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Technology Assessment Report for the Soyland Power Cooperative, Inc. Compressed-Air Energy-Storage System (CAES)

Environmental Science and Engineering

January 1982

Prepared for
Pacific Northwest Laboratory
under Agreement B-B5494-A-L

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

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TECHNOLOGY ASSESSMENT REPORT FOR THE SOYLAND POWER COOPERATIVE, INC. COMPRESSED AIR ENERGY STORAGE SYSTEM (CAES)

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Pacific Northwest Laboratory
Richland, Washington 99352

FOREWORD

Compressed air energy storage (CAES) is a technique for supplying electric power to meet peak load requirements of electric utility systems. Using low-cost power from base load plants during off-peak periods, a CAES plant compresses air for storage in an underground reservoir--an aquifer, solution-mined salt cavity, or mined hard rock cavern. During subsequent peak load periods, the compressed air is withdrawn from storage, heated, and expanded through turbines to generate peak power. This relatively new technology offers significant potential for reducing costs and improving efficiency of electric power generation, as well as reducing petroleum fuel consumption.

Based on these potential benefits, the U.S. Department of Energy (DOE) is sponsoring a comprehensive program to accelerate commercialization of CAES technology. The Pacific Northwest Laboratory (PNL) was designated the lead laboratory for the CAES Program. As such, PNL is responsible for assisting the DOE in planning, budgeting, contracting, managing, reporting, and disseminating information. Under subcontract to PNL are a number of companies, universities, and consultants responsible for various research tasks within the program.

An important element of the program is to promote commercialization of CAES technology through the transfer of research results and experience to interested utilities. Toward this end, Environmental Science and Engineering, Inc., of St. Louis, Missouri, performed a study aimed at developing an appropriate methodology for siting CAES facilities. Conducted for the Soyland Power Cooperative, Inc., an Illinois utility actively planning the first CAES facility in the U.S., the study resulted in two reports.

The Technology Assessment Report describes the design and operational features of CAES systems in general and, more specifically, of the proposed Soyland plant. These features are then evaluated in terms of their relationship to environmental siting and licensing considerations. The second document, Siting Selection Study, uses geotechnical and environmental criteria to outline a method for siting CAES facilities. The work described is based on detailed analyses of geologic, environmental, regulatory, socioeconomic, and other factors.

Taken together, these two documents provide a case study of the first attempt to commercially develop a CAES facility in the U.S. As such, they are intended as a basis upon which other interested utilities can make initial decisions regarding this promising technology.

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EXECUTIVE SUMMARY

This study was conducted to briefly describe the design and operational features of compressed air energy storage systems (CAES) and relate them to environmental siting and licensing. Characteristics of all CAES plants are described, as well as those of a 220-MW (net) unit proposed by Soyland Power Cooperative, Inc. of Decatur, Illinois.

As a peak demand facility, CAES is shown to offer utilities several advantages over gas turbines, which is the usual alternative chosen. These advantages include: (1) oil or gas fuel savings of two-thirds, (2) better utilization of baseload capacity, (3) economy of operation, (4) rapid on-line time, (5) high efficiency at less than full load, and (6) potential spinning reserve capacity.

Because CAES is a new technology in the United States, both general and Soyland's specific CAES plants are described in terms of land requirements, fuel use, efficiency, plant layout, turbomachinery, cavern structure, and water compensation. Plant interfaces with the environment are described and evaluated as they pertain to siting and licensing. Specific areas discussed include:

1. Air Quality--including fuel use, emission potential, and impact on ambient air quality;
2. Noise--noting the need for design features to attenuate localized and temporary sound generated;
3. Water Resources--noting expected water needs for compression cooling, water compensation, and other plant process waters;
4. Waste Discharge--or waste such as cooling water blowdown, chemical treatment, and oily wastes;
5. Ecological Effects--such as land clearing, disturbance, emissions, noise, and human activity; and
6. Socioeconomics--evaluating construction and operational labor force, tax values, and impact on local community structure.

The report concludes that the overall environmental impact of a CAES facility is minimal; most direct effects are much less than similar-sized baseload facilities and generally less than gas turbines. Specific comparisons between these systems are presented.

State and federal regulations associated with siting and licensing Soyland's proposed plant are discussed. No potential fatal flaws or difficulties associated with CAES licensing are noted.

