MEMORANDUM

TO: Fawwaz Ulaby, Vice President for Research

FROM: James J. Duderstadt, chair, Ad Hoc Committee on Hydrogen Initiatives

SUBJECT: Progress Report

This report summarizes the discussions of an ad hoc committee of university faculty and industry experts charged with conducting a quick scan of various approaches to building a significant research program addressing alternative energy supplies with a particular focus on hydrogen. Key in this effort was to explore the opportunities and challenges (e.g. a SWOT analysis) of various possible initiatives that could then be presented to an industry advisory board.

There are few contemporary challenges facing our nation, indeed our world, more threatening than the unsustainable nature of our current energy infrastructure. Every aspect of contemporary society is dependent upon the availability of clean, affordable, flexible, and sustainable energy sources–meeting human needs such as sustenance, shelter, employment, transportation, and health; the viability of our economy, in which over 7% of GDP is spent on energy; the fragile nature of our environment, seriously impacted by current technologies for producing and utilizing energy; and the security of our nation, threatened by an our greater reliance on foreign energy imports from unstable parts of the world. One could well make the case that not only should energy research, development, and policy receive the highest priority among national concerns, but such energy research should be a major focus at a leading public research university such as the University of Michigan, which has a strong responsibility to address the most urgent needs of our state, nation, and world.

With this urgency in mind, the committee considered three key criteria in our discussions:

i) achieving national energy independence
ii) minimizing impact on global climate
iii) addressing the particular needs of the transportation industry

Although our initial charge involved assessing possible initiatives concerning roadmaps to a possible future "hydrogen economy", with an emphasis on the use of hydrogen as a transportation fuel, the committee rapidly broadened this discussion to include an array of alternative energy options characterized by zero- or low-hydrocarbon emissions. Such considerations were embedded in a broader discussion of long-term energy options for both stationary and mobile applications.

Our discussions finally converged on four initiatives at the national, regional, state, and university level:

- At the national level, a major Department of Energy initiative to fund 8 to 10 "Energy Research Centers" on university campuses, organized much along the lines of the NSF Engineering Research Center Program.

- At the regional level, a consortium of university energy research centers focused on the energy needs of the Great Lakes states (e.g., manufacturing and transportation).

- At the state level, the establishment of several major energy research centers with a focus on transportation fuels, along the lines of the major initiatives in California ($300 million supporting R&D centers at UC campuses), Texas (Texas Energy Center) and Ohio ($20 million for its Fuel Cell Consortium), closely coordinated with existing efforts such as NextEnergy and the needs of Michigan industry.

- At the university level, establishing a major Energy Research Institute, aimed at building the University's capacity and presence in a range of scientific, technological, and policy issues involving transportation energy resources.

While each of these initiatives is self-standing, it is important to recognize key linkages that will determine Michigan's role. For example, a rapid and substantial effort is necessary to draw together and expand the University of Michigan's capacity in energy research if it is to have the capability and credibility either to participate in or lead such efforts at the regional or national level. So too, a substantial commitment at the state level (comparable to those in California, Texas, and Ohio) would be necessary for it to lead a Great Lakes consortium. The same linkages are true for participation, since any of these initiatives will eventually require strong collaboration among the University, the state, federal agencies, and Michigan industry.

A final word about University priorities here is important. As one of the world's leading research universities, the University of Michigan already has substantial activity and capability in a range of scientific, technological, and policy investigations important to future energy options. Yet, in part because these activities are dispersed across the University, and in part because of the dominance of other priorities both at the level of academic units and the university (e.g., the "bio-nano-info" initiatives), the University's energy research efforts are currently subcritical, receiving neither the institutional attention nor the external visibility they deserve. One could well make the case that there is no issue more critical to the future of our society than its capacity to meet future energy needs without destroying Planet Earth, either through permanently damaging our environment through energy production, or triggering massive geopolitical instability over energy resources. It is the committee's view that the staggering impact of energy issues for future generations compels the University to take a far more strategic approach to organizing, supporting, and building its energy research programs. The initiatives we have analyzed provide a possible framework for this effort.

