Appendix A - University of Michigan Hydrogen-based Energy Research and Expertise Matrix (updated Fall, 2002)

Topic & POC	Research Issues & Challenges	CoE Expertise/Facilities	Societal/Business Issues	Personnel [2]
Generation Erdogan Gulari John Lee	- H2 generation by reforming of hydrocarbons, coal or biomass either with partial oxidation or steam requires temperatures on the order of 800 C to 1200 °C! - Elimination of sulfur in the fuels. Heavy diesel oils can have as much as a 1-2% of sulfur and coals can be just as dirty if not dirtier. - Hydrogen production by "cracking" of water using nuclear power is not developed on a large scale but is feasible. - Hydrogen production using solar energy is not economical at present but holds the potential for the future. - Participate in the development of high-temperature helium-cooled reactors providing helium at T > 1000 C - Study productive use of waste heat or cogeneration of hydrogen in nuclear power plants - Study materials and safety issues associated with chemical processing separate from radiation environment	- Catalysis. Researchers who are experienced in developing hydrocarbon oxidation catalysts. - Expertise for autothermal reforming, water gas shift and selective CO oxidation will enable us to go from hydrocarbon all the way to pure hydrogen. - Separation of complex mixtures. - Hydrogen production by thermal water cracking using nuclear energy. - Use of solar energy for hydrogen production, perhaps the ultimate clean source of hydrogen. - Nuclear reactors and processes	-Source of H2: going from a hydrocarbon-based economy to a hydrogen-based economy -Independence from foreign oil imports	Levi Thompson, ChE Erdogan Gulari, ChE Johannes Schwank, ChE Phil Savage, ChE Werner Dahm, Aero Ken Powell, Aero Arvind Atreya, ME
Storage Levi Thompson Ralph Yang Omar Yaghi	- Existing Technologies (adsorption and hydrides) Low capacities Low hydrogen release rates Adsorbents too expensive - Development of alternative storage mechanisms Chemical incorporation	- Adsorption - Nanomaterials design and synthesis - Catalysis - Surface science - Ally with other experts (e.g. Terry Baker) - Hydrogen embrittlement analyses using Ford Nuclear Reactor neutron diffraction/neutron scattering capabilities	-Enhanced safety -Storage and distribution infrastructure	Ralph Yang, ChE Levi Thompson, ChE Johannes Schwank, ChE Arvind Atreya, ME Ron Berliner, NERS Omar Yaghi, Chemistry
Utilization, General Arvind Atreya Johannes Schwank	- Gasification of coal (or other low-grade fuels such as biomass, shale, heavy oil, etc.) - Economical and efficient removal of sulfur and nitrogen compounds from low-grade fossil fuels - Thermal integration of fuel processors, and utilization of waste heat from other processes - Modeling of electrochemical, thermal, catalytic processes - Power density, energy density - System integration and transient response - Innovative materials for catalyst design - Hydrogen storage - Sensors and controls - Hybridization and use as APUs - Start-up, sub-freezing operation, durability - Affordable manufacturing	- Hydrodesulfurization and hydrodenitrogenation catalysis - Reactor modeling and design -Expertise and state-of-the-art facilities for materials characterization - Advanced materials processing -State of-the-art solid state laboratory with clean room facilities for MEMS-based devices - Automotive engineering - Miniaturized manufacturing - Micro-channel based system design and analysis	-Reduction in size and cost of fuel processors and fuel cell stacks to make them competitive with IC engines -Stationary vs. mobile use -Distributed power generation (less vulnerable to disruption by hostile actions) - Cost-effective manufacturing of fuel cells and fuel processors	Arvind Atreya, ME Dennis Assanis, ME Jun Ni, ME Margaret Woolridge, ME Johannes Schwank, ChE Erdogan Gulari, ChE Massound Kaviany, ME Steve Skerlos, ME Hong Im, ME Jyoti Mazumder, ME Jwo Pan, ME Michael Thouless, ME Galip Ulsoy, ME Yoram Koren, ME Jack Hu, ME

Appendix A (continued)

Topic	Research Issues & Challenges	CoE Expertise/Facilities	Societal/Business Issues	Personnel

[2] Personnel and UM Expertise listings are a continuing work in process.

Utilization, Tranportation Dennis Assanis	-Optimal use of H2 in the automotive sector IC engine vs. fuel cell Fuel cell as auxiliary vs. primary power unit Economics of synfuels (consider environ impact) -Challenges for H2 engines Hydrogen on-board storage Pre-ignition and backflash Combustion control Thermal efficiency Emissions (NOx, Unburned hydrogen, H peroxide)	-Tremendous depth and breadth in almost every area of automotive and energy research - Fuel cell system controls - Battery research - First class experimental facilities engine test cells fuel cells modern data acquisition systems emission analyzers computational facilities		Dennis Assanis, ME Anna Stefanopoulo, ME Zoran Filipi, ME Hui Peng, ME Ann Marie Sastry
Energy System Metrics Greg Keoleian, SNRE	-Sustainability assessment of energy systems Life cycle energy performance (total fuel cycle analyses) Life cycle environmental impacts (e.g., greenhouse effect, smog formation, acidification, human health effects) Social-economic costs	-SNRE Center for Sustainable Systems: expertise in life cycle modeling of automotive and energy systems (examples of systems studied): fuel cell vehicles ICE vehicles Photovoltaics Biomass energy Wind energy	-Developing and implementing systems that maximize the net energy ratio (e.g., electricity output/total fossil energy inputs) and minimize environmental impacts -Developing sustainable sources for hydrogen production -"Chicken and egg problem" for fuel cell vehicles and hydrogen infrastructure -Policies to encourage the adoption of more sustainable energy systems	Gregory Keoeleian, SNRE Jonathan Bulkley, EWRE/SNRE Michael Moore, SNRE Stuart Batterman, SPH Marc Ross, Physics A.N. Perakis, NAME
Business, Policy & Economic Issues Business School School of Public Policy Engineering SNRE	- Impact on/role of the petroleum industry - Impact on/role of the vehicle industry - Ownership, financing , and building of the generation and refueling infrastructure - Transitional marketing issues (segmentation, persuading consumers to change, etc.) - Incentives for consumer to change, including role of governmental bodies in providing incentives			To be determined