

Unconventional Energy Sources and Research in Moldova

Dr. Greg Mowry

University of St. Thomas, School of Engineering

Abstract

Located in Eastern Europe Moldova is sandwiched between the Ukraine and Romania just west of the Black Sea. Moldova imports approximately 96% of its energy from the Ukraine and Romania. This situation is clearly unsustainable and highly undesirable. Moldova is also one of the poorest countries in Europe with little native mineral wealth but blessed with incredibly fertile soil. The primary industries in Moldova are based on agriculture and wine products. The energy situation provides Moldova with the incentive for developing a detailed review and analysis of its renewable energy potential which will then provide the basis for developing a long-term energy strategy. The current energy situation in Moldova can be characterized as follows¹:

- A lack of local traditional energy resources;
- A lack of funds combined with the country's energy debt (> \$270 million) towards external gas suppliers (Russia) and electricity suppliers (Ukraine and Romania);
- Energy system inefficiency: energy intensity reaches 1.7 tcf/\$1000 (vs. 0.15 for the European Union (EU), 0.50 in Hungary, 0.60 in Poland, 0.82 in Slovakia or 1.28 in Romania);
- Significant difficulties within the national economy; e.g. the government does not directly control its own internal energy suppliers.

Given this backdrop, and in cooperation with faculty colleagues at the Technical University of Moldova (TUM) lead by Dr. Petru Todos (Vice-rector of the TUM), a team of student researchers from the University of St. Thomas were engaged in alternative-energy research for almost a month in Moldova. The alternative-energy research opportunities in Moldova and the results of the research will be briefly discussed. In addition, since Moldova is a former Soviet Eastern-Block country, this paper will also address the team selection process, the trip preparations, the general conditions in Moldova, what worked well during the trip as well as what did not work, and the challenges of performing research in a country that does not generally speak English.

Introduction

There were several prominent universities in the former Soviet Union. Among these were the Lomonosov Moscow State University, the University of Kiev, and the TUM². The TUM is located in Chisinau, the capital city of Moldova (see figure 1³). During the decades of Soviet control, the TUM served as one of the primary institutes of higher education for the Soviet Eastern Block countries. In Moldova, the presence of the TUM combined with the relatively small population resulted in an educated population. In the years following the collapse of the former Soviet Union (circa 1990) many of the more educated citizens left Moldova to seek

employment in the EU (approximately 1-in-4 from a base population of ~4 million). During the Soviet withdrawal much of the sustaining infrastructure in Moldova was destroyed. In particular, the country-wide transportation systems along with the electrical power grid were severely degraded. Today, only the main cities in Moldova are connected to a power grid and the country-wide transportation system is inadequate for supporting a rapid economic recovery. To further complicate the political landscape the former Soviet Union left the Russian 14th Army in the Transdniestra region. The Transdniestra region is located just north of the Dniestr River between Moldova and the Ukraine. This region, which is part of Moldova but not controlled by the Moldavian government, continues to operate in a state of political unrest⁴. Unfortunately, the aging electrical generation facilities (circa 1940s generation technology) that supply electrical power to Moldova are located in this region. These factors, combined with the country's financial debt, continue to hamper general economic recovery. The economic difficulties in Moldova also have a negative affect on the ability of TUM to modernize. In spite of these challenges, the TUM is a vibrant comprehensive university. Additional details and information regarding the TUM can be found at the main university web site².



Figure 1. Map of Moldova ³

Energy Sources in Moldova

Moldova lacks traditional energy resources and consequently most of their required energy is imported. As noted, this has resulted in a significant energy-related debt load. Moldova also has little mineral wealth. Since the economy of Moldova is largely based on agriculture, viniculture, and food processing, the traditional means of enabling economic recovery and debt reduction through industrialization are not possible. Furthermore the aging Transdniestra power facilities, which constitute the only source of electrical energy indigenous to the country, have never been

upgraded nor has the associated green-house-gas and particulate emissions ever been managed. An additional challenge, somewhat unique to Moldova, is that due to the agricultural economy a significant portion of the population (~ 25%) is distributed throughout country living in small villages and generally isolated farms.