INITIATIVE 1: A National Energy Research Program

The compelling nature of energy issues facing the nation, coupled with the clear imbalance between intramural (e.g., national laboratory) and extramural research (e.g., university and industry) characterizing Department of Energy research programs, suggests the need for a major university-based research center program similar to the very successful Engineering Research Center program of the National Science Foundation. To this end, one might consider that DOE fund a major "Energy Research Center" program, establishing 8 to 10 energy research centers on university campuses, each funded at an ongoing level of approximately $15 million per year, with supplemental support from state and industrial partners. The Energy Research Centers would be determined through a competitive grants program, with each center involving a lead university with both university and industry partners. The centers would conduct research, education, training, and technology transfer in specific but broad areas (e.g., hydrogen production, storage, distribution, and use; transportation energy sources; synfuels technology; advanced nuclear power technologies, etc.).

Such an initiative would respond well to the recent Vest Report[1] recommending both a major new initiative in energy research as well as a better balance between intramural and extramural research funded by the Department of Energy. The Advanced Strategic Computing Initiative center program funded at a number of university consortia by the National Nuclear Security Agency with DOE provides a model for such a DOE-based university center program. Key elements of the national research program are shown in Table 1.

Table 1. Key Characteristics of a University-based National Energy Research Program

Format	National university-based basic research initiative composed of 8-10 university centers addressing energy research, education, and training issues.
Focus	Broad portfolio of energy-related basic research topics. Each center focuses on a different aspect of energy challenge. At each center, carry out energy education programs at undergrad, grad levels, and industry-oriented continuing education program.
Organization	10-20 separate but coordinated university centers of excellence. Each center would be composed of a consortium of universities with one university as the lead. Emulate NSF Engineering Research Center structure.
Industry Liaison	Each university center emulates an NSF Engineering Research Center model. Each carries out an active industry/government liaison program. Each supports an active technology transfer program. Industry technology adoption is facilitated by an independent NIST ATP-like funded activity
Government Liaison	Each Center would engage federal/state agencies and organizations with interest in energy. Could include DOE, DOD, DOT, EPA, NSF, as well as relevant state organizations (e.g., NextEnergy).
K-12 Outreach	K-12 outreach addressed within each university research and education activity.
Annual Funding	Federal: $120-150M for university centers initiative Federal: $100M to leverage industry technology adoption projects Industry membership per center: $50K per company; $10K for SMEs State: Supplemental funding from participating university states
Duration	5 year base funding with 5 year renewal based upon performance
Oversight	Federal funding organization(s), each center Industry role on Executive Committee, each center

INITIATIVE 2: A Regional Consortium of Energy Research Centers

Many regions of the nation, such as the Great Lakes, will face serious energy-related challenges in future economic development. While in Michigan the availability of low pollution mobile energy sources will likely determine the future of the domestic automobile industry (and hence Michigan's future economic engine), there are similar concerns about stationary and distributed energy sources for the manufacturing industries of the Midwestern United States. There is also a strong desire on the part of agricultural community in the Midwest to develop biomass as an energy source.

Hence, the committee considered the possibility of a state-federal-industry funded consortium of energy research centers focused on the needs of the Great Lakes states, located on the campuses of the region's major research universities. Such an effort would likely be led by the Great Lakes governors (possibly with a leadership role played by Michigan's governor) and would be greatly facilitated by the long history of strong collaboration among the Big Ten universities (including the University of Chicago). In point of fact, the Big Ten universities represent the world's leading concentration of scientific and engineering research talent, a particularly powerful asset in addressing energy issues. Furthermore, a major federal laboratory

[1] *Critical Choices: Science, Energy and Security*, Final report of the Secretary of Energy Advisory Board's Task Force on the Future of Science Program at the Deparment of Energy, Charles Vest (Chm.), 2003

such as Argonne National Laboratory might be repurposed to support this regional effort. The specific characteristics of a regional consortium are shown in Table 2.

One variation on this theme would involve a coalition based on technology interests rather than regional location. For example, one could imagine a coalition involving Michigan, Texas, and California focused on future transportation fuels.

