WRITTEN TESTIMONY OF
RICHARD ROCHELEAU & TERRY SURLES
HAWAII NATURAL ENERGY INSTITUTE
UNIVERSITY OF HAWAII AT MANOA

HEARING ON
Climate Change Impacts and Responses in Island Communities

Before
SENATE COMMITTEE ON COMMERCE, SCIENCE, AND TRANSPORTATION
HAWAII FIELD HEARING

March 19, 2008

INTRODUCTION

Good morning Chairman Inouye and members of the Committee. Thank you for the opportunity to testify on this very important matter - *Climate Change Impacts and Responses in Island Communities*. My name is Richard Rocheleau. I am Director of the Hawaii Natural Energy Institute (HNEI). The Institute is an organized research unit in the School of Ocean and Earth Science and Technology at the University of Hawaii at Manoa. HNEI's faculty and staff conduct a range of research in the areas of renewable energy and ocean resources and manage several larger public-private partnerships to accelerate the acceptance and deployment of renewable energy technologies into Hawaii's energy mix. Our primary areas of emphasis includes development and deployment of hydrogen and fuel cell technologies, conversion of biomass into fuels and other high value products, advanced batteries and their applications, photovoltaics, seabed methane hydrates, and analysis of integrated energy systems to facilitate high penetration of intermittent renewable energy technologies into electrical grid systems. As the renewable technologies mature, the ability to deploy them in an economic and environmentally sound manner without negatively impacting the reliability of our energy systems becomes of paramount importance.

My own personal research has been in the areas of photovoltaics, hydrogen technology and fuel cells. As Director, I have focused considerable effort on development of public-private partnerships directed toward the implementation and deployment of renewable energy technologies into the islands' energy mix. My coauthor of this testimony, Dr. Terry Surles, is a member of the HNEI faculty. Prior to joining HNEI he was the Associate Lab Director at Livermore National Laboratory for Energy, was General Manager of Environmental Programs at Argonne National Laboratory, was the head of the Public Interest Energy Research Program at the California Energy Commission, and served on a National Academy of Sciences committee examining prospective benefits of federally funded energy research. Dr. Surles' primary interests are integrated energy systems as they relate to solutions for global climate change and energy security issues.

I have been asked by this committee to discuss our work related to clean energy technologies. Hawaii is very concerned about global climate change and energy security. It is unique among the 50 states in its dependence on oil for the production of electricity – about 86% of Hawaii's electricity is produced from oil. The grid systems are small by mainland utility standards and on the neighbor islands are relatively sparse leading to high costs for transmission and distribution. These factors, and Hawaii's abundant supply of renewable energy resources, offer a unique opportunity for Hawaii to serve as a "living laboratory" to identify the achievable limits for the deployment of renewable energy systems and to evaluate the impacts, benefits, and issues associated with such deployment to ameliorate global climate change and petroleum dependency.

The problems are not simple. Even renewable energy systems can have a CO_2 footprint - some such as ethanol from corn can be almost as large as that from petroleum. Due to intermittency and reliability, there are practical limits to the penetration of renewable systems on the grid. Can these limits be pushed sufficiently far and fast enough to have a significant impact on emissions and global climate change? HNEI and its partners are attempting to address these issues. In the last section of this testimony I do describe a few of HNEI's activities in this area, ones which if successful will impact not only the state but also the nation. However, before describing what HNEI's activities are, I would like to take a few minutes to address global climate change and energy from the larger context. This discussion comes largely from the recent reports of the Intergovernmental Panel on Climate Change (IPCC) and related publically available studies.