1.0 CAES TECHNICAL OVERVIEW

1.1 NEED FOR PEAKING CAPACITY

Energy sources for meeting peak demand in utility systems are primarily supplied by combustion turbines which are characterized by relatively low capital costs and proven technology. The ever-increasing cost of gas and oil, however, continues to offset the original capital benefits. Consequently, utilities are investigating and implementing more efficient alternatives which take advantage of installed base load generation for storing energy off peak for use during peak demand. The Compressed Air Energy Storage System (CAES) uses basic turbine technology in conjunction with air storage facilities.

All public utilities face the problem of establishing an economical and reliable power supply to meet fluctuating demands for power. To meet these fluctuating demands, a utility will use base load units to provide a portion (40 to 60 percent) of its peak demand. These typically are large coal or nuclear units which have the highest efficiency and lowest fuel costs. The units have a high capital cost and are generally not very flexible in following load demand. The remaining power requirements are met by cycling units. These units are more flexible operationally but typically utilize more expensive fuels (oils or gas) and are less efficient (>11,000 Btu/kwh).

Energy storage is one approach to minimize fuel oil and gas consumption. Energy storage systems displace a utility's power output by transferring excess energy from base load units during periods of low demand to peak periods of high demand. This utilization of off-peak energy reduces use of higher heat rate petroleum peaking systems, oil or gas-fired turbines, and improves the capacity factor of more efficient base load units. The result can be an overall improvement of generating economics due to fuel cost savings and lower maintenance resulting from the uniform steady-state operating mode of the base load units. Energy storage systems also provide additional flexibility due to their rapid response times and better efficiency at partial loads than base load units.

CAES overcomes one of the major disadvantages of the gas turbine, which is the use of two-thirds of its generating power in providing energy for the compression of intake air. The CAES system performs the compression cycle independent of and prior to the generation phase. As such, lower-cost fuel utilized by efficient base load units supplies the energy needed for compression. The unique underground holding systems employed in CAES technology store compressed air until needed in the generation phase.

A full-scale 290-MW CAES facility has been developed and is operating at a 98 percent availability in Huntorf, Germany. As a logical occurrence, several U.S. electrical utilities are investigating the commercial development of CAES plants. These include Potomac Electric Power Company (PEPCO), Middle South Services, and Soyland Power Cooperative, Inc., which is actively planning to develop a 220-MW CAES facility in Illinois.

The purpose of this report is to describe CAES technology and licensing considerations and to discuss pertinent aspects of Soyland's CAES project implementation.

1.2 COMPRESSED AIR ENERGY SYSTEM

A method for storing energy is a compressed air energy storage system. CAES plants use energy available during off-peak periods from efficient coal or nuclear plants to compress air and store it in underground reservoirs. During peak demand periods this compressed air is directed to a gas turbine for power generation.

Although CAES plants use oil or gas, the quantity of this fuel used per KWH generated is reduced by as much as 60 to 70 percent compared to conventional gas turbines. Because the air reservoir is underground, as opposed to a large surface reservoir similar to that needed for pumped hydro storage systems, locating environmentally suitable sites for a CAES plant may be easier. In addition, the smaller physical size of a CAES system compared with a pumped hydroelectric storage system is a more economical approach for utilities because it minimizes capital investment and reduces construction time.