Table 2. Key Characteristics of a University-based Regional Energy Research Program

Format	A Great Lakes consortium of universities addressing energy research and education issues. (Alternatively, a geographically distributed set of universities strategically chosen from around the country).
Focus	Basic research topics addressing both mobile and stationary energy issues with a focus on transportation, manufacturing, and agriculture. Carry out energy education programs at undergrad, grad levels, and industry-oriented continuing education program.
Organization	Single university lead. Other universities are consortium members. Emulate NSF Engineering Research Center structure.
Industry Liaison	Engage energy, transportation, manufacturing, agricultural community and their 1st- and 2nd-tier supplier as partners on research projects. Offer favorable terms on licenses and patents. Provide access to test facilities. Provide support for high tech spin offs. Charge nominal fee for participation. Hold annual technology review and liaison meeting.
Government Liaison	Include regionally relevant federal agencies such as DOE (Argonne), DOD (TACOM, WPAFB), NASA Glenn, and EPA as well as state-based energy organizations (e.g., NextEnergy).
K-12 Outreach	K-12 handled within each university research and education activity.
Annual Funding	Federal: $15M per participating state State: $10M from each participating state Industry: $50K per large company; $10K for SMEs
Duration	5 year base funding with 5 year renewal based upon performance
Oversight	Federal funding organization(s) Participating states Industry member role on Center Executive Committee

INITIATIVE 3: A State Initiative

The State of Michigan could launch a major effort to build a State-based university research consortium to address scientific, technology, and policy issues associated with the development of future transportation fuels. Such an effort would be closely coordinated with existing state initiatives such as NextEnergy as well as tightly coupled to Michigan industry. In view of the increasing concern about Michigan's economic future, and the manner in which that future is inevitably coupled to energy issues, one might well make the case that an effort comparable to California's establishment of three $100 million research centers at University of California campuses, the Texas's Energy Center, or Ohio's is warranted.

Such a state-based initiative also aligns well with Michigan's traditional strengths in transportation technology and would likely capture significant federal funding, including the possible establishment of a new federal FFRDC in Michigan for research and development on advanced mobile energy sources.

It is important here, however, to learn from past experiences such as the Industrial Technology Institute, the Michigan Biotechnology Institute, and the Michigan Molecular Institute. These major initiatives of the 1980s demonstrated that such research centers formed outside of the state's research universities will inevitably fail, since they are unable to build the

critical mass of scientists, engineers, facilities, and support to thrive. The key here is to invest in centers within the research universities, with strong incentives to link to Michigan industry. The specific characteristics of a State of Michigan initiative are shown in Table 3.

Table 3. Key Characteristics of a State of Michigan-based State Energy Research Program

Format	State of Michigan consortium of universities addressing energy research and education issues. (Include MSU, WSU, MTU and other Michigan schools addressing energy research and education issues.)
Focus	Basic research topics addressing both mobile and stationary energy issues with a focus on transportation, manufacturing, and agriculture. Carry out energy education programs at undergrad, grad levels, and industry-oriented continuing education program.
Organization	Led by the University of Michigan. Other universities are consortium members. Emulate NSF Engineering Research Center structure.
Industry Liaison	Engage energy, transportation, manufacturing, agricultural community and their 1st- and 2nd-tier supplier as partners on research projects. Offer favorable terms on licenses and patents. Provide access to test facilities. Provide support for high tech spin offs. Charge nominal fee for participation. Hold annual technology review and liaison meeting.
Government Liaison	Include relevant federal agencies such as DOE, DOD (TACOM), and EPA (Ann Arbor) as well as Michigan-based energy organizations (e.g., NextEnergy).
K-12 Outreach	K-12 handled within each university research and education activity.
Annual Funding	Federal: $15-20M Industry: $50K per large company; $10K for SMEs State of Michigan: $1M in supplemental funding
Duration	5 year base funding with 5 year renewal based upon performance
Oversight	Federal funding organization(s) State of Michigan Industry role on Executive Committee

INITIATIVE 4: A University-Based Initiative

This initiative would involve forming a major Energy Research Institute at the University of Michigan, drawing both on existing capacity and building new capacity to conduct research on a broad range of scientific, technological, and policy issues involving the future of transportation energy systems (with hydrogen-based energy sources as a key focus). Although the startup funding for such an effort would come from University resources, it is anticipated that within 12-18 months, significant federal, state, and industrial support could be achieved.

