Analysis and Optimization of Sustainable Energy Systems

Today, a myriad of new sustainable energy technologies and energy systems is rapidly emerging. Thousands of new start-up companies offer an amazing array of new technologies and products for the collection, storage, and end use of energy from solar, wind, geothermal, waste heat, and biomass energy resources. Numerous possibilities for the synthesis of these technologies into new hybrid *systems* and into the larger framework of society are also emerging. At the same time, fundamental advances in physics, chemistry, biology, and engineering of these technologies are occurring at universities, government labs, and in the private sector that will likely lead to even more energy technology options.

This bewildering array of new options for sustainable energy production offers great promise, but also an increasingly difficult challenge in deciding how much to invest in which technologies, how to integrate these technologies, and how to optimize the overall new energy economy. Our success as a society, in addressing fundamental issues such as climate change and economic and environmental sustainability in general, may well depend on our ability to meet this challenge.

We propose to establish a new collaborative research initiative involving Vermont scientists, in both academia and the private sector, to provide both critical analysis and optimization of this wide range of emerging options. A central goal of this initiative will be to advance our scientific understanding of *systems* that combine multiple technologies. We believe that little is actually understood at this time about the potential combinations and interactions of emerging energy technologies, and about the potential benefits or other impacts on society and the environment. Other goals of this initiative include proposing new ideas for technologies and optimization strategies, and to provide decision makers and the public with a source of scientifically informed and objective assessments and ideas, as well as online-interactive exploration and simulation tools that can be used in planning and policy decisions.

This initiative will utilize a wide range of techniques, including simulation and modeling, data mining, resource assessment, device testing in scientifically controlled settings, and monitoring of real world systems. Emphasis will be placed on determining what works, what else might work, and what is likely to work in the foreseeable future from the point of view of fundamental scientific principles and technological advances. Deliverables will include publications that disseminate our findings, and other tools such as the above-mentioned online-interactive exploration and simulation tools.

Some of the particular systems and questions we anticipate analyzing are:

- The potential for the synthesis of carbon-based but carbon-neutral fuels such as methanol and di-methyl ether from atmospheric (direct-captured) carbon dioxide and with energy from highly efficient renewable energy sources such a wind and solar (via hydrogen production and catalytically assisted fuel synthesis) or geothermal (via thermally driven bulk processes). Elements for critical analysis include air-capture technologies, hydrogen production technologies, and fuel synthesis processes. Promising but under-recognized aspects are the economic advantages of retaining the existing fueling infrastructure, including the energy density advantages of carbon-based fuels.
- The potential for a hydrogen economy, and more specifically how new technologies for the production, storage, transport, and end use of hydrogen might be combined. One promising idea, for example, recently proposed for the community of Alta-Utah, is the piping of hydrogen via powdered metal hydrides in liquid (light-oil) form, with converters at the point of use to produce hydrogen for use in heating and fuel cells.
- The potential for new hybrid systems that combine wind and solar energy systems with emerging energy storage technologies and load management in a technically and economically optimal way, so that investments in these systems can be justified as true alternatives to conventional generation. Elements for critical analysis include the solar and wind collection systems, new types of batteries

such as the new graphite foam batteries under development by Firefly Energy Inc., flywheels, and other emerging storage technologies, and the overall system performance of these components.

- The potential of thermal renewable energy sources, including geothermal heat pumps, solar thermal, and biomass technologies, to be *integrated* and *optimized* as viable substitutes for heating oil and propane. Critical elements for analysis include evaluation of the different collection approaches and their integration, both in terms of technology and economics, but also as a function of local factors such as geological conditions, seasonal solar resource characteristics, and biomass resources. This would include the development of simulation tools to allow the environmental assessment of geothermal heat exchanges with aquifers, lakes, ponds, rivers and streams in Vermont.
- The potential for the use of renewable energy systems for transportation energy, including the vehicle-integrated-photovoltaics, charging of plug-in hybrids from stationary renewable energy resources, mass-transit powering applications, and biodiesel production from algae in Vermont.
- The optimization potential for super-efficient zero-energy buildings that combine advanced thermal envelope techniques and renewable energy generation in innovative and envelope pushing ways.

To investigate these and other topics, we seek funding to support research labor, workshops, and technical resources including various types of monitoring equipment and analysis tools.

