CREATING A SMOOTH PATHWAY FROM INNOVATION TO COMMERCIALIZATION WITHIN THE CALIFORNIA PUBLIC INTEREST ENERGY RESEARCH PROGRAM

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Introduction

Funding for energy related research and development in the United States has declined dramatically over the last two decades. Federal funding dropped by 74% since 1980 as a result of low energy prices, a lack of public interest, and frustrations with the mixed results of past energy projects. Private funding for energy R&D has been low as well, since many of the benefits accrue to society and not to the firm undertaking the research. The move to deregulated energy markets has reduced utility funding for R&D in the last decade. As utilities shift from regulated public service entities to unregulated for-profit businesses their incentives have changed. No longer able to pass R&D expenses to ratepayers' utilities have dramatically cut research budgets, even in states that have not yet set deregulation in motion.

In addition to the decline in both federal and utility funding, the focus of energy related research and development has changed as well. Research programs have shifted to funding relatively short-term projects, which may provide incremental changes to our energy structure but are unlikely to create new technologies that radically alter the ways we produce and consume energy. These projects are unlikely to lead to large societal gains, but will instead provide short-term profits to the firms that produced them.

The projects that are most difficult to fund are those that attempt to prove the feasibility of new technologies. These technologies could radically change the future of energy production and consumption. They have to potential to create huge societal gains in the form of a cleaner environment, cheaper energy for all and a better standard of living. Private firms are unlikely to take on the research since it will take a long time, cost millions of dollars, and if successful will be difficult to protect from competitors. It is therefore left to the public sector to support this research.

The Public Interest Energy Research Program was formed to provide support for the energy related research that has become scarce over recent years. The program is funded at $62.5 million dollars per year and was created to support the energy related research and development "that would not otherwise be done in competitive and deregulated markets" (CEC, 1997).

The program was split into two parts, the Energy Innovations Small Grants Program (EISG) and the Public Interest Energy Research (PIER) Program. Both fund energy related research and development, but they focus on different stages of research. The EISG program funds projects that are designed to prove the feasibility of new, innovative technologies. The PIER program focuses on developing proven technologies and providing support to bring these technologies to the commercial marketplace. Both activities are necessary to actively plan our energy future. To date there has not been a good connection between the two programs. Although there appears to be a natural progression from the early-stage EISG program to the later-stage PIER program I will argue that there are many factors which prohibit this transition. Consequently EISG researchers have few options for continuing research within the California R&D system. Furthermore, by participating in the EISG program their ability to receive funding from other programs is restricted. Considering the large positive impact these technologies might have on our future energy system we should not leave them without proper support.

This evaluation is of the renewable energy program area only, but many of the observations and suggestions relate to the entire program. I finish with a list of options for how these programs can be connected in order that projects flow smoothly from idea generation through the research, development and demonstration process and into the commercial marketplace. It is only when technologies have become widely accepted and used that the program will be deemed a success.

R&D Overview

Research, development and demonstration (RD&D) activities are all the actions that take place before a new technology enters the marketplace to compete with other products. They include any activity that generates further knowledge, directs this knowledge to meet a recognized need or uses knowledge to produce new materials, devices, systems or methods (DOE, 2001).

RD&D is often publicly funded because of the social returns to investment that are not captured by individual firms. Public energy RD&D funds are typically focused on areas that are not heavily sponsored by the private sector. These areas include early-stage research carried out at the pre-competitive level, innovative high-risk research which may not lead to a marketable product and broad-based research which benefits an entire industry. There are also social and institutional reasons causing firms to underinvest in RD&D. Research and development yields public benefits which are perceived to have more value to society that to individual companies. For example, the environmental benefits of reducing air emissions from an electricity generator may not increase profits but will result in a better standard of living for the surrounding community. The inability of individual firms to capture most, or all, of the benefits associated with RD&D will inevitably lead to private underinvestment.

The return on investment for research and development is extremely high. Rates of return have been estimated at more than 100%, and continue to increase when further investments are made. This indicates that there is underinvestment in RD&D, for if funding levels were reaching a saturation point there would be decreasing returns on investment (Ruttan, 1979;Margolis and Kammen, 1999). A 100% return in investment is extremely high in comparison to the 10% ROI of normal investments. However this return on investment is split between the firm or state undertaking the research and others who can utilize the results. So even though returns to the company are higher than most other investments, there is a lack of will to invest because 'all' of the returns are not captured.

Public funds should not be used to fund all stages of research and development. The private sector is willing and able to carry out late stage RD&D, including market transformation and commercialization programs as well as research to resolve manufacturing problems. The private sector is also successful at funding research and development, to increase the competitiveness of an existing product. This RD&D does not require public funds as the benefits may accrue to the firm. However, some aspects of R&D at the commercial level do warrant public support. There are many examples of technologies that have reached economic competitiveness, such as some distributed generation technologies, but have not been able to capture a market share. The reasons for this are varied, but public funding is justified to reduce regulatory market barriers and educate potential users about the benefits of new technologies.

The importance of public funds for innovative research has been noted by numerous government and industry representatives. Public funds tend to sponsor innovative research, rather than the incremental research in which industry excels (Loiter, 1999). Scientists at Lawrence Berkeley National Laboratory (LBNL) have calculated that the net present value of technologies derived from energy efficiency research is more than 100 times the amount of money spent on the research itself (LBNL, 1995). Research and development contributes to the production of new products and the formation of new industries. It is therefore imperative that public funding for research and development continue.

Energy R&D Funding in Decline

There has been a steady decline in federal energy research funding. Department of Energy (DOE) funding has declined 80%, from $6.2 billion to $1.3 billion (in constant 1997 dollars), over the last twenty years (PCAST, 1997). This drop has directly reduced energy R&D funding through the Small Business Innovative Research (SBIR) program which sponsors entrepreneurs in energy related R&D. Reductions in federal energy funding have been directly correlated to a decline in new energy technology patents (Margolis and Kammen, 1999). These patents lead to new products, which shape the way we will produce and consume energy.

There has been a decline in funding for energy RD&D at the state level as well. Utilities in California performed much of the energy related RD&D in the past. Prior to 1997 IOU’s expensed R&D and passed the costs to ratepayers. This was facilitated and regulated by the California Public Utilities Commission (CPUC). California utilities led the nation in progressive energy related RD&D which reduced consumption, benefited the environment, and saved ratepayers billions of dollars. However, California utility sponsored R&D fell 50% between 1991 and 1996, as deregulation became a reality (Dooley, 1997). Since 1997, in response to deregulation, utilities have reduced investments in research programs even further. These reductions are in response to competitive pressures resulting from a free market system. Utilities can no longer pass on research expenditures; furthermore RD&D that results in higher energy efficiency will reduce the amount of electricity/gas the utility sells, reducing profits. Therefore, utility incentives to participate in many types of public benefit R&D are greatly reduced.

Utilities have also reduced funding for industry consortia like the Electric Power Research Institute (EPRI) which performs industry wide energy RD&D (LBNL, 1995). EPRI was established to support R&D that benefits its members, which comprise a major portion of the electricity industry. This research resulted in social and industry wide benefits, and like the public benefit R&D done by utilities, EPRI sponsorship is diminishing as utility budgets tighten. EPRI member contributions declined 30% from 1994 to 1996 (GAO, 98).