The present energy situation in Moldova is clearly not sustainable and highly undesirable. However, the lack of traditional energy resources and mineral wealth, combined with the factors previously noted, excludes traditional energy solutions. Hence any long-term energy plan must factor in the present debt load, the general lack of mineral resources, a distributed population base, and the existing agricultural economy. Consequently the unique conditions that currently exist in Moldova are conducive to unconventional approaches for resolving the present dependence on foreign energy. Given the lack of an existing wide-spread power grid combined with lack of energy resources, serious consideration for the wide-spread use of distributed renewable energy is currently being explored. Based on the relevant conditions unique to Moldova, the primary candidates for non-grid alternative energy production are bio-mass, low-head hydro, solar PV and wind power.

Since a significant portion of the Moldavian economy is based on agriculture, bio-mass power generation appears to be a candidate for their energy needs. Unfortunately, bio-mass power generation is not, at present, economically viable even in the more wealthy industrialized nations. The unfavorable economics of bio-mass power generation (due in part to the immaturity of the technology and the capital intensive start up costs) combined with the existing national debt relegates this alternative to a future 'possibility'.

Low-head hydro power generation is another alternative energy option since there is an abundance of small rivers and streams in Moldova. Furthermore, low-head hydro technology is sufficiently advanced enough that this approach is being seriously studied at the TUM. However, in a practical sense only the communities located in the immediate vicinity of any such installation can benefit from the generated power due to the lack of a country-wide power distribution grid. Although the amount of power that can be generated in this manner might support enough of a population base to be economically viable, the distributed rural population makes the wide spread use of this solution less effective than desired. Consequently low-head hydro power generation is not currently practical for powering the entire Moldavian rural population but may be an option in the next few decades.

The remaining options for alternative energy production in Moldova are solar PV and wind. The combination of wind power supplemented by solar PV systems appears to be an ideal solution for the distributed rural population of Moldova. Indeed, the economics for this energy solution are close to being viable in industrialized countries. However, in the rural portions of Moldova, the average yearly income (of over a million people) is approximately \$600 US⁵. Hence the costs associated with a combined wind and solar solution (which are roughly on the order of \$20 – 50k US), without some form of supplementary assistance, are beyond the financial means of the intended population. To date, there has been little to no interest or incentive by any party to invest in Moldavian 'farmers' with no mineral resources and no heavy industry. To further complicate matters the data in the European Wind Atlas⁶, which was published in 1989, indicates that the wind potential in Moldova is insufficient for power generation. This data seriously

jeopardizes the consideration of any wind power solution. However, if it could be demonstrated that there is wind potential in Moldova, and if a combined wind and solar PV system could be economically designed and implemented, then Moldova would serve as an ideal location for testing such a system. Research on such a system is underway. Furthermore, since the general population of Moldova is educated, the wide spread implementation of such systems could be maintained and given sufficient system design foresight, the isolated wind turbine installations might ultimately be connectable into a country-wide rural power grid. Finally, the possibility of manufacturing such systems in Moldova might help the local economy and serve as a test-case for economic development in other countries.

Research in Moldova

The funding for this exploratory research opportunity in Moldova was enabled by an INTREU grant^{7, 8}. The initial contact and round of exploratory discussions with the faculty at the TUM was facilitated by a colleague familiar with the faculty at the TUM and fluent in Romanian. Based on several preliminary discussions combined with a preparatory week-long exploratory visit to the TUM several possible undergraduate research projects were identified. The topics were broadly organized into three categories: wind data organization and analysis, small electric machine research for alternative energy applications (e.g. wind turbine and low-head hydro generators), and energy strategies and related economics in Moldova. The TUM faculty that are predominantly interested in alternative energy research are in the Electrical and Mechanical Engineering Colleges. In addition, several of these faculty members also work through the university on behalf of the government as advisors for government energy policy. Consequently a strong link exists between the proposed research projects, the ultimate goal of these projects, and the potential meaningful application of the project results.