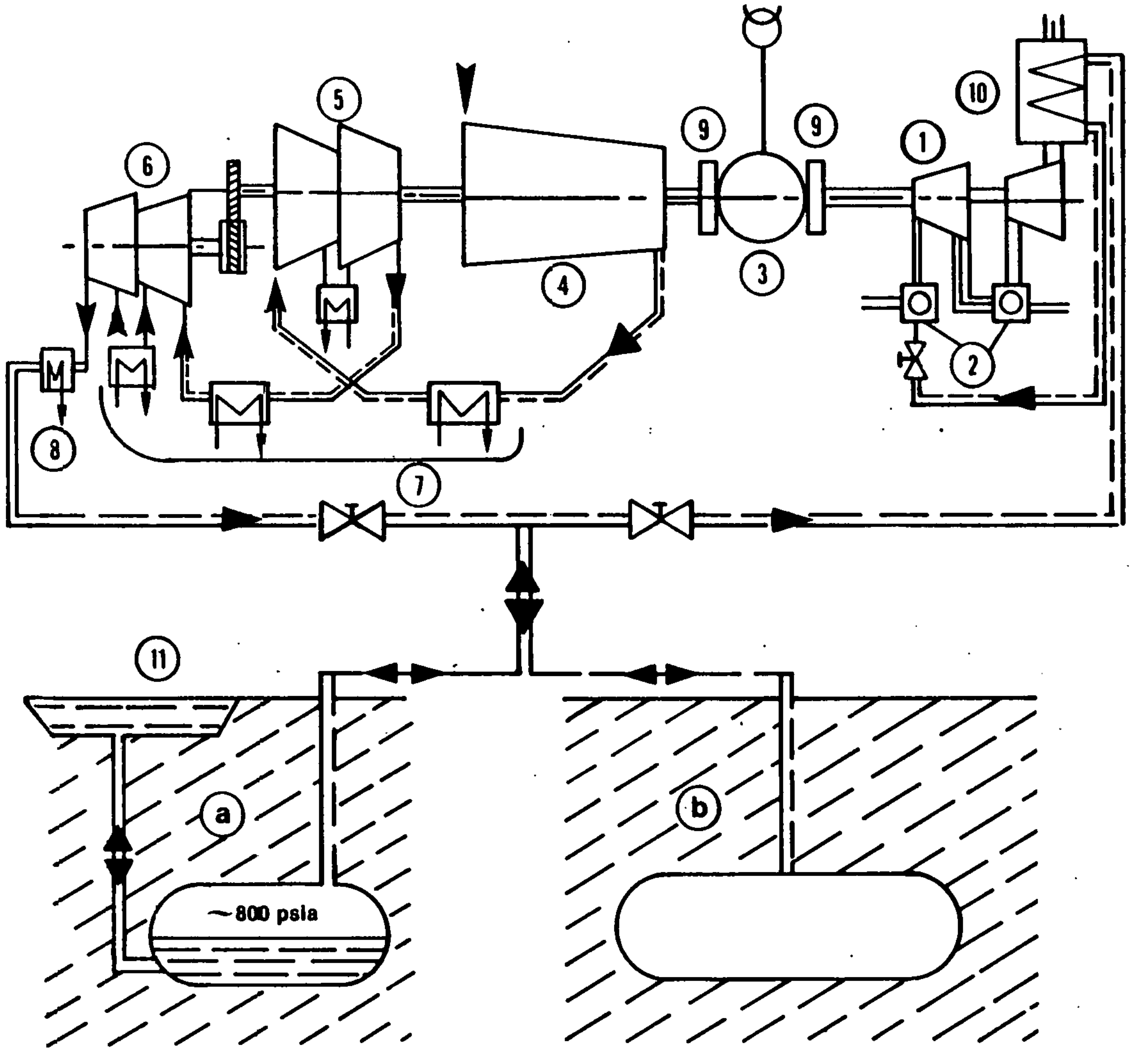
1.3 SYSTEM DESIGN AND OPERATION

The main CAES design components are presented in Figure 1-1. In a conventional system, the gas turbine drives both a generator and a compressor simultaneously with approximately two-thirds of the power used for compressing air. In a CAES plant, a motor/generator with two disconnect couplings is located between the turbine and compressor. This permits the unit to operate in either a compression mode or a power production mode, alternately disconnecting the gas turbine or compressor.

1.3.1 COMPRESSION MODE

During off-peak hours the turbine end of the motor/generator is disengaged, and the compressor end is engaged. The motor/generator operating as a motor consumes power from the electric grid to charge the air storage reservoir. Air is compressed by compressors in series which raise the pressure to approximately 800 to 1,000 pounds per square inch absolute (psia). The final determination of cavern pressure is a function of the type of air storage (variable pressure or water-compensated) and turbomachinery cost and efficiency. If the system is water compensated the pressure is determined by the depth of the cavern, which may be dependent on subsurface geology.

The compressor train uses an axial, low-pressure compressor; a radial, intermediate compressor; and a high-pressure compressor. Heat produced during compression is rejected through a series of intercoolers and an aftercooler. Cooling the air after the last stage of compression reduces the required cavern volume. The waste heat is rejected to the atmosphere through cooling towers or other appropriate heat rejection systems. Because compression usually takes place at night, cooler nighttime temperatures further reduce compressing power requirements.