ENERGY AND GLOBAL CLIMATE CHANGE

At the most basic level, the balance between incoming solar radiation and outgoing infrared radiation (as heat) determines Earth's climate. Earth, it should be noted, is a greenhouse gas planet. Greenhouse gases, which include water vapor, absorb this infrared radiation, thus trapping heat near the earth's surface. Other gases, such as carbon dioxide, methane, and nitrous oxide, are also greenhouse gases. While these occur naturally, anthropogenic emissions of these gases, as well as man-made greenhouse gases (i.e., chlorofluorocarbons), have substantially increased the amount of these heat trapping gases in the atmosphere

Warming of the earth, according to the most recent Intergovernmental Panel on Climate Change (IPCC, 2007), is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global mean sea levels. The IPCC attributes this warming to the increase in greenhouse gas concentrations in the atmosphere. For example, the concentration of carbon dioxide, arguably the most important greenhouse gas, in the atmosphere has increased from about 280 parts per million (ppm) in the atmosphere prior to the Industrial Revolution to over 380 ppm at present. The continuously recorded data at the Mauna Loa Observatory demonstrate a seasonal, but monotonic, increase from about 315 ppm in 1958 to today's levels.

There are arguments that these changes are part of the natural climate cycles of the earth and not attributable to human factors. However, paleo-climate information supports the interpretation that the warmth of the last 50 years is unusual over at least the last 1300 years. The last time the Polar Regions were this warm for an extended period was about 125,000 years ago. Vostok (the Russian research station in Antarctica) ice core data suggest that the earth may be as warm as it has been in the past 400,000 years.

Recent data also support the fact that the past ten years contain many of the warmest years since weather data were being recorded. In fact, despite the increasing concerns about climate change and global warming, the rate at which carbon dioxide is being released into the atmosphere continues to increase from 6.4 Gigatonnes carbon (GtC) per year (6,400,000,000 tonnes C/yr) during the 1990s to about 7.2 GtC per year between 2000 and 2005, an increase in the rate of emission release of over 10% in 10 years.

The IPCC report provides projections for the future of earth's climate which include significant continued increases in temperature. For temperature change, the models are reasonably consistent in predicting increased temperatures based on the amount of carbon dioxide being emitted over this coming century. Since carbon dioxide will remain in the atmosphere for a very long time, even an aggressive response for reducing emissions is expected to result in an increase in temperature. Thus, a best case estimate for a low emissions and related temperature rise scenario will be between 1.1°C to 2.9°C (a global temperature increase of about 3°F) by 2100. Other scenarios predict likely temperature increases in the range of 2.4°C to 6.4°C (a global temperature increase of about 7°F) by 2100.

The implications of this considerable increase in temperature have been documented in numerous peer reviewed journal articles. Some of these impacts would include changes in cropping patterns due to an increase in drought and precipitation in agricultural areas. Other impacts on our food supply can include the introduction of invasive species, such as plant and animal pests as the climatic conditions may change. Additional impacts may be related to human health as tropical diseases become prevalent in formerly temperate climates.

The impacts of the changing climate are now beginning to manifest themselves. Over the past decade, we have seen increased precipitation in the mid-latitudes, further drying of lower latitudes (leading to increased desertification), and more intense and longer droughts in the tropics and sub-tropics. The lack of water will potentially impact Pacific Island nations in the nearer-term. There is reasonable expectation for these precipitation trends to continue.

In the longer term, some island nations may simply cease to exist due to rising sea levels associated with melting land-based glaciers and sea water expansion due to increased water temperature. *Conservative projections for sea level rise, even under the best of circumstances, are for a rise of slightly over three feet over the course of this century.* For many low lying islands, this amount of sea level rise would have a substantive impact. Sustained temperature increases that are implied in the higher scenarios, described in the preceding paragraph, could eventually – over the course of this century - melt the Greenland ice sheet, causing a sea level rise on the order of twenty feet.

A substantial amount of carbon dioxide emissions is due to our use of energy. The onset of the Industrial Revolution is generally equated with the start of large-scale burning of coal in England. The majority of today's carbon dioxide emissions arise from the burning of fossil fuel including coal, oil, and natural gas. In the mainland US, coal-fired power plants, the worst emitters, account for slightly more than 50% of the electricity generation. In Hawaii, about 86% of electricity is provided by oil-fired generation and 7.4% is provided by coal-fired generation.

