Task 3.12 - Small Power Systems

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TASK 3.12 – SMALL POWER SYSTEMS

1.0 INTRODUCTION

One of the overall goals of the U.S. Department of Energy (DOE) is the development of the technology necessary to provide for a secure, reliable, affordable, and environmentally sound source of energy. This technology is important to ensure economic stability and growth in the next century as well as to reduce current and minimize future environmental impacts associated with power generation in the United States and the world.

Throughout the world, coal will play an expanded role in the production of affordable energy necessary to meet the demands of economic development and growth. The development of more efficient and environmentally sound technology in the United States may present export market opportunities throughout the world. For coal to play a key role in the energy mix, it will be necessary to develop and commercialize technologies capable of producing electricity at significantly higher overall system efficiencies with minimum emissions. A number of demonstration projects addressing these needs for large utility plants are being performed under the Clean Coal Technology Program. A need also exists for smaller (500-kW – 20-MW) systems to satisfy the needs of remote-site markets. Many of these markets are in areas where a small increment of power is needed to meet demand and the installation of transmission lines to bring in the power is not practical or economical. Diesel engines have traditionally filled this market niche; however, some of the advanced power systems currently under development could provide power more economically and with reduced environmental risk. Innovative solutions to barrier issues, in some measure common to all advanced power system processes, can be developed and demonstrated more economically and effectively in small-scale systems. Examples are material issues, involving ceramic and refractory components, and operational issues unique to high-temperature pressurized systems.

In addition to power generation needs, many communities require water treatment and/or waste disposal. Many communities in rural America have been losing population because of a migration of people to larger urban areas. In the midwestern region of the United States, this migration is partially due to larger farms and less of a need for local support services. Concurrently, federal and state regulations pertaining to waste disposal and water supply treatment have become more stringent. The economic base of smaller communities is often not large enough to support the added burden of more sophisticated treatment facilities further stressing the resources of these rural communities.

In underdeveloped nations, waste disposal and water treatment capabilities are often not available to the general population outside the larger urban centers. In many cases, this is due to a lack of infrastructure to support these capabilities. Access to required power supplies is extremely limited and power generation capabilities nonexistent. Of particular concern are the increasing occurrences of outbreaks of infectious diseases within the last 30 years in these areas. As these occurrences have become more frequent, concern has increased over the potential for transmission of these diseases to other countries. At least partially, the trend for increasing infectious disease occurrences has been attributed to human-induced environmental stresses and the lack of even the most rudimentary control techniques in many areas of the world. It is now becoming evident that

the best method for controlling infectious diseases is through the development and implementation of preventive measures and containment capabilities.

2.0 OBJECTIVES

The programmatic goal in advanced power systems will be to develop small power systems in the range of 20 kW to 20 MW in cooperation with commercial vendors. These systems will be designed to incorporate the advanced technical capabilities of the Energy & Environmental Research Center (EERC) with the latest advancement in vendor-offered hardware and software.

Work during this program year has focused on developing an integrated modular support system (IMSS) for small communities. A concept has been developed along with an approach for demonstrating an IMSS. Some of the constraints that must be overcome before the concept can be fully commercialized have also been identified and are presented here.

3.0 CONCEPT

The EERC's proposed solution to these concerns involves the use of integrated energy and environmental technology modules to meet the specific needs of each community. This modular approach uses new and existing technologies to provide waste disposal, water supply treatment, and/or power generation capabilities on a scale appropriate to the situation. Integration of specific modules allows the total needs of the community to be met. In some cases, a specific technology, such as fluid-bed combustion, can be used to solve several problems. Fluid-bed combustion can be used to dispose of agricultural and municipal solid wastes and sludge while utilizing these carbon sources for the production of energy or heat. The use of integrated and multifunctional modules increases flexibility, mobility, efficiency, and cost effectiveness.

The development activities for IMSSs are designed to incorporate a number of elements which are important to any energy solution:

- An integrated solution that addresses energy, heating, transportation, and waste disposal needs
- An emphasis on improving the health of community members
- Attention centered on the environment and identifying power systems that are environmentally friendly
- Power generation options that are more cost-effective than diesel generators
- The use of local resources to create more jobs and keep more dollars in the local economy
- Demonstration of technologies that can meet many or all of these needs
- An improvement in the quality of life

Development of an energy system for a particular site will involve tailoring existing systems or developing new systems. The generic attributes that the EERC is promoting for these power systems include a size range of 0.2 to 20 MW; the ability to burn environmentally benign solid fuels, to generate electricity, steam, and/or hot air, to generate potable water, and to treat solid and liquid wastes; control of gaseous and solid pollutants; reliability and ease of operation and maintenance; and levelized costs of electricity competitive with diesel generators. The goal is a highly flexible system that burns a variety of solid fuels and can be configured to meet unique site-specific issues and conditions such as climate, load patterns, and fuel choices.

The EERC has identified systems that are applicable to the generic issues listed above. Preliminary designs for a "generic community" are being performed to provide a baseline that can be used to better evaluate the commercial potential of these systems. To focus in on the issues specific to a given site, meetings will be held with community officials to identify communal needs and the design of an integrated modular support system that provides a solution to their problems. Flexibility for meeting future demands, efficiency, cost-effectiveness, and potential for economic development will also be considered in this design. Strong business partnerships will be established between vendors whose components will make up this integrated system. Finally, this design would be demonstrated by construction and operation of an integrated modular support system at a selected location. The EERC would then perform a long-term evaluation of the technologies used to determine efficiency, cost-effectiveness, equipment dependability, and versatility in meeting community needs. Within the scope of the EERC's current plans, the potential customer types for the small-scale power systems include remote community, town, and village governmental agencies and service organizations; utility firms and cooperatives; industrial firms; and schools, hospitals, and other institutions. Because of the worldwide need for integrated energy and environmental systems of this type, the export market for the EERC and our commercial partners is expected to be significant.