The private sector has also reduced investments in energy related R&D. Private sector funding of energy related R&D declined by 42% from 1985 to 1994 (Dooley, 1997). Low energy prices have reduced incentives to produce new technologies and reduce energy consumption (LBNL, 1995). Businesses have little incentive to push for new technologies because energy related costs are tiny fraction of monthly expenses. There has been little pressure from the general population because of confidence that the armed forces will be able to keep petroleum flowing from the Middle East and a wait and see attitude on the impact of global warming. Many citizens are also leery of large renewable energy subsidies because of perceived failures of past renewable energy demonstration projects. For instance, the public believes that subsidized wind turbine installations were a failure, because many of the turbines are no longer functioning. However, they fail to take into account that the price of energy from wind dropped dramatically as a result of those installations. Although the subsidies could have been structured better, they were by no means a failure. These factors have combined to reduce interest in investing in energy related R&D.

Shift in R&D Focus

The focus of research and development programs has shifted in response to competitive pressures. Utility, governmental and private sector researchers are moving away from long-term research and toward short-term goals with payback times as little as one year. As utilities become deregulated, their focus has altered from providing energy as a public service to providing energy as a for-profit venture. Memberships in collaborative research ventures with other utilities and technology developers have declined because utilities are focusing on in-house research on proprietary products.

In a deregulated market some innovation will be stimulated. This innovation tends to be incremental and focused on creating a better version of an existing product or grouping existing technologies to serve the customer better. R&D programs will research how to combine existing technologies to gain a competitive edge, instead of focusing on next generation technologies which may modify the structure of energy systems. This is exemplified by the current focus on computer-controlled systems that react to real time electricity prices. These systems are designed to reduce peak electricity loads, but will not significantly reduce the overall amount of electricity consumed.

This shift to short-term R&D is exemplified in European countries which have completely deregulated the provision of energy services. Sweden's largest utility, Vattenfall, has reversed its research portfolio from 70% corporate R&D and 30% business R&D completely around. Now the business department controls the R&D and the utility has virtually terminated its long-term corporate R&D program. British utility R&D programs used to fund projects with 5-7 year time frames. Now, post-deregulation projects with 3-year time frames are considered long-term, with 1-year projects becoming the norm (Dooley, 1997). Some types of innovation will be stimulated as deregulation becomes predominant, but these innovations are profit motivated and will not contribute to a major shift in how we generate and consume energy.

Utility managers in the US have predicted a shift in their research programs as well. A 1996 study revealed that a majority of utility mangers expected utility R&D to shift away from long-term research as utilities attempt to compete as for profit businesses (GAO, 1998). The shifting focus of utility priorities affects collaborative R&D organizations as well. EPRI funding for advanced power generation and renewable energy dropped by 66% and 45% respectively from 1994-1997 (Dooley, 1997). The motivation for EPRI to fund long-term research projects that will substantially alter the current paradigm is negligible. As a consortium funded by and for the utility industry, it is in EPRI's interest to fund projects that benefit the utilities, not the community at large. Utilities are large institutions that are heavily invested in the current infrastructure. To date utilities have not been supportive of new technologies that are radically different from the fossil fuel based approach they are accustomed to. A full-scale transition to new technologies would necessitate further investment in new infrastructure and the entrance of new, smaller movers who could effectively remove customers from the utility rate base. EPRI programs will therefore tend to enforce the status quo by continually making incremental changes, not aggressively researching technologies that will change the entire system.

The shift in R&D program focus will have a dramatic impact on how our energy system develops over the coming years. Incremental improvements that are supported by short-term research will surely lead to changes. We will develop slightly more efficient generation and distribution systems feeding incrementally better end-use appliances. We also have the ability to find new solutions to our energy needs if we can keep focused on the possible solutions, as well as the probable ones. We need to maintain a long-term focus in our energy research and development programs to keep up the pressure to innovate beyond the small adjustments that simply create a better product that is slightly more profitable in the short-term. The decline in funding combined with a shift away from long-term research will have dramatic effects on the number of new energy technologies developed in the years to come. This has created an urgent need for a research and development program which is long-term in scope and will take the initiative to fund innovative energy ideas.

Public Interest Energy Research Program

California began deregulating the generation side of the electricity market in 1996 with the passing of AB1890. Since deregulation utilities have not been required to fund research and development in the public interest. Understanding that funding would dramatically decline programs were written into the bill to provide funding for public benefit research and development. The Public Interest Energy Research Program (PIER) was created to administer this funding. PIER was created to support longer-term innovative research and bring technologies through the RD&D progression to commercialization.

The mission of PIER is to support public interest energy research. This research "seeks to improve the quality of life for California's citizens by providing environmentally sound, safe, reliable, and affordable energy services and products" and "includes the full range of research, development and demonstration activities that will advance science or technology not adequately provided by competitive and regulated markets" (CEC, 1997). As stated above the type of research that needs support is that which focuses on long-term innovative research with the potential to radically change our energy system. PIER had these goals from the start, as explained by Commissioner David Rohy, in to the Committee in Science in the US House of Representatives. He explained the increased private investment in late stage commercialization would "allow government programs to remain focused on the early stages of R&D, and maintain the long-term perspective (CEC, 1998). PIER policies also stated that the program needs to "fund some higher risk research that has the potential to make significant breakthroughs in the long run" (CEC, 2001). This is the research that PIER was set up to support.

After many meetings with technology developers, researchers, and interested stakeholders PIER has focused on six program areas; renewable energy, building energy efficiency, industrial/agricultural/end-use efficiency, environmentally preferred advanced generation (EPAG), environmental issues and strategic energy research. Introducing innovative technological solutions in these areas will have the greatest effect on shaping the future of California's energy system.

The program has been in a constant state of flux since its inception. Program administration was given to the California Energy Commission without the necessary staffing to support the program requirements. This created some chaos because many of the contract mangers and even program area managers were asked to accept PIER related duties on top of full work loads. This made the administration of PIER duties a secondary priority to many contract managers, and slowed the processes involved with contract management and funding. Many of the kinks have since been smoothed out as program managers have been designated as 100% PIER employees and the hiring of Terry Surles as the PIER Program Manager has provided necessary leadership. However, the energy crisis in the Summer of 2001 has again created difficulties for PIER because the CEC has ordered many of the staff to focus on non-PIER related issues. All CEC employees are now working to reduce the number of blackouts that will roll across the state this summer.

The longevity of PIER has also been modified twice over duration of the program. Originally legislated for four years, the program was extended for 10 more years in 2001. This may have influenced the type of projects which received funding over the first two years. Program success will be rated on how many projects reach commercialization and are successfully assimilated into the market. Before the extension was granted in 2000- PIER had only four years to commercialize technologies and prove that the program is a valuable use of taxpayer money. This four-year time frame and the political atmosphere would have pressured program managers to grant awards to very late stage demonstration projects, to justify the program.

Since the program began there have been many Policy Advisory Council (PAC) Meetings and an Independent Review Panel Report aimed at improving the program as a whole. The program has been responding to input from these outside sources and continues to redefine itself.

Program Organization

The Public Interest Energy Research program has been split into two separate programs, administered from different locations. These programs are each focused on supporting projects at different stages of research. The Energy Innovations Small Grants (EISG) Program supports technological feasibility studies, while the PIER program supports projects that work on a wide range of research, development and demonstration activities. The programs have different goals and each program contracts different types of institutions to carry out the research.