(a) CAVERN WITH HYDROSTATIC COMPENSATION
(b) CAVERN WITH CONSTANT VOLUME
(1) TURBINE
(2) COMBUSTION CHAMBERS
(3) GENERATOR OUTPUT: 220 MW/MOTOR INPUT: 162.3 MW
(4) LP-COMPRESSOR
(5) IP-COMPRESSOR
(6) HP-COMPRESSOR
(7) INTERCOOLERS
(8) AFTERCOOLER
(9) CLUTCHES
(10) AIR PREHEATER
(11) WATER COMPENSATION RESERVOIR

SOURCE: BBC, 1980

Figure 1-1
GENERAL SCHEMATIC——
CAES FACILITY

CAES TECHNOLOGY ASSESSMENT

1.3.2 POWER PRODUCTION MODE

During the cycle, air is led from the cavern through an expansion valve to the recuperator and gas turbines. The recuperator uses exhaust gas heat from the low-pressure turbine to preheat the high-pressure air before it enters the high-pressure combustion chamber. The use of a recuperator improves the power generation performance by approximately 20 percent, representing a direct 20-percent reduction in the oil or gas consumed. The recuperator is an exhaust gas-to-air heat exchanger with the air passing through the tubes and the flue gas passing between the tubes.

The CAES plant operates at pressures higher than normal gas turbines; therefore, the expansion of combustion products takes place in two turbines. Each gas turbine has its own combustion chamber. The air is heated in the high-pressure combustor, expanded in the high-pressure turbine, heated a second time in the low-pressure combustor, and expanded in the low-pressure turbine to the exhaust pressure. The combustion chamber may be designed to burn either fuel oil or natural gas. This permits the utility to make use of whichever fuel is more available.

The high-pressure gas turbine is similar in design to an intermediate pressure steam turbine, allowing operation at higher pressures. The low-pressure gas turbine is of standard gas turbine design. The two turbines are on a single shaft which drive the generator.

1.3.3 AIR STORAGE MEDIA

Studies on storage media have been performed by several utilities. These studies consider developing reservoirs for air storage in salt (Middle South Services), in rock (Potomac Electric Power), and in aquifers (Public Service of Indiana). Energy storage is accomplished utilizing either constant volume or constant pressure systems, as discussed in Section 3.3.

Salt reservoirs result in the least expensive of the storage methods as they are typically produced by solution mining. Rock caverns are more expensive but have the distinct advantage of operating at nearly constant pressure.

Hydraulic compensation requires that a water impoundment be located at the surface such that the weight of the water column will be equal to the storage pressure.

If water compensation were not used, it would be necessary to compress the air to a pressure substantially above the turbine operating pressure. Water compensation provides constant pressure operation with maximum capacity for minimum cavern excavation.