We envision this initiative as one that complements and amplifies existing research efforts in Vermont, such as the sustainable transportation and wind power research at UVM, and the work on climate and sustainability at Middlebury College. Lyndon State College, where two co-authors of this idea paper are located (B. Luce and C. Kezar), is launching a new sustainability major this year, which will include a strong focus on sustainable energy, and LSC plans to integrate green building and renewable energy into its operations. Green Mountain College, where another co-author is located (S. Letendre), has already integrated sustainable energy related content into many of its course offerings and operations. One of our private sector collaborators (A. Shapiro) is intimately involved with the design and verification of many sustainable energy projects and programs throughout Vermont.

Vermont also has a rich variety of sustainable energy providers with whom we anticipate collaborating, including local companies such as GroSolar (photovoltaics and solar thermal), Radiantec (solar thermal), the Biomass Resource Center, NRG Systems and Earth Turbines (wind power), and many others. We also anticipate working closely with analysts associated with the Vermont Public Service Board, utilities, national laboratories, and organizations such as the Vermont Energy Investment Corporation.

Indeed, from the standpoint of the many energy oriented researchers, businesses, and government resources already in place in Vermont, the very strong public support here for sustainable energy, and the rich but also challenging renewable energy resources and climate of the state, Vermont is an ideal location for a strong science initiative in sustainable energy.

Specific obstacles today include the absence of funds for labor, especially in the summertime, and for equipment and collaboration expenses. The relative geographical isolation and small overall research budgets of Vermont colleges is also a barrier. We address this in part by focusing on problems of system integration and by taking advantage of local energy development projects and expertise.

Over the next five years, we envision our initiative as making useful contributions to the scientific understanding and also the real world development of sustainable energy, both locally and nationally, such that we will be able to attract further support from both public and private sources. We anticipate that there may be much more federal support for the type of work proposed here, such that it would be helpful to have an organized program already in place when the time comes. After five years we expect to have created a large and vibrant network of sustainable energy researchers and research projects that is tightly integrated with actual sustainable energy development and accessible to decision makers and the public, including via a central clearinghouse of online information.

Dr. Benjamin P. Luce

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Dr. Benjamin P. Luce is a physicist and assistant professor of physics at Lyndon State College, where he teaches physics and sustainability. Dr. Luce received his B.S. in physics from the State University of New York at Fredonia in 1989, and his M.S. and Ph.D. in physics from Clarkson University in 1991 and 1993, respectively. Dr. Luce's thesis pioneered the application of finite-dimensional dynamical systems theory to the analysis of an infinite-dimensional nonlinear partial differential equation, the Complex Ginsburg-Landau Equation, which finds wide application in wave dynamics and superconductivity. At this time Dr. Luce also acquired an academic background in quantum mechanics, including solid-state physics and statistical mechanics. Prior to graduate school, in addition to the requirements of his B.S. degree in physics, Dr. Luce also acquired training in electricity and electronics, acoustics, and sound recording (the latter for which he holds an additional B.S. degree).

In 1993 Dr. Luce began a three-year postdoctoral appointment at the Center for Nonlinear Studies at Los Alamos National Laboratory, where he pursued further research in nonlinear waves, with applications to fiber optics, ocean circulation, bioremediation, and microwave heating. He became a technical staff member of LANL in 1994, and remained with LANL until 2006. In 1997 Dr. Luce became interested in climate change and energy technology research, and gradually became involved with both energy R&D at LANL. He served as Renewable Energy Program Manager for LANL from 2002-2004, where he assisted program development efforts around advanced photovoltaic materials and LANL's overall energy research plan. He also pursued research in biomass energy generation, exploring the potential for LANL to generate space heat from surrounding biomass clearing efforts, and of the potential for the production of carbon-neutral methanol from carbon-free energy sources and atmospheric carbon dioxide, a topic which is now a major research focus at LANL.

Outside of LANL, Dr. Luce served as president of the New Mexico Solar Energy Association from 1999-2004, receiving an Outstanding Contributions Award in 2001.
He continued to serve as vice-president for NMSEA from 2004-2006. During this time Dr. Luce acquired extensive experience in the design, installation, and operation of photovoltaic and solar thermal systems. He participated directly in installations, and experimented with charging electric vehicles with solar power. He created extensive educational materials and curricula for the NMSEA, made presentations at over 60 schools, and gave hundreds of public presentations throughout New Mexico. Dr. Luce also worked with DOE scientists and architects to collate and publish up-to-date passive solar design guidelines for the NMSEA, and organized community educational programs in Los Alamos on green design following the Cerro Grande Fire.