The PIER program is funded by a non-bypassible surcharge, the Public Benefits Charge, which is placed on all retail sales of electricity. This surcharge provides $62.5 million dollars per year, $700,000 of which is for utilities to use for transmission and distribution (T&D) research. PIER distributes the remaining $61.8 million dollars for non-T&D related research.

The funds are divided into two programs. The Energy Innovations Small Grants Program (EISG) is administered by San Diego State University (SDSU) and provides a maximum of $75,000 dollars for projects lasting twelve to eighteen months. EISG projects range from feasibility analyses to full-scale prototype construction and testing.

The California Energy Commission (CEC) executes PIER funds. Projects in the renewable energy program area have received awards ranging from $90,000 to $1.38 million dollars over a period of one to three years. PIER projects cover many stages of research, from feasibility analyses to product development. A few projects have even been funded for commercialization activities, which pushes the bound of public interest research.

EISG Program

The EISG program is focused on proving technical feasibility of emerging technologies that coincide with the requirements of the PIER program. The CEC understands that there is a lack of funding for early stage research in the PIER program and has created the EISG program to fill this need. The program is expressly designed to promote new technologies, and concepts that have already been proven feasible are not eligible. To encourage small innovators who may lack the skills to pursue other types of funding only individuals, small businesses, non-profits and academic institutions may apply. This may lead to an inability to take the research all the way through the RD&D cycle, because the researchers may lack the necessary tools to carry the work through the demonstration phase or successfully market the finished product.

Even though the EISG program is aimed at the earliest research stages, there is still a need to understand the market into which the end product will be introduced. Although marketing studies are not eligible for EISG awards, the program does require that the research team demonstrate an understanding of where the product will enter the market. All proposals must show what particular energy problem they will address, as well as what other products and processes exist that provide similar services. There must also be a viable route to market entry that must be verified before projects receive funding (CEC, 2001). Maintaining an eye on the market is an important aspect of creating a product that fits seamlessly into the marketplace and is readily adopted.

The EISG program has had 7 solicitations, four in 1999, two in 2000 and the current solicitation which is still open. Seventeen projects have been funded in the renewable energy program area in many areas of research including; solar, wind, geothermal, biomass and hydrogen and waste gas extraction. The awardees from the first solicitation have reached the end of their projects and are require funding for the next stage of research.

PIER Program

The Renewable Energy Program Area of the PIER program funds a broader set of research activities than the EISG program. Projects in the PIER program cover topics varying from technical feasibility to product commercialization. The program has focused on the development and demonstration of already proven technologies preparing to enter the marketplace. There are no restrictions on who can apply for PIER funding, but the recent solicitations have required that certain types of researchers be involved with the project. The majority of awards given have been for late stage development projects as a result of this focus.

A comprehensive market analysis is required to apply for a PIER award. The analysis is more comprehensive than that required in an EISG grant because the projects are closer to commercialization. Proposals are required to identify the product market as well as forecast growth and potential market share. The project teams must prove that they have the financial ability to facilitate product entry into the marketplace, including market launch and advertising campaigns. Proposals are required to provide a production readiness plan that outlines critical production processes and a plan for full scale manufacturing ramp up.

There have been four solicitations which have included renewable energy projects. The transition solicitation was the first solicitation that the PIER program funded. It was focused on continuing projects that had been started by California utilities, but would have been dropped as deregulation proceeded. This was a one-year, one time grant that was available only to utilities. Four renewable energy projects were funded, but one was later dropped because it was impossible to obtain the necessary equipment to proceed with the demonstration. These projects were in the demonstration phase and were supported so that research which had already been paid for by California ratepayers was not abandoned.

The first general solicitation was sent out in 1997 and included requests for proposals for three different program areas. Eighty proposals were submitted for renewable energy projects and twelve awards were given for a total of $10.9 million dollars. The solicitation focused on very short-term projects that would most likely provide benefits “within the next few years” (CEC, 1997).

There was also a competitive negotiation solicitation to support small modular biomass production that I was not able to review. Two awards were given for a total of $1.6 million dollars, and both products are being demonstrated and installed in the field.

The most recent solicitation closed on April 20,2001. This solicitation was the most closely tied to the marketplace as it required that research teams collaborate with energy service companies (ESCO) so that once the new technologies are developed they will have easy access to the market. The solicitation also requires that proposals have at least three different generation technologies and demonstrate synergies between the technologies that will aid in the success of the project.

Bringing innovative ideas and emerging technologies to the market is one of the main goals of the program. The question of how best to accomplish this task has been the topic of much debate. Where do ideas for new technologies come from? What interchange is there between science, existing technologies and the market? In what environment do scientists best carry out their research? To understand how these factors affect the flow of research I will briefly review two theoretical models of research, followed by a look at how two current R&D programs channel the flow of research along the RD&D pathway.

Theoretical Research and Development Models:

There are two research and development models that attempt to show how ideas flow through the scientific realm and into the marketplace. The linear research model views the flow of ideas to be uni-directional, from science to technology. The chain-link model, recently developed and growing in popularity, theorizes that knowledge flows in both directions, from science to technology and vice-versa.

Linear Model of Research

The linear research model derived authority from the successful technological developments throughout and after World War II. Since then many research institutions have continued to utilize this model, holding that "basic research is the pacemaker of technological progress" (Bush, 1945). The linear model relies on three main stages of research and development. These stages are defined as (Perlack, 1996):

- ♦ Basic research – Creates new knowledge, is generic, non-appropriable, and openly available. It is done with no specific purpose and requires a long-term commitment.
- ♦ Applied research – Uses research methods to address questions with a specific purpose, produces knowledge for developing a specific technology and overlaps with basic research. It can be short or long-term.
- ♦ Technology development – Develops prototypes for developing practical applications and is of general interest to sectors but full returns are non-capturable by single firms. It makes use of knowledge from basic and applied research.

This research progression was originally outlined by Vannevar Bush and assumes that basic research is conducted without any thought to practical applications. Bush believed that basic science performed for a particular application would taint the creativity of scientists, which is essential for fostering innovative ideas. The model assumes that revolutionary ideas are generated at the basic research phase. These ideas are then carried through applied research to technology development and eventually reach the marketplace. There may be some flow of ideas from the market in driving basic research, but the majority of information flows from science to technology. This flow of ideas is illustrated in Figure 1.

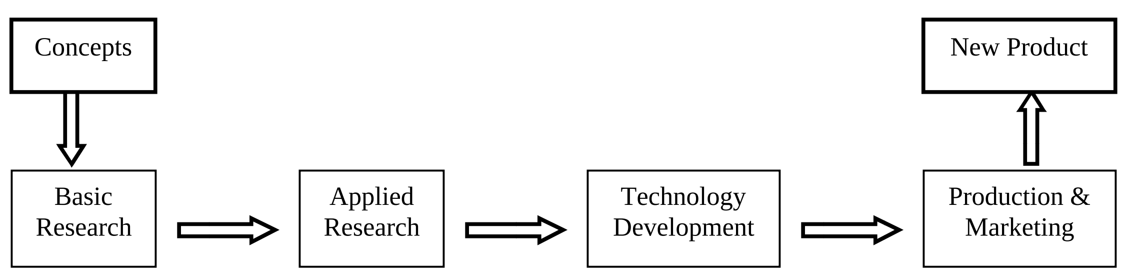

Figure 1. Linear model of innovation

This model functions well with technologies that do not need to survive in a competitive market, such as national defense. There has always been a buyer for the product and the government justified the R&D expenditures through the provision of the public good. Government supported research brings the technology along the development chain until production. By producing units for the government the developer was able to surmount some of the barriers having to do with economies of scale in production. Because there was a guaranteed buyer for the product the investment in manufacturing and production equipment was low risk. The company could use the same technology and manufacturing equipment to produce items for sale to the general population. In this manner public funding has supported the inception and development of many products and even industries over the last decades.