Here the challenge is both to create a workable organizational structure that provides adequate visibility for existing activities (which are considerable, if out of sight and all too frequently out of mind. See Appendix A) and to make the investments to build new capacity (e.g., attracting lead researchers or programs to the University, much as was done in the high intensity laser field when Gerard Mourou's group was moved from the University of Rochester in the 1980s), invest in facilities.

Although the University already has made substantial commitments in other research areas, notably the life sciences, we believe that it cannot disregard the compelling nature of the energy issues facing this nation. As one of the world's leading research universities, one could make the case that Michigan has a major responsibility to build and sustain major research programs in the energy area. (Indeed, if the energy problems facing our society cannot be solved, then initiatives such as the life sciences institute will not matter anyway.) Such an effort would be of direct relevance to the needs of Michigan's dominant industry and respond well to the University's responsibilities as a state university. The specific characteristics of a UM Energy Research Institute are shown in Table 4.

Table 4. Key Characteristics of a UM Energy Research Institute

Format	UM Energy Research Institute. Include following UM schools and colleges: Engineering, Natural Resources & Environment, LS&A and Business.
Focus	Basic research topics addressing both mobile and stationary energy issues with a focus on transportation and manufacturing. Carry out energy education programs at undergrad, grad levels, and industry-oriented continuing education program.
Organization	Led by Engineering. Emulate NSF Engineering Research Center structure.
Industry Liaison	Engage energy, transportation, manufacturing and their 1st- and 2nd-tier supplier as partners on research projects. Offer favorable terms on licenses and patents. Provide access to test facilities. Provide support for high tech spin offs. Charge nominal fee for participation. Hold annual technology review and liaison meeting.
Government Liaison	Include relevant federal agencies such as DOE, DOD (TACOM), and EPA (Ann Arbor) as well as Michigan-based energy organizations (e.g., NextEnergy).
K-12 Outreach	K-12 handled within each university research and education activity.
Annual Funding	Federal: $6-10M State of Michigan: $1M Industry: $50K per large company; $10K for SMEs
Duration	5 year base funding with 5 year renewal based upon performance
Oversight	Federal funding organization(s) State of Michigan Industry role on Executive Committee

Implementation Considerations for the Four Options

In the foregoing, the key characteristics of the four options, University, State, regional, and national, were presented. The committee also discussed the ways and means for making

each option a reality. At this point, this consideration poses as many questions as it does answers. Some of the implementation issues for each option are presented below. The intent here is to encourage wider discussion of and solicit additional guidance on these issues.

National Energy Research Program

Support for a national university-based research program will necessitate the support of the Administration, the Congress, and relevant federal agencies such as DOE, DOD, and NSF. The DOE, through either its Office of Basic Energy Sciences or its Office of Energy Efficiency and Renewable Energy, would be the most logical organization to oversee such a program, although the National Science Foundation could also fill this role as well. That being said, the DOE would likely see a large university program as a threat to its internally funded activities. As such, the national program would have to be developed and driven "top down" from the Congress, the Administration (Office of Management and Budget), hopefully with the support and assistance of Secretary of Energy Spencer Abraham.

It is important to note that over the past year, a group of faculty and staff at the UM have been promoting a national initiative called the Hydrogen Energy University Research Initiative or HEURI, which is very similar to the program described above. The group has briefed and gathered the support of more than twenty universities across the country, plus the American Association of Universities and the American Physical Society. They have written a joint university letter (Dec, 2003) to the Director of the OMB and to the Secretary of Energy promoting the HEURI concept. They have also made key Michigan legislators (Levin, Stabenow, and Dingell) aware of the program. All have been supportive of the concept. It is very important that the efforts of the UM HEURI group be leveraged in pursuit of a national energy research initiative if that option is chosen.

Finally, such an initiative would only be possible through a national competitive process. The University of Michigan through its College of Engineering, School of Natural Resources and Environment, LS&A, and Business School, is ideally positioned to take the lead and win one of the centers in such a competition.

Regional Consortium of Energy Research Centers

Any initiative that is not national in scope poses additional challenges in soliciting federal money. Such is the case for a regional initiative. Here, for the sake of discussion, we define our "region" as one including Michigan, Illinois, Indiana, Ohio, and Wisconsin. As noted above, rather than a geographic format, the consortium could also be based on strategic technology issues. Such a consortium might include universities from Michigan, California, Texas, and Louisiana. In either case, a regional initiative will require the buy-in and financial support of the participating states and, ideally, financial support from their respective legislators in Washington DC. The form of this latter support may have to be set aside funding. The support from the states may be a challenge considering their current financial problems.

