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Subtask 3.12 - Small Power Systems

Semi-Annual Report
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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 impact 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 (20-kW to 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 that are 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.

Because of their size, small communities are faced with a variety of problems that make the construction and operation of community-wide managed waste and wastewater cleanup, reuse, and/or disposal a difficult undertaking. Many communities in rural America have been losing population as a result of migration to large urban areas. Concurrently, federal and state regulations pertaining to waste disposal and water supply treatment have become more stringent. Small communities must provide the same degree of treatment that is now provided by large communities. Small communities cannot enjoy the economies of scale that are possible with the construction of waste and wastewater treatment facilities for larger communities. In addition, 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 many cases, the smaller communities have a lower per capita income, a residential tax base with few commercial or industrial entities, and difficulties in arranging financing because of low bond ratings (1). In many cases, the small community has limited economic resources and experience to manage wastewater treatment facilities. Problems are often experienced in design, contracting, inadequate construction supervision, project management, billing, accounting, budgeting, and maintenance (2). Overcoming these problems makes the implementation of treatment facilities in the United States a major undertaking. Low-maintenance solutions must be developed to provide proper water and waste treatment for small communities.

In many developing countries, waste disposal and water treatment capabilities are often not available to the general population outside the larger urban centers because of a lack of infrastructure to support these capabilities. Access to required power supplies is extremely limited, and power generation capabilities are nonexistent. Of particular concern is the increasing number of outbreaks of infectious diseases within the last 30 years in these areas. With the increased frequency, concern has risen 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 stress 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 disease is through the development and implementation of preventive measures and containment capabilities.

During the past 15 years, interest in small treatment systems has been overshadowed by design, construction, and operation of large regional systems. Small systems were often designed and constructed as small-scale models of larger plants. As a consequence, many are operationally energy- and resource-intensive. Greater attention needs to be focused on the design, operation, and maintenance of individual on-site systems. Decentralized technologies can reduce construction costs, minimize operation and maintenance costs, lower energy consumption, and drop infrastructure requirements as compared to the centralized options. These technologies are especially important in areas where centralized options are not possible.

The health and pollution hazards, including groundwater contamination, caused by the use of such systems warrant special attention and represent an area of need not only in the United States, but worldwide. In many cases, although effective treatment methods exist to provide safe drinking water and disposal of wastes, lack of sophistication and funds may impede implementation of these methods. Some small systems do not have access to skilled technicians, good support services, or the economies of scale available to larger systems.

2.0 OBJECTIVES

The programmatic goal in advanced power systems is to develop small integrated waste treatment, water purification, and 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. The primary objective for the work to be performed under this subtask is to develop a commercialization plan for small power systems, evaluate alternative design concepts, and select practical and economical designs for targeted development in upcoming years. A leading objective for the EERC will be to continue to form strong business partnerships with equipment manufacturers who can commercialize the selected power system and treatment design(s).

FY95 activities were focused on collecting information from vendors and evaluating alternative design concepts. This year's activities began with the process of selecting one or more designs for targeted development. Once the design(s) are selected, specific technical requirements will be defined that will be the subject of focused studies to overcome technical barriers to achieving a clean, cost-effective generating system. During this program year, the technical barriers limiting the use of the selected technology in the small power system market will be identified. A plan will be devised to overcome these barriers.

Also during this program year, strong business partnerships will be developed between the EERC, Federal Energy Technology Center (FETC), and equipment manufacturers who can commercialize the selected power system(s). A plan will be created for rapid development leading to commercialization. This may involve integration of this task with other research activities currently ongoing at the EERC and FETC.

3.0 THE INTEGRATED MODULAR SUPPORT SYSTEM CONCEPT

The solution to the energy, water, and waste treatment needs of the small community 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 purification, wastewater treatment, and 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, industrial, and municipal solid wastes and sludges while utilizing these carbon sources for the production of energy or heat. The use of integrated, multifunctional modules increases flexibility, mobility, efficiency, and cost-effectiveness.

Several components must be considered in selecting wastewater treatment and water purification technology, the main consideration being the ability of the process to destroy microorganisms. In addition to their biological disinfection capabilities, these technologies must require relatively low maintenance, be modular and transportable, and be relatively cost-effective. Community size and geographical constraints must also be taken into account in selecting a technology. There are several treatment options that can be used alone or in a treatment series to solve one or several problems. These options include ultraviolet radiation, ozonation, reverse osmosis, filtration, chemical treatment, and distillation. Also, these systems can be designed to address a variety of water disposal situations, from well-drawn water to wastewater and industrial process water. The benefits that may be realized by this approach include a potential for economic development, protection of the environment, improvement of health for community members, job creation, and a general improvement in the quality of life.