The petro-chemical, pharmaceutical and semiconductor industries have blossomed because of government supported basic research (Perlack, 1996). Basic research was undertaken to better understand the natural properties of the materials, and the ideas generated from this research were appropriated by private firms for further development. Public funding of early stage research is legitimized because of the non-appropriable nature of the work. Firms are not necessarily able to capture the benefits of their investment and basic research may be too expensive or lengthy for a single firm to undertake without financial support. Once the finished products reach the marketplace the public benefits of the research accrue to society as a whole. The dominance of the US in the three industries listed above illustrates the importance of basic research in driving the economy.

The linear model does not account for the incremental changes that are required to create a superior product in the marketplace. Commercial products are continually modified and re-invented as consumers and the market place grow. Research programs that ignore this source of information will miss possible research venues as the majority of commercialized innovations are now driven by the market and not scientific discovery (Branscomb, 1993). A comprehensive study of innovations documented at the U.S. Patent Office reported that almost 75% of the patents had been initiated in response to market needs and less than 25% as a result of perceived technological opportunities (Kline, 1986). Potential innovations are also generated by the drive to improve manufacturing processes and the requirements for new chemicals and materials with specific properties.

The Chain Link, or Interactive, Model

The chain link model of research and development has arisen to account for the interactive flow of ideas between science, existing technologies and the marketplace. Ideas do not only flow out from science, instead they circulate among the three areas. If a research program does not open itself to the opportunities afforded by current technological knowledge and the market, it is closing itself off from valuable sources of information and ideas.

The interconnection between the market and new products cannot be overstated. For an innovation to be successful both the technical and market requirements must be satisfied. One of Thomas Edison's first inventions was a machine, which would tally Congressional votes almost instantaneously, but Congressmen told him that it was the last thing they wanted. He then decided that he would never again work on an invention without first assuring himself of a strong market need (Kline, 1986).

There must also be awareness of the potential barriers to the technology being introduced. The transformation of any system will require the replacement of the current technological regime. The dominant regime will not willingly allow a new technology to enter the market; therefore the current system must be understood in order to create a superior product that fits into the existing paradigm. Business, regulatory and technical barriers can all act to inhibit the penetration of a new technology (Starrs, 2000).

The chain link model takes into account the complexity of today's products. Products have evolved from a few simple components arranged in a linear progression, to many components, which are all subsystems of each other. It is no longer possible to assess the quality or functionality of a product as a sum of its parts. This makes it difficult for a scientist, removed from products and the market, to make an informed decision about research agendas. Therefore, in the development of complex technologies, users, suppliers, and assemblers need to be connected to manufacturers, products designers and those performing basic and applied research (Rycroft, 1994).

This is not an argument that all basic research programs should focus on incremental changes to existing products and technologies, but that program administrators need to be aware of the market and the opportunities it affords. The chain-link model illuminates the fact that evolutionary and revolutionary ideas come from many areas including, the market, current technologies and the scientific arena. The chain-link model, originally proposed by Kline and Rosenberg (1986) is illustrated in Figure 2. This is my own rendition of the model, which shows how information flows between science and the world at large.

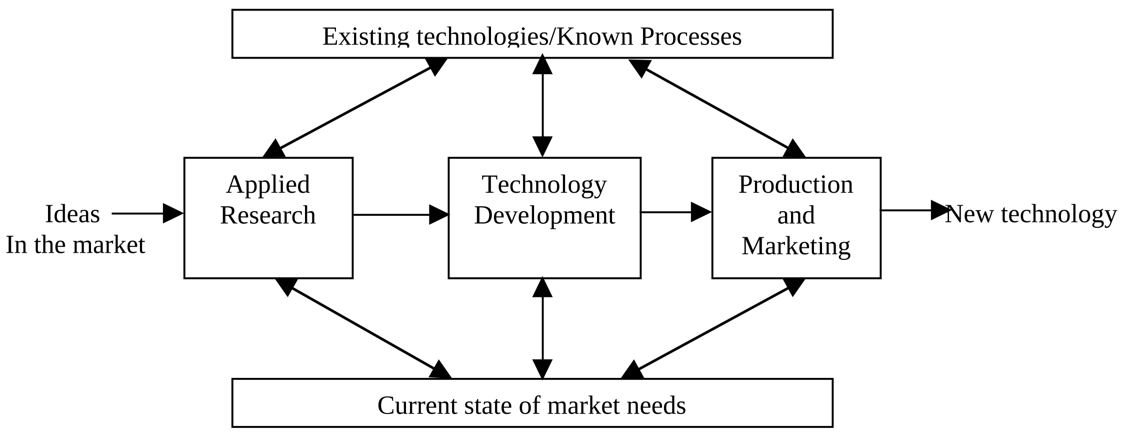

Figure 2. The Chain Link Model of Research

This model is especially applicable to the PIER and EISG programs because the goal is to create products that enter the marketplace and change the way we produce and consume energy. Early stage research is supported to obtain a better understanding of materials and processes, but with a particular application in mind. If this model were to be placed within the structure of the linear model, there would be no "basic research". All the research has an applied component because applications for the research are constantly being evaluated and influencing the direction of research. This applied component helps to focus the research process on the end goal creating a product that will truly fit into the market.

Current Research and Development Programs

The review of research and development models gives a theoretical framework for the impetus and progression of R&D. However, a practical innovation strategy is useful for understanding how an R&D program might be constructed. I have chosen to review two R&D programs that are designed to bring new innovations through the progression of research and development to commercialization. I chose programs that have been developed for both the public and the private sector, and represent different types of organizational structure. The publicly funded program that I studied supports R&D projects similar to those in the PIER and EISG programs. The DOE Small Business Innovative Research Program (SBIR) is a three-stage program that supports technology feasibility research and development projects. This is completed while working within the bureaucratic structure of the DOE, similar to the PIER program working within the CEC. The Gas Research Institute (GRI) has developed a 7-stage RD&D program based on the Stages and Gates model. R&D programs in the private sector have developed in an environment where productivity must be high and new products must enter into a competitive marketplace. The Stages and Gates model has been developed after extensive review of industry R&D programs and the successes and failures which have come forth (Cooper, 1993).

Department of Energy Small Business Innovative Research Program

All Federal Agencies that have budgets over $100 million dollars are required to have SBIR programs funded at 2.5% of their budget. The Department of Energy SBIR RD&D program is split into three phases of research. Phases I and II are federally funded R&D programs. Phase III projects receive assistance, such as training in writing business plans, for pursuing private funding. The program has one yearly solicitation and the structure is set up so that projects completing Phase I research can apply for and flow directly into Phase II without a large lag in funding. .