For transportation, the situation is similar and possibly even worse. Almost all of our nation's transportation fuel is derived from petroleum. It should be noted that this dependence on petroleum is also a key contributor to our nation's energy security issues as well as the foreign debt/balance of payments problems. Thus, there is clear reason for linking security and climate change issues for our country's well-being.

The magnitude of this problem is daunting. For example, we discussed the fact that the world is currently emitting 7.2 gigatonnes of carbon a year. To put this into perspective we offer some examples of the changes to our energy infrastructure that would be required to reduce emissions of carbon dioxide by one gigatonne per year (from R. Socolow, Stanford Hydrogen Workshop, 2003). These include:

- Install 700 1000MW coal-fired power plants that include carbon capture and geological storage (not even available yet);
- Install two thousand times (2000x) the world's current supply of photovoltaics.
- Install 150 times (150x) the current world wide capacity of wind turbines; Replace two billion 30 mpg efficiency cars with 60 mpg efficiency cars.

The implication of climate change mitigation is that we must try to stabilize the concentration of carbon dioxide in our atmosphere to a doubling of pre-industrial concentrations in order to not suffer unknown, but potentially catastrophic effects. In other words, we need to take immediate action to limit carbon dioxide in the atmosphere to a concentration of 550 ppm. Since we are already seeing impacts at 380 ppm concentrations, even this may be too high. However, as discussed in the preceding paragraph, the changes in our energy infrastructure required to control carbon dioxide emissions are daunting. In order to achieve and maintain a 550 ppm atmospheric concentration of carbon dioxide by the end of the century, we will need to reduce our carbon intensity to less than 10% of what it is today. (Carbon intensity is the measure of carbon dioxide emitted to the atmosphere divided by the gross domestic product.)

Projected requirements to achieve this 10% goal include accomplishing ALL of the following:

- Generate 75% of all electricity from non-fossil sources
- Increase end use energy efficiency increases by 1% per year every year
- Increase electricity generation efficiency to 67% (currently about 35%) by 2050
- Increase passenger car mileage to average 50 mpg by 2050

Even if all of these are achieved, we will need additional technological breakthroughs to achieve a carbon intensity goal of less than 10% of our current value and even that will only limit the planet to a doubling of its atmospheric carbon dioxide concentrations from pre-industrial times.

For our country and for our state, we must pursue all technology solutions. The most effective solution is to simply use less energy. The highest priority for many state public utility commissions starts with end-use energy efficiency. This needs to involve not only the request to change lifestyles, but to develop and commercialize new end-use technologies that are more energy efficient in meeting the demands of the economy.

Another mechanism is to sequester (capture and store) carbon dioxide from coal-fired power plants. This is currently a technology under development that still faces a number of environmental, engineering, and financial challenges before reaching any stage of commercialization. Recent estimates report that CO_2 capture may require at least 25% of a pulverized coal-fired power plant's total output (C&E News, March 3, 2008). Newer technologies, such as oxy-combustor and integrated gasification/combined cycle systems, may allow for the continued use of coal and the more cost-effective capture and geological storage of carbon dioxide. This will allow our country to continue to utilize indigenous national energy resources.

Another approach – and one which will now be discussed at greater length – is the increased utilization of renewable energy resources. The greater use of these indigenous resources will allow us to reduce our dependence on foreign energy resources, while at the same time reducing carbon dioxide emissions for the amount of energy we consume. As noted earlier, the carbon emissions for any renewable resource technology are not zero. When one takes the technology's life cycle into considerations, carbon dioxide and other greenhouse gases are emitted during the fabrication or operation of these technologies.

As indicated, if we are to make progress against increasing CO_2 emissions, the solutions will necessarily be multifaceted. Renewables offer one potential solution for reduction of fossil fuel usage in both the electricity and transportation sectors. With its wealth of renewable resources, renewables can be a particularly effective approach for the state of Hawaii. The issue before the state is how to utilize these resources in an economic, environmentally-sensitive, and societal-acceptable manner. The next section provides a very brief summary of the status of various renewable energy resources and issues related to the deployment of related commercial technologies.