4.0 COMMERCIALIZATION OF NEW TECHNOLOGIES

The successful commercialization of any new technology must meet a number of stringent business constraints. Any new entry into the commercial market must:

- be cost-competitive with the technologies it replaces;
- have a record of proven reliability in meeting the service warranties with which it is sold;
- have a service duration with reasonable replacement and operations and maintenance costs for the expected performance life;
- offer real or perceived operational advantages over competing technologies for successful marketing.

There is a reasonable expectation that new technologies meeting these criteria will be supported by private venture capital prior to large-scale market entry. There are, however, numerous examples of new commercial devices which bankrupt venture capitalists as the result of commercialization efforts. The percentage of successful new entries of promising new technologies

is probably smaller than 10%. The chief causes for failures are well catalogued and generally stated in the following order of prevalence: 1) undercapitalization; 2) failure to meet reliability estimates in the real world when operations were turned over to relatively unskilled personnel, thereby causing excessive repair costs; 3) failure to implement successful marketing, i.e., inability to demonstrate the superiority of the new technology to the extent necessary for purchases by buyers who were fundamentally satisfied with the product mix they were using; and 4) failure to allow for the fact that many obsolete or obsolescent devices can be refurbished at much lower costs than purchases of an apparently cost-competitive new technology.

In the private sector, fund allocations for commercialization must compete with other business opportunities. Because of emphasis on the near-term bottom line, any new technology with a time horizon for return on investment longer than about three years is at a significant disadvantage with respect to alternatives offering shorter periods for returns on investment. This issue has been well recognized, and its optimal resolution with respect to IMSS commercialization needs to be more fully addressed. As stated in Section 3, IMSS commercialization merits public-sector investments because of environmental cleanliness, high efficiency, positive impact on human health, anticipated contributions to job creation, and augmentation of the U.S. balance of trade.

5.0 THE MARKET FOR IMSS

The market includes 1) on-site systems on the customer or utility side of the meter with requirements from a few tens of kW to a few MW, 2) substation systems from a few to tens of MW, and 3) communities lacking adequate treatment facilities for water treatment and waste disposal. For each power range, there are competing technologies at capital costs per kW of output well below those that can currently be met with IMSS. Nevertheless, for selected applications and regions, and provided proper allowance is made for environmental and transmission and distribution advantages of the IMSS, the use of IMSS may allow delivery of lower-cost electricity to consumers than conventional power generation technologies coupled with separate water purification and waste treatment facilities. While it is generally agreed that system costs of \$1500/kW would be attractive in assuring market penetration, there are applications and situations where the competitive price is much higher (i.e., \$2500-\$3000/kW). It is also important to note that economic benefits to users of IMSS power plants may result from entirely new application concepts that become possible because of the unique features of IMSS. No reliable methodology exists for estimating the likely market share of the IMSS technologies as a function of time. However, the potential market (from 1995 to 2005, approximately 100 GW of new and of replacement U.S. capacity) is so large that only a small percentage of the total is required to assure the success of the IMSS commercialization effort. The need for improved sanitary conditions currently exists in many parts of the world.

The commercial entry of IMSS technologies into the marketplace will be negatively affected by deregulation of the utility industries. Major structural changes have occurred, first for the gas and now for the electric utilities. These industries have in the past pioneered new technologies. The associated risks have been moderated by monopoly status and allowance of rate-based costs to be passed on to customers. The new regulatory changes favor enhanced competition and lowest-cost providers. This change, coupled with after-the-fact prudence reviews, has inevitably led to a policy of avoidance of real or perceived risks. Electric utilities have begun to place generation

assets into unregulated subsidiaries. As a result, it has become less likely that either utilities or their competitors will purchase high-cost market-entry units without subsidies from other entities. Properly valuing reliability and power quality, minimizing transmissions and distribution (T&D) investments, considering T&D losses, and properly crediting emissions and efficiency benefits may, however, lead to acceptance of market-entry hardware with costs above the market clearing price.

IMSS purchases will be made because of the environmental and other advantages of using IMSS. A market may develop because the use of conventional combustion systems is interdicted as the result of one of the many real or perceived problems that accompany their use. A market is also expected to develop because of the needs and costs associated with local purification of water and treatment of wastes. However, all of these sales incentives combined will not lead to commercial success unless competitive costs for delivery of electricity at acceptable reliability and quality are achieved.

6.0 FUTURE PLANS

Based on the results of the recently completed study, one or two practical and economic designs will be selected for further development in the upcoming year. Developmental activities will be identified and a plan devised to address remaining issues with the selected technologies. A commercialization plan for the selected technologies will also be developed.

Once a specific site is identified, system design and construction activities can commence, followed by a system demonstration. This demonstration should provide the information required to market the IMSS worldwide. Activities within the cooperative agreement will focus on the generation of a generic design and a commercialization plan. Additional funding will be sought from a variety of sources to perform the site-specific studies and system demonstration.

*milestones removed.
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