable Energy (1.818J/2.65J/10.391J/11.371J/22.811J/ESD.166J)

Appendix D: Ways to Lead by Example

The following is a list of examples on how MIT can practice energy efficiency and demonstrate energy innovation on campus. These suggestions were compiled from the MIT Energy Club survey of the student body.

- Perform detailed assessment of energy use on campus
- Set energy use reduction goals and track progress
- Install renewable energy system on campus
- Use recycled paper at Athena print stations
- Make double-sided printing the default printing format at Athena stations
- Increase recycling
- Instate composting program
- LEED certify buildings
- Less extreme temperature control in buildings: It is currently too cold in the summer and too hot in the winter.
- Instate incentives and/or subsidies for students, faculty, and employees to bike to MIT or to use public transportation.
- Use motion sensing lights
- Use low-flow toilettes
- Install revolving doors.

Appendix E: Summary of Student Energy Survey Results

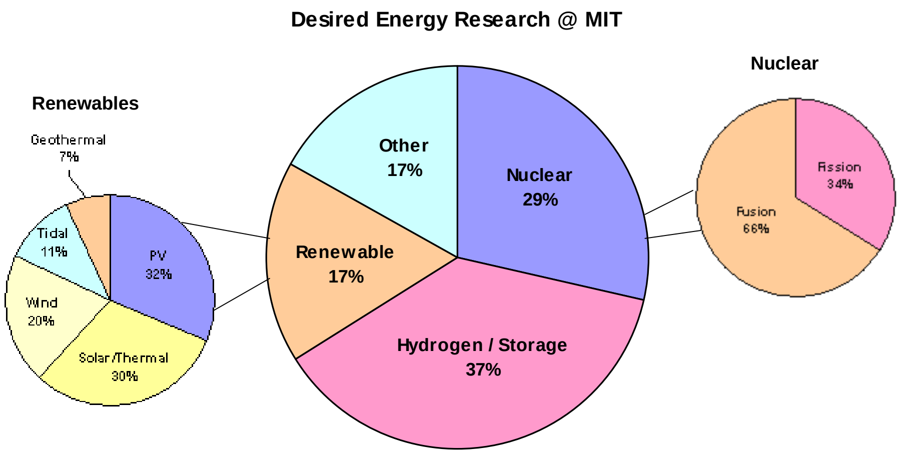
2005 Energy Survey Findings

Prepared by MIT Energy Club as
Supplement to Fall '05 ERC
Whitepaper

RENEWABLES, NUCLEAR & HYDROGEN RESEARCH CONSIDERED MOST IMPORTANT TECHNICAL AREAS FOR MIT TO ADDRESS

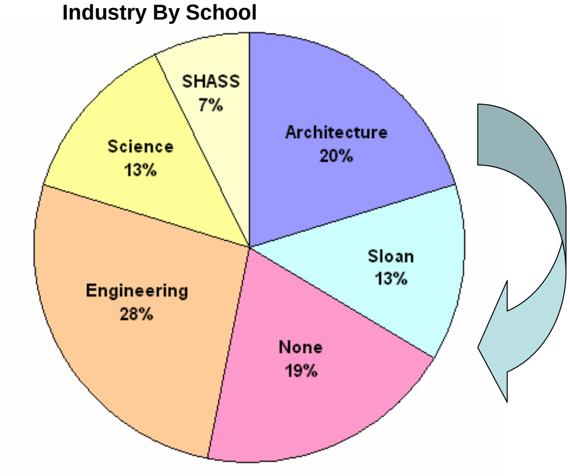
TOP 3 STUDENT CONCERNS:
1) Resource Depletion
2) Global Climate Change
3) Local Pollution Issues

TOP 3 ENERGY RESEARCH AREAS:
1) Renewable Energy Technology
2) Improvement in Conventional Energy
3) Transportation Technology



MIT STUDENTS WHO GO INTO ENERGY WANT TO BE BETTER PREPARED FOR ENTREPRENEURSHIP, POLICY AND MANAGEMENT

Students Planning to Enter the Energy Industry By School



Suggested Improvement @ MIT

- Energy Entrepreneurship
- Energy Policy
- Energy Related Management

MIT NEEDS CENTRALIZED ORGANIZATION TO PROMOTE ENERGY ENTREPRENEURSHIP AND PROVIDE ACCESS TO MIT ENERGY RESEARCH

71% of survey respondents express interest in exploring an energy career	Less than 10% have actively tried to get involved with MIT's scattered but sizable energy community	Low visibility across the Institute results in diminished student interest

MIT needs to support efforts to create a center promoting current research and providing more access to energy opportunities to develop student interest

MIT HAS PRE-EXISTING AVENUES TO IT CAN EXPLOIT TO PROMOTE ENERGY TECHNOLOGY RELATED ENTREPRENEURSHIP AND COMMERCIALIZATION