RENEWABLE ENERGY TECHNOLOGIES

Hawaii is blessed with almost every renewable energy resource imaginable. With its high cost of electricity and fuels, wealth of renewable resources, and stand-alone grid systems, Hawaii can serve as a model system for the rest of the nation in the deployment of renewable energy systems. However, before moving onto the Hawaii energy situation and HNEI's energy activities, I would like take a few minutes to provide a very brief review of the status, potential and unresolved challenges associate with the various renewable energy technologies.

Wind

Other than conventional hydroelectric power, wind is arguably the most developed of the renewable technologies. Megawatt (MW) sized wind turbines are available from a number of suppliers and have been shown to be cost effective where siting and integration are not issues. However, wind is characterized by restrictive operational constraints in terms of its intermittency (on both a second-by-second and day-by-day basis) that can have a substantive effect on the stability and reliability of the electricity grid limiting the allowable penetration onto the grid system. Siting can also be a challenge. Resource maps for wind can be useful, but wind is a localized resource. These resources are not always located where the electricity load is. Thus, long distance transmission is a challenge. Additionally, there can be localized opposition to wind due to perceived visual, noise, and aesthetic effects. Off-shore wind development has been proposed as an answer to land-use issues, but deployment is limited to relatively shallow regions which open the door for visual impact concerns. This has been part of the on-going discussions over the development of a wind farm in the near-shore area of Cape Cod in Massachusetts. Wind capacity factors (% of energy relative to nameplate) are typically around 35% and only 45% in best wind regimes. Thus, as with other intermittent renewable resources, the utility must have nearly equal back-up capacity for each MW of wind. Even when the operating utility has spinning and regulating reserve on line to control power quality and to allow rapid response to sudden losses in wind, sudden changes in wind speeds can destabilize the grid. Power quality and response issues increase non-linearly as wind penetration increases and become significant at percentages in the 10 to 20% range. Issues, as we are finding in Hawaii, are seen first on smaller grid systems. However, even on a large continental-based grid, reliability issues may arise. For example, just two weeks ago, the Texas grid system almost went down when there was a sudden and significant loss of wind.

Biomass

Biomass, organic matter of biogenic origins, is currently used as a feedstock for the production of fuels, chemicals, power, and heat. This flexibility to serve both fuels and power applications is a major difference between biomass and other renewables. The three primary sources of biomass in the U.S. today are wood, waste (e.g. Municipal Solid Waste), and crops for alcohol and plant oil based fuels. The first two groups are used almost exclusively for the generation of heat and power, and in 2005 accounted for 82% of biomass consumption on an energy basis.
(EIA, http://www.eia.doe.gov/cneaf/solar.renewables/page/biomass/biomass.html).

The current development efforts for biofuels in the U.S. has focused primarily on ethanol produced from corn and biodiesel produced from soybeans. Ethanol production from corn approached 5 billion gallons in 2006 (~3% of overall gasoline consumption) and is expected to show continued growth. Biodiesel production was significantly less at ~100 million gallons representing only about 0.25% of distillate fuel consumption. The impacts of rising petroleum prices and growth in demand for biofuels have resulted in increased biofuel production and, even at these modest levels of production, have led to competition with food supplies. Unlike electricity, where several renewable technologies can be used to displace fossil fuel power generation, renewable liquid transportation fuels are expected to come almost exclusively from biomass.

It is generally agreed that current biofuels systems (crops and conversion technology) are not sustainable, certainly not at the scale needed to impact long-term energy security or climate change. To achieve sustainable biofuels systems, production of biomass will need to focus on the use of marginal agricultural lands, improved crop yields, reduced production inputs (i.e. water, fertilizer, etc.), development of non-agricultural biomass resources, and improved biofuel production technologies and end-use efficiency. The transition from fossil fuels to biofuels will only be achievable with development of appropriate policy that will provide the sustainability and stability needed for long-term investment at all points along the value chain.

