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**ENERGY AND ENVIRONMENTAL SYSTEMS
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PHILADELPHIA'S GALLERY II SHOPPING CENTER COMPLEX:
AN ANALYSIS FOR THE APPLICATION OF AN
INTEGRATED COMMUNITY ENERGY SYSTEM
Vol. 1: Executive Summary

by

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Energy and Environmental Systems Division

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Artist's Conception of Market Street East Redevelopment Area

PHILADELPHIA'S GALLERY II SHOPPING CENTER COMPLEX:
AN ANALYSIS FOR THE APPLICATION OF AN
INTEGRATED COMMUNITY ENERGY SYSTEM

ABSTRACT

This report summarizes the results of ANL's study of the energy and economic aspects of energy system options for the Gallery II development. Gallery II is a 1.3 million ft² office and shopping complex to be built in downtown Philadelphia. Seven centralized energy system alternatives, including five total energy systems and two heat-pump systems, were analyzed and compared with a decentralized, all-electric, conventional system. Comparisons among systems indicate that, in today's economy, the heat-pump-centered system which redistributes heat among different zones of buildings through the operation of heat pumps can achieve significant energy and economic savings.

1 INTRODUCTION

Gallery II is a 1.3 million ft² shopping and office development proposed for the Market Street East Redevelopment Area in downtown Philadelphia. This massive complex, an extension of the highly successful Gallery I shopping center, is part of a joint venture by private developers and the city to help improve the downtown business climate through improved urban services.

The main organizations developing Gallery II are The Rouse Company, J.C. Penney Realty, Cadillac-Fairview, and the City of Philadelphia. Partly

because of the City of Philadelphia's Department of Energy (DOE) sponsored Comprehensive Community Energy Management Program (CCEMP) and a desire to lower energy costs to stimulate private investment, the City CCEMP staff became interested in the possibility of developing an Integrated Community Energy System (ICES)* for Gallery II.

DOE's CCEMP program is being funded and managed through Argonne National Laboratory (ANL), a federally funded research institution operated by the University of Chicago. The Energy and Environmental Systems Division of ANL has responsibility for CCEMP and conducts studies of many topics, an important one of which is the evaluation, development, and application of ICES. In mid 1979, City CCEMP staff asked ANL for technical assistance in studying the Gallery II ICES opportunity. After discussion with City and the Market Street East Development Corporation, ANL entered the Gallery II study with several objectives and limits in mind:

1. ANL was to study the technical and economic feasibility of various ICES for Gallery II. Social, political, legal, and environmental impacts should be given consideration by local organizations more familiar with the local situation.
2. DOE and ANL are interested in discovering what local government can do to promote ICES implementation. The results of Philadelphia's experience could be extended to other CCEMP communities, agencies participating in the Farmer's Home Administration (FmHA) and DOE sponsored Small Town Energy Planning (STEP) program, or to others interested in local energy management.
3. The Gallery II project is designed to test a model for DOE technical assistance. The objective is to see if ANL, by providing some preliminary design work, can break through the inertia that may keep a good ICES project from coming on line.
4. ANL's study was to lead to the conceptual design of an ICES for Gallery II. Extensive work by engineering consultants will be required to complete preliminary and final designs of the system.

*An introduction to ICES is presented in the Appendix.

2 THE GALLERY II COMPLEX

2.1 LOCATION AND ARCHITECTURE

When Gallery II is completed in 1987, it will be an ultra-modern structure encompassing two 25-story office towers, a 4-level shopping mall, and a 4-level J.C. Penney store. The entire complex will contain 1.3 million ft² of floor space, divided as shown in Table 2.1.

Gallery II will be built in the Market Street East Redevelopment area of Philadelphia. A map showing Gallery II's location is given in Fig. 2.1. Figures 2.2 and 2.3 provide a site plan and a longitudinal section, respectively.

2.2 ENERGY LOAD CHARACTERISTICS

The community energy loads for lighting, power, space heating, space cooling and domestic hot water were estimated on the bases of local climatological data and on data supplied by the Market Street East Corporation. Daily load profiles for peak winter and summer days and typical days of each season were established according to occupancy patterns of the buildings and the climatological data. Table 2.2 summarizes peak loads.

