NBSIR 78-1563

Guidelines for Evaluation of a MIUS Demonstration

Richard A. Grot
David J. Mitchell
John R. Schaefgen
Allen C. Chao
Mark E. Kuklewicz
Stephen F. Weber

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

December 1978

hudmius

MODULAR INTEGRATED UTILITY SYSTEMS
improving community utility services by supplying electricity, heating, cooling, and water/ processing liquid and solid wastes/ conserving energy and natural resources/ minimizing environmental impact

Prepared for

Division of Energy, Building Technology and Standards
Office of Policy Development and Research
Department of Housing and Urban Development
Washington, D.C. 20410

NBSIR 78-1563

GUIDELINES FOR EVALUATION OF A MIUS DEMONSTRATION

Richard A. Grot
David J. Mitchell
John R. Schaefgen
Allen C. Chao
Mark E. Kuklewicz
Stephen F. Weber

Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
Washington, D.C. 20234

December 1978

Prepared for
Division of Energy, Building Technology and Standards
Office of Policy Development and Research
Department of Housing and Urban Development
Washington, D.C. 20410

U.S. DEPARTMENT OF COMMERCE, Juanita M. Kreps, ***Secretary***

Dr. Sidney Harman, ***Under Secretary***

Jordan J. Baruch, ***Assistant Secretary for Science and Technology***

NATIONAL BUREAU OF STANDARDS, Ernest Ambler, ***Director***

FOREWORD

The development of communities is often restricted by the lack of adequate utility services to handle the requirements of additional population, industry, institutions and commercial establishments. The nation's fossil fuel reserves, particularly petroleum and natural gas, are diminishing. New connections to natural gas distribution systems are unavailable in many parts of the country. The capacity of many electric utility companies is being pushed to the limit, and addition of new generating facilities is both expensive and slow. The use of coal, the nation's most abundant fuel, is constrained by air pollution regulations, potentially inadequate coal transportation systems and declining productivity in underground coal mining. The growth of nuclear generating facilities is behind schedule due to environmental problems, financing difficulties, uncertainty in future load demands, and questions of safety.

Most urban areas have serious problems related to the adequate treatment and disposal of wastewater and solid waste. The deterioration of the quality of our natural bodies of water has imposed requirements for upgraded wastewater treatment systems in most urban areas. The capital investment required to upgrade existing facilities has added to the solvency problems of local governments. In order to prevent increases in existing pollution levels, until facilities can be expanded or upgraded, moratoria have been imposed on new connections to the sewer system. Restrictions on incineration due to air pollutant emissions from incinerators have forced most municipalities to depend on costly transportation of sludge and solid wastes to increasingly remote landfill sites.

The solutions to these problems are implemented on two extremes of scale: either regionally with large complex facilities, or individually at each residence or building. Each utility service is provided separately, even though the inability to solve problems with any one service restricts the orderly development of communities.

The Department of Housing and Urban Development's (HUD's) Office of Policy Development and Research had been working to reduce the cost of utility services, thereby lessening a major constraint on production and marketability of housing. This effort was directed increasing attention at the consumer side of the energy problem, especially as it relates to residential energy consumption. HUD's research efforts were directed at more efficient utilization of energy rather than increased production of energy. Overall efficient use of energy in housing and associated facilities is important. The residential and associated commercial sectors account for one-third of the total energy consumed in the United States. Thus, significant energy resources savings and environmental improvements can be affected by improved energy utilization within these sectors. As a part of its work in energy research for community development, HUD embarked upon an important research effort, the development of a Modular Integrated Utility System (MIUS).

The concept of a Modular Integrated Utility System is to combine the five basic community utilities: electrical service, thermal services, wastewater treatment, solid waste management and water purification, into one system. The overall objectives of the MIUS concept are to:

- Provide utility services in an improved manner with advantages in lower total cost, decreased environmental impact, and increased efficiency in the utilization of natural resources;
- Provide utility service capacity at a pace equal to the rate of growth of the new development; and
- Make land available for development in areas that are not being serviced by conventional utilities.

Conceptually, significant energy resources savings and environmental improvements can be affected. MIUS can recover and recycle energy that would normally be wasted by larger-scale conventional utility systems. Conventional methods of generating electricity waste about 65% of the energy input in the form of excess heat. MIUS has the potential of recovering over half of this excess heat and of using it for space heating, space cooling and potable water. An additional 5-10% fuel savings can be achieved by recycling solid waste for its energy content. Recovered excess heat can be utilized to stabilize the wastewater treatment processes. The effluent from the wastewater treatment process can be utilized for non-potable uses such as irrigation, condenser cooling, thermal energy conveyance or for other non-potable MIUS plant purposes. Incineration of solid waste reduces the landfill requirement of the community, and can significantly alter the character of the solid waste, since the disposed material is a sterile ash instead of putrescible solids.

The HUD MIUS Program was a multi-agency undertaking which has included the Department of Commerce through the National Bureau of Standards (NBS); the Energy Research and Development Administration through the Oak Ridge National Laboratory, the Office of Conservation, and the Office of Fossil Energy; the National Aeronautics and Space Administration through the Johnson Space-flight Center; the National Academy of Engineering; the Environmental Protection Agency through the Municipal Environmental Research Laboratory; the Department of Health, Education and Welfare; the Department of Defense; the Federal Energy Administration; the Federal Power Commission; the Veterans Administration; and three representatives of the private sector -- the International District Heating Association, the Edison Electric Institute and the American Public Power Association. Inclusion of the last three listed organizations as participants is one indication of industrial interest in MIUS. The dependence of the MIUS concept on district heating and cooling systems made IDHA participation a valuable asset. The EEI formed a Task Force on Co-Generation to comment on MIUS analyses and data and to explore industry attitudes toward the MIUS concept.

The National Bureau of Standards' prime responsibility had been in the experimental design, data collection, and evaluation of ongoing and planned HUD MIUS demonstration projects. Planning for the evaluation of a MIUS demonstration is the subject of this report. Although such a demonstration did not occur, the issues identified and the strategy developed to address them should be of interest to those envolved in the field evaluation of integrated energy systems.

ACKNOWLEDGEMENT

The authors wish to acknowledge the invaluable technical assistance of Donna L. Brown in editing several portions of this report.

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

UNITS OF MEASURE AND S.I. CONVERSION FACTORS

In NBS Document LC 1056, revised August 1975, guidelines were established to reaffirm and strengthen the commitment of NBS to the greatest practicable use of the International System of Units (S.I.) in all of its publications and also in all of its dealings with the science and engineering communities and with the public. In this report the measurements are those of the U.S. Customary units as they appear in the referenced standards, in order that the readers may give full attention to the organization and compilation of the criteria.

The following conversion factors are appropriate for the units of measure that appear in this report:

Area

1 acre = 4046.873 square meter (m^2)
1 square foot (ft^2) = .09290304 square meter (m^2)

Energy

1 British Thermal Unit (Btu) = 1055.056 Joule (J)
1 kilowatt-hour (kWh) = 3600000.0 Joule (J)
1 ton-hour = 12660672.0 Joule (J)

Flow Rate

1 U.S. gallon per minute (gpm) = 0.0000630902 $meters^3$/second
= 63.0902 $centimeters^3$/second (cm^3/s)
= 0.0630902 liters/second (L/s)

Length

1 inch (in.) = 0.0254 meter (m)
1 foot (ft.) = 0.3048 meter (m)
1 mile = 1609.347 meter (m)

Mass

1 pound-mass (lbm) = .4535924 kilogram

Temperature

1 Degree Fahrenheit (°F) = $(1.8)^{-1}$ kelvin (K) or (°K)
Temperature Fahrenheit (°F) = (459.67 + temp. °F)/1.8 (°K)

Time

1 hour (h) = 60 minutes (min) = 3600 seconds (s)

Volume

1 U.S. liquid gallon (gal) = 0.003785412 $meter^3$ (m^3)
= 3.785412 liters (L)

GUIDELINES FOR EVALUATION OF A MIUS DEMONSTRATION

Richard A. Grot
David J. Mitchell
John R. Schaefgen
Allen C. Chao
Mark E. Kuklewicz
Stephen K. Weber

Abstract

In order to obtain maximum benefits from a demonstration of a Modular Integrated Utility System (MIUS), a carefully-planned evaluation should: assess the technical performance; determine the public benefits; show the viability of private ownership; and provide a data base to support future analyses of MIUS. This document is a guideline for the development of a detailed evaluation plan for a MIUS facility which was planned for demonstration at St. Charles, Maryland. Generic types of technical, institutional and economic issues are discussed. General performance measures for the total system and each subsystem are indentified. The classes of data required and the types of data analyses that should be employed are outlined.

Keywords: Co-generation; integrated utility systems; solid waste management; thermal systems; total energy; wastewater treatment.

1. INTRODUCTION

The integration of the normally separate utility services which a community requires into an integrated utility system and the development of that system on a modular basis in step with the development of the community are conceptually attractive. However, the nature of the process under which a community is established and the lack of experience and expertise which a conventional developer has at his disposal led the Department of Housing and Urban Development (HUD) to undertake a demonstration project to investigate how a Modular Integrated Utility System (MIUS) would be designed, constructed and evaluated as a part of the total development of the community [1][1]. The principal objectives of the MIUS demonstration were:

- To demonstrate the technical performance of a MIUS,
- To demonstrate the public benefits of a MIUS,
- To demonstrate the viability of private sector ownership and operation of a MIUS, and
- To establish a data base to further implementation of MIUS.

1 See reference 1 at end of text.

1.1 DEMONSTRATION OF THE TECHNICAL PERFORMANCE OF A MIUS

A Modular Integrated Utility System can provide community utility services using less resources. However, there are a series of technical issues to be addressed and answered by the MIUS demonstration. The quality of service should be established, and compared with applicable laws and regulations, conventional practices, the contractual performance specifications, and the aspirations of the MIUS users. Reliability of the MIUS plant and utility service should be determined in comparison to conventional utility services. Practicality of the MIUS Performance Guidelines [14] must be determined. The contractual performance specifications represent what appears to be a realistic and economic level of attainment, based on numerous analytical systems studies and technology evaluations. Technical and cost information from the evaluation will be necessary to assess the practicality of the guidelines and revise them where necessary. The relation between MIUS characteristics and technical performance should be determined. There should be a determination of the effects of integration of several separate utility subsystems on maintenance, reliability, and efficiency. There should also be a determination of the effects of size and complexity on maintenance and efficiency.

1.2 DEMONSTRATION OF MIUS PUBLIC BENEFITS

An assessment of the public benefits of a MIUS entails determining:

- The reduction in environmental degradation due to MIUS deployment;
- The efficiency with which MIUS utilizes natural resources;
- The reduction in total costs to the community for MIUS - provided utility services;
- The reduction in use of fossil fuels due to a MIUS;
- The reaction of a community to a MIUS and its services; and
- The consistency of a MIUS approach with other governmental regulations and policies.

1.3 DEMONSTRATION OF THE VIABILITY OF PRIVATE SECTOR OWNERSHIP AND OPERATION OF A MIUS

Efforts to promote implementation of the MIUS concept require that the MIUS demonstration provide information on the following topics:

- Profitability of ownership and operation;
- Risk of ownership and operation;
- The phasing of MIUS capacity to community growth;
- Clarification of institutional and legal barriers which inhibit developer implementation;
- The effect of merging services on productivity and cost savings; and
- The response of a design professional to a performance specification.

1.4 ESTABLISHMENT OF A DATA BASE FOR FURTHER MIUS IMPLEMENTATION

Successful implementation of MIUS at a minimum cost requires design improvements which cannot be accomplished with existing data. Economic, technical, institutional and plant design data is insufficient for sound private investment. The accuracy of preliminary estimates of MIUS benefits and markets should be established. The necessary institutional scenarios for MIUS should be specified. Technological improvements which optimize MIUS cost effectiveness should be identified in order to obtain private sector follow-on. Legislation to remedy institutional disincentives to MIUS should be identified and described. Data identifying effects of integration on MIUS performance and efficiency should be collected.

1.5 SCOPE OF THE MIUS EVALUATION GUIDELINES

The following sections of this document provide guidelines for developing an evaluation plan for a MIUS in St. Charles, Maryland. This evaluation plan should address the technical, economic and environmental issues necessary for a successful implementation of the MIUS concept. An evaluation conducted according to these guidelines should provide answers to the important issues noted above and supply knowledge necessary to minimize impediments to the future application of MIUS.

The implementation of the guidelines to produce a final evaluation plan for determining the performance of the MIUS demonstration project should entail:

- Development of specific performance factors for both the total MIUS and the individual subsystems;
- Specification of the data requirements (e.g. location, accuracy, frequency);
- Identification of critical system components and their impact on system performance;
- Development of analysis schemes and models for evaluating benefits from a MIUS; and
- Identification of alternative utility systems for comparison with MIUS.

It is important that the evaluation plan be not only technically correct but also that it provide information that will be practical for the individuals and institutions which will be involved in the implementation of the MIUS concept. Therefore the evalution plan should be developed in close conjunction with individuals, groups, institutions and governmental agencies who will eventually be involved in the future implementation of the MIUS concept.

2. DESCRIPTION OF MIUS DEMONSTRATION SITE: ST. CHARLES, MARYLAND

The Department of Housing and Urban Development awarded a grant to Interstate Land Development, Inc. (ILD), the developer of St. Charles, Maryland, to develop the design of a MIUS which can provide utility services within a limited service area at St. Charles. St. Charles, a HUD New Community, is located approximately 25 miles south of Washington, D.C. The entire HUD New Community consists of approximately 8,000 acres, including residential, commercial and industrial elements.

The MIUS site was to constitute 130 acres of St. Charles (Figure 2.1)[2][2], to be occupied by a mix of residential, commercial and institutional buildings. The MIUS was to provide electrical service (partial), space heating, space cooling, domestic hot water service, solid waste disposal and treatment, and wastewater management for the MIUS site. Due to institutional constraints, some (if not all) of the customer buildings would have received electricity from Southern Maryland Electric Cooperative (SMECO), the remainder being provided electricity directly by the MIUS. A portion of the electricity furnished by SMECO was to be generated by the MIUS as a byproduct of satisfying thermal heating demands of the site, or during SMECO system peaking periods when the MIUS was to operate at maximum available electrical output. The remainder of the electrical energy consumed on the site was to be purchased from another utility, since SMECO is a non-generating cooperative. The projected loads for the utilities' services are presented in Table 2.1 (adapted from reference 2).

---

2 Figure 2.1, is taken from reference 2. Reference 2 contains a detailed description of the total MIUS site and preliminary plant design.

Figure 2.1

MIUS SITE PLAN
ST CHARLES MARYLAND

TABLE 2.1. MIUS DEMONSTRATION SITE BUILDINGS DESCRIPTION

BUILDING DESIGNATION	SIZE	PROPOSED HEATING/COOLING	WASTEWATER ESTIMATE		SOLID WASTE	ANNUAL ENERGY CONSUMPTION ESTIMATE			
			FLOW (GPD)	BOD_5 (LB/DAY)	QUANTITY (LB/DAY)	ELECTRIC KWH	SPACE HEATING BTU x 10^6	DOM. H. WATER BTU x 10^6	SPACE COOLING TON - HOURS x 10^3
MIUS Plant	20,000 sq. ft. initially	Hydronic				4,152,000	-0-	---	7
Wakefield Terrace Apartments	6 buildings 238,000 sq. ft 205 units	Hydronic space heating/ cooling and domestic water heating	81,500	180	1,600	1,799,000	6,340	3,390	394
Third Age Center	26 buildings 110,000 sq. ft. (4-plex) 104 units	Hydronic space heating/ cooling and domestic water heating	20,800	45	600	953,000	1,940	1,800	180
Smallwood Village Center	100,000 sq. ft. retail office and institu- tional space	Hydronic space heating/ cooling and domestic	20,000	43	4,600	2,489,000	2,275	92	445
Stoddert Middle School	94,500 sq. ft. 900 students	Hydronic space heating/ cooling and domestic water heating	22,500	49	600	1,605,000	2,900	1,800	135
Wakefield High-Rise Apartments	8 story bldg. 141,000 sq. ft. 108 units	Hydronic space heating/ cooling and domestic hot water	43,200	94	1,000	1,090,000	3,720	1,765	256
Bannister Apartments	12 buildings 200,000 sq. ft. 208 units	Hydronic space heating/ cooling	---	---	1,700	2,280,000	7,300	-0-	412
Crossland Apartments	24 buildings, one story 4-plexes (to be completed in 1977) 100,000 sq. ft. 96 units	Hydronic space heating/ cooling	38,400	83	600	1,056,000	1,800	-0-	166
TOTAL			226,500	494	10,700	15,424,000	26,275	8,847	1,995

3. MIUS TECHNICAL EVALUATION PLAN GUIDELINES

The MIUS technical evaluation should consist of six parts: a system evaluation of MIUS; an evaluation of the electrical service, thermal, solid waste management, and wastewater treatment subsystems; and an evaluation of the individual building loads.

3.1 MIUS

3.1.1 System Definition

The total MIUS plant was to consist of a group of four major subsystems: an electrical service subsystem, a thermal subsystem, a solid waste management subsystem and a wastewater treatment subsystem. The integration of these typically separate functions into an integrated utility system was accomplished with the goal of providing the accustomed utility services quality at a reduced cost (Figure 3.1.1).

3.1.2 Technical Issues to be Addressed by the Evaluation Plan

The total system performance should be determined by evaluating the actual performance of a MIUS plant in comparison to a series of other utility configurations which could have been implemented at St. Charles and by determining the marginal utility of integrating the utility subsystems into one system. The major categories of this evaluation should consist of:

- The effectiveness of a MIUS plant in reducing the consumption of natural resources;
- The operational reliability of a MIUS plant;
- The maintenance requirements of a MIUS plant; and
- The nature of the emissions from a MIUS plant.

3.1.3 System Data Requirements

The parameters which should be measured for a total-system evaluation of the MIUS plant are those related to the major MIUS energy and mass flows (see Figure 3.1.1). One should measure:

1) the fuel consumed by the total MIUS, by the engine-generators, by the boilers and by the solid waste management subsystem;
2) the total electricity produced, the electricity delivered to the site, the electricity used by the major subsystems and the electricity used by centrifugal chillers;
3) the total heat produced, the heat delivered to the site by type, the heat recovered from the major subsystems, and the heat delivered to the absorption chillers;
4) the total quantity of cooling produced, the heat removed from the site, and the cooling produced by each type of refrigeration equipment;

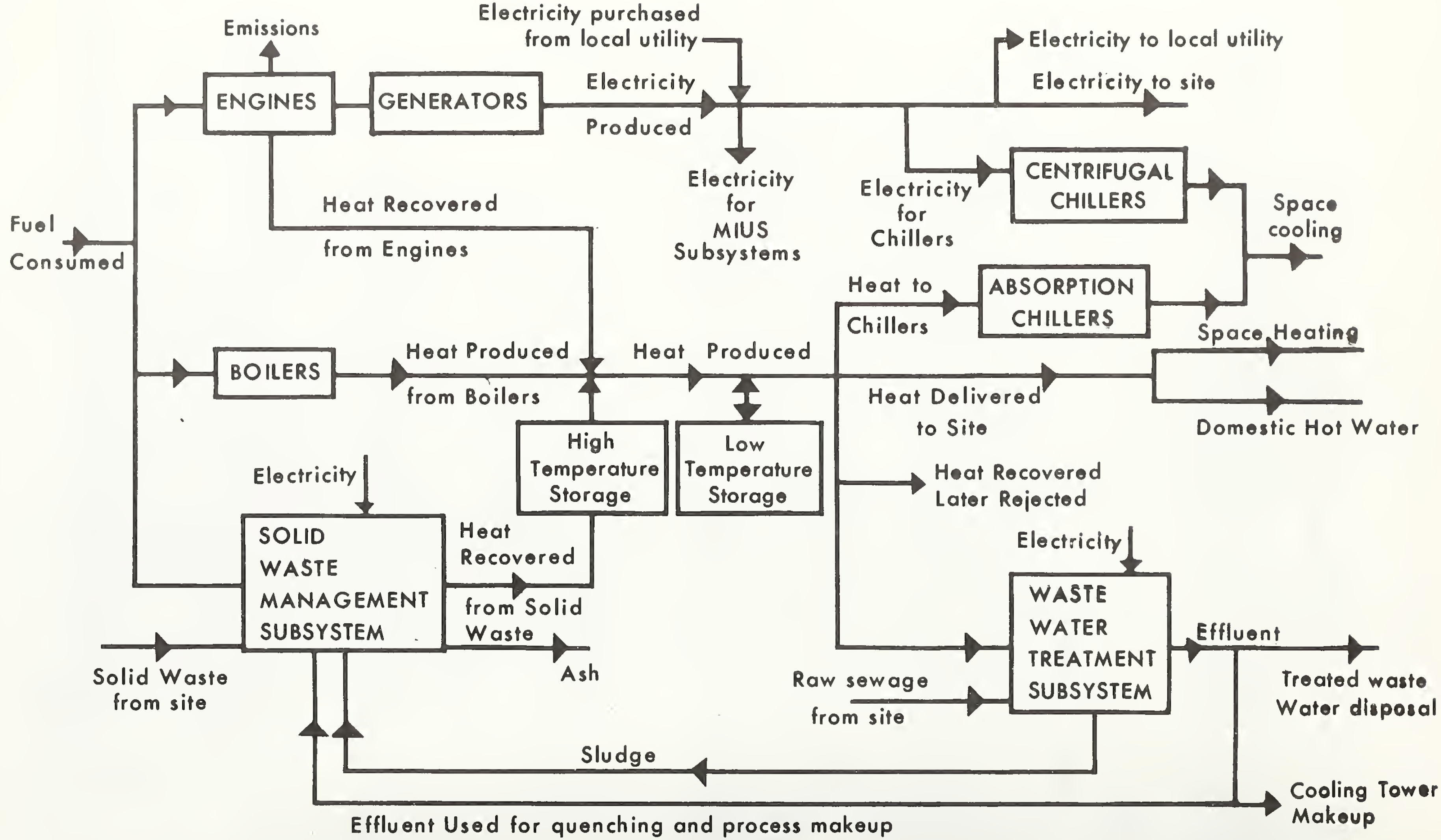

Figure 3.1.1 MIUS FUNCTIONAL DIAGRAM

5) quantity of the solid waste incinerated and quantity of ash disposed;
6) quantity and quality of raw sewage;
7) quality and quantity of the treated effluent; and
8) the emissions from the MIUS plant.

3.2 ELECTRICAL SERVICE SUBSYSTEM

3.2.1 Subsystem Definition

The function of the electrical service subsystem was to provide electrical energy for use by the MIUS site users and by other MIUS subsystems. The electrical service subsystem was also a source of heat energy which potentially can be recovered and utilized by other MIUS subsystems and by the MIUS site (see Figure 3.2.1). The electricity generated by the electrical service subsystem was to be utilized in three ways: 1) by other MIUS subsystems in performing their prescribed functions, 2) by the MIUS site users directly, and 3) by MIUS site users or users exterior to the MIUS site indirectly through the local utility (SMECO). In the event of a failure of the local utility system, the MIUS electrical subsystem would have been able to satisfy most electrical needs of the MIUS site directly.

3.2.2 Technical Issues to be Addressed by the Evaluation Plan

A technical evaluation plan for the electrical service subsystem should provide a methodology for determining:

- The operational efficiency of the electrical service subsystem;
- The quality of the electrical service;
- The quality of the recoverable heat from the subsystem;
- The reliability of operation of the electrical subsystem; and
- The emissions from the diesel engines.

Operational Efficiency

There are potentially three operating efficiencies of importance to the evaluation of the electrical service subsystem: the electrical generating efficiency, the total operational efficiency and the potential operating efficiency. The electrical generating efficiency is a measure of the ability of the subsystem to convert fossil fuel energy into electricity and is defined as the ratio of the energy content of the electricity generated by the subsystem divided by the energy content of the fuel consumed. The electrical generating efficiency is a subsystem peformance measure that permits a direct comparison of the subsystem's performance in producing electricity with the efficiency of a conventional generating facility (which has electricity as its only product). The total operational efficiency of the electrical service subsystem can be defined as a ratio of the total useful energy generated by the subsystem divided by the energy content of the fuel consumed. The total useful energy

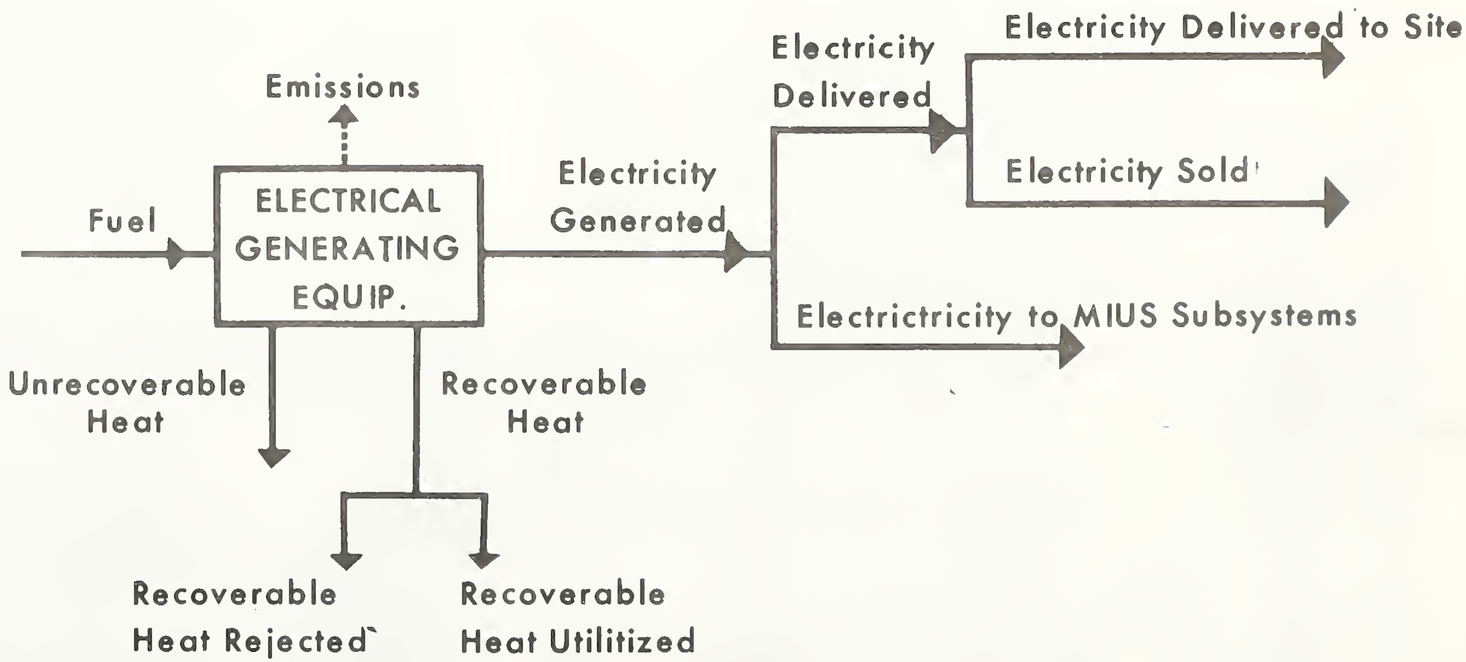

Figure 3.2.1 ELECTRICAL SERVICE SUBSYSTEM FUNCTIONAL DIAGRAM

generated is the sum of the energy content of the electricity generated and the thermal energy recovered from the subsystem. The total operational efficiency is a true measure of the effectiveness of the subsystem in utilizing fuel resources. Whereas it is expected that the electrical generating efficiency will be lower than that of a large-scale generating facility, the recovery and useful application of the normally rejected thermal energy should result in an operating efficiency significantly greater than that of a conventional facility. The potential operating efficiency is defined as the ratio of the potential delivered energy to the energy content of the fuel consumed. The potential delivered energy is the sum of the recoverable energy (energy available for use by the thermal subsystem) and the electrical energy generated. The potential operational efficiency is a measure of the maximum obtainable performance of the subsystem in its present design configuration. It is a useful criterion for evaluating potential design improvements and modifications to operational procedures.

The Quality of Service

The quality of electrical service is a measure of the electrical service subsystem's ability to provide electrical power which will permit user's equipment to function properly and without risk of damage. The specific performance measures of quality of electrical services are: the ability of the electrical generating equipment to meet the users' load, line voltage stability, the frequency stability of the A-C signal, and the nature and duration electrical transients. Any inability of a MIUS plant to meet user load requirements without reducing voltage could cause damage to users' equipment. Similarly, excessive variations in line voltage are unacceptable. Frequency stability is important for proper functioning of clocks and many electronic devices. Spikes or transients can seriously damage modern electronic equipment that MIUS users may be operating. Future acceptance of MIUS installations will depend on the confidence of potential users in the ability of a MIUS to provide an electrical service of the quality required by their applications.

Thermal Quality of the Recoverable Heat

The temperature and pressure of heating energy required by the site users largely dictate the selection of the MIUS prime mover. Several quality levels of heat may be available from the prime mover for different applications. High grade heat with a temperature in excess of 200°F has many applications. Low grade thermal energy in the temperature region of 140 to 180°F can be used in some instances for heating domestic hot water, space heating or as preheat.

Reliability of Operation

Maintenance requirements and downtime of the subystem are important measures for determining the economic viability of the future MIUS installation. Uncertainity in reliability tends to lead to an over-design of the subsystem. This could make the MIUS economically less attractive. Furthermore the reliability of the installation is of prime concern to potential MIUS users.

Emissions from the Diesel Engines

The Ambient Air Quality Standards for the State of Maryland regulate the amount of sulfur oxides, particulate matter, carbon monoxide, non-methane hydrocarbon, photo-chemical oxidants and nitrogen dioxide resulting from power plant combustion. It will be necessary to obtain data on the amounts of these pollutants which the electrical subsystem's prime movers are emitting to the environment. In addition, the amount and nature of noise pollution generated by the engine generators should be measured as a part of the environmental impact evaluation.

3.2.3 Subsystem Data Requirements

Subsystem data requirements for the evaluation of the performance of the electrical subsystem should include: fuel consumed, electrical energy generated, recovered thermal energy, recoverable thermal energy, subsystem down-time, subsystem maintenance requirements, line voltage (over time), line frequency (over time), the temperature of the available thermal energy, the concentrations of the major emissions in the surrounding community, and the magnitude and frequency of the plant noise.

3.3 THERMAL SUBSYSTEM

3.3.1 Subsystem Definition

The thermal subsystem (TS) of a MIUS facility was to consist of the assembly of equipment that generates and distributes heating and cooling services to the site, and serves to transfer thermal energy between other subsystems within a plant. The basic energy transfers are shown in Figure 3.3.1. The thermal subsystem component equipment consists of boilers, chillers, heat exchangers, heat rejection equipment (cooling towers), fuel supply, thermal storage devices and thermal service distribution throughout the site.

3.3.2 Technical Issues to be Addressed by the Evaluation Plan

The evaluation of the thermal subsystem should provide technical and cost information to analyze the energy savings resulting from several heat recovery techniques. Performance information should include energy efficiency, utilization effectiveness, and operational information necessary for cost and reliability studies. The major areas of evaluation are:

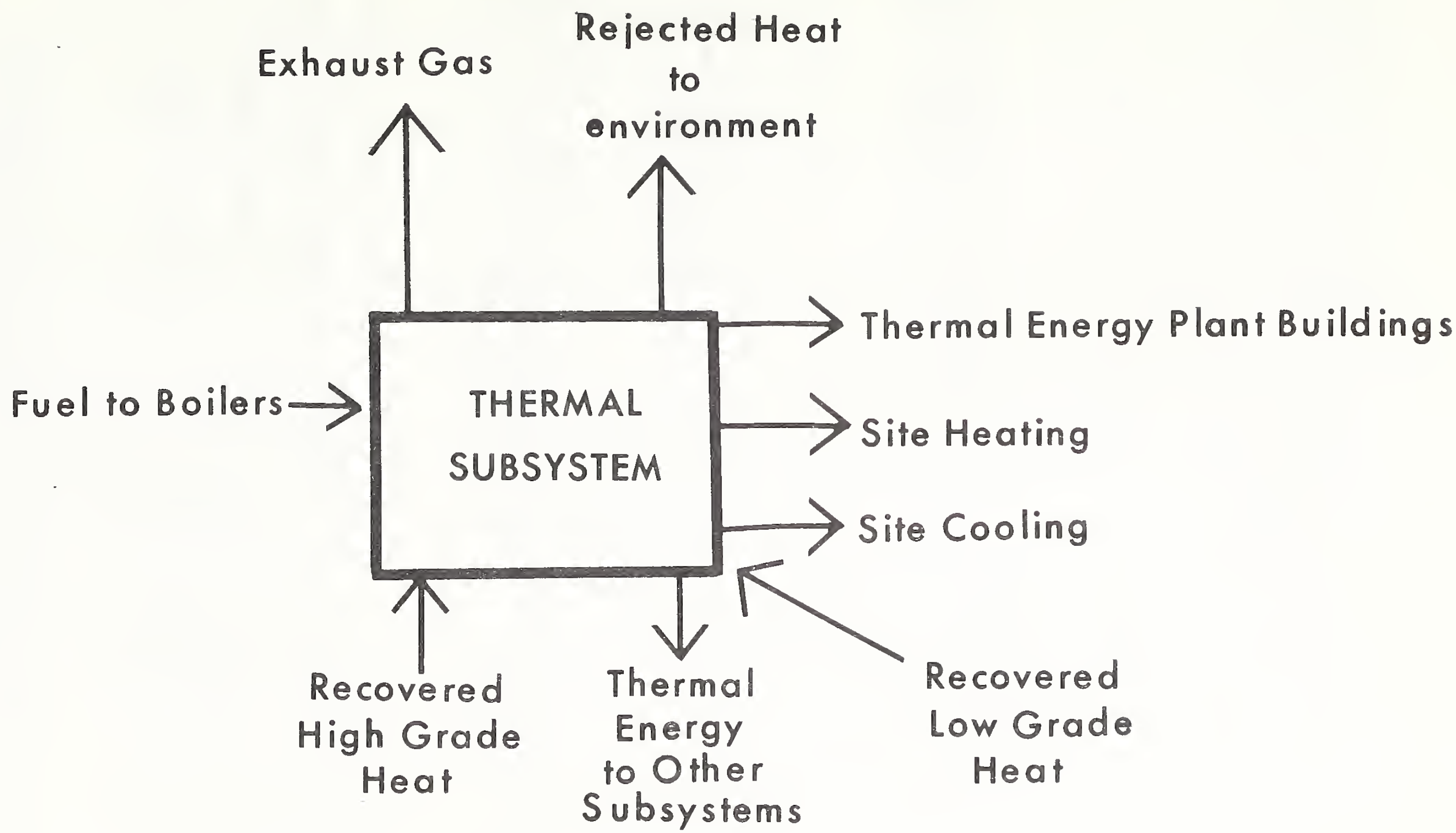

Figure 3.3.1 THERMAL SUBSYSTEM FUNCTIONAL DIAGRAM

Heat Recovery

- Reliability and service requirements of heat recovery equipment,
- Reduction of thermal pollution of surface water and ambient air,
- Effectiveness of heat recovery techniques in actual demonstration, and
- Degradation of thermal transfer surfaces;

Cooling Production

- Thermal energy requirements of the site,
- Subsystem heating loads,
- Heat produced by solid waste incineration and its usefulness,
- Reliability and performance of thermal heat production equipment,
- Heat required by the wastewater treatment system and heat made available to it, and
- Fuel savings due to MIUS supplying the site;

Cooling Production

- Energy required to provide cooling to site,
- Energy required to provide cooling to MIUS subsystems, and
- Reliability, load factors and equipment efficiencies;

Heat Rejection

- MIUS heat rejection, equipment load factors and use patterns, and
- For each thermal equipment group determine the cause and percent of input energy rejection during operation;

Thermal Storage

- Potential for reduced capacity of thermal subsystem equipment by use of thermal storage techniques,
- Technical performance of thermal storage integrated with other subsystems,
- Comparison of actual performance against equipment specifications and subsystem design criteria, and
- Potential for saving of fuel resources by use of thermal storage in integrated systems; and

Service Distribution

- Load patterns for different users and site buildings (for comparison with design values and to demonstrate potential for controlled subsystem and user peak loads), and
- Performance (load factors, maintenance requirement, reliability and cost).

3.3.3 Subsystem Data Requirements

Energy Flows

The evaluation of the thermal subsystem should have information concerning the supply (and removal) of thermal energy to (or from) the site. The evaluation of the subsystem's ability to meet the design thermal load limits should be undertaken. Seasonal (typical day) and peak consumption and production values should be reported. Values from adjusted loads on individual equipment or separate tests should also be used to verify specified capacities.

Summaries of heat and chilled water production using weekly summaries correlated with season, weather and site characteristics should be reported. Some characteristic hourly plots during the heating, cooling, Spring and Fall seasons should be included.

The measured peak, seasonal average, daily, and monthly heating and cooling loads should be charted, along with site characteristics and weather parameters. Prime-mover recovered-heat charts should be assembled from measured data. The flow rates and pumping power of major TS loops (and the TS net electrical load) should be measured. Thermal energy distribution losses and thermal energy storage effectiveness should be measured by special tests. Measurement of the energy transfer parameters at the point of delivery to site building groups should be accomplished and the average thermal load in one-hour intervals for four two-week periods of the year should be reported. These periods should correspond to the annual heating, cooling, Spring and Fall seasons. Service distribution results should provide quantitative data on the quantity of thermal energy lost between the MIUS plant and the user building interfaces.

Service Quality

Verification of thermal subsystem performance with respect to the design limits specified in the performance specification should be accomplished. This will require monitoring of pressure, flow and temperatures, as appropriate, for each type of plant thermal service and/or heat exchanger. The percentage of time that the MIUS TS plant/distribution system performs within the design limits should be calculated based on this information. Service quality at the consumer end of the TS distribution system should also be summarized based on information from pressure, flow and temperature measurements.

Subsystem Energy Efficiency and Effectiveness

The utilization of supplied and recovered thermal energy to/from other subsystems should be analyzed. The information should be used to determine if the inter-subsystem thermal transfers actually improve the thermal efficiencies, energy effectiveness and financial performance of the MIUS. Emphasis should be given to determining the appropriate measure of utilization of recovered energy.

TS Subsystem Integration

Thermal subsystem interfaces occur with all of the other MIUS subsystems. The minimum interface would be TS heating and cooling service to the MIUS personnel and the enclosed building space. Any study of TS integration should include the documentation of input (recovered) and output (consumed) energy.

The principal integration with the electrical service subsystem (ESS) occurs where recovered usable prime-mover thermal energy is transferred. A study of the ESS and TS integration should determine the net energy flows and includes TS cost and energy utilization information. It should address whether the ESS and TS integration results in either fuel or dollar savings over conventional alternates.

TS integration with the solid waste management subsystem and the wastewater management subsystem (WMS) should be documented in the same way as the TS-ESS integration. Utilization of the recovered heat should not be credited to more than one subsystem source, and should be considered separately from thermal energy generated by TS boilers using fossil fuels. Much of the thermal energy information needed for evaluation of integration concepts is also required for studies of energy efficiency, energy effectiveness, and energy conserved. Extensive instrumentation will be required to monitor the actual MIUS TS energy transfers. Information collected to review the service quality and quantity criteria will also be useful in the integration study. As an example, the MIUS specifications limit the thermal energy rejection to the WMS by limiting effluent temperatures to 5°F above the temperature of the receiving body of water. Thermal subsystem fluids drained to the WMS should also be considered.

Component Energy Efficiency and Effectiveness

Energy efficiency ratings of individual equipment and component groups should be generated at varying intervals depending upon the specific equipment characteristics in a final MIUS plant design. These data should be reported on a monthly basis for equipment such as boilers and heat exchangers in order to establish any degradation of the heat transfer surfaces. Cooling towers, some chillers, and heat pumps that have variable efficiencies with time or weather conditions will require more frequent monitoring of operating efficiency.

Energy Conserved

Determination of the energy conserved by the as-built MIUS plant should be a major goal of the evaluation. How well each TS component group transfers or changes the form of energy which it is dealing with has a significant impact. The selected equipment in each of the component groups of heat recovery, heat production, cooling production, heat rejection, thermal storage and service distribution affects the final plant energy consumption rate. The major elements of thermal and electrical production, as well as fuel consumption, should be measured to determine the actual TS plant performance.

The energy conservation comparison can be approached from different bases. One comparison should be against two or three alternate total energy and MIUS plant designs. Alternates would include different prime movers, subsystem interfaces, cooling equipment, and variations in operating schedules and philosophy. Another comparison should be the performance of the conventional utilities with which ILD had planned to market the buildings on the site. With the exception of two buildings, the site was planned to be all-electric, with space conditioning accomplished by either resistance elements or heat pumps in a forced-air system. Data on the energy consumption of each building collected during the period of evaluation will be useful in determining if the predicted values were adequate for use in the design process to compare alternate service designs.

Environmental Study

Environmental studies should need certain TS operational information dependent upon the type of pollution monitoring techniques selected. The TS environmental information should fall into two basic categories which are: stack pollution and cooling process water drift (moisture and chemical precipitate). The stack pollution analysis should require information concerning plant operating schedules, equipment operation time, maintenance records, fossil fuel burner adjustments, fuel characteristics and ambient air measurements. Cooling equipment process analysis should require information concerning operating schedules, ambient air measurements and equipment loads from the TS information.

Economic Study

TS maintenance expenses in the form of materials and labor should be reported by the MIUS plant operators for life-cycle-cost studies. TS energy consumption, taxes and insurance costs will also be needed for this work. TS first-cost information should be separated into heating, cooling, and site distribution system costs and aggregated for each group into that for subsystem design, equipment and installation. As described in Section 4, this cost data should be used to simulate and evaluate the various relevant alternatives which investors in a MIUS are likely to consider.

Institutional Factors

Institutional factors should be identified as design and construction proceed. For example, regulations of the Maryland Department of Natural Resources may limit the utilization of multi-purpose cooling ponds as chiller condenser water sources, if the overflow will be a risk to the sensitive Zekiah swamp.

Reliability/Availability

Individual TS equipment availability and reliability information should come from plant operators' operation and maintenance logs. For complete evaluation of the TS, these should be supplemented by the information recorded to meet the service quantity and quality requirements and by status monitoring devices. This study should be closely coordinated with that for the maintenance requirements of equipment, since correct and timely maintenance is an important factor in proper mechanical equipment operation.

Maintenance Requirements

A review of the TS equipment maintenance requirements should be conducted and a summary prepared. Alternate equipment requirements should be reviewed to see if any improvements are possible. Service logs of the TS equipment should be reviewed to determine if unexpected maintenance requirements (parts or labor) can be traced to any particular equipment. Literature and product data should also be analyzed in those cases.

3.4 SOLID WASTE MANAGEMENT SUBSYSTEM

3.4.1 Subsystem Definition

MIUS Perspective

The MIUS solid waste management subsystem was to provide complete refuse removal services to all buildings assigned. The solid waste management subsystem was to process a portion of the refuse collected and create low pressure hot water as supplemental energy to the MIUS plant. The solid waste management subsystem was to remove to disposal all non-processed refuse. The buildings for which removal service is to be provided ranged from single-family-attached housing to commercial establishments such as service stations and fast food stores. The estimated weekly average refuse load was approximately seven tons per day.

Figure 3.4.1 depicts the solid waste management subsystem as one element of the MIUS. The boundaries of the MIUS-SWMS should be as follows.

- The user interface for the SWMS should be the Dempster Standard Universal trash container.
- The interface between the county sanitary landfill and the SWMS should be the residue container which an offsite cartman was to pick up as required. In the future, St. Charles was to design and operate a sanitary landfill within the confines of the St. Charles community. The site under consideration was to be located approximately 2 miles south of the MIUS Plant on Piney Church Road.
- The MIUS interface for the SWMS should be the interior envelope of the space which houses the MIUS-SWMS. All MIUS/SWMS interactions should be monitored at this point.

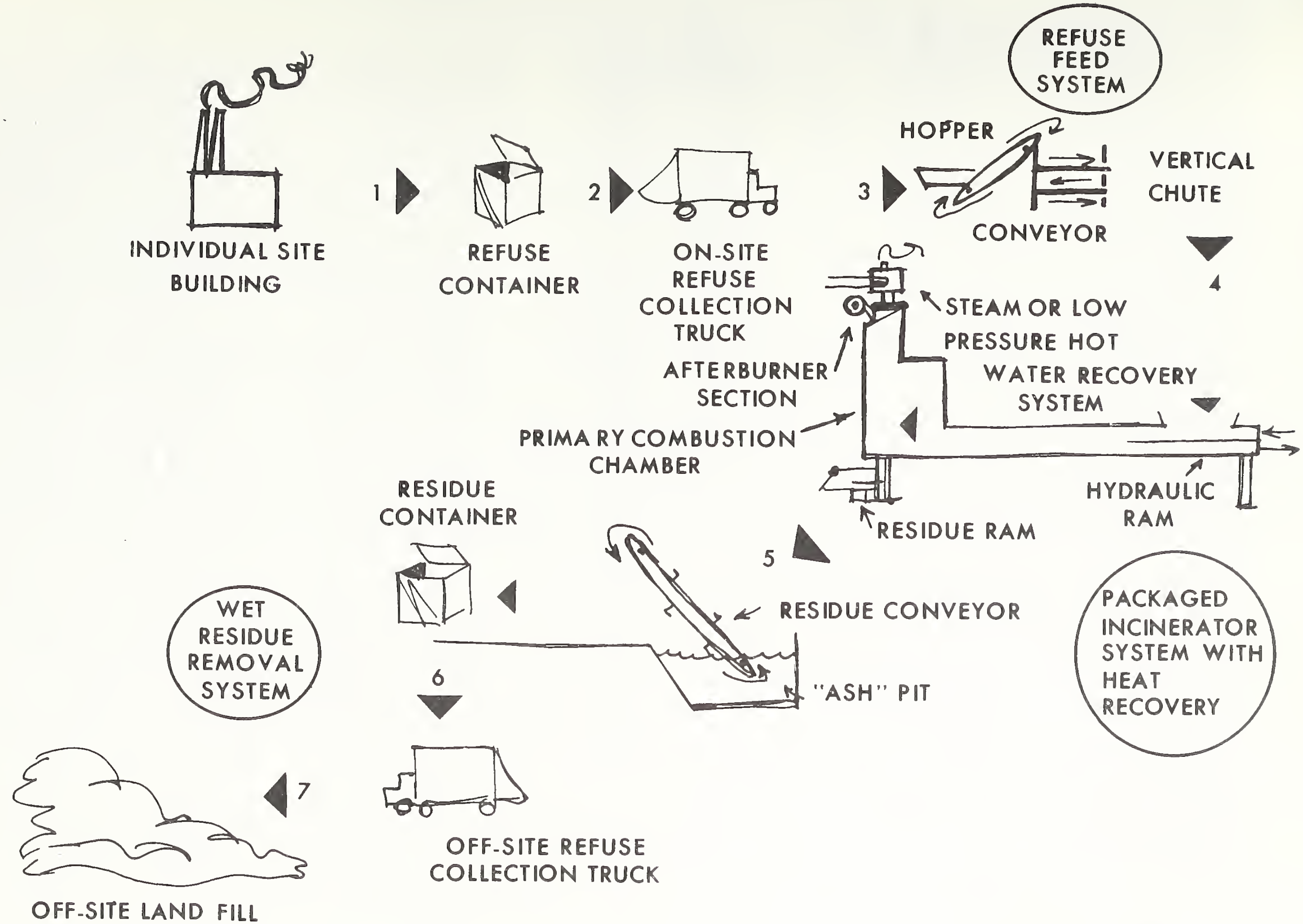

Figure 3.4.1 SOLID WASTE SUBSYSTEM FUNCTIONAL DIAGRAM

° The SWMS ecological interface should consist of the areas immediately surrounding this subsystem's many potential point sources of environmental pollution. Examples of such potential point sources are the incinerator stack and the route of the refuse collection vehicle. Specific identification and location of these potential point sources are not possible until the SWMS design is completed.

Subsystem Perspective

The solid waste management subsystem was to provide complete refuse removal service to each building and was to process a portion of the refuse to generate supplemental energy. In addition, the solid waste incinerator was to process 5% solids sludge from the MIUS wastewater management subsystem. The solid waste incinerator was also to dispose of spent lubricants which may be mixed with the relatively large volume of incinerator auxiliary fuel. Energy was to be recovered in the form of low pressure hot water which was to be utilized by other MIUS utilities or vented to the atmosphere. Each use should be monitored to properly credit the solid waste management subsystem for the value of the recovered energy actually utilized. The solid waste management subsystem was a potential customer for part of the treated wastewater. Wastewater was to keep the primary combustion chamber within design temperature limits and was to quench hot residues for disposal.

Figure 3.4.1 also is a schematic of the materials flow projected for the MIUS solid waste management subsystem. For the purpose of these guidelines the solid waste management subsystem is defined between arrows #1 and #6. The purpose of Figure 3.4.1 is not to describe a paticular subsystem design but to illustrate how the subsystem might operate and identify points which should be monitored.

Solid wastes are to be generated in individual buildings. The custodial staff or occupants at each building would have transfered the solid wastes from the interior of the building to a refuse container which, in most cases, would have been located outside the building (Arrow #1). An SWMS refuse truck was to pick up each full container on its collection route (Arrow #2). The truck was to dump the solid wastes collected from its collection route into a refuse feed system (Arrow #3).

The refuse feed system depicted consists of a hopper which receives the refuse from the onsite collection truck, a conveyor which transports the refuse from the hopper to a short vertical chute, and a short vertical chute with a series of two internal guillotine doors which measure a unit volume of refuse to be placed into the hydraulic ram of the incinerator. A premeasured volume of solid waste would have fallen from the vertical chute into the hopper of the refuse hydraulic ram (Arrow #4). The incinerator system, as depicted, consists of: a hydraulic ram which would have transfered the refuse from the short vertical chute to the incinerator (a primary combustion chamber and after-burner section); a hydraulic ram which would have pushed the processed solid waste (residue) out of the base of the primary combustion chamber; and a heat recovery unit which would have reduced the energy level of the flue gases to a set level above dew point and created supplemental energy to sustain the other MIUS subsystem utility services. Residue was to fall from the hydraulic residue ram into the residue pit (Arrow #5). The residual removal system depicted is a wet type, i.e., it was to use a liquid to quench the residue. The liquid was to be treated wastewater. The residue removal system would have consisted of a residue pit which temporarily would have held the residue, a drag conveyor which was to remove the quenched residue from the residue pit, and a wet residue container which was to hold the quenched residue and its associated water. The residue container was to be picked up by an offsite refuse collection truck (Arrow #6). A roll-on container truck would have most likely serviced this account. An offsite refuse collection truck was to transport and dump the quenched residue at an offsite landfill.

3.4.2 Technical Issues to be Addressed by the Evaluation Plan

MIUS Perspective

The purpose of this section is to establish the guidelines for the evaluation of the solid waste management subsystem as an integral part of a Modular Integrated Utility System. The fundamental question to be answered is "Are there any benefits from the integration of solid waste management with other utilities in a small, on-site facility?" Traditional municipal approaches usually do not practice any form of resource recovery and tend to be regional rather than small in size.

Subsystem Perspective

Another purpose of this section is to establish guidelines to evaluate the MIUS solid waste management subsystem as an independently functioning system. Unlike the system level evaluation, the MIUS integration points should be identified and evaluated at this level to determine how they benefit the solid waste management subsystem alone. There should be more emphasis on the individual processes which make up the solid waste management subsystem. The question to be answered is how well did the solid waste management subsystem address the needs of the service area and perform under a given set of operating, financial, and design constraints.

Solid waste management consists of many sectors of technical responsibility. For these guidelines, four sectors should be monitored and evaluated. The definition of these sectors should facilitate comparison with conventional solid waste management. The first sector is the quality and cost of refuse removal service. The MIUS utility is responsible for the removal and transport of all solid wastes generated in and around all buildings assigned and for the removal of residue and unprocessed refuse (bulky waste) from the MIUS utility building. The second sector is the refuse incineration. Here, there are six areas of responsibility which should be monitored and evaluated. The solid waste incinerator must comply with Maryland and Federal air pollution laws on point source emissions. It must reduce the volume and weight of the refuse charge as much as practical. (This is its primary function.) It must also release the heat content contained in refuse with the minimum practical use of supplementary energy. It must be able to co-fire refuse with 5% solid sludges. It must dispose of spent lubricants and other waste volatiles. It must have the flexibility to adapt to treated wastewater in lieu of potable water to maintain the temperature of the primary combustion chamber and to quench hot residue.

The third sector is support services. A significant number of the outages and service reductions experienced by solid waste management facilities such as incinerators and materials-recovery systems are the result of failures in material-handling and support items. The performance (reliability, capacity, efficiency) of items such as belt conveyors, hopper, hydraulic rams, drag conveyors, containers, and guillotine chute systems should be monitored and calculated The fourth sector is heat recovery which should be monitored and evaluated. The heat recovery unit must transfer as much energy as practical from the incoming hot flue gas stream to the heat recovery loop in a form and quantity, and at a time compatible with the other MIUS utilities.

3.4.3 Subsystem Data Requirements

MIUS Perspective

The quantity of refuse removed from each individual building, the type of refuse collection for each building, and individual building descriptions should be recorded to obtain an accurate determination of the utility service provided by the MIUS-SWMS. The solid waste management equipment in each building served by the MIUS-SWMS should be identified as to type, performance, and design. Each individual building's solid waste stream should be sampled, and ultimate, proximate, and bomb calorimetric laboratory analyses should be performed on the field samples to achieve accurate material and energy balances for the SWMS subsystem.

The evaluation of the technical performance on a systems level should incorporate a determintion of items such as reliability of service, ability to unobtrusively achieve its mission as an onsite utility, and compliance with all Federal, State and Local laws and regulations. Data should be required to support an analysis of the ability of the SWMS to utilize treated wastewater, and of the ability of the thermal subsystem to utilize the heat recovered from incineration. Treated wastewater was to be used to quench the incinerator ash. Full utilization of the heat recovered from incineration may require modification of the incinerator operating schedule. The impact of these modifications should be assessed as the operators seek to optimize system performance.

A cost analysis of the MIUS-SWMS utility service should include capital design, installation, operating, and maintenance costs (incurred from the user interface to the ultimate disposal point which is the landfill). Cost elements include items such as individual building elements, handling equipment, refuse collection equipment and MIUS-SWMS process equipment.

The actual day-to-day operation of the MIUS-SWMS should be correlated with the ability of the subsystem to comply with the Ambient Air Quality Standards. Maryland Air Pollution Regulations (10.03.35, Regulations Governing the Control of Air Pollution in the State of Maryland, as amended) define Ambient Air Quality Standards applicable to the MIUS-SWMS. The Ambient Air Quality Standards regulate the emission of certain elemental substances as pollutants and also specify the conditions under which the Air Pollution Episode System will go into effect.

Any interruption to the utility service provided by the MIUS-SWMS caused by the air pollution episodes should be documented. The Maryland Air Pollution Episode System consists of three stages of adverse meteorological conditions: Alert, Warning and Emergency. The impact of the emission reduction objectives on the MIUS-SWMS by the Maryland Air Pollution Episode System for the Alert stage is to "Stop all incineration except that resulting from public collection of refuse." The Warning and Emergency stages demand "Complete elimination of the use of all incinerators."

The air pollution technology employed by the MIUS-SWMS to comply with the Maryland Ambient Air Quality Standards should be measured for comparison with relevant similar and alternate methods of implementing the best state-of-the-art equipment. The Ambient Air Quality Standards regulate the following pollutants: sulfur oxides; particulate matter; carbon monoxide; non-methane hydrocarbons; photochemical oxidants; and oxides of nitrogen.

Subsystem Perspective

The thrust of the data to be acquired concerning the solid waste management subsystem should be the documentation of the performance of an onsite small-scale solid waste facility and its component technology over an extended period of time. Most equipment tests have a short duration. The technology to be documented should be that of standard articles of commerce. The evaluation should impartially document representative packaged solid waste management equipment under field conditions. These data should be in great demand to evaluate other similar installations in the future as refuse disposal sites and fossil fuels become harder to find.

The first set of data should pertain to the performance of the refuse removal service provided to the individual site buildings and the MIUS utility building. The data requirements for evaluating building refuse removal service are addressed under MIUS Perspective.

The second set of data should pertain to the technical performance of the solid waste incinerator. The incinerator emissions as previously stated should be monitored and correlated with system load and environmental conditions. The weight and volume of refuse before and after incineration should be recorded to document the ability of the incinerator to reduce the volume and weight of the refuse charge. There should be ultimate, proximate, and bomb calorimetric analyses of the refuse charge, residue and the supplementary fuel consumed to document the total heat released by the incinerator. Peak and average sustained heat recovery efficiencies should require time correlation of data on recovered heat and total heat release. The impact on fuel consumption, volume and weight reduction, air emissions, and heat release efficiency should be recorded during periods of sludge processing. When spent lubricant and other waste volatiles are diluted in or burned with supplemental fuel, the effects on burner performance and air emissions should be recorded. If treated wastewater is used to replace potable water as a means of thermal regulation of the primary combustion chamber, the emissions and reliability data should also be recorded. If treated wastewater is used to quench the hot incinerator residue, its impact on overall SWMS subsystem performance should be determined.

The third set of data should include information concerning the quality of support services. Data such as on/off times, energy consumption, maintenance, and failure data should be recorded for equipment items mentioned earlier such as residue removal equipment and refuse feed mechanisms. These data should be correlated with data on the total system to differentiate failures due to support equipment from those related to the incinerator.

The fourth set of data should include information concerning the recovery of energy from the incinerator stack gases and its subsequent utilization. The flow rate and enthalpy of stack gases entering and leaving the heat exchanger should be recorded and compared with those of the heat transfer media, which should be collected during the same time period. Documenting the utilization of recovered energy is somewhat more difficult. The uses of the energy recovered from solid waste can vary from drying sludge and heating wastewater treatment processes to direct venting to the atmosphere. This problem is further complicated by the fact that a cascade heat utilization system is used (Figure 3.1.1). The recoverable heat from solid waste is piped to a High Temperature Storage device. From there it can either go to the WMS or to the Thermal Subsystem to heat or cool the primary hot or chilled water loop. If there is no need for this energy at the time, the energy can either be vented to the atmosphere or stored in a low temperature Storage device and used at a later time. It should be noted that MIUS will also recover and utilize supplemental energy from the ESS. The actual operation of the ESS, WMS, and the SWMS should be recorded. The enthalpies of the High Temperature Storage and Low Temperature Storage devices should be continuously monitored. By recording the recovered energy vented to the atmosphere and the requirements for thermal energy on a continuous basis, the relative contribution of the solid waste management facility can be prorated from the total recoverable heat available and the value of its benefit determined.

3.5 WASTEWATER MANAGEMENT SUBSYSTEM

3.5.1 Subsystem Definition

The MIUS Wastewater Management Subsystem (WMS) was to provide treatment of the aqueous liquid wastes generated by the MIUS community and other MIUS subsystems. System inputs were to include the wastewater to be treated and the power input required for treating the wastewater. The wastewater was expected to be domestic in nature because most of it originates from the apartments, although a small portion can result from operation of the solid waste, electrical and thermal subsystems. The power was to be supplied by the electrical service subystem, and was to be mainly consumed for moving the wastewater and the sludge streams through the treatment plant. After being treated in a series of primary, secondary and tertiary processes, the wastewater was to be discharged as a major system output, pumped either to the MIUS Community for disposal by land application or to the thermal subsystem for use as cooling water. Another system output was the sludge resulting from the primary screening and the secondary biological treatment. The sludge was to be pumped to the solid waste subsystem where it was to be incinerated with solid waste. The treatment facilities, inputs and outputs of the wastewater management subsystem as well as its relationship with the site and other MIUS subsystems are schematically shown in Figure 3.5.1.

The primary treatment facilities for the St. Charles MIUS was to consist of an equalization wet-well and a set of rotary strainers. The wet-well was sized for retaining the peak flow, whose rate is calculated as 2.5 times the average flow rate for 100 minutes. The wastewater was then to be transferred by a pair of pumps and split into two streams, each passing through a rotary strainer. The strainers were to remove coarse suspended organic matter which is pumped to a sludge holding tank. The liquid streams then were to combine and subsequently split and fed into two biological rotary disc contactors.

Rotary biological discs and subsequent sedimentation tanks were the major secondary biological treatment facilities. In the rotary disc contactor, colloidal and soluble organic matter were utilized by microorganisms growing on the disc surface and decomposed into inorganic matter or synthesized into microbial mass. The biologically stabilized wastewater streams were to flow into rectangular sedimentation tanks where biological solids were to be separated from the liquid. Clear supernatant was to pass on to a subsequent clear well while the solids were to be collected and discharged into a sludge holding tank where they were to be mixed with the primary screenings.

The settled biological effluent was to be pumped from the clear well into tertiary dual-media pressure filter units where remaining biological particles were to be removed by filtration. The filtered water was to be temporarily stored in one of the two elevated storage tanks and then pumped to a county golf course for use in spray irrigation. A small portion of the treated wastewater was expected to be used as cooling water and in-plant wash water. Periodically, the filter units were to be backwashed with water pumped directly from the storage tanks. The wasted backwash water, which contained the biological solids removed during the filtration period, was to be discharged into the wet-well and treated with the raw wastewater.

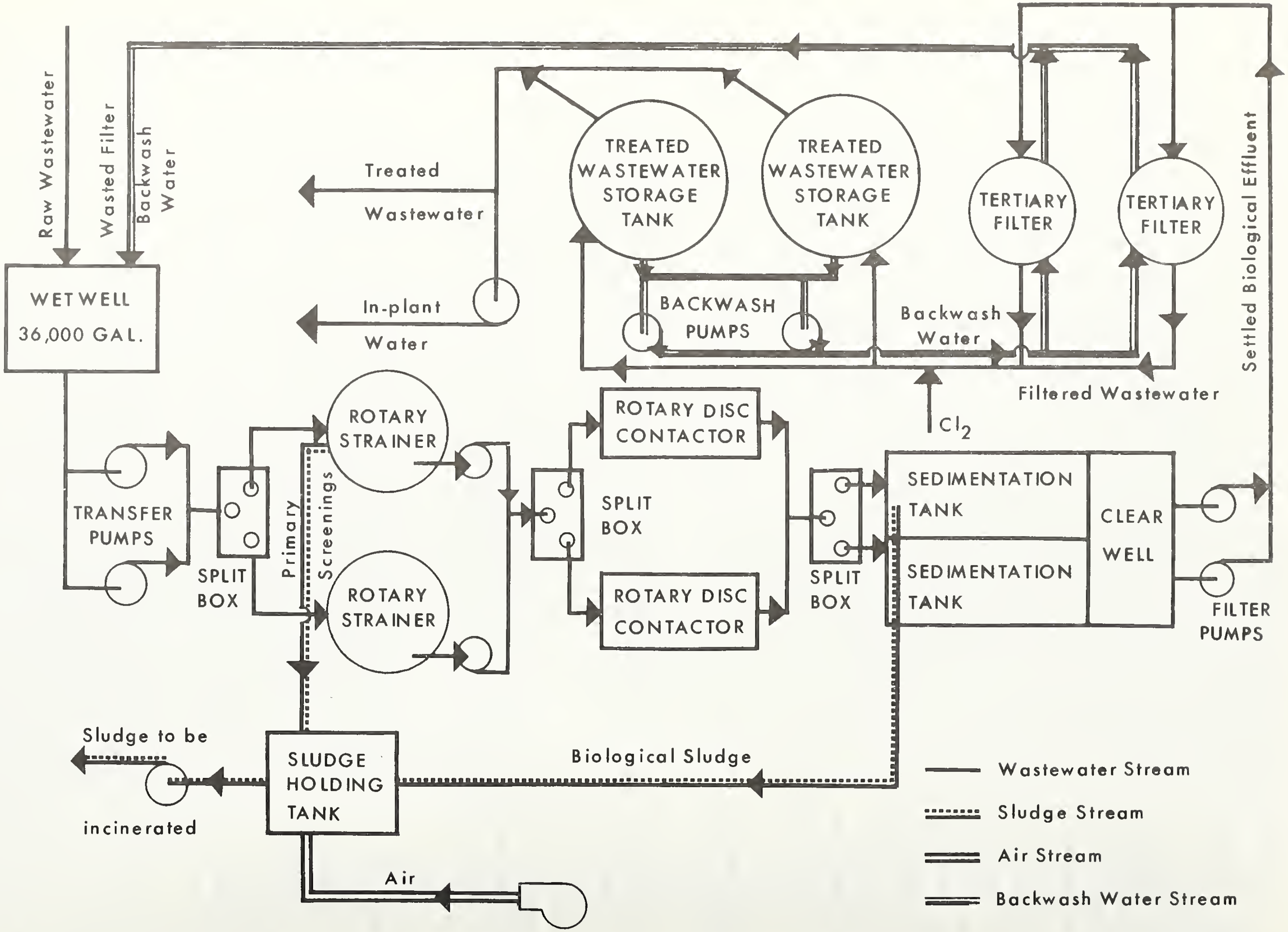

Figure 3.5.1 WASTEWATER MANAGEMENT SUBSYSTEM FUNCTIONAL DIAGRAM

3.5.2 Technical Issues to be Addressed by the Evaluation Plan

St. Charles provided an excellent opportunity to obtain full-scale performance information relevant to the design and operation of future MIUS wastewater management subsystems. The MIUS-WMS was to have several unique features, which resulted from its integration with the other MIUS subsystems. Like most private wastewater treatment plants, the MIUS wastewater management subsystem was to be a small facility which is more difficult to operate in a manner which produces a consistently high quality effluent than is a large municipal wastewater treatment plant. Unlike most treatment plants, the MIUS-WMS was to be located near the center of the MIUS residential and commercial areas. Any system failure could result in a tremendous loss of residential and commercial activity. Therefore, its performance should be more reliable than a wastewater treatment plant serving a subdivision community. Successful performance of the MIUS-WMS is reflected not only by a high system efficiency or effluent quality, but also by the reliability and availability of equipment. The MIUS-WMS should have adequate treatment capability, sufficient flexibility and system monitoring equipment. However, the system should not be wastefully over-designed, which invites an unnecessary financial burden. Hence, in addition to treatment efficiency and effluent quality, equipment reliability as well as data collection relevant to future system optimization should be included in the evaluation.

The MIUS-WMS is an integral part of the MIUS complex. Its performance and service are highly dependent upon and also can affect the performance and functions of the other MIUS subsystems. This interrelationship does not exist for a normal wastewater treatment system serving a community, and thus should be a prime target of the evalution. Outputs of the MIUS-WMS which were to be utilized or accepted by other subsystems included the treated effluent and sludge. The treated effluent was to be utilized to quench the incinerator residue, as makeup to the primary and secondary thermal loops, and as makeup to the condenser water loop. The remaining effluent was not to be discharged directly to a surface receiving body of water, but sprayed on a county golf course to provide the necessary irrigation supply. The excess sludge was to be incinerated by the MIUS-SWMS. The quantity and quality of the system discharges were not only limited by regulatory agencies but were also dictated by the disposal capability of the downstream subsystems. It is obvious that sufficient flexibility should be provided in system design, and careful management should be exercised to regulate this relationship. Hence, mass balances of the liquids and solids transported across the subsystem boundary should be documented and used in further analyses.

The MIUS-WMS was to accept excess heat from the thermal subsystem, and use it to raise the wastewater temperature. This should result in a better and more consistent treatment efficiency. The expected benefit of utilization of excess thermal energy was attributed to the increase in treatment kinetics, but more supporting data from full-scale plant operation are needed to establish a practical benefit justifying the expense. At this time, there were no plans to fire a boiler to provide heat to that MIUS-WMS when excess thermal energy is unavailable. The erratic "dumping" of heat to the MIUS-WMS could have a deleterious effect on subsystem performance. Hence, the reliability of the heat source and its influence on wastewater treatment should be evaluated.

Additional objectives of the evaluation of the MIUS-WMS should be to evaluate its performance as a wastewater treatment subsystem serving the site and to collect performance data to be used in the design and operation of future MIUS project.

3.5.3 Subsystem Data Requirements

For an evaluation of the performance of the wastewater management subsystem, data should be collected on:

(1) The performance of the wastewater treatment system and the major units;
(2) The reliability of the wastewater treatment subsystem and the impact of subsystem failure (to identify the most critical process or unit);
(3) System efficiency in connection with the utilization of waste heat;
(4) The quantity of treated wastewater and resulting sludge;
(5) The energy consumption of each major process of unit;
(6) The cost effectivensss of the wastewater management subsystem;
(7) Flow rates and total flow of raw wastewater, plant effluent, equalized effluent, treated effluent, filter backwash and wasted sludge;
(8) Treatment efficiencies for removal of total and soluble organic matter (BOD_5, COD or TOC)[1], solids, nutrients and other constituents;
(9) The temperature of important internal wastewater streams using recovered heat;
(10) Parameters related to process control such as pH, dissolved oxygen, sludge settleability, effluent turbidity, etc.;
(11) Subsystem reliability; and
(12) Operation and maintenance costs, as well as acquisition, installation and construction costs.

3.6 BUILDING LOADS

3.6.1 Technical Issues to be Addressed by the Evaluation Plan

The evaluation of the building loads for the MIUS site should be accomplished by individual metering of selected buildings and subcomponents of buildings. The major loads for the large users (electrical, thermal, water and solid waste) should be determined along with a statistically selected sample from the small users. Wherever possible master meters should be installed on groups of small-user buildings in order to determine aggregate loads and load diversity. These load data should be analyzed

1 BOD_5 - biological Oxygen demand (5 day)
COD - chemical oxygen demand
TOC - total organic carbon

statistically and employed to check the accuracy of the load prediction programs used for evaluating the MIUS design. It is envisioned that this effort should augument the existing data base to improve the design methodology at future MIUS sites.

3.6.2 Data Requirements

The classes of data required for the building load analysis would be: electrical load data, space heating load data, domestic hot water energy and water data, lighting data for institutional and commercial buildings, water (hot and cold) usage data, and solid waste generation data by classification. The scheme for collecting this data is depicted in Figure 3.6.1.

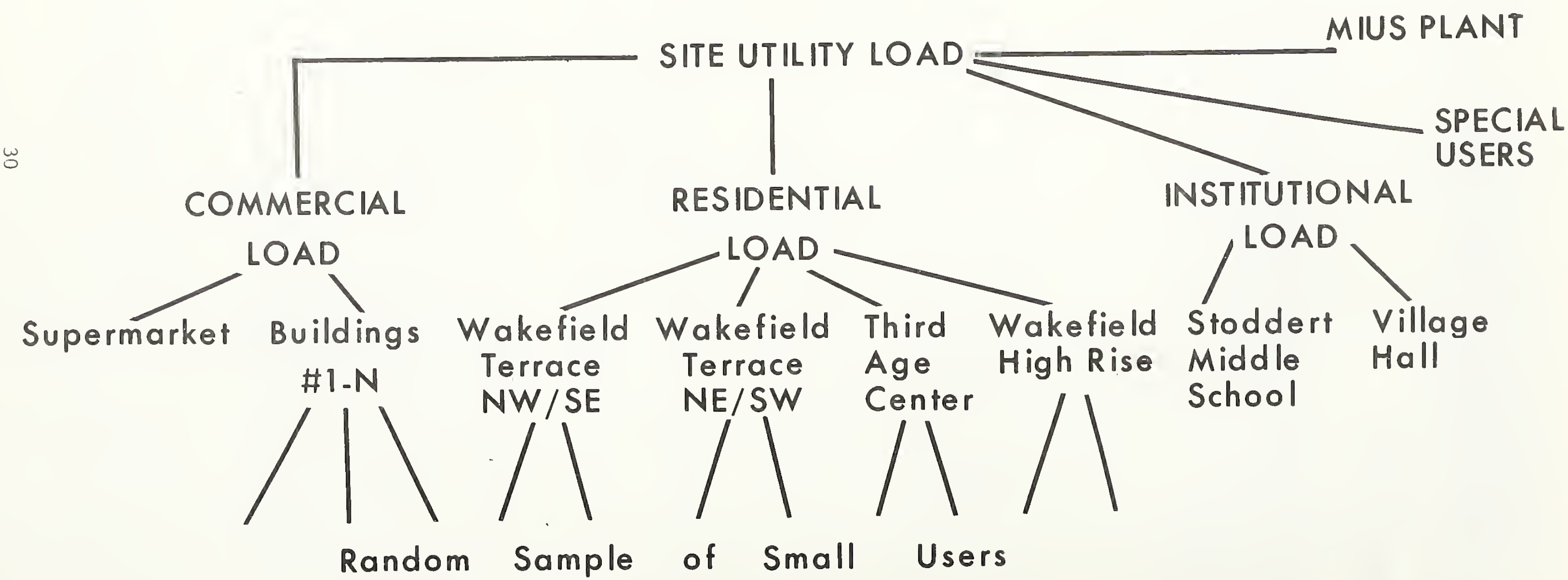

Figure 3.6.1 SITE UTILITY LOAD DATA ACQUISITION SCHEME

4. THE FINANCIAL/ECONOMIC EVALUATION PLAN

Any particular MIUS project can be evaluated by means of a number of different criteria depending on the point of view of the investor and his objectives [3-13]. Thus a proper evaluation of a MIUS requires specification of the viewpoint of interest; i.e., what type of investor is expected to make the decision between a MIUS and conventional utility services? Whether a MIUS is relatively more attractive than its conventional alternatives depends on the economic/financial environment of the decision maker. What is required, then, for the economic evaluation of a MIUS is a specification of the possible types of investors who are most likely to give a MIUS serious consideration. Four of the most significant candidates are: (1) real estate developers; (2) electric utility companies; (3) state and local governments; and (4) the Federal government.

4.1 REAL ESTATE DEVELOPER VIEWPOINT

In the proposed MIUS project at St. Charles, a real estate development company, Interstate Land Development, is the decision-making investor. Such developers are likely to have an interest in MIUS as one solution to the problem of sewer moratoria which have recently inhibited land development in many districts [11-12]. Moreover, MIUS offers land developers a convenient avenue for their natural expansion into a new activity, but one which is closely related to their traditional areas of interest. Research is needed to determine the investment criteria most appropriate for such a real estate developer. Several approaches should be explored. Those actually engaged in real estate development as well as their accountants should be contacted. Other possible contacts familiar with real estate developers' objectives can be found at such institutions as the National Association of Homebuilders, the Urban Land Institute, the National Association of Housing and Redevelopment Officials and HUD.

In addition to the evalution criteria appropriate to the developers' viewpoint, the alternatives and options available to developers must be considered. If a developer would subdivide land and build residences, he is legally required to supply wastewater treatment services to the planned structures. The options to be considered by a developer depend on whether or not a sewer moratorium exists in the area. If there is a moratorium, then there appear to be four alternatives facing the developer:

1. Not build and wait for the moratorium to be lifted.
2. Build the residences and service them with a package wastewater treatment plant.

3. Build the residences, service them with a package wastewater treatment plant, and supply electricity and central heating and cooling with a total energy plant. [Partial MIUS][1]
4. Build and service all utility needs, including solid waste disposal, with a full MIUS.[2]

One of the problems with using a MIUS in a moratorium area may be the unavailability of a backup system for reliability.

On the other hand, if regional sewer and water are available, the options facing the developer are different:

1. Not build and keep land in present use (agriculture).
2. Build residences and hook up to regional sewer, paying tap fees and front footage fees, which are a function of distance of the site from the nearest interceptor.
3. Build residences and service with a package wastewater treatment plant.
4. Build residences and supply with a package plant plus a total energy plant [Partial MIUS].
5. Build residences and a full MIUS.

Each of these alternatives facing the developer will have to be evaluated to the extent possible by separate accounting of the capital, operating and maintenance costs of those utility subsystems which can be considered "marginal". These costs will have to be measured as incurred by the developer. Thus one area of investigation concerns the point at which metering and charging for all utility services takes place. For example, the major commercial stores would be individually metered for electricity and thermal energy use, while electric service is metered at each apartment but the heating and cooling are not.

---

[1] It may be appropriate to consider three alternatives for solid waste disposal:
a) Normal refuse collection and disposal in a sanitary landfill;
b) A package incinerator system without waste heat recovery; and
c) A package incinerator system with waste heat recovery.

[2] As noted in Subsection 3.3 above, it is also appropriate to compare the actual MIUS with alternative total energy plants using different prime movers and equipment, as well as with several remote-unit configurations.

4.2 ELECTRIC UTILITY VIEWPOINT

Another likely investor in a MIUS would be an electric utility company. Since a MIUS would be at least partially in competition with electric utilities, they can be expected to show some interest in the possibilities offered by a MIUS. The viewpoint and financial evaluation criteria of such utility companies should be studied and characterized so that the attractiveness of a MIUS can be further assessed. Individual utility companies should be contacted as well as industry associations, such as the Edison Electric Institute (especially the EEI Task Force on Co-generation), and the Electric Power Research Institute.

Besides the evalution criteria used by utilities, there is a need to consider the alternatives facing utilities. The electric utility is legally required to supply power to all buildings within its franchise area. Thus, if a subdivision is being built, the utility can meet those needs in one of four alternative ways:

1. Utilize existing reserve capacity.
2. Purchase additional energy through the interconnected grid.
3. Produce more power by adding capacity.
4. Build a MIUS on the development site.

4.3 STATE AND LOCAL GOVERNMENT VIEWPOINT

State and local governments might also be interested in investing in a MIUS either as a substitute for, or expansion of, their current operations in public utility services or as a means of influencing the pattern of growth and development within their jurisdictions. The decision criteria of these governmental bodies with respect to a MIUS investment must be specified. State and local authorities, such as the Charles County Department of Public Works which holds the sewage franchise in the area should be contacted. The American Public Power Association should also prove useful in determining the appropriate evaluation criteria in this instance. The Maryland Public Service Commission and the National Association of Regulatory Utility Commissioners should be able to provide guidance in determining cost of service and the criteria for public evaluation of a MIUS. One of the unique aspects of the viewpoint likely to be taken by local governments is that the property taxes paid on strutures being served by a MIUS constitute a benefit in terms of additional revenue (provided those structures could not have been built without a MIUS).

The basic question which State and local governments would ask is: Does a MIUS represent a less costly way of providing wastewater treatment and solid waste disposal services than would the normal method of supply through connection to or utilization of their regional facilities? Can a MIUS provide necessary services at an earlier time? These questions can be approached by comparing the costs of service using a MIUS with expansion of the conventional regional systems.

The significant alternatives which a State or local government would likely be interested in evaluating would be the following:

1. Not provide wastewater treatment to the prospective development.
2. Provide wastewater treatment by expanding the capacity of the existing regional system.
3. Provide wastewater treatment by building and operating a MIUS.

4.4 FEDERAL GOVERNMENT VIEWPOINT

The other viewpoint that should be taken is that of the Federal government. Such a viewpoint is appropriate not only because investment by the government indirectly through subsidies (or even directly as military or research facility) is a possibility, but also because justification of a federal program to encourage MIUS requires a social or national benefit/cost evaluation. The literature in this area is truly voluminous. General agreement among economists has been reached on the appropriate methodology for such public project evalutions. Difficutly arises, however, in the areas of the measurement of environmental effects and the comparison of different distributions of costs and benefits among the affected parties. One method of approximating the Federal government viewpoint would be to evaluate the MIUS on the basis of its purely economic merits -- an approach which would involve measuring the quantifiable benefits and costs of the projects in terms of its impact on the national welfare. Thus, MIUS would be evaluated independent of such issues as the special financial constraints facing the developer or utility company, and the income and indirect business taxes incurred by the private developer.

4.5 OTHER INSTITUTIONS' VIEWPOINTS

Certain special applications of a MIUS might also be worth investigating. These would include large nonresidential facilities such as universities, research centers, hospitals, or military bases. The institutions which operate such facilities may well have special interests and objectives because of their non-profit or public status. Such objectives would have to be defined so that appropriate evaluation criteria could be specified for each institution.

4.6 DATA COLLECTION

All of the data needed for the financial and economic evaluation of the MIUS demonstration should be identified. The data should include both physical quantities and price information on each service provided by the MIUS. All of the cost items associated with the construction, installation, operation, and maintenance of the MIUS should be specified. In addition, all of the revenue items from the services provided by the MIUS should be identified and rate structures established for them.

Once these data needs have been identified and rate structures established for them then a detailed format for collecting the data should be developed. This detailed format should also permit separate data collection on a subsystem basis within the limits permitted by the separability of the cost elements. An example of a cost item which should prove difficult to assign to separate subsystems is fuel, since its benefits accrue to both the electrical and solid waste management subsystems. The separate cost and revenue data should be used to construct the relevant alternatives discussed above, which the various investors in a MIUS would be likely to consider.

5. CONCLUSIONS

The successful evaluation of the MIUS will entail the formulation and implementation of an evaluation plan along the guidelines established in this report. This plan should specify the performance factors for both the total MIUS and the individual subsystems; specify the data requirements of the MIUS evaluation, identify critical system components, develop analysis schemes and models for evaluting the MIUS performance, and identify alternate utility systems for comparison. The evaluation plan should be developed in close conjunction with individuals, groups, institutions and agencies who will eventually be involved in the future implementation of the MIUS concept.

The technical evaluation of the MIUS should consist of a system evaluation of the total MIUS plant; evaluations of the electrical service subsystem, the thermal subsystem, the solid waste management subsystem, the wastewater management subsystem; and an evaluation of the building loads, service demands and consumptions.

The financial and economic evaluation of the MIUS demonstration should develop criteria depending on the viewpoint of potential MIUS investors such as real estate developers, electric utility companies, state and local governments and the federal government.

6. REFERENCES

1. J. H. Rothenberg, "The Modular Integrated Utility Systems (MIUS) Program," Eleventh Intersociety Energy Conservation Engineering Conference Proceedings, September 1976.

2. Interstate Land Development, et al., Preliminary Design Summary, July 1977.

3. Benson, H. E., and Monford, L. G., Initial Comparisons of Modular-Sized, Integrated Utility Systems and Conventional Systems for Several Building Types, NASA, April 1976.

4. Caceres, Luis Rene, "On the Relative Efficiency of Electric Utilities," Public Utilities Fortnightly, Vol. 99, No. 9, April 28, 1977.

5. Call, William L., "An Evaluation of Cost Standards for Joint Products," The Engineering Economist, Vol. 20, No. 3, Spring 1975.

6. Christensen, L. R., and Greene, W. H., "Economics of Scale in U.S. Electric Power Generation," Journal of Political Economy, Vol. 84, August 1976.

7. Coase, R. H., "The Theory of Public Utility Pricing and Its Application," Bell Journal of Economics and Management Science, Vol. 1, No. 1, Spring 1970.

8. Lin, Steven A. Y., "The Modified Interval Rate of Return and Investment Criterion," Engineering Economist, Summer 1976.

9. Pingry, David E., Energy Costs of Wastewater Reuse, Arizona University.

10. Solomon, Ezra, "Alternative Rate of Return Concepts and Their Implications for Utility Regulation," Bell Journal of Economics and Management Science, Vol. 1, No. 1, Spring 1970.

11. Wendt, Paul F., and Cerf, Allen R., Real Estate Investment Analysis and Taxation, New York: McGraw-Hill Book Co., 1969.

12. White, John R., "How Real Estate Decisions are Made," Real Estate Review, Fall 1975.

13. Wiley, Robert J., "Real Estate Investment Analysis: An Empirical Study," The Appraisal Journal, Vol. XLIV, No. 4, October 1976.

14. Mitchell, David J., Performance Guidelines for a Modular Integrated Utility System, National Bureau of Standards, NBSIR 77-1395, November 1978.

NBS-114A (REV. 7-73)

U.S. DEPT. OF COMM. **BIBLIOGRAPHIC DATA SHEET**	1. PUBLICATION OR REPORT NO. NBSIR 78-1563	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

GUIDELINES FOR EVALUATION OF A MIUS DEMONSTRATION

5. Publication Date December 1978

6. Performing Organization Code

7. AUTHOR(S)

M.E.Kuklewicz
R.A.Grot, J.R.Schaefgen, D.J.Mitchell, A.C.Chao, S.R.Weber,

8. Performing Organ. Report No.

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Complete Address *(Street, City, State, ZIP)*

Department of Housing and Urban Development
Division of Energy, Building Technology and Standards
Office of Policy Development and Research
Washington, D. C. 20410

13. Type of Report & Period Covered

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

In order to obtain maximum benefits from a MIUS demonstration facility, a carefully planned evaluation should: assess the technical performance of the MIUS demonstration plant, determine the public benefits of a Modular Integrated Utility System (MIUS); show the viability of private ownership and operation of a MIUS plant, and provide a data base to support future analysis. This document is a guideline for the development of a detailed evaluation plant for a MIUS facility which was planned for demonstration at St. Charles, Maryland. The generic types of technical, institutional, and economic issues are discussed. General performance measures for the total system and each subsystem are indicated. The classes of data that will be required and the types of data analyses to be employed are outlined.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Co-generation; integrated utility systems; solid waste management; thermal systems; Total Energy; wastewater treatment.

18. AVAILABILITY [X] Unlimited

[ ] For Official Distribution. Do Not Release to NTIS

[ ] Order From Sup. of Doc., U.S. Government Printing Office Washington, D.C. 20402, SD Cat. No. C13

[X] Order From National Technical Information Service (NTIS) Springfield, Virginia 22151

19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
UNCLASSIFIED	45
20. SECURITY CLASS (THIS PAGE)	**22. Price**
UNCLASSIFIED	$4.50