The development of technology to produce transportation fuels from materials less valuable than corn or sugar has focused on using fiber (i.e. wood, straw, bagasse, etc.) as the feedstock. Integrated biochemical and thermo-chemical technologies currently under development are positioned for use in bio-refineries of the future and show great promise. However considerable time and investment in R&D and commercialization are required. These efforts need to be afforded a high priority.

Photovoltaics

Solar photovoltaics are reliable and commercially available but continue to suffer from high costs. The current market is dependent on subsidies and/or tax credits with a significant part of the commercial sales taking place in only a few places (Germany, California, and New Jersey) where aggressive subsidies are provided. The majority of the market today is served by some form of silicon wafer but a number of thin-film and 3rd and 4th generation materials are under development. Since a PV system includes the other module components, hardware for mounting and installation, and balance of plant for integration to the household or grid; cost of the actual semiconductor is only one of the cost factors that must be addressed. Integration into the grid is simpler than for wind (predictability better) but the relatively high cost is likely to limit deployment except in locations with high electricity costs such as Hawaii.

Solar Thermal

This technology is of interest in that it can provide for the use of power even when the sun isn’t shining through the use of heat transfer and storage fluids in its system. Currently, these systems are in use in parts of the world, such as the Negev Desert, where there is little scattering of the incident light. Their potential, while considerable in Hawaii, still awaits further reductions in operational costs and in confirmation of longer term efficacy of stable operation.

Geothermal

This is a proven technology where the resource allows use of conventional power generation technologies, i.e. geothermal resource provides steam for power generation. Newer technologies such as engineered geothermal systems (EGS) which use water injection to utilize dry geothermal heat for steam production are under development. There are positive projections of cost for EGS, but these systems have not yet been demonstrated in a commercial setting. Under heavy use, long term viability of a geothermal resource can be an issue. Siting for naturally occurring geothermal fluid systems is an issue in that they are only available in a limited number of locations. EGS systems however have a much greater area upon which to draw and could form the basis of a distributed generation system. Unlike most other renewable technologies, intermittency is not an issue. Thus, geothermal energy can be used for base load power.

Ocean Energy Technologies

Ocean Thermal Energy Conversion (OTEC) – Net power production has been demonstrated from OTEC but questions remain about the efficiency of the process, cost, demonstrated lifetime, and design efficiency. In addition, there is limited potential for the mainland US without some form of chemical energy transfer which today is too expensive. At the gigawatt scale, this technology uses enormous amounts of deep sea and surface sea water which may have significant long term environmental impacts.

Wave – There are many (up to 40) competing wave energy technologies world wide. While there has been significant progress in recent years, many ocean deployments to validate system performance have met with limited success. Capital, including installation costs, is a significant factor. One point that is seldom made, although obvious, is that the ocean environment is harsh from both corrosion and simple wear and tear. Therefore, longer term efficacy related to O&M needs to be demonstrated. Intermittency will require back-up energy generation technology, but rapid transients such as those associated with wind are not expected to be apparent. Thus, high penetration is theoretically possible.

Hydrogen and Fuel Cells

Hydrogen is an energy source, such as the sun or a fossil fuel. Rather, hydrogen is an energy carrier like electricity. While hydrogen is the most plentiful element in the universe it does not occur freely. It must be manufactured from compounds in which it is bound. Hydrogen can be produced by electrolyzing water and from the gasification of biomass.

Hydrogen can be used to generate electrical power electrochemically in a fuel cell or to produce mechanical energy by thermo-chemical combustion in an internal combustion engine. In the case of a fuel cell, the product of combustion is pure water; in an engine it is water and some nitrogen oxide. Economics dictate that renewable electricity is best utilized to power the utility grid with any surplus used for hydrogen production via electrolysis.