Exploratory Evaluation

Several factors were considered in preparing for the student research trip to Moldova. First of all, the government in Moldova is a republic with a communist ruling party⁹. Given the historical friction between western democratic and eastern communist governments, combined with the potential stereotyping that might exist, as well as the uniqueness of the opportunity to perform practical and applied research in Moldova, it was necessary to visit Moldova prior to bringing student researchers to the country. The objective of the preliminary exploratory visit was to assess potential issues such as safety, possible gender problems, general living and research conditions, support from the TUM, the impact of language, and so forth. The outcome of the exploratory visit was completely positive and all potential issues were successfully addressed. For the most part, most of the perceived issues were simply unfounded. Based on this very positive start the decision was made to proceed. Of the many possible impressions and revelations that occurred during the initial exploratory visit, two were memorable. The first occurred during a tour of the country. In Moldova, communication towers are relatively common and widespread. These towers are typically fenced off from the surroundings and guarded. During one of the tour stops our entourage visited a communication tower where I met the guard – a former soviet soldier. Through our interpreter he commented that based on watching television, he thought that all Americans would be bigger than I clearly am. My response, through our laughter, was similar to his. He was not as large as a soviet ‘bear’. The exploratory

visit also happened to coincide with the Moldavian Independence Day. During the government formalities I was introduced to a former soviet army general who had remained behind after the withdrawal. When he learned that I was an American doing research in Moldova, he stated the following through an interpreter, “you used to be my enemy, today you are my friend, I hope you can help my country.” As a product of the cold war, his comment was profound, impressionable and very indicative of those times.

Trip Preparations and the Team Selection Process

The team selection process was carried out in several systematic steps. The first step was spending time with colleagues experienced in study abroad programs and overseas student research. Although the trip to Moldova was unique, much was learned from listening to and discussing the general trip experiences of other colleagues. This in turn was very beneficial for establishing a baseline set of team expectations and a foundation for anticipating potential problems. The International Education Center (IEC) was also very helpful during the preparatory and team selection phases of the project. The IEC is one of several administrative offices at UST and is responsible for coordinating study abroad programs. However, since this project was research and not offered for credit, this activity was beyond the scope of the IEC. Hence the principal investigator was responsible for all of the project planning and coordination activities. An IEC resource that was very helpful is titled, “The Guide to Successful Short-Term Programs Abroad.”¹⁰ In particular, chapters 6 and 11 on “Logistics” and “Student selection and Enrollment” were very helpful. The preparatory steps for the research trip are summarized in table 1.

Table 1: Trip Preparation Outline and Timeline: September 2004 – March 2005

Step	Activity
1 R&D opportunity announcement (September)	➤ Generation and distribution of an information flyer describing the research opportunity and the public information meeting describing the exploratory visit.
2 Public information forum (September)	➤ Open forum presentation describing the research opportunity in Moldova; what was learned during the exploratory visit; signup for the team selection process.
3 Interviews (October)	➤ Motivation for joining the research team ➤ Essay describing the skills that the student brings to the team and how these support the research objectives ➤ Prior experiences that could help the team
4 Team selection (October)	➤ Based on the interviews and essays, select the team
5 Travel arrangements (October)	➤ Transportation arrangements ➤ Housing – done in cooperation with TUM colleagues
6 Documentation (October – December)	➤ Obtain passports ➤ Obtain visas <ul style="list-style-type: none"> • Documentation outlining visit details • Trip duration
7 Selection of research topics (November)	➤ Student selection of research topics based on the joint UST and TUM topic list

8	Weekly preparatory team meetings (October – December)	<ul style="list-style-type: none"> ➤ Research support requirements ➤ Team ethics and team behavior ➤ Pairing for research and daily activity ➤ Work product requirements <ul style="list-style-type: none"> • Research summary reports • Support documentation • Pictures • Concluding experience papers ➤ Contingency plans for trouble <ul style="list-style-type: none"> • Emergency meeting location • Location of US embassy
9	Team building activities (October – December)	<ul style="list-style-type: none"> ➤ Dining together ➤ Scenario discussions ➤ Getting to know each other
10	Departure (January 2005)	<ul style="list-style-type: none"> ➤ Family/friends gathering and send off
11	Research (January 2005)	<ul style="list-style-type: none"> ➤ Execute research ➤ Experience culture ➤ Learn about Moldova through trips and exploration
12	Return (January – March 2005)	<ul style="list-style-type: none"> ➤ Family/friends welcome home ➤ Finalize work products ➤ Experience papers written ➤ Trip summary

In retrospect, there were several very important preliminary planning activities that contributed to the success of this project. First of all, developing an overall, high-level checklist of preparatory actions was essential. Developing the checklist is an activity similar to the roll performed in industry by a project manager. The anticipated duration of each activity was also accounted for in the overall planning of the project. Table 1 represents a high-level version of the master project check-list which was based on the integration of my own personal travel-abroad experiences, the information found in the IEC resource, inputs from our Moldavian colleagues, and the experiences and recommendations gleaned from discussions with other colleagues.