This concept revolves around packaged systems, each a proven technology, integrated in such a manner as to take advantage of the synergistic effects that the treatment and power generation modules offer to each other. Technologies that are easy to install and operate are particularly appropriate for use in package plants. These treatment plants are factory-designed to implement effective methodologies in the more restricted conditions typical of remote applications. The “packaged plant” modularity of the units is meant to address the financial, operational, regulatory, and installation limitations that hamper small water and waste treatment ability to deliver safe waste and comply with current disposal standards.

The ultimate disposal of the solid and semisolid residuals (sludge) and concentration contaminants removed by treatment has been and continues to be one to the most difficult and expensive problems in the field of wastewater engineering. Recent legislation banning the ocean discharge of sludge has eliminated one disposal option used by some large coastal cities. Because of concerns about air and groundwater pollution, the disposal of sludge by incineration and by the application on land or in landfills offers an attractive alternative. Land application of sludge is used extensively as a means of disposal, as a means of reclaiming marginal land for productive use, and as a means of utilizing the nutrient content in the sludges. However, landfilling and land application of sludge are becoming more strictly regulated, and landfill sites for the disposal of sludge are more difficult to locate. Landfilling and land application are also poor choices when infectious diseases are a concern.

The integration of the power system with the water and waste treatment facilities offers a solution to the problem of sludge disposal. The fluid-bed combustor offers a means to destroy the pathogens that cause serious health problems in some communities and greatly reduces the volume of material for final disposal. The integration of the power generation module with waste disposal, wastewater treatment, and water purification is depicted in Figure 1. The synergistic effects of integrating these modules can be clearly seen. For example, the power generation system can provide steam, heat, and/or electricity to any of the other modules while accepting the sludges generated from the various treatment processes as its fuel. Having a use for the low-level heat that is produced from the power generation system helps improve its overall efficiency and thereby reduces the overall cost of electricity to the consumer. Likewise, having the ability to route difficult-to-dispose-of sludges to the power generation system, rather than to a costly landfill or to a site for further treatment, can significantly reduce the cost of the treatment option.

The overall function of the integrated modular support system (IMSS) is to supply cheap and efficient power, water, and waste treatment for domestic and industrial use. This is essential to sustain any community. A very attractive benefit of the IMSS is to provide the opportunity for economic development. If properly designed, the IMSS should produce a relatively inexpensive source of steam, heat, electricity, and water and an established and convenient method of dealing with the by-products produced from new economic developments. These developments not only benefit the community in the traditional manner, but also will help reduce the overall cost of power and treatment to the individual resident.

4.0 CURRENT ACTIVITIES

A case study is currently under way to determine the preliminary feasibility of an IMSS for a small community. The case study is focused around the community of Tok, Alaska. This city was chosen firstly because it fit the profile for the type of community that would benefit from an IMSS, and secondly because other on-going studies have generated much of the input data required for this analysis.

Tok is a small community with a population of approximately 1250. There are 537 residential homes, 135 commercial facilities, and 32 community facilities. There is currently no centralized water or sewage system. Seventy-five percent of the water used is extracted from wells, with the remaining coming from the Tananna River. Sixty percent of the wastes are disposed of in septic or cesspool systems, with the remaining 40% going to an open landfill. This landfill, like others

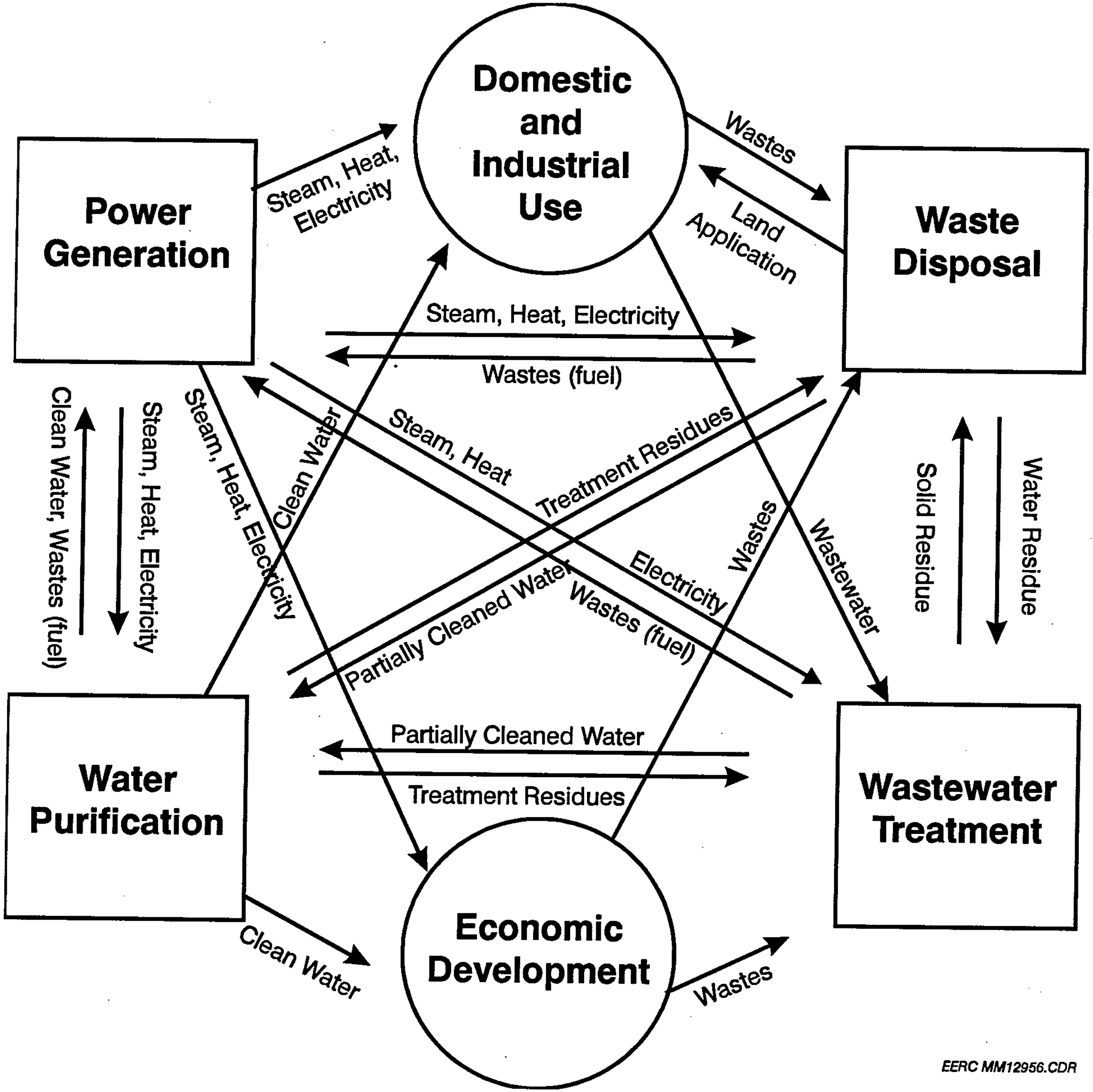

Figure 1. Schematic of the integrated modular support system.

throughout the United States, is facing closure unless major investments are made to bring it into compliance with current regulations.

Electricity is currently generated using diesel generator sets. The cost of power of \$0.20/kWh for Tok is relatively low compared to other small Alaskan communities but very high compared to the cost in the lower 48 states. The usage for 1994 was 5285 kWh for residential, 20,000 kWh for commercial, and 980,000 kWh for community facilities. The cost of fuel oil to Tok and other Alaskan communities is very high, ranging from \$1 to \$5 per gallon because of the cost of shipping the oil to the remote sites.

Heating is currently provided by fuel oil for commercial and community facilities. Fuel oil accounts for 57% of the needs for residential homes, with 38% being provided by wood and 5% from bottled gas. The costs associated with heating are very high because of the high costs of fuel oil to the community.

A preliminary study performed by Gilbert/Commonwealth, Inc., indicated a need for a power system capable of producing 2100 kW_e and 15 MMBtu/hr steam for district heating. Other information available indicates that subbituminous coal from the Jarvis Creek mine could be made available at a cost of approximately \$40/ton. In addition, approximately 400 tons of sawdust and wood wastes and 665 tons of municipal solid waste per year are currently being disposed of in the community.

The lack of a centralized water and sewage treatment facility, regulatory problems with the current landfill, local coal resources of good quality, and a current high cost of electricity make this an ideal community to use for a pilot study of the IMSS. Current activities include designing a basic plant layout, preparing material and energy balances, and finally preparing economic projections for implementing an IMSS in the community of Tok. Results of this specific evaluation will be used to determine the relative benefits of the IMSS in general.

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FORM EIA-459E
(10/88)

U.S DEPARTMENT OF ENERGY
FEDERAL ASSISTANCE MANAGEMENT SUMMARY REPORT

FORM APPROVED
OMB NO. 1900 0127
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1. Program/Project Identification No.	2. Program/Project Title	3. Reporting Period
DE-FC21-93MC30097	TASK 3.0 ADVANCED POWER SYSTEMS	10-1-96 through 12-31-96

4. Name and Address
Energy & Environmental Research Center
University of North Dakota
PO Box 9018, Grand Forks, ND 58202-9018 (701) 777-5000

5. Program Start Date 01-12-93

6. Completion Date 12-31-97

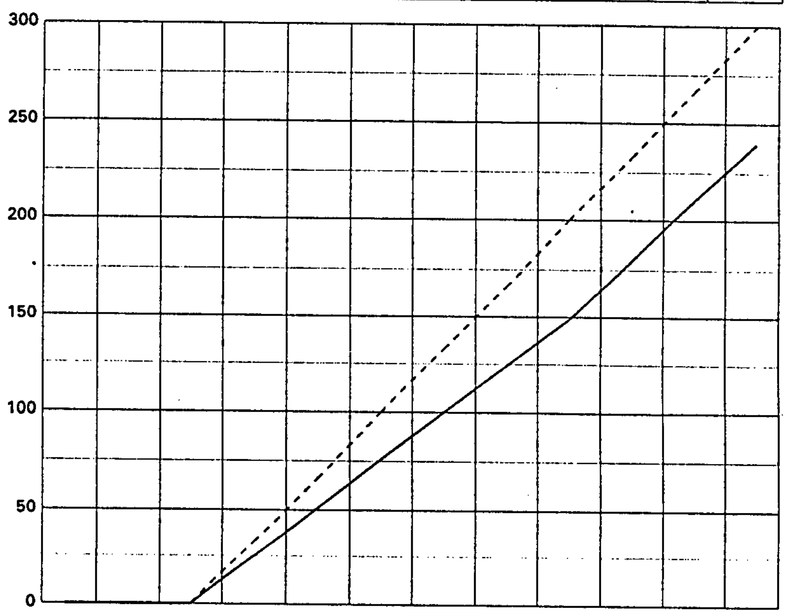
7. FY 96/97

8. Months or Quarters Quarters

b. Dollar Scale

1st			2nd			3rd			4th		
JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

9. Cost Status a. Dollars Expressed In Thousands



10. Cost Chart

Fund Source		Quarter 1st	2nd	3rd	4th	Cum. to Date	Tot. Plan
DOE	P	0	100	100	100	300	300
	A	0	76	73	91	240	
	P						
	A						
	P						
	A						
	P						
	A						
Total P		0	100	100	100	300	300
Total A		0	76	73	91	240	
Variance		0	24	27	9	60	

P = Planned A = Actual

Total Planned Costs for Program/Project
$300

c. Cumulative Accrued Costs

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Planned			0			100			200			300
Actual			0			76			149			240
Variance			0			24			51			60

11. Major Milestone Status

	Units Planned / Units Complete	
3.12 Small Power Systems Commercialization Plan	P	
	C	
3.15 Impacts of Low-NOx Combustion Fly Ash and Slagging	P	
	C	
3.16 Low-Cost CWF for Entrained Flow Gasification	P	
	C	
3.17 Hot-Gas Cleanup	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	
	P	
	C	

12. Remarks

13. Signature of Recipient and Date

14. Signature of DOE Reviewing Representative and Date

FORM EIA-459E
(10/80)

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Milestone ID. No.	Description	Planned Completion Date	Actual Completion Date	Comments
Subtask 3.12	Small Power Systems Commercialization Plan			
	Develop commercialization plan	3-97		
Subtask 3.15	Impacts of Low-NOx Combustion on Fly Ash and Slagging			
a	Modification of CEPS for Low-NOx combustion and ash deposition	3-96	7-96	Completed
b	Low-NOx fly ash generation and analysis	6-96	10-96	Completed
c	Low-NOx slagging tests and analysis	8-96	12-96	Completed
d	Submit draft topical report and article for publication	3-97		Revised Date
Subtask 3.16	Low-Cost CWF for Entrained Flow Gasification			
a	Procure samples for vendors	3-97		Delayed
b	Technical evaluation for dewatering	3-97		
Subtask 3.17	Hot-Gas Cleanup			
a	Screening of PFBC sorbents	6-96	9-96	
b	Optimization of selected PFBC sorbents	12-96	12-96	
c	Optimize conditions for tar-cracking catalysts	9-96		

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