Phase I grants are designed to support research which proves the scientific and technical merits of a project. The awards last 6 moths and are funded at $100,000. Success in Phase I is a prerequisite to further DOE support in Phase II. Market research is required for Phase I proposals. The likelihood that the research will lead to a marketable product must be estimated and specific groups in the commercial sector who would benefit from commercialization of the technology must be identified. The research team must also present any information on similar research, products or processes to demonstrate a knowledge of the competition.

After receiving a Phase I award businesses can apply for Phase II grants within the SBIR program. These grants last up to 24 months and can total $750,000. Businesses continue the research started during Phase I while also taking commercialization issues into account. The marketing studies that were performed for the Phase I proposal must be refined and research teams must demonstrate an ability to commercialize their research.

It is critical to have a continuous flow of funding for the small businesses which are carrying out the research. Any small gaps in funding are detrimental to the firm and the research project. One SBIR program manager reported that most businesses lack the ability to pay their research teams when funding was not continuous (GAO, 1998). In response to this most SBIR programs have instituted policies to reduce funding gaps. The DOE program allows Phase I research teams to apply for Phase II awards prior to completion of Phase I projects. Another SBIR program has created a Fast Track program that prioritizes Phase I projects which have obtained private funding.

Gas Research Institute - Stages and Gates Model of Innovation

The Gas Research Institute is using a Stages and Gates system to develop new energy technologies and services for the natural gas industry. The program brings new ideas from inception to commercialization through a series of short, concise stages where research on technology, market characteristics and administrative needs are carried out coincidentally. Many R&D programs focus only on technology development and postpone market research until the end. This results in too much money being spent on projects with little chance of success because the ability to fit into the market was not factored in enough during technology development. The Stages and Gates system creates many decision points based on different types of information so that projects can be terminated as soon as they are deemed to be unsuccessful. This frees up money for supporting projects with a better chance of success.

The Stages and Gates model is a combination of the theoretical models discussed above. Stages and Gates outlines a progression of research from idea generation to commercialization, befitting the linear R&D paradigm. However, though the project proceeds in a stepwise fashion there is not a one-way flow of ideas. Researchers are continually incorporating information from the market and current technologies. In each successive stage more comprehensive information is required pertaining to; permits, regulations, consumer needs, potential competitive responses, as well as technology feasibility and development. This constant interchange between product development and the market into which it will enter is emphasized in the chain-link model by the many directions in which ideas flow in the development of a new product.

The Gas Research Institute has established a 7-stage/gate system for the research and development program. Stages are blocks of time in which researchers perform a set of tasks that address certain questions about the project. The seven stages are very similar to the eight-stage program outlined in Table 1 (on page 22). Gates are decision points at which the fate of a project is decided. Analysis of business and market issues are performed, as well as technology development. The goal is to produce enough information in each stage so that a decision can be made at the subsequent gate. Researchers and gatekeepers agree upon decision criteria before the stage has begun. This facilitates data evaluation by the gatekeepers after the activities have been completed leading to a succinct decision at the next gate. Gatekeepers can either; terminate the project, send it back to the prior stage for more research or pass it on to the next stage with the proper allocation of funding.

It is important to understand that this is not a process where researchers are continually writing proposals to request funding for the next stage of research. Once a project has begun it moves through the system until it is deemed to be infeasible, or completes the RD&D cycle and enters the market. The process is based on a continual process of gathering, processing and displaying information, not of writing reports and proposals. However, gates are not project review sessions, but project decision sessions where Go/Kill decisions must be made. Gate meetings are short, concentrated, discussions of the information gathered in the previous stage, and decisions should be made within hours about weather or not a project will be continued. This has the benefit of not leaving researchers without support between funding cycles. As mentioned in the section on the SBIR program, the time between funding cycles is critical and often very difficult for researchers. The continual flow of information and funding in the Stages and Gates system keeps research moving toward a well-defined goal.

The main focus of the Stages and Gates model is to bring products successfully to the marketplace. It is estimated that more than 46% of private R&D funds are spent on products that never reach commercialization (Cooper, 1993). A research program must enforce the termination of projects that have been deemed unsuccessful. Projects will tend to get a life of their own as research continues, making them harder to terminate when the probability of success decreases (Edelstein, 2000). It is therefore imperative that projects, which do not have a good chance of success in the market, be terminated as soon as possible. Gatekeepers must be empowered to make decisions, and know that they can stick by them; otherwise money will continue to be spent on projects that have little chance of success. Figure 3 illustrates how the number of R&D projects should be reduced at each gate (Edelstein, 2000).

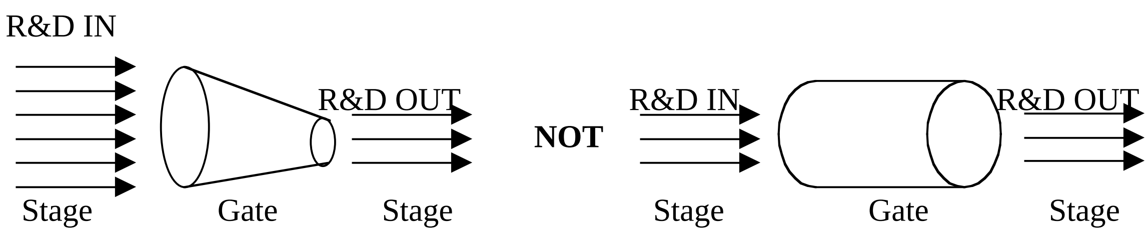

Figure 3. The R&D funnel, culling out projects with low likelihood of success

The Stages and Gates process minimizes financial risk by advancing projects incrementally. Stages are short and concise so that only small investments are required; this process has been equated to a horserace where you can bet on the winner along the way. At each gate more information about potential costs and benefits are known about the project. When the gatekeepers decide that a project is worth passing on to the next stage this signifies that the benefits are likely to outweigh the costs and the risks of investing in the project have declined. This concept is illustrated in Figure 4.

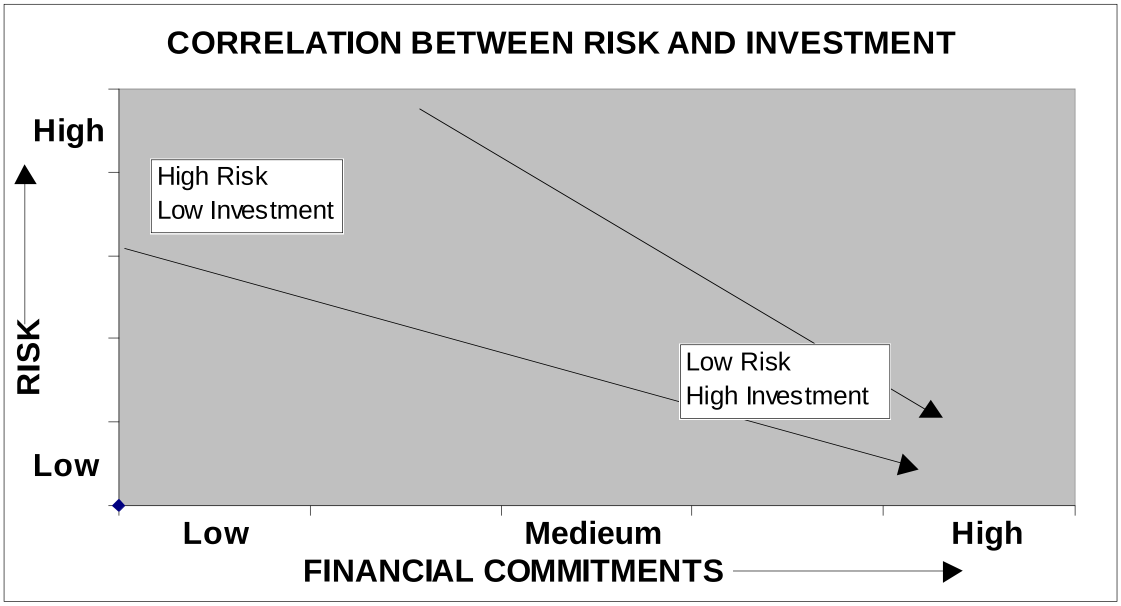

Figure 4. Correlation between risk and investment in RD&D

The Stages and Gates system can create an environment in which long-term, high-risk, high-reward projects are brought into the research portfolio without the accompanying high financial risk. Many projects that offer high potential rewards do not receive funding because of economic risks associated with investing a large sum of money in an unproven technology. By reducing the time and investment between each decision point longer-term research projects can be justified because program managers are not locked into long-term contracts to fund research that may not be successful.