The student interviews and essays were also very useful for selecting the research team. The objective of the essay and interview process was to learn about the students and determine their motivation, skill sets, prior experiences, and any additional relevant information. The essay required the students to address the following questions:

1. Have you had any experiences living and/or traveling away from home or abroad (besides going to college)? If so, briefly describe where, when and for how long.
2. Have you ever been in a situation where you worked or lived closely with a group of people other than your family? What did you learn and gain from that experience? What were the challenges? How did you demonstrate maturity, tolerance, and handle the small-group dynamics?
3. The expedition to Moldova is part of an exploratory R&D experience with the long-term goal of using the inputs from your initial experience as part of the process for establishing a multi-year undergraduate exchange and R&D program with the Technical University of Moldova (TUM). Selecting from the list of business and research opportunities, which topics/areas of study are you interested in? Based on this

selection, what are your educational goals for this experience? What do you want to get out of this research experience? How will your participation tie into the long-term goals of this project?

4. Conditions in Moldova are not primitive relative to the USA, but on the other hand are definitely not exactly like those found in the USA.
 - We will live in a TUM dorm for 3 to 4 weeks. The rooms are small, clean and utilitarian. TVs, fans, stereos and so forth will be non-existent or at best, in short supply. Power is 220-V, 50-Hz instead of our standard 110-V 60-Hz power. The dorm rooms typically share a common bathroom and shower facility (which is private).
 - The food will mainly consist of a local Moldavian meals which are largely based on fruits, breads, cheese, vegetables, wine, and either chicken or pork. We might be able to bring additional food to supplement diets but it may be difficult or impossible to support special dietary requirements. In the Moldavian culture, it could be insulting to the local hospitality to refuse their generous offers of food.
 - The primary language of Moldova and the TUM staff is Romanian with some English (we will have some interpreters but you should not expect to have one interpreter per person). Hence general communications may require a bit of patience and “Pictionary®” type of efforts which can be a lot of fun given the proper attitude ☺.
 - Daily research will occur in small groups or one-on-one with a corresponding TUM researcher. Summary team group meetings will be held every evening to discuss the day’s events and make plans for the following days.

Given this information, in paragraph form discuss how you will adapt to this environment and contribute to the success of the research. In addition, please include any additional information that you consider relevant to the selection process.

The essay served as a starting point for the subsequent interviews. Every student that wrote an essay was interviewed. Based on the essay responses and the interviews, the research team was selected and the proposed research projects identified. Ultimately a team of 5 student researchers formed ‘Team Moldova’.

Another important factor that contributed to the overall success of the research and to the student selection process was that the students were ‘share holders’. By mutual consensus between the respective UST and TUM faculty, prior to selecting the student teams, several candidate research project were identified with the intent of letting the students select the actual research projects. As noted in the essay questions, the students were asked to identify the research projects that they were interested in. Their inputs were then used to determine the research that was performed in Moldova. This process gave the student researchers the opportunity and resulting incentive to proactively accomplish their goals during the time spent in Moldova.

Finally, once ‘Team Moldova’ was formed, weekly preparatory meeting and discussions were very instrumental in building an integrated and flexible team. Weekly discussions covered a broad range of topics including ethics, drinking and personal behavior, emergency plans and so forth. The weekly meetings were also used for identifying supplementary resources that needed to be brought in order to support the research. By departure time the team was ready.

Research, Results, and Outcomes

Based on a range of proposed research topics the students selected: 'Wind energy potential in Moldova' and 'Energy strategies and policies of the Republic of Moldova'. The project objectives for these topics are summarized in table 2.

Table 2: Research Objectives

Research Topic	Objectives
1. Wind energy potential in Moldova	<ul style="list-style-type: none"> ➤ Establish a central data base for integrating several decades of wind data from several disparate sources. ➤ Determine the optimal locations in Moldova for harvesting wind energy. ➤ Perform a pre-feasibility study on the economics of wind power generation in Moldova.
2. Energy strategies and policies of the Republic of Moldova	<ul style="list-style-type: none"> ➤ Based on the Kyoto Protocol, identify opportunities for collaborative application of energy credit in Moldova. ➤ Investigate the applicability of energy strategies and studies in other countries to Moldova.