When considering hydrogen as a potential energy carrier, all of the elements making up the system must be considered. These elements include the production, storage, and transport requirements, plus the end-use utilization of the hydrogen. Although considerable progress has been made over the past 10 years, all of these components of the hydrogen system are in the development stage and not yet commercial. However as the price of oil increases, the value of clean energy solutions becomes more important, and technical progress is made, hydrogen is expected to become and important component of future energy systems, and Hawaii could be one of the earliest adopters

HNEI ACTIVITIES RELATED TO CLEAN ENERGY TECHNOLOGIES

Hawaii imports fuel for generation of the majority of its energy (93%) characterized by an unusually high dependence on oil for power generation. This substantial reliance on fossil fuels is juxtaposed against an abundance of renewable resources which could be used for energy. With this array of renewable resources and the opportunity for high productivity energy crops; renewable electricity and bio-derived fuels offer great promise to reduce the states' dependence on fossil fuels and for Hawaii to demonstrate for the nation, the potential of energy independence through renewable energy. This was recognized in the recent MOU between the State of Hawaii and US Department of Energy where a goal of 70% of the State's energy from renewable sources by 2030 was announced. While an admirable goal, and arguably one that is necessary nationally and internationally if we are to impact CO_2 emissions and climate there are very significant hurdles – technical, economic, and policy – to be overcome if there is to be significant progress toward this goal within the critical 10 to 15 year timeframe in which consensus estimates agree that world-wide conventional oil and gas resources will not meet demand. Although the goals are less aggressive, in 2004, the State enacted a new Renewable Portfolio Standards law (SB 2474) setting a renewable energy goal of 20% for 2020. However, implementation even at this modest level of penetration remains a challenge.

As summarized in the introduction, HNEI conducts research and development in a number of technology areas. HNEI has also committed substantial resources and effort to development of public-private partnerships which will (1) provide for development of analysis and tools to identify the optimal path(s) forward (2) identify critical projects to validate key renewable technologies and the ability to integrate these technologies into the energy mix. It is these latter integration activities which can most quickly effect change in the state and for that reason, will be the focus on my discussion today of HNEI activities.

Renewable Energy Deployment: There are a number of commercial and emerging technologies such as wind, solar, and ocean energy systems that offer the potential for large scale penetration of renewable electricity into the grid. However, each of these technologies is inherently more variable and less dispatchable than conventional generation. Their implementation will require utility system planners and operators to adopt new technology and new strategies to ensure reliable and efficient electric grid operation. HNEI, in partnership with the local utility, GE Global Research Center, the state, and US DOE, has developed a substantial program to identify potential solutions to high penetration of renewables. HNEI holds a unique position in being able to merge interests and funding from a variety of public and private resources.

The thrust of this current project is to develop models and other analytical tools that can be used to evaluate the future development of renewable energy systems on each of the islands, addressing specific island energy systems and resources. This effort was initiated on the Big Island, now includes Maui, and is expected later this year to include Oahu and Kauai. Using the Big Island effort as an example, operations and modeling show that the electricity that is available from existing wind power on the island can compromise the stability and reliability of the grid. At the same time, the state Renewable Portfolio Standard is mandating additional renewable energy installation between now and 2020 and independent power producers are pushing for increased use of wind by the utility. Use of these scenario analysis and management tools is providing information on approaches for placing more renewable energy systems on the Big Island. These analyses also demonstrate the need for development, demonstration, and deployment of enabling technologies for renewable systems. These enabling technologies will necessarily include electricity storage systems (for both second-by-second response and for bulk storage), advanced power electronics, and demand response technologies.

These scenario analysis and management tools also allow characterization of the benefits, costs, performance issues, environmental and societal issues, and impacts of various solution scenarios for each of the main islands.