PIER and R&D models

The flow of ideas through the PIER and EISG programs follows the tenets of the chain-link model more than the linear model. There have been numerous feedback sessions where the business and technology communities have participated in discussions about current needs in the California energy market. Ideas therefore have not moved only from science to technology and the market, but between all three sectors simultaneously. However, the PIER program has not been successful at bringing technologies along the research chain from early stage research to product development.

Successful researchers who have completed an EISG project do not necessarily have access to funding from the PIER program because of the current structure of solicitations.

PIER and the Linear Model

Basic research, as defined by Vannevar Bush, is not supported by the PIER program. All research is focused on providing benefits to the California market, and therefore considered applied research. The PIER program has neither the time nor the resources to support basic research that is carried out with no particular purpose. The goal of the program is to effectively reduce the amount and impacts of California's energy consumption. However, supporting early stage pre-competitive applied research, as is done in the EISG program, is extremely important. This funding fills a critical niche of supporting unproven technologies which will have great impacts on the future energy system.

Evaluation of Transition from EISG to PIER

Projects in the EISG and PIER programs are not supported though the progressive stages of research and development as outlined and practiced by the models reviewed. Instead they are one-time events with no ability to receive follow-up funding if more research is required. The EISG and PIER programs fund projects which are closely aligned along the research and development chain. As noted in the mission statements EISG supports feasibility analyses and PIER funds further development and demonstration. To illustrate how closely linked the programs are along the R&D pathway I needed to create a framework to evaluate which stages of research each program is funding.

To understand how the EISG and PIER programs relate to each other it was necessary to evaluate them to see what stages of research each program is funding. I evaluated all of the projects in the renewable energy program area using a Stages and Gates framework developed by employees at the CEC as a possible model for the PIER program (Edelstein, 2000). The system defines eight stages of research beginning with idea generation and progressing to commercialization. The eight stages of research are shown in Table 1.

Stage 1 - Idea Generation
Stage 2 - Technical and market analysis
Stage 3 - Research and Bench Scale Testing
Stage 4 - Technology Development and Field Experiments
Stage 5 - Product Development and Field Testing
Stage 6 - Demonstration and Full-Scale Testing
Stage 7 - Market Transformation
Stage 8 – Commercialization

Table 1. Gas Research Institute Stages 1-8

Each stage of research has several criteria, covering activities such as obtaining permits, securing match funding, completing phases of technology development, and performing different levels of market analyses. I evaluated work statements of both PIER and EISG projects to find which activities were completed by each project. Although the projects were not required to complete the activities outlined in the Stages and Gates model I thought it was important to use a framework to evaluate which stages of research are being carried out in the programs. Stages 1-8 are listed in Appendix 1 along with the evaluation results.

The evaluation revealed that EISG projects are completed where PIER projects begin. EISG projects were predominately in stages 2 and 3, with only one project beginning in stage 4. Most of the projects are completed in stage 3, with the construction and testing of a bench scale model. However 1/3 of the projects were completed in stage 4 with the construction of a full-scale prototype. PIER projects were more widely distributed throughout all stages of research. Project work statements included tasks in all stages of research, but the majority of tasks were completed in stages 3-6. Figure 5 is a graphical representation of the results. Stages 1 through 8 are shown on the x-axis and the percentage of projects with activities in a given stage are on the y-axis. For example 70% of the projects within the Renewable Energy Program Area of the EISG program completed tasks outlined in stage 2, whereas only 20% of the PIER projects completed stage 2 activities. This figure illustrates how the PIER program begins where the EISG program leaves off.

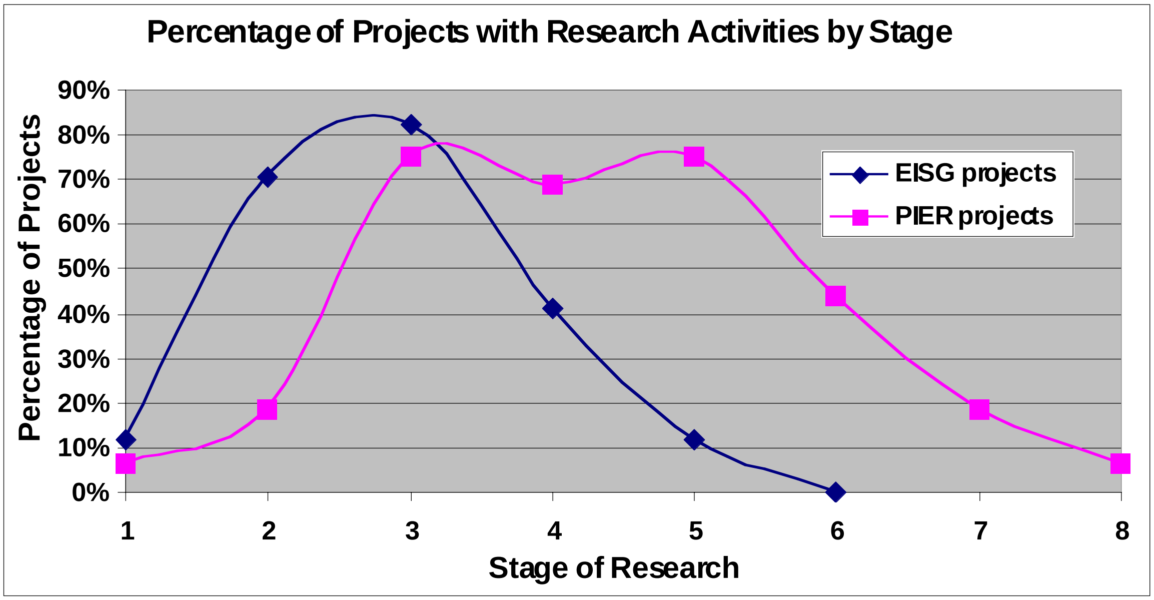

Figure 5. Overlap of EISG and PIER programs

The evaluation established that the EISG and PIER programs do indeed lie closely together along the RD&D pathway. PIER is the natural next step for successful EISG projects. Therefore, there needs to be a pathway by which EISG projects are brought into the PIER program. To see whether this is the case I evaluated the programs to see what connections existed.