Table 2.1. Gallery II Buildings and Areas

Buildings	Areas (ft ²)
North and South Office Towers	880,000
J.C. Penney	250,000
Gallery II Shopping Mall	170,000
Total	1,300,000

Table 2.2. Peak Loads of Gallery II Complex (MW)

Service	Gallery II Mall	J.C. Penney	Office Towers	Total
Lighting	0.51	0.75	2.64	3.90
Power	0.51	0.75	3.52	4.78
Heating	1.49	2.20	9.02	12.71
Cooling	2.04	3.00	12.10	17.14
Domestic Hot Water Heating	0.04	0.05	0.23	0.32

Fig. 2.1. Location of Gallery II

Fig. 2.2. Site Plan of Gallery II

Fig. 2.3. Longitudinal Section of Gallery II

3 CANDIDATE ENERGY SYSTEMS FOR GALLERY II

Several energy technologies suggested for Gallery II have been ruled out for various reasons. For example, solar heating was eliminated because of inadequate roof area for solar collectors. Even if the entire roofs of the two office towers, J.C. Penney and the Gallery II mall were covered with solar panels, they would absorb less than 6 MW of heat (maximum); whereas a peak of 13 MW is required.

Coal-fired systems, although good candidates for scarce-fuel substitution, were rejected because of the air pollution they would create in downtown Philadelphia. The downtown area already is a National Ambient Air Quality Standard (NAAQS) non-attainment area; any addition to the particulate or sulfur dioxide (SO_2) concentrations would worsen the problem. Waste disposal systems, such as large-scale incinerators with heat recovery, were ruled out because of the air quality problems cited above and the aesthetic and traffic problems that may result. Energy systems with steam turbines as prime movers were not considered good options for the following reasons: (1) two huge high-pressure industrial steam generators, each over 5,000 boiler horse-power (bhp), would be required and erected outside the buildings, and (2) a stack higher than the surrounding buildings would be required. Both problems would present space and aesthetic problems in the center city.

In considering the characteristics of the Gallery II complex and its environmental limitations, the following four energy technologies appear to be appropriate:

- (1) all-electric conventional system;
- (2) internal combustion engine total energy systems:
 - (a) diesel engine
 - (b) gas engine (Otto cycle)
 - (c) dual-fuel engine
- (3) gas turbine (Brayton cycle) total energy systems:
 - (a) oil fired
 - (b) gas fired
- (4) heat-pump-centered system:
 - (a) using Delaware River water as heat sink/source
 - (b) without exterior heat source

The all-electric conventional system, which uses electricity purchased from Philadelphia Electric Company (PECO), is a decentralized system in which each building has its own heating and cooling generating devices. It utilizes compression chillers as cooling devices and electric resistance heaters as heating devices.

The total energy systems include a central plant that uses oil or gas to produce both electricity and thermal energy (cogeneration), and a distribution network that conveys the energy generated to buildings where energy is consumed. In a cogeneration plant, the prime mover and generator sets produce electricity. Heat, released to the exhaust gas, jacket water, and/or

lube oil, is recovered and used for space-heating, domestic hot water, or to run absorption chillers for cooling purposes. The total energy system supplies the entire energy needs of the community without connection to an electric utility such as PECO.

The heat-pump-centered systems employ electrically driven, two-stage, double-bundle, water-to-water heat pumps in a central heating and cooling plant to provide the space-conditioning needs of the complex. There would be no on-site generation of electricity. Electricity required for the operation of the plant and for lighting, power, and domestic hot water heating in the buildings would be purchased from PECO as in the conventional system. A heat pump transfers heat from where it is available (or undesirable) to where it is required (or acceptable). It has the ability of simultaneously providing heating and cooling and thus, is an excellent method for energy conservation.

One of the heat pump systems studied would make use of water from the nearby Delaware River as a heat source/sink for the heat pumps. The existence of a subway tunnel between the river and the Market Street site would reduce the water transportation cost and increase the feasibility of the system. The other heat pump system studied would use no external heat source. Instead, through the operation of heat pumps, it would redistribute heat generated at the interior zones of buildings (where it is undesirable) to the exterior zones (where it is required) in the heating seasons. The cooling loop of the system transports the heat to heat pumps which, in turn, pump it to the heating loops. In both heat-pump systems, auxiliary boilers supplement any deficiency in space-heating demand.

The central plant of all the ICES studied is assumed to be located in the basement of the North Tower.