State of Michigan Energy Research Initiative

While this option has the advantage that a large number of Michigan's federal legislators could be convinced to support it, particularly if their favorite school or university were participating, any federal funding would either have to be in the form set aside or come through the Army Tank-armaments and Automotive Command (TACOM) in Warren, Michigan. In the latter case, it would have DOD oversight and not DOE. It is also questionable whether the state has any funds to support such an activity. Finally, it would be important to include NextEnergy in a State wide program. One possible role for NextEnergy could be the "industry

conduit" for the university basic research program. Another could be as a testbed or integrator of promising technologies.

University of Michigan-based Initiative

Of the four options, this is the one over which the UM has the most control and, if given the go ahead and internal resources, could initiate immediately. It is also the case that a rapid and significant investment of effort, resources, and reorganization will be necessary for Michigan to play a role in any of the suggested initiatives or, indeed, meet its responsibilities as one of the world's leading research universities.

More specifically, the committee believes that the University should move rapidly to pull together and augment existing energy research in areas designed to achieve greater impact and visibility, while building the credibility for leadership and attracting substantial external resources. Among the possible programs discussed were the following:

- A research center aimed at investigating the interplay between fuel processing and utilization, e.g., the production of hydrogen-based fuels to be utilized in fuel cells for auxiliary or vehicular power units. There has already been considerable industrial interest in working with the University to build the experimental infrastructure on campus to investigate such subjects. In addition, the US Army Tank-armaments Automotive Command (TACOM, Warren, Michigan) has expressed an interest in working with the UM to develop a new facility to conduct fundamental and applied research in decentralized or mobile-platform mounted transportation fuel processing production and reforming systems. This would include research and development of decentralized (or mobile) gas-to-liquid synfuel processes, and of decentralized (or mobile) biomass conversion processes.

- A collaboration with NextEnergy, the state-funded R&D public corporation founded to advance the use of alternative energy technologies by supporting research, design, manufacturing, education, commercialization, and marketing. Many of NextEnergy's initial thrusts align well with the interests of University faculty, plus, NextEnergy already has a well-established industry network which could be use to move technology out of the University. ~~The possibility of collocating expensive experimental facilities and building joint university-industrial-government research programs with NextEnergy umbrella may hold considerable promise.~~

- The complex interaction between government regulation and market economics is one of the most serious challenges facing the development and implementation of advanced energy sources. The battle on alternative energy sources is likely to be won or lost in the hearing rooms of public regulatory bodies, where technological expertise is limited, and policies tend to be more focused on the political pressures of the moment than the social needs of tomorrow, and muddled regulation strangles technological evolution. The University could pull together its considerable expertise on the technological, legal, economic, and social aspects of energy regulation, working with both government and industry, to develop regulatory policies and structures that more effectively address the urgent energy issues facing our state and nation rather than allowing them to continue being dictated by the old political wars of the past.

- Since biomass energy technology could have significant impact on the economy of agriculture-intensive states such as Michigan, more visionary technologies such as "chemical reactor combines" that simultaneously harvest and process biomass into synfuels should be explored.

More generally, the committee believes that the University of Michigan can play a significant leadership role and meet its public responsibilities only by a concerted effort to organize, support, and build world-class programs in energy research that align with the needs of our state and our nation. In this effort it should move rapidly to executive the following steps:

1. Conduct a comprehensive survey of existing energy research activities on our campus.

2. Develop a plan to build and strengthen linkages with other state and federal initiatives such as NextEnergy

3. Create a University-wide organizational structure for such interdisciplinary energy research activities.

4. Begin a series of investments in particular projects (such as those mentioned above) while seeking external support from state, federal, and industrial sources.

5. Commit itself to achieving leadership in energy research in areas of importance to the state (particularly transportation and manufacturing) with a five year period.

Such steps will be a necessary precursor for effective University leadership of any of more comprehensive initiatives at the state, regional, and federal levels considered by our committee.