Lack of Connection Between EISG and PIER Programs

The PIER program is not successful at bringing technologies along the path from idea generation to commercialization. As is the case with many public research programs the funding generally stops before manufacturing and commercialization, stages thought to be adequately supported by the private sector. However, PIER leaves fledgling technologies without funding at the key stage between technical feasibility and prototype demonstration. This is not a phenomenon exclusive to the PIER program. There is a general belief that flagging American competitiveness in a multitude of industries can be attributed to technologies that were initially developed in American laboratories, but commercialized by companies abroad (Stokes, 1997).

The EISG program is designed to support energy technologies in the early stages of research. However, there is no built in connection between the EISG and PIER programs. The only tenuous connection between the programs involves one of the technical criteria used to evaluate PIER project proposals. Research teams that have proven their ability to produce deliverables, administer contracts and control costs are prioritized over those that have not. Therefore, research teams that have successfully completed EISG projects could possibly be prioritized when applying for PIER funding. However the points attributed for this criterion are small, comprising only a fraction of a category that is worth 70 of 526 total points. This point is further negated by the fact that the EISG program is managed by SDSU, whereas PIER is managed by the CEC. There is little contact between EISG research scientists and contract managers within the CEC. Therefore, there may be no personal recognition of the positive work completed by an EISG research team when applying for PIER funding.

The fact that there are no explicit connection between the EISG and PIER programs would not create such a difficulty for EISG scientists planning to continue with their research were there not other factors inherent in the current system. The timing and focus of PIER solicitations make continuation of EISG projects within the California system very difficult. EISG projects will not necessarily end at the same time that a PIER RFP is distributed; furthermore any open RFP may not include the area of research covered by the EISG project. EISG research teams are further disadvantaged by the fact that they may not be eligible for other federal funds because of their participation in the program. For example, SBIR Phase II grants are only available to recipients of Phase I grants, therefore by participating in the EISG program small businesses exclude themselves from sources of follow on funding.

The timing of PIER RFP’s makes it very difficult for EISG researchers to apply for PIER funding once they have completed their project. When scientists are attempting to develop a technology they require a steady stream of funding. Many of the EISG researchers I interviewed talked about the problems inherent in intermittent funding. It is difficult to keep a project moving when funding from one agency ends and the researcher must apply to another agency, with totally different requirements, for the next allotment of funding. The SBIR program has addressed this issue by limiting “the gap between

Phase I and II to no more than three months in order to minimize problems associated with cash flow and the retention of key personnel" (DOE, 2001). The type of institutions eligible for EISG funding exacerbates this problem. Only individuals, small businesses, non-profit organizations and academic institutions are eligible for funding. These smaller entities are less likely to have multiple projects and sources of funding with which to maintain project personnel and momentum. Therefore, it is crucial to supply some route of entry for EISG research teams to apply for PIER funding when the project comes to a close.

The targeted RFP's now used by PIER for renewable energy proposals will make it even more difficult for EISG researchers to obtain more funding because the focus of the RFP and the EISG program may not coincide. The format of the first general solicitation would have been a viable next step for successful EISG projects. The RFP was broad enough that EISG projects would have been eligible to apply. PIER is now moving towards more targeted RFP's, exemplified by the Biomass Competitive Negotiation Solicitation, the planned Wind Power with Energy Storage, Biogas, and Photovoltaics with Energy Efficiency solicitations. These narrowly focused RFP's will make it even more difficult for EISG researchers to obtain funding from the PIER program, even if the RFP were to coincide with the completion of their project.

The most recent RFP, although broad in scope, has not provided EISG researchers with access to PIER funds. Only two of the researchers I interviewed were considering submitting proposals. One of these scientists discussed the requirement of teaming up with an Energy Service Company (ESCO). This requirement made it difficult to apply for funding, because the ESCO they had been planning on working with was reneging on their agreement to work together. The ESCO did not want to participate in renewable energy research. In essence this requirement brings the technology developers back to the initial problem where utilities were not interested in performing energy R&D that would eventually reduce the amount of energy consumed at the customer level and reduce utility profits.

By requiring that researchers team up with ESCO's the technologies will have access to a market, but the requirement will skew the projects to later stages of development. This will make it harder for EISG projects to receive further funding. The majority of products being developed in the EISG program are not ready for the last stages of development and demonstration. They will require more research, anywhere form 2-10 years, before being ready for commercialization. ESCO's may not be interested in working on projects of this time frame. The California energy crisis has stressed energy service companies, and they may not be willing to invest funds in projects that will not provide benefits in the near term.

Participation in the EISG program will also exclude researchers from applying to other sources of funding, such as the SBIR program. The type of research completed in the EISG program is equivalent to the research of a Phase I SBIR grant. However, only SBIR Phase I recipients can apply for a Phase II SBIR grant. Therefore, by receiving an EISG grant a scientist has effectively removed themselves from contention from other types of follow up funding, without the possibility of follow up funding within the PIER program. This does not affect all projects because the SBIR program only funds small businesses, whereas the EISG program funds different institutions. However, 72% of the projects within the EISG program were carried out by small businesses. This fact may inhibit researchers with good ideas from applying to the EISG, and may be reducing the number of quality applications to the EISG program.

There are also direct incentives within the PIER RFP's that will skew projects away from long-term research and the continuation of EISG projects. The first general solicitation was aimed directly at short-term results. The focus of the solicitation was to support "projects that are most likely to provide the greatest public benefits to California in the next few years" (CEC, 1997). The most recent RFP has similar short-term goals. Although one of four focus areas is "Developing Renewables for Tomorrows Energy System", which has a longer-term focus, the RFP states "proposals that will have some beneficial results in a relatively short period of time (i.e. 2002) will likely receive higher scores" (CEC, 2000). This explicit emphasis on short-term goals has prioritized proposals that focus on product development and demonstration over earlier stage technology development and testing. The late stage emphasis of PIER solicitations makes the creation of a link between the EISG and PIER programs an imperative addition to the program.

There are many factors, which collaborate to separate the EISG and PIER programs. There is no connection built into the programs and the timing and focus of PIER requests for proposals make it very difficult for EISG researchers to apply for follow on funding through the PIER program. There needs to be a link established between the EISG and PIER programs so that innovative unproven technologies can be brought through the R&D system to commercialization *within California.*

Options for Connecting the EISG and PIER Programs

The following suggestions represent three alternatives for establishing a connection between the EISG and PIER research programs. This will facilitate the commercialization of innovative new energy technologies and contribute to the success of the PIER program as a whole.

Application Using Unsolicited Proposals

One possibility is for the two programs to remain virtually the same while encouraging successful EISG researchers to apply for PIER funding through unsolicited proposals.

More information about the PIER program would need to be communicated to EISG researchers. One EISG researcher I interviewed, who is now completing their project and looking for funding, was not aware of the PIER program and the funding opportunities it offers. Therefore EISG contract managers would need to take on an educational role, telling researchers about the PIER program and offering assistance to lead people though the solicitation procedure.

The PIER program would need to modify the policy on unsolicited proposals. There is currently a moratorium on all unsolicited proposals within the Renewable Energy program area. The moratorium would need to be removed in order to accept proposals from EISG researchers. Unsolicited proposals were not successful at winning contracts even before the moratorium was set in place. No unsolicited proposal has received a contract within the Renewable Energy program area since the inception of the PIER program.