1.4 ENERGY REQUIREMENTS

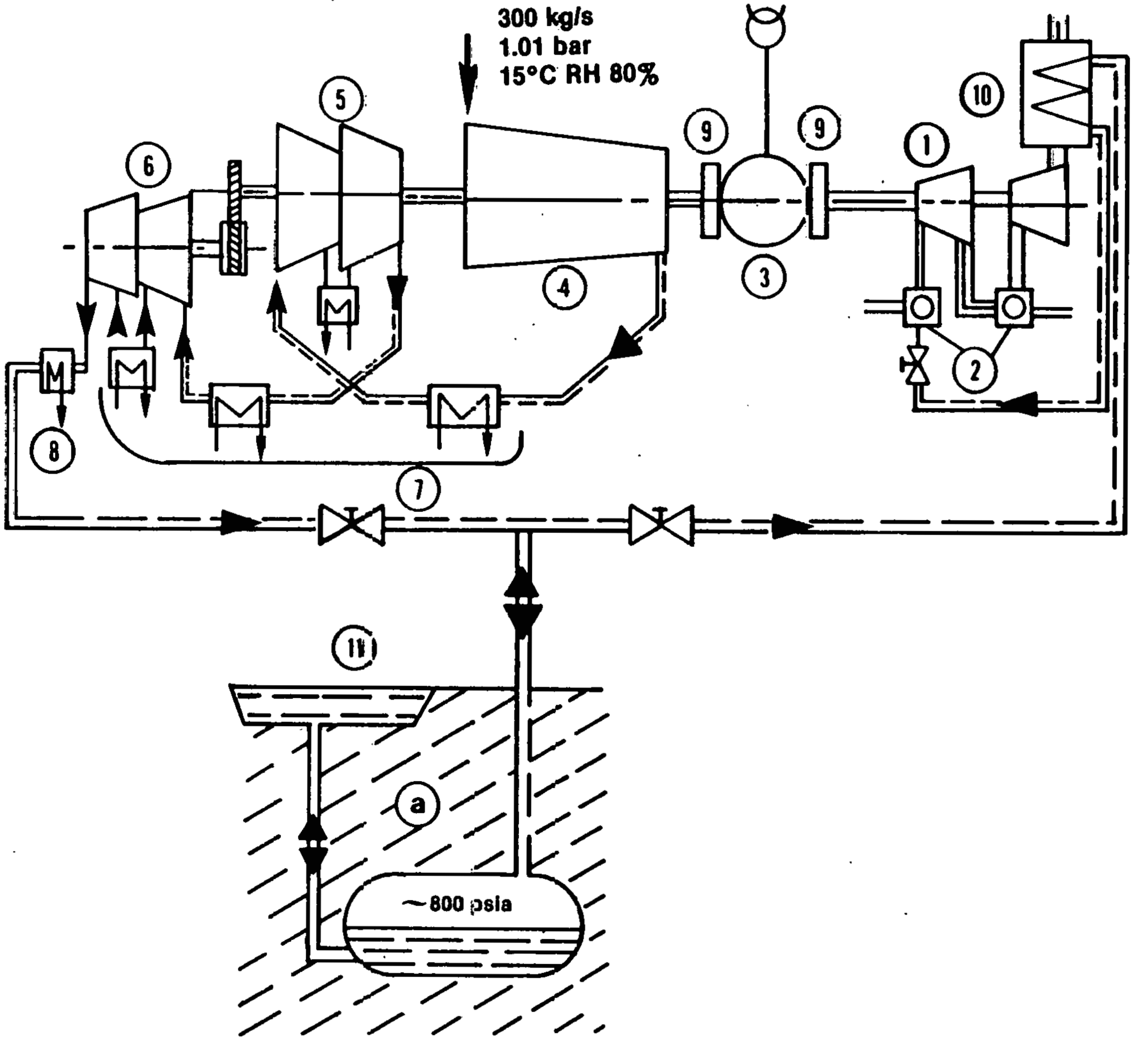
The CAES turbomachinery during power generation produces electricity with a heat rate of about 4,100 Btu/KW. The electrical energy required to compress air is dependent on the inlet temperature of the air. With an air temperature of 68°F the compressing energy is approximately 0.780 KW/hr for each 1 KW/hr of output when the storage pressure is 800 pounds per square inch gage (psig).

2.0 CAES SYSTEM DESCRIPTION

2.1 SOYLAND 220-MW CAES PROJECT

Selection of the rationale for charging and discharging the CAES system is based on many different criteria, including the power consumption curve, local grid characteristics, and Soyland's installed capacity economics. Based on these considerations and assuming an expected growth of power consumption, it was decided to design Soyland's CAES facility for an 11-hour charging cycle followed by an 11-hour power generation cycle.

The basic assumption is that the Soyland CAES plant will charge during the night and discharge during the day. Within these bounds, Soyland has several options for specific operating criteria. The simplest involves using the CAES unit to flatten the daytime/nighttime variations in the loading curves; however, Soyland will select that operation mode or modes that will best serve current needs. Because of the quick startup times for CAES (<10 minutes to full load), the unit can also be used as spinning reserve to back up Soyland's other generating capacity. A schematic for the 220-MW facility is presented in Figure 2-1, and preliminary design values are provided in Table 2-1.



- (a) CAVERN WITH HYDROSTATIC COMPENSATION
- (1) TURBINE
- (2) COMBUSTION CHAMBERS
- (3) GENERATOR OUTPUT: 220 MW/MOTOR IMPUT: 162.3 MW
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- (8) AFTERCOOLER
- (9) CLUTCHES
- (10) AIR PREHEATER
- (11) WATER COMPENSATION RESERVOIR

SOURCE: BBC, 1980

Figure 2-1
TYPICAL 220-MW CAES FACILITY

CAES TECHNOLOGY ASSESSMENT

Table 2-1. Compressed Air Energy Storage Data

Power output (net)	220 MW
Power consumption during compression mode	162.3 MW
Compressed air pressure	800 psig
Temperature (air)	59°C
Flow	300 kg/s
Heat Rate (of CAES