In addition to public education efforts, Dr. Luce was also a founding member of the New Mexico Coalition for Clean Affordable Energy, an energy policy advocacy group, which he served as co-chair, chair, and then director of from 2000-2007. In that capacity Dr. Luce was centrally involved in the passage by the New Mexico State Legislature of a Renewable Energy Standard, Solar Tax Credits, Production Tax Credits for Wind and Solar Power, Solar Rights Legislation, and other laws. Dr. Luce also served as chair of Governor Bill Richardson's Distributed Solar Task Force in 2004, and served as an appointee on Governor Richardson's Electricity Transmission Task Force, Concentrating Solar Task Force, and Climate Change Advisory Group. He also served on the Western Governors Association Solar Working Group and Advanced Coal Working Group. Finally, Dr. Luce served as a member of the New Mexico Sustainable Energy Collaborative (a public-private collaborative), as a member of the New Mexico Project Power Working Group for the City of Santa Fe and as a commissioner on the Sustainable Santa Fe Commission.

Dr. Luce has also assisted due diligence efforts for some investors in new solar power technologies, and in wind power development efforts by large power users in New Mexico.

Since arriving at Lyndon State College, Dr. Luce has begun pursuing research into the integration of energy storage with solar energy systems, other design aspects of renewable energy systems, and alternative fuel synthesis. He is also engaged in the development of web-interactive database software, with the goal of creating web-interactive energy system simulations for use by decision makers and the public.

RESUME

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EDUCATION

1992	Defense Systems Management College (Resident).
1982	USAF Air War College (Resident).
1972	ABD, Department of Economics, American University, Washington, DC.
1962	MS Operations Research, Rensselaer Polytechnic Institute, Troy, NY.
1961	BS Engineering, Rensselaer Polytechnic Institute, Troy, NY.

EMPLOYMENT

1996-present	Adjunct Professor: Information Systems, Industrial Production, Business Communications, and Statistics.
1989-1996	Assistant Secretary of the Army (R,D and A). Deputy Director, Special Programs. Served as the HQ Department of the Army subject matter expert and advisor on High Power Microwave, Low Observable, Counter Low Observable and other highly technical and highly secure weapons technologies. Coordinated secure technology and acquisition programs weekly with the Navy, Air Force, OSD(A) and ARPA. Served as Congressional liaison for Army technology and Acquisition Special Programs. Directed Army "Black" state of the art development and acquisition programs.
1988-1989	Riverside Research Institute. Technical Staff. Evaluated the effectiveness of the United States Strategic Defense Operational Requirements via simulation and crafted Strategic Defense Policy and Force Structure.
1985	SRS Technologies. SDI Technology Director. Directed technology and policy studies for the Department of Defense on Anti-Ballistic Missile Treaty limitations. Directed the creation of the Strategic Defense Master Plan and Policy Guidance.
1982-1985	ANSER Corporation. Study Director. Directed studies for the Joint Chiefs of Staff and the USAF on Strategic Defense and the military utility of space. Crafted policy and strategy for the ballistic missile defense office. Wrote USAF legislative issue papers.
1980-1982	United States Department of Energy. Director, Planning and Evaluation. GS- 15.Evaluated the technical, economic and social impact of Energy Conservation and Solar Energy programs. Produced the first Emergency Energy Conservation plan.
1975-1980	United States House of Representatives. Committee on Science and Technology. Staff. Staffed the energy and science hearings, crafted legislation, and supported bills through the legislative process. Testified as a staff expert witness.
1972-1975	System Analyses Office, U.S. General Accounting Office. Analyst.
1966-1991	USAF Reserve Duty. Space Operations and Plans. Colonel.
1962-1966	USAF Active Duty. Flight and Space Test Engineer & Vietnam 1962-1966.

Eight Papers available upon request

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Summary:

College professor at innovative, environmental liberal arts college located in Poultney, Vermont. Over twelve years of research, analysis, and writing focused on a variety of energy topics. Recognized expert on renewable, distributed energy technologies and nationally known for work on the vehicle-to-grid concept. Wide range of experience in the energy field; working with a variety of non-governmental organizations, state and federal agencies, and private firms.