Unsolicited proposals are extremely time consuming for CEC staff to process and evaluate. Unlike evaluating proposals from RFP's, where administration time and costs can be spread over many proposals, each unsolicited proposal must be addressed individually. If the EISG research teams systematically submit proposals at the end of the project, these administration costs can be diffused over multiple projects.

This option would require the least amount of modification within the two programs, and would most likely result in little substantive change. The PIER program has already attempted to improve the process for evaluating unsolicited proposals (noted in the 1999 annual report) and since then has simply stopped accepting them. Therefore I do not put this forward as a suggestion, but merely an option.

Expanding the Scope of the EISG Program

There have been discussions about the EISG program expanding to provide something akin to SBIR Phase II grants. The current solicitation notes that follow up funding may be provided in the future, but as of now the program is "designed to serve as a one time funding source for projects seeking to establish initial concept feasibility". As stated above this is not an efficient way to allocate funding. The EISG program could be expanded to provide funding for projects moving into the next stage of research as well as projects needing a second round of EISG scale funding. San Diego State University has administered the program well to, which reflects on the ability of SDSU to evaluate and process proposals.

Expanding the scope of the EISG program is another way that the CEC can reduce the administrative load associated with the PIER program. This load is obviously a concern, and the CEC is currently passing much of the administration on to other entities in the form of programmatic solicitations. The most recent solicitation in the renewable energy program area was for $40 million dollars. This amount totals almost 4 times what had been spent on the renewable energy program area since the beginning of the PIER program. Programmatic solicitations are a way to outsource much of the administrative load of the PIER program. This may be necessary because many of the CEC staff are being pulled from PIER tasks to work on the Summer, 2001 energy crisis. Instead of outsourcing this work to less known entities the PIER program could minimize risk by giving the task to SDSU, which has a proven ability to administer funds for Energy related R&D and is familiar with the PIER program requirements.

The EISG program would need to turn project proposals for phase II funding around quickly to avoid the lags which are so difficult for research teams to handle. This is easier to accomplish in the EISG program because it is not stuck within the bureaucracy of the CEC as the PIER program is. Although the PIER program has become better at getting contracts signed and funding started, there is still a major lag between proposal submission and contract commencement. This may be frustrating for businesses planning on starting a large project, but can be extremely difficult for research teams that have hired staff and are paying for equipment when they have to wait for funding before beginning the next stage of research.

Creating a second stage within the EISG program would also provide a stepping-stone for projects moving toward commercialization which are not yet ready to respond to a PIER solicitation. As discussed earlier the PIER program solicitations are moving toward late stage demonstration of technologies and projects coming out of the EISG program may not be ready to move into that stage of research. A Stage II EISG program would provide a bridge between the early stage research in the EISG program and the late stage demonstrations that are taking place in the PIER program. There would again be issues concerning timing and PIER solicitation focus that would need to be addressed, but EISG projects would meet the requirements of the later stage PIER solicitations.

Creating a second stage within the EISG program would create a better flow for projects moving from early stage innovative research to late-stage commercialization activities. It would take some of the administrative burden away from PIER and the CEC and may speed up the contract processes. San Diego State University has shown that it can successfully administer funds and manage projects within the PIER framework and the CEC is already outsourcing many of these administration activities in the form of large programmatic solicitations. A second stage EISG program would also provide a medium for the support of successful EISG projects that are not ready for the late-stage work required in the most recent PIER solicitations.

Adoption of a Stages and Gates Model

Another option would be for the CEC to dismantle the current two-program system and move to a stages and gates framework. The current system makes it very difficult to fund long-term innovative research in the PIER program because of the large financial risks involved. PIER awards are large and it may be difficult to justify further funding for EISG projects that have just been proven feasible. By moving to a stages and gates system longer-term projects can be evaluated more on possible impacts than financial risks because the funding allotments are smaller and more concise. This gives contract managers the ability to terminate projects as soon as they decide that the project is unlikely to succeed. In this system projects can be evaluated more on their potential impacts than their time to commercialization.

It may be difficult to justify the larger, long-term awards normally provided by the PIER program to projects coming out of the EISG program that have recently been proven technically feasible. Much more research must be completed before reliable estimates can be made about product cost, manufacturability and final specifications. To fund this research in one large investment is risky because of the many changes that can take place over the time period of the research. In a stages and gates system the stages of research are smaller and the project is evaluated at each successive gate. The information gathered during each stage is critical for deciding whether or not to continue funding. This system reduces the risk inherent in investing in R&D because information is processed in smaller steps and projects are terminated when they are deemed unlikely to succeed.

In order for the stages and gates system to be used to promote long-term research the California Energy Commission would need to enforce the termination of projects when necessary. There are currently policies in PIER that allow the termination of projects during review sessions, but the option has yet to be utilized. Only one project has been terminated in the renewable energy program area. The project was terminated because the research team could not obtain a necessary piece of equipment, not because the contract manager decided the project was unsuccessful. In fact few problems are ever publicized about the PIER program. Every project in the annual reports are listed as “on time and within budget”, which is difficult to believe. The environment of approval within the PIER program would have to be modified if a stages and gates framework were to be successful. Projects that are not delivering the public benefits must be aborted to free up funds for other projects with higher potential benefits.

The need for continuous funding of RD&D projects has been discussed. A stages and gates system lends itself to this requirement by allotting funding at gate meetings, which are completed within a day. Projects would not have long lags between funding making RD&D process flow smoother and quicker.

Merely moving to a stages and gates system will not guarantee that long-term research receives funding. There needs to be a supportive environment for long-term research and the system needs to be set up so that RFP's are structured to bring in proposals for new unproven technologies. RFP's would continue to focus on different types of renewable energy technologies, but they would be set up to support research all the way from feasibility to commercialization.

Summary

The three options above do not represent all of the possibilities that could be used to modify the Public Interest Energy Research Program. There are many other ways that projects could be brought through the RD&D process. What needs to be addressed is the fact that no connection exists between the two programs. Although EISG projects would seem to naturally flow into the PIER program this is not encouraged and is in fact very difficult. There must be a better system in place to provide funding for EISG projects that merit further research. This funding needs to be made available immediately after the EISG funding ceases, otherwise projects stagnate and institutions are burdened with supporting employees without funding. If we are serious about planning our future energy system we cannot rely on incremental improvements to the current paradigm. We must be proactive in our efforts to make breakthroughs that will radically alter the ways we produce and consume energy. The Public Interest Energy Research Program has made some effort to promote this research by creating the EISG program, but the link to further research funding must be provided so that new innovative technologies can be developed and introduced to the market in such a way that the energy system of tomorrow is cleaner, safer and more resilient than the one we rely on today.

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Acronyms

CEC	California Energy Commission
CalPX	California Price Exchange
CPUC	California Public Utilities Commission
CNS	Competitive Negotiation Solicitation
DOE	Department of Energy
EISG	Energy Innovations Small Grants Program
EPAG	Environmentally Preferred Advanced Generation
EPRI	Electric Power Research Institute
ESCO	Energy Service Company
GRI	Gas Research Institute
ISO	Independent System Operator
IOU’s	Investor Owned Utilities
LBNL	Lawrence Berkeley National Laboratory
NPV	Net Present Value
PAC	Policy Advisory Council
PIER	Public Interest Energy Research Program
RFP	Requests for Proposals
RD&D	Research Development and Demonstration
ROI	Return on Investment
SBIR	Small Business Innovation Research
SDSU	San Diego State University
T&D	Transmission and Distribution