As noted in the introduction, most of Moldova is without a power grid. Wind and low-head hydro power production are two alternative energy options that do not require a power grid. However, the data in the European Wind Atlas suggests that there is inadequate wind power potential in Moldova. Based on political factors and Moldavian wind data acquired from 1985 - 2005, the TUM faculty suspected that the European Wind Atlas was incorrect with respect to wind potential in Moldova. The goals of the first research project were to re-assess the conclusions found in the European Wind Atlas and given a favorable conclusion, determine the locations in Moldova best suited for harvesting wind power.

The goal of developing a central data base incorporating all Moldavian wind data was successfully accomplished. However, this task was not trivial or straight forward due to the age and disparate formats of the data sets. Furthermore, much of the support documentation was written in Russian or Romanian which added to the sport of the developing the data base. These obstacles were successfully overcome and a wind data base was established. WASP® software¹¹ was then used to analyze the wind potential in southern Moldova. Based on the integrated wind data and the resulting analysis, it was determined that there was significant wind potential in southern Moldova, contrary to the conclusions found in the European Wind Atlas. In fact, the wind potential in southern Moldova was found to be equivalent to that in Minnesota, USA. Minnesota is currently the third largest provider of wind energy in the USA. Based on these results, a pre-feasibility study on the economics of wind power generation in Moldova was completed. The feasibility study¹² included an economic analysis of site development, infrastructure, and candidate wind-turbines along with potential investors. Due to the lack of an existing power grid combined with the national debt, the implication of the economic analysis was that grid-level wind-power is not economically feasible. A map of southern Moldova

marked with candidate wind-farm locations is shown in figure 2. The location of Chisinau (oval star) is also noted for reference. However, since Moldova has wind potential, if a small, robust



Figure 2. Acceptable wind-turbine locations in Southern Moldova

and cost effective wind turbine system could be developed, then it might successfully be introduced into Moldova in a wide variety of non-grid applications for rural, single family dwellings. A network of such these small system, if properly designed, might subsequently be interconnected into a rural power grid.

With regard to the second research topic, the student researchers were also able to successfully support existing research and further help identify opportunities in Moldova that would provide first-tier countries the opportunity of obtaining energy credits as provided for by the recently ratified Kyoto Protocol¹³. Two significant opportunities for obtaining energy credit included renovating or replacing the existing power generating facilities in Moldova and upgrading the heating units used in almost all of the hot water and building environmental control system in all of the buildings in Moldova. The student research on this topic was considered to be of such quality that one of the researchers was asked to consider doctoral level work on this topic at the TUM.

Finally, there was one contribution by our team that potentially outweighed all of the other technical contributions previously noted. During the coordination meeting held upon our arrival at the TUM, our team surprised our hosts by requesting daily Romanian language lessons. The team decided that since we were going to be immersed in the Moldavian culture, we should begin learning the national language. We could not have anticipated the affect of this request. As

the daily language studies progressed, our hosts repeatedly commented on how impressed they were with our efforts. Since our TUM colleagues were concurrently learning English, we were puzzled by these positive comments. Eventually we asked why our language studies were so obviously significant. To our surprise, we learned that approximately one-third of the Moldavian citizens refuse to speak the national language. However, the first American researchers not only requested to learn the language, but actively engaged in using the native language. This effort helped dispel an ‘ugly’ American stereotype and ultimately overshadowed much of our research in a very positive manner. Based on this very experience, and as a general recommendation¹⁴, the opportunity to study the native language while performing overseas research should be seriously considered. As documented by the students in their daily journals and experience papers, the impact of learning the native language can be far reaching, very positive, and very profound for all involved parties.

Future Research Opportunities

The TUM is an institution that has flourished under very adverse conditions. Consequently, rather than being a relic of the cold war, there are many research opportunities at the TUM. Based on our preliminary research there is significant wind potential in Moldova. Hence the opportunity for alternative energy research and energy-credit business opportunities abound in Moldova. In addition, several of the faculty members at the TUM are experts in electric machines, power engineering, and mechanical engineering¹. Several follow-on research projects including the development of small, robust and cost-effective wind-turbines are currently being jointly pursued. The generator technology for the small wind-turbines is also being considered for low-head hydro power applications in Moldova.