4 COMPARISON OF ENERGY SYSTEM ALTERNATIVES FOR GALLERY II

4.1 GENERAL EVALUATION CRITERIA

In general, the following seven factors will play important roles in determining whether an ICES concept is feasible and, if so, the type of system to be implemented:

(1) economics	(5) expandability
(2) reliability	(6) energy savings
(3) availability of fuel	(7) substitution or conservation of scarce fuels
(4) environmental effects	

The economics would determine if the investment or additional investment in an ICES can be justified. The reliability of an ICES is the degree of ability of providing services when they are required. Fuel availability refers to fuel supply for the operation of the energy systems. Environmental effects relate primarily to air and water quality impact on the site. Expandability measures the ability of the energy system to be enlarged to satisfy additional energy loads.

4.2 RELIABILITY, FUEL AVAILABILITY, ENVIRONMENTAL EFFECTS AND EXPANDABILITY

Each of the total energy systems is designed to have at least two prime movers. With an extra unit as standby, the system would be a highly reliable energy supplier. However, availability of oil and natural gas to drive the total energy systems might pose a problem. Recent uncertainty in supply and considerable price increases have caused anxiety over recommending energy systems that utilize such fuels.

The heat-pump-centered system, which uses electric energy from PECO, is at least as reliable as the conventional system. Better backup characteristics can be provided because the central plant has more cooling devices than would be available in any individual building.

Air pollution, particularly nitrogen oxides, produced by the total energy systems could cause air quality problems. The heat-pump systems would cause no air pollution, and the effects of thermal pollution on the Delaware River would be minimal. No problems are expected as to the expandability of ICES, as long as any expected new loads are taken into account in the initial design of subsystems, e.g., in the distribution network.

4.3 ENERGY AND SCARCE-FUEL ANALYSIS

The energy requirements of candidate ICES were compared to those of the conventional system, and the savings are presented in Table 4.1. The conventional system would consume 6.37×10^7 kWh/yr of electricity and

Table 4.1. Energy Savings of Candidate ICES

System Type	Energy Type	Energy Input (Per Year)	Preliminary Fuel Input (But/Y)	Fuel Saved (Btu/Y)	% of Fuel Saved vs. Conventional
Internal Combustion Engines					
Diesel Engines	#6 Oil	4.56×10^{11} Btu	4.56×10^{11}	2.69×10^{11}	37
Gas Engines	Natural Gas	6.35×10^{11} Btu	6.38×10^{11}	0.87×10^{11}	12
Dual Fuel	#6 Oil and Natural Gas	5.61×10^{11} Btu	5.61×10^{11}	1.64×10^{11}	23
Gas Turbines					
Gas Fired	Natural Gas	5.57×10^{11} Btu	5.57×10^{11}	1.68×10^{11}	23
Oil Fired	#6 Oil	5.57×10^{11} Btu	5.57×10^{11}	1.68×10^{11}	23
Heat-Pump Centered System	Grid Electricity	5.19×10^7 kWh	5.90×10^{11}	1.35×10^{11}	19
Heat-Pump-Centered System with River Water					
W/O River Water Return	Grid Electricity	4.86×10^7 kWh	5.53×10^{11}	1.72×10^{11}	24
With River Water Return	Grid Electricity	4.97×10^7 kWh	5.65×10^{11}	1.60×10^{11}	22

require 7.25×10^{11} Btu/yr of preliminary fuel input at the PECO generating stations.*

Scarce fuel savings are listed in Table 4.2. The scarce fuel used at the PECO generating stations is 31.8%** of the total fuel consumed. Therefore, scarce-fuel consumption by the conventional system is 2.32×10^{11} Btu/yr. As shown in Tables 4.1 and 4.2, the total energy systems -- especially the diesel engine system -- are efficient energy savers. Nevertheless, because they consume more scarce fuel than the conventional system, they are not good candidates from the viewpoint of scarce-fuel conservation. Heat-pump systems are good energy and scarce fuel savers.

4.4 ECONOMICS

Table 4.3 summarizes the expected capital expenditures and operation/maintenance costs of the candidate systems. Capital costs include the central plant (up to the building boundary) and the in-building systems for the Gallery II mall and the two office towers. It is expected that J.C. Penney's in-building system will be installed and maintained by its own personnel. The owner of the ICES -- most likely the Market Street East Development Corporation -- should try to convince J.C. Penney to connect to the ICES. This should not be difficult because, by connecting to an ICES, J.C. Penney will be able to secure advantages in equipment and fuel economy if an ICES is proved to be feasible. For purposes of this study, J.C. Penney's continued independence is assumed, and the store's in-building system and operation/maintenance costs are not included in the following economic analysis.