Additional projects in these areas have been proposed using the existing partnerships to leverage resources to validate technology integration solutions through field demonstrations. As discussed in more detail below, these analyses also help provide robust policy analysis to support legislative solutions to ensure a systematic and reliable transformation of Hawaii's energy systems. The Department of Energy is interested in this work, since the current stability and reliability issues facing the Big Island are expected to be replicated on the mainland.

Tropical Biofuels**:** In the biomass arena, there are numerous technologies in various stages of development in Hawaii and elsewhere with potential to contribute to Hawaii's energy solutions. Analogous to the integration issues being addressed for high penetration of renewables onto the electricity grid, cost-effective deployment of these emerging biomass conversion technologies for power or fuels production require substantial integration to effectively utilize the biomass resource. Additionally, many of the biomass resources and conversion technologies are yet to be validated for commercial deployment. HNEI has embarked on a number of partnerships to address these issues.

Researchers in HNEI and the College of Tropical Agriculture and Human Resources are working collaboratively to develop new bioenergy production systems for Hawaii. Crop production research activities include screening candidate crops suited for the tropics under different soil and climatic conditions (benchmark locations) and selecting for high yielding varieties with the greatest energy production potential. The feedstock properties that are important in bioenergy conversion vary between crops and may depend on environmental factors. These properties are quantified for selected candidate feedstocks and conversion tests are performed in laboratory or bench-scale equipment to optimize biomass conversion methods across the range of fuel properties. The economic feasibility and energy productivity of an integrated bioenergy system based on the production of candidate crops and selected conversion technology options are evaluated. This integrated approach provides necessary analysis in support of bioenergy systems development.

Finally, HNEI is working with private industry to demonstrate promising biofuel technologies in small scale tropical biorefinery. Under this activity, HNEI is undertaking technology assessment including models of resource requirements for crop production and conversion technologies, integrated systems evaluation including characterization of benefits, costs, performance issues, and environmental and societal impacts of various systems. The eventual goal of this work is pre-commercial demonstration of a tropical biorefinery system.

The latter activity will be used to validate key process components and production targets and provide continuous, operational data at a scale sufficient to lower the technical risks associated with financing future commercial plants. All three tasks will seek to build partnerships with entities (land owners, businesses, State agencies, etc.) in the Hawaii biomass community and with groups from outside Hawaii that can provide technology, capabilities, and significant leveraging of project funds to help overcome the technical, economic, and resource barriers which have, to date, prevented significant progress in the development of new bioenergy projects in Hawaii.

***Policy**:* HNEI is working closely with the US DOE, the State Energy Office, the PUC, and energy providers to provide unbiased information for development of a set of policies which can help move the state forward. This project effort and other HNEI activities allow for the integration of knowledge gained from technology assessment with public policy analysis. One of the most efficient paths forward for commercializing new technology in this area is to link technology advances with public policy tools and initiatives. The information gained from this effort will provide the state Public Utilities Commission, for example, with information on how new power purchase agreements may be configured to reduce costs to the rate payer. This project can also provide information to commercial technology interests on how best to modify and configure their technologies for emerging electricity markets that are increasingly dependent on renewable and distributed energy. In short, there are many means and mechanisms for how public policy initiatives and technology development can be linked to provide benefits to consumers and – more broadly – to the state and nation. HNEI is working on ensuring that these mechanisms are as effective as possible.

CLOSING REMARKS

Hawaii can and should be a "living laboratory" to explore the potential for validating the performance of various renewable energy technologies in commercial deployment. Our state also can provide a unique environment to allow for a quantitative evaluation of grid integration and commercialization of new technologies, not only for our state, but for the country as a whole. The active interest by state government, Congress, the energy community and the private sector state allows for the integration of technology, commercial deployment and policy. While these are initially directed to Hawaii, in the future they can be applicable to national needs. This is particularly important for many of the larger scale issues facing our energy systems. It is unlikely that either the public or the private sectors can solve any of the large scale issues independently of the other. These issues – global climate change, energy security, grid modernization, and critical infrastructure, to name a few – require concerted and collaborative efforts and continuity of funding to be solved in the national interest.