89% of students think it is very important for MIT to support the commercialization of energy technology developed at MIT

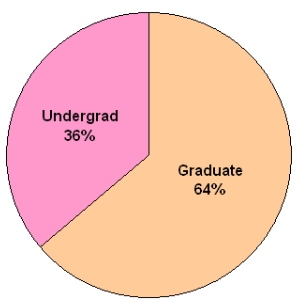
76% of students believe energy competitions are important for MIT to become a leader in energy research

I-teams, now entering its third semester has been tremendously successful and is vastly oversubscribed. MIT has an opportunity to leverage expertise from I-teams to design an energy commercialization program or class

The $50k is a nationally recognized entrepreneurship competition. MIT could do more to promote energy in the competition as well leveraging the $50k assets to design an energy specific event

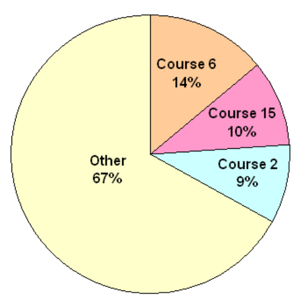
The Ignite Clean Energy competition is a business plan competition devoted solely to clean energy technologies. MIT should support this event and encourage and enable students to participate.

SURVEY RESPONDANTS REPRESENT DIVERSE SAMPLING OF MIT STUDENT COMMUNITY



Survey respondents are a representative mix of graduate and undergraduate participation. Actual: 40%:60%

Respondents from across university with small clusterings in Electrical Engineering, Comp. Sci, Management and Mechanical Engineering

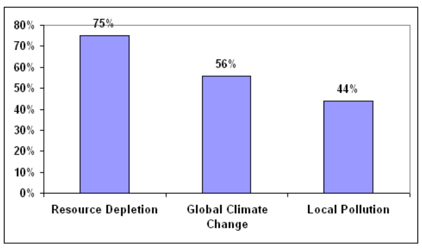


SURVEY ENCOMPASSES TWO MAIN INTEREST GROUPS: FUTURISTS AND ENVIRONMENTALISTS

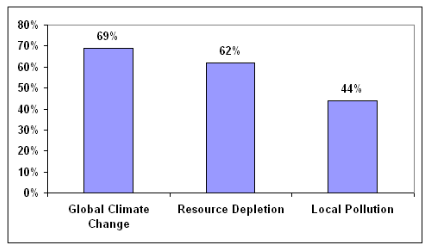
- Futurists – Primarily concerned with ensuring sufficient energy for future needs
- Environmentalists – Primarily concerned with environmental impact of global economic growth

Although respondents often have interests in both categories one interest is usually dominant over the other

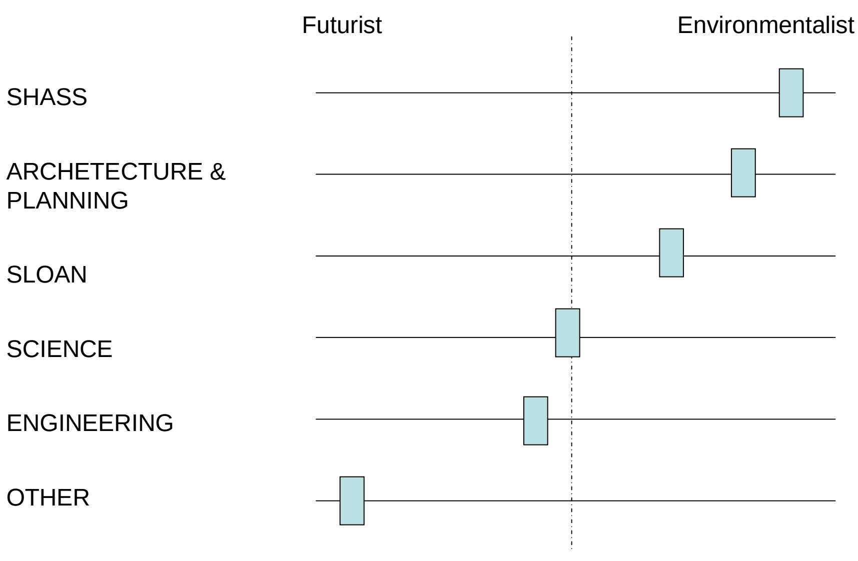
Undergrads are Futurists



Grads are Green



SCHOOLS WITHIN MIT REFLECT BIASES TOWARDS FUTURIST OR ENVIRONMENTAL LEANINGS



Appendix F: Complete Survey Results Link

The Energy Club received an overwhelming response to our Energy Club Student Survey on Energy at MIT, with responses from almost 20% of the student body.

Some key illustrative statistical results from this survey have been summarized in Appendix E. For a complete summary of Survey Results, including individual comments, ideas, and suggestions, please refer to our Survey Summary at the following link.

http://web.mit.edu/mit_energy/Energy_Survey_Summary.html