The cost of the central plant for each ICES is obtained by cost itemizing system components in the plant. In-building system costs include plumbing, heating, ventilation and air conditioning (HVAC), and electrical systems. The conventional system cost is based on cost records of Gallery I with the system costs for offices adjusted according to Mean's Mechanical & Electrical Cost Data (1979) which provides average square-foot building costs with respect to building types. The in-building system costs for ICES take into account the differences in components between ICES and the conventional system. These differences include: (1) the addition of heat exchangers for domestic hot water,*** in-building hot water distribution, and two water pipes, if necessary, for central plant cooling towers; and (2) the omission of chillers, cooling towers in individual buildings, electric resistance heaters in fan coil units and electric domestic hot water heaters. The size of the mechanical room in each building also would be reduced by about 50%.

*The average efficiency of the PECO generating plants and transmission and distribution systems is assumed to be 30%.

**The fuel mix of PECO in 1978 was: 37.8% coal, 31.8% oil, 26.3% nuclear, and 4.1% hydropower.

***Domestic hot water heaters still would be required in the heat-pump system; therefore, no domestic hot water heat exchangers would be needed.

Table 4.2. Scarce Fuel Savings of Candidate ICES

System Type	Scarce Fuel Used (Btu/Y)	Scarce Fuel Saved (Btu/Y)	% of Scarce Fuel Saved vs. Conventional
Internal Combustion Engines			
Diesel Engines	4.56×10^{11}	-2.24×10^{11}	(97) ^a
Gas Engines	6.38×10^{11}	-4.06×10^{11}	(175)
Dual-Fuel	5.61×10^{11}	-3.29×10^{11}	(142)
Gas Turbines			
Gas Fired	5.57×10^{11}	-3.25×10^{11}	(140)
Oil Fired	5.57×10^{11}	-3.25×10^{11}	(140)
Heat-Pump Centered System	1.89×10^{11}	0.43×10^{11}	19
Heat Pump Centered System with River Water			
W/O River Water Return	1.77×10^{11}	0.55×10^{11}	24
With River Water	1.81×10^{11}	0.51×10^{11}	22

^aParentheses denote that the ICES would use more scarce fuel than the conventional system.

Operation and maintenance costs include personnel and material required, insurance, and property tax on the property. The conventional system is assumed to be under a service contract to provide material and staff for operation and maintenance. With ICES, the operation and maintenance of the in-building systems, other than J.C. Penney's system, is assumed to be performed by personnel employed by the ICES owner and dispatched from the central plant. This results in lower personnel expenses for ICES; however, two extra engine engineers would have to be employed for total energy systems.

For energy costs, the rate for electricity purchased from PECO is averaged at 3¢/kWh, and natural gas purchased from Philadelphia Gas Works (PGW) at \$2.56/10⁶ Btu (or \$2.60/1000 ft³, which is 90% of the general rate). The price of #6 oil is estimated at \$3.00/10⁶ Btu or 45¢/gal.

Switching from the conventional operating system to ICES increases the initial capital investment but saves in annual costs. For an ICES, personnel expenses are lower, but the insurance and property tax are higher. This leads to the situation that some ICES have higher O/M costs than those of the conventional system. Nevertheless, to satisfy the energy requirements of the complex, it costs less overall (in O/M and fuel costs) to operate an ICES than a conventional system.

The first column of Table 4.4 lists incremental capital expenditures for ICES over the conventional system. The extra capital requirement should

Table 4.3. System Costs of Candidate ICES (1979 \$)

System Type	Capital			O/M			Energy
	Plant	In-Building	Total	Plant	In-Building	Total	
Conventional	0	16.87×10^6	16.87×10^6	0	9.81×10^5	9.81×10^5	1.91×10^6
Internal Combustion Engines							
Diesel	11.03×10^6	15.08×10^6	26.11×10^6	7.82×10^5	4.52×10^5	12.34×10^5	1.37×10^6
Gas	7.98×10^6	15.08×10^6	23.06×10^6	6.81×10^5	4.52×10^5	11.33×10^5	1.64×10^6
Dual-Fuel	10.06×10^6	15.08×10^6	25.68×10^6	7.64×10^5	4.52×10^5	12.16×10^5	1.53×10^6
Gas	9.51×10^6	15.02×10^6	24.53×10^6	7.16×10^5	4.51×10^5	11.67×10^5	1.43×10^6
Oil	10.22×10^6	15.02×10^6	25.24×10^6	7.52×10^5	4.51×10^5	12.03×10^5	1.67×10^6
Heat-Pump Centered System	2.84×10^6	15.01×10^6	17.85×10^6	4.23×10^5	4.50×10^5	8.73×10^5	1.56×10^6
Heat Pump Centered System with River Water							
W/O River Water Return	3.85×10^6	14.93×10^6	19.30×10^6	4.54×10^5	4.48×10^5	9.02×10^5	1.45×10^6
With River Water Return	4.79×10^6	14.93×10^6	19.72×10^6	4.82×10^5	4.48×10^5	9.30×10^5	1.47×10^6