With regard to agriculture, Moldova is blessed with incredibly fertile soil and an agricultural economy. Hence there are many opportunities for agricultural research. In addition, some of the best vineyards in the world are found in Moldova. Advanced degrees in wine culture are also available at the TUM. For instance, much of the present vine stock in France came from Moldova. Hence the opportunity and potential exists for productive long term research at the TUM and for business opportunities in Moldova.

Conclusions

The exploratory nature of this INTREU funded research opportunity was very successful. The team of student researchers succeeded in accomplishing their objectives at the TUM and funding for continued alternative energy research with the TUM is being pursued. The faculty at the TUM are very talented and very skilled in their respective areas of research. Many opportunities exist for joint research with the TUM. The people of Moldova are warm, sharing, and educated while the country itself is very picturesque. Moldova is slowly recovering from the consequences of the soviet withdrawal and has the spirit and will to succeed. The main obstacle standing in the path of economic recovery is the lack of mineral resources and an economy based largely on agriculture. Will the world in general consider potential opportunities there worth pursuing? I truly hope so.

Acknowledgements

Proceedings of the International Conference on Renewable Energy for Developing Countries-2006

The exploratory opportunity for developing the alternative energy research in Moldova was funded by the National Science Foundation (NSF), the Office for Central Europe and Eurasia of the National Research Council (NRC), the operating arm of the National Academies via the INTREU Program (International Research Experiences for U.S. Undergraduates Visiting Central and Eastern Europe and the Newly Independent States - INTREU). This program was intended to help establish multi-year research opportunities and provide Research Experiences for Undergraduates (REU). For additional details on the INTREU program and the various funded grants, see references 7 and 8. I would also like to acknowledge Dr. Cristian Domnisoru for his help with the initial TUM contacts and Dr. Lisa Lamb and Dr. Camille George for their many discussions regarding overseas research. Furthermore, I am indebted to the student researchers who stepped out of their comfort zone and made the trip a success: Brian Petschel, Jacob Braegelmann, John Glanton, Yumi Nagato, and Jerad Poling. Finally, I am indebted to my colleagues at the TUM whose hospitality and dedication made this preliminary research possible: Dr. Petru Todos, Dr. Ion Sobor, Dr. Andrei Chiciuc, Dr. Ilie Nuca, and Dr. Valentin Arion.

Bibliography

1. Data supplied by Dr. Andrei Chiciuc.
2. www.utm.md/en/
3. www.lonelyplanet.com/mapshells/europe/moldova/moldova.htm
4. Transnistria or Trans-Dniester; see for example, <http://en.wikipedia.org/wiki/Transdniestra>
5. TUM data.
6. European Wind Atlas; www.windatlas.dk/Europe/about.html.
7. <http://www7.nationalacademies.org/dsc/INTREU.html>
8. http://www7.nationalacademies.org/dsc/INTREU_Grantees_2004-05.html
9. See for example see <http://www.traveldocs.com/md/govern.htm> and <http://www.cia.gov/cia/publications/factbook/geos/md.html>
10. "The guide to Successful Short-Term Programs Abroad," edited by Sarah E. Spencer and Kathy Tuma. NAFSA, 2002.
11. WAsP – the Wind Atlas Analysis and Application Program. www.wasp.dk
12. "Wind Power Feasibility Study of Southern Moldova," J. Braegelmann, B. Petschel, Dr. Greg Mowry (UST), Dr. Ion Sober (TUM), and Andrea Chiciuc (TUM)
13. For information on the Kyoto Protocol see <http://unfccc.int/2860.php>. An excellent introduction can be found at: http://en.wikipedia.org/wiki/United_Nations_Framework_Convention_on_Climate_Change
14. "Developing a Study Abroad Opportunity for Engineering Undergraduates," S. R. Eisenberg, J. M. Murray, U. DeWinter, Proceedings of the 2003 ASEE Annual Conference.

Greg Mowry received his B.S. and M.S. degree in metallurgical engineering from Iowa State University in 1976 and 1978 respectively. He attended Stanford University from 1979 to 1981 for a non-thesis M.S.E.E. program. He received his Ph.D. in electrical engineering from the University of Minnesota in 1995. He joined the School of Engineering at the University of St. Thomas in 2003 with 24 years of industrial and entrepreneurial experience. His interests include

alternative energy research, thin-films, MEMs, laser-optics, electromagnetic phenomena, study abroad networking, and the pedagogy of engineering teaching.