Education & Work History:

- **Green Mountain College,** Poultney, VT (September 1997 – present)
  Associate Professor of Management and Environmental Studies
- **Prometheus Institute,** Cambridge, MA (April 2006 – May 2007, part time)
  Director of Research, Solar Energy Program
- **University of Delaware,** Ph.D., Urban Affairs and Public Policy (August 1997)
  Dissertation title: *Photovoltaic Technology for Sustainability: An Investigation of the Distributed Utility Concept as a Policy Framework*
- **New York State Energy Office,** Albany, NY (Summer 1994)
  Policy Analyst Intern, Division of Policy Analysis and Planning
- **Center for Energy and Environmental Policy**, University of Delaware (August 1993 – August 1997)
  Research Assistant
- **Research Triangle Institute,** Research Triangle Park, NC (January 1992 – May 1993)
  Economist, Energy Resource Planning Group
- **Binghamton University,** M.A., Economics (January 1992)
- **Bryant College,** B.S., Business Administration (May 1989)

Research Interests:

- solar electricity's (photovoltaics) value as a distributed energy resource
- vehicle to grid power: concept development and economic and regulatory assessment
- plug-in hybrid vehicles and grid impacts
- policy and regulatory frameworks to promote sustainable energy technologies
- education for and the role of non-profits in promoting sustainable development

Professional Associations:

- American Solar Energy Society, member
- Northeast Sustainable Energy Association, member
- Renewable Energy Vermont, member
- SolarFest Inc., board treasurer

Recent Funded Research:

- University of Vermont, Transportation Center, Plug-in Hybrid Vehicles and the Vermont Grid
- Solar Electric Power Association, Utility Metering and Interconnection Survey
- National Renewable Energy Laboratory, Vehicle to Grid Value Assessment

Steven E. Letendre, PhD

Publications:

Journal Articles:

Letendre, S., Denholm, P., & Lilienthal, P. (2006). Plug-in hybrid and all-electric vehicles: new load or new resource. *Public Utilities Fortnightly*, 144, 28 - 37.

Letendre, S., & Perez, R. (2006). Understanding the benefits of dispersed grid-connected photovoltaic: from avoiding the next major outage to taming wholesale power markets. *The Electricity Journal*, 19, 64-72.

Letendre, S., Perez, R., & Herig, C. (2006). Solar vehicles at last? *Solar Today*, 20, 26-29.

Perez, R., Collins, B., Margolis, R., Hoff, T,. Herig, C. Williams, J., & Letendre S. (2005). Summer blackouts? How dispersed solar power-generating systems can help prevent the next major outage, *Solar Today*, 19, 32–35.

Letendre, S., & Kempton, W. (2002). V2G: a new model for power. *Public Utilities Fortnightly*, 140, 16-26.

Kempton, W., & Letendre, S. (1997). Electric vehicles as a new power source for electric utilities. *Transportation Research-D,* 2, 157-175.

Byrne, J., Letendre, S., Wang, Y., Govindarajalu, C., & Nigro, R. (1996). Evaluating the economics of photovoltaics in a demand-side management role. *Energy Policy,* 24, 177-185.

Byrne, J., Letendre, S., Wang, Y., Govindarajalu, C., & Nigro, R. (1995). Photovoltaics: a dispatchable peak-shaving option. *Public Utilities Fortnightly*, 133.

Letendre, S. (1994). Incorporating environmental externalities into electricity markets: methods and policies. *Bulletin of Science, Technology, & Society,* 14, 256-261.

Additional Published Articles:

Letendre, S. & M. Taylor. (2008). *Residential photovoltaic metering and interconnection study: Utility perspectives and practices.* A report prepared for the Solar Electric Power Associations, Washington, DC.

Letendre, S. R. Watts, & M. Cross. (2008). *Plug-in hybrid vehicles and the Vermont grid: A scoping analysis.* A report prepared for the University of Vermont's Transportation Research Center, Burlington, VT.

Letendre, S (2007). Vehicle integrated PV: Exploring the potential. *Proceedings of the EVS23 (23rd Electric Vehicle Symposium)*, Anaheim, CA.

Letendre, S (2006). Ushering in an era of solar-power mobility. *Proceedings of the 2006 International Workshop on Hybrid and Solar Vehicles*, Salerno, Italy.

Letendre, S (2006). A quarter a kilowatt hour: getting serious about ushering in a solar energy future. *Proceedings of the 2006 American Solar Energy Society Annual Conference*, Boulder, CO.

Letendre, S (2003). Vehicle integrated PV: a clean and secure fuel for hybrid electric vehicles. *Proceedings of the 2003 American Solar Energy Society Annual Conference*, Boulder, CO.

Andrew M. Shapiro

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Services range from sustainable building design to research and monitoring projects, including:

Environmental design consulting for new and existing single and multi-family housing, schools, commercial and institutional buildings; reviewing and recommending energy systems (HVAC), building envelope, daylighting, systems durability, moisture control, indoor air quality, and materials and systems choices. Computer modeling of building performance in support of the design process, integrated systems analysis, schematic, design development and construction document review, cost/benefit, cash flow and life-cycle analysis and on-site training and supervision for installation of high performance features. Two net zero-houses recently completed construction. LEED accredited professional, with one Gold and two Certified projects completed in Vermont.

Consultant to demand-side management (energy efficiency) programs, including design, development and evaluation and assessment of potential, program impact analysis, development of monitoring and evaluation strategies and procedures.

Energy Scientist for the Vermont Energy Education Program, teaching from elementary to high school to college level, principles and applications of energy efficiency and renewable energy, training both students and teachers.

Current and Recent projects:

Environmental design consultant for the expansion of the NRG facility to house a new manufacturing program, with similar but improved systems as the current NRG facility. LEED Gold anticipated.

Energy consultant and designer for three "net zero" houses in Vermont, with ultra-insulation, passive solar and renewable electricity powered heat pumps for heat and hot water, and performance monitoring.

Environmental design consultant for the reconstruction and addition to the Aiken Building of the University of Vermont School of Natural Resources. Currently in design development phase.

Environmental design consultant for the reconstruction of the Old Dairy Barn at Shelburne Farms into the Residential Learning Center. Currently in schematic design.

Environmental design consultant for the Wind NRG manufacturing and office facility, a 45,000 square foot state-of-the-art building in Hinesburg, Vermont, incorporating full daylighting, super-insulation, renewable electricity and heating sources, innovative radiant slab for both heating and cooling, pond heat rejection, automatic lighting controls and more. LEED Gold.

Environmental design consultant for Burlington Land Trust and Housing Vermont, for Waterfront Apartments, a 40 unit high performance affordable apartment building in Burlington Vermont, the first LEED certified affordable housing project in the US. Awarded first place in Home Depot Foundation national competition for green affordable housing.

Environmental design consultant for ECHO Center for Lake Champlain, a science museum focusing on Lake Champlain, Burlington, VT, Vermont's first LEED certified building.

Environmental design consultant for the Downtown Bennington State Office Building, incorporating high efficiency thermal envelope, ground source heat pumps, energy recovery ventilation, high efficiency lighting with automatic controls.

Environmental design consultant to the New Jersey Department of Community Affairs Sustainable Design/Affordable Housing Pilot Program. Work included development of rules and guidelines for affordable housing, monitoring projects and technical consultation.

Design of a side-by-side field study of durability of paint on historic houses, varying surface preparation techniques, for Vermont Energy Investment Corporation,

Consultant to Vermont Energy Investment Corporation, data analysis and recommendations for a study of performance of exhaust-only ventilation for single-family house.

Analyst for Study of Renewable Electric Resources for Rhode Island and Massachusetts, solar domestic hot water heating systems.

Principal investigator for the Vermont Division of Historic Preservation for *Testing the Energy Performance of Historic Wood Windows in Cold Climates.*

Principal investigator of *A Field Study of Ventilation, Indoor Air Quality and Energy Use Associated with Three Ventilation system Types in Elderly Housing*, research comparing performance of three ventilation system types in Central Vermont.

EDUCATION

Brown University, Bachelor of Arts in Engineering, Magna Cum Laude with Honors. (1988)

PROFESSIONAL AFFILIATIONS

New England Sustainable Energy Society
American Solar Energy Society
US Green Building Council LEED accredited professional

SELECTED PUBLICATIONS

Testing the Energy Performance of Wood Windows in Cold Climates, with B. James, 1996

Market-Based Program Designs for Accelerated Implementation of Rooftop Photo-Voltaics in New England, with Blair Hamilton, VEIC, April, 1996

Quiet Bathroom Fans, Journal of Light Construction, August 1995. *Simple Whole House Ventilation,* Journal of Light Construction, August 1995

A Field Study of Ventilation, Indoor Air Quality and Energy Use Associated with Three Ventilation System Types in Elderly Housing, November 30, 1994

An Integrated Assessment of Electric Power Resource Options in the U.S. Virgin Islands, co-author, with L. Hill ORNL and R. Chronowski, AEDI, ORNL/TM-12186, May 1993.

Efficient Energy Use, ES 41/42, curriculum for Brown University class in energy efficiency.

The Complete Guide to Add-On Solar Greenhouses and Sunspaces, Rodale Press, 1985.