Table 4.4. Economics of ICES Compared to the Conventional System (1979 \$)

Central Plant Type	Incremental Capital Investment	O/M Saving	Straight Payback (Years)	Internal Rate of Return (%)
Internal Combustion Engines				
Diesel Engines	9.24×10^6	2.87×10^5	20.0	0
Gas Engines	6.10×10^6	1.18×10^5	27.4	0
Dual-Fuel Engines	8.81×10^6	1.45×10^5	29.5	0
Gas Turbines				
Gas Fired	7.88×10^6	2.88×10^5	17.5	6.5
Oil Fired	8.37×10^6	0.18×10^5	∞	0
Heat-Pump-Centered System	0.98×10^6	4.58×10^5	2.1	52
Heat-Pump-Centered System with River Water				
W/O River Water Return	1.91×10^6	5.39×10^5	3.3	33
With River Water Return	2.85×10^6	4.91×10^5	5.2	21

be offset by savings in the operation of the system and thereby justify the implementation of an ICES. Column 2 of Table 4.4 shows savings in operation (tax benefits, such as depreciation and investment tax credits, are not included). Straight payback periods, listed in the third column, represent the number of years that the incremental capital expenditure can be compensated due to the simple accumulation of savings in operation. The internal rate of return on the incremental capital expenditure, provided in column 4, gives the discount rate at which the accumulated operation cost savings over the life of the ICES plan just balance the incremental investment. Savings in operating costs are assumed to increase at a conservative annual rate of 5%. The life of the ICES plant is assumed to be 20 yrs.

4.5 CONCLUSION

Based on the evaluation criteria, the heat-pump-centered ICES without using river water will have:

- fastest payback,
- highest internal rate of return,
- lowest incremental capital expenditure,
- fair scarce fuel savings,
- fair energy savings, and
- high reliability.

Of all the systems studied, the heat-pump-centered ICES stands out as the best way to proceed in today's economy.

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5 DESCRIPTION OF THE RECOMMENDED SYSTEM

HEAT-PUMP-CENTERED ICES

5.1 INTRODUCTION

A heat pump operates as a refrigeration machine, i.e., it transfers heat from where the temperature is lower (evaporator) to where the temperature is higher (condenser). It can provide simultaneous heating and cooling. If water is circulated through the evaporator, it will be chilled and can be pumped to the buildings for cooling. If water is circulated through the condenser, heat will be absorbed and may be used for heating. When simultaneous heating and cooling requirements just balance each other, the heat pump simply transfers heat from one part of the building to another. However, if cooling demand is much larger than the heating demand, the higher temperature side would become increasingly hotter, and a heat sink should be provided to dissipate the undesirable heat. On the other hand, when heating demand exceeds the heat extracted from the cooling loop plus the compression heat, a heat source is required.

The interior areas of the office buildings and shopping mall of the Gallery II Complex, which consist of no walls adjacent to the ambient air, require cooling during the heating season because of the internal heat generation due to lighting, operation of machines, and people in these interior zones. It is conventionally removed by using an economizer cycle which mixes cold outside air with hot return air. With the application of heat pumps, the economizer cycle can be eliminated and the cooling of the interior zones can be provided by operating heat pumps. The heat removed from the cooling loop by the heat pumps' evaporator is reclaimed by the condenser and pumped through the heating loop to heat periphery zones. However, the heat recovered is normally not sufficient to satisfy the total heating load. Therefore, auxiliary boilers, sized to supplement the heating demand, are installed in parallel with the heating loop. The heat pumps used for this system have two tube bundles. One is used for heating, and the other for the cooling tower.

5.2 HEAT-PUMP SYSTEM OPERATION

Figure 5.1 shows the central plant of the heat-pump-centered ICES. For simplicity, a one-stage heat pump is shown instead of the double-stage unit actually used.

The heat pump operates to satisfy the cooling load of the community. Its stop-start and capacity modulation is controlled solely by the temperature controller TC 1 which senses the temperature of leaving chilled water, and controls the operation of heat pump accordingly through the pneumatic electric switch PE 1.

In a cooling season when no heating is required, all the heat carried by the chilled water loop is pumped from the evaporator to the condenser which, in turn, dissipates it to the cooling towers. The thermostat, TC 2, controls the condenser water temperature and, when called, activates the cooling tower fan which is interlocked with cooling tower water pumps.

Fig. 5.1. Schematic of Heat-Pump Centered ICES

When demand for heat increases, the temperature controller, TC 3, senses the drop in return hot water temperature and transmits the signal to TC 4, which slowly closes valve V1, and reduces the amount of heat rejected to the cooling tower. This increases the heat rejected to the heating bundle and raises the exiting hot water temperature. If this fails to increase the temperature to the required value, TC 4 closes V1 completely and starts to open valve V2 and activates PE 3 to start the boiler pumps. This feeds heated boiler water into the loop.

A reverse sequence of events occurs when the heating load decreases.

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6 RECOMMENDATION

Based on the preceeding analysis, the heat-pump-centered ICES with heat redistribution uses commercially available technology and, of the systems studied, was shown to be the most attractive system for meeting the energy requirements of the Gallery II Complex.

The heat-pump-centered ICES concept is recommended for Gallery II, and consulting engineers should be hired to perform preliminary and final system design.

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APPENDIX

INTRODUCTION TO INTEGRATED COMMUNITY ENERGY SYSTEM (ICES)

Traditionally, utility services such as heating, cooling, and lighting, have been served by separate energy forms and supply systems. Because most existing building and energy supply systems were designed when energy was cheap and abundant, few attempts were made to conserve energy. However, increasingly higher prices of energy and uncertain supplies of oil and natural gas have created a need to: (1) increase efficiency in the ways fuels are used, and (2) replace scarce fuels with more abundant fuels.

One factor responsible for the inefficiency of conventional energy supply systems is the lack of coordination among the various systems supplying different energy services. For example, a conventional electrical generating plant utilizes only about one-third of its fuel input energy, and rejects great amounts of heat to the environment. At the same time, scarce fuels, such as oil and natural gas, are burned to provide heat for purposes such as space heating. One way to address this lack of coordination is through the concept of cogeneration. Cogeneration plants integrate conventionally separate energy supply processes by simultaneously generating electricity while recovering "waste" heat. This recovered heat then can be used for: (1) space and water heating, (2) space cooling with the aid of absorption chillers, and (3) other processes. By providing the useful application of otherwise wasted heat, cogeneration systems offer the potential to increase efficiencies of energy utilization and thus to conserve natural energy resources.

Furthermore, in a conventional, decentralized system, each user would install its own energy conversion devices, such as chillers and boilers, to serve the energy needs of the building. Little coordination exists among users in a community. It may happen that one building uses energy to reject heat, while the other building consumes energy to keep warm. Integration of energy users not only would make efficient use of valuable energy, but also would take advantage of diversity of energy demands of different users and thereby decrease the capacity of energy conversion equipment.

An ICES generally has three main components: (1) the central plant, (2) distribution systems, and (3) end-use devices. The central plant converts primary fuels, such as coal, solid waste, geothermal, solar energy, oil, gas, biomass, or wind, into more readily usable forms of energy, such as electricity, steam, and hot or chilled water. A typical cogeneration plant consists of the following components:

- (1) fuel storage and supply steam,
- (2) prime movers with electric generators, such as internal combustion engines, steam turbines, gas turbines, fuel cells, etc.,
- (3) heat recovery systems, such as heat recovery boilers or heat exchangers,
- (4) unserviceable heat rejection system,
- (5) cooling devices, such as absorption chillers, and compression chillers,

- (6) auxiliary heating devices,
- (7) water treatment devices, and
- (8) control and metering devices.

The distribution system transports the energy produced in the central plant to consumers. End-use devices link the energy distribution system to the site where energy will be used.

An ICES can provide all the community's basic utility needs (those for space heating, space cooling, domestic hot water, electricity, process steam, etc.) or part of them. It could operate independently of existing electric utilities, or it may be "grid-connected," and capable of buying or selling electricity from or to the utility grid.

Sites with high potential for ICES implementation include places with high utility rates, high demand density, and new developments. Typical applications include:

university campuses,
medical complexes,
office complexes,
industrial parks,

urban renewal projects,
downtown areas,
military bases, and
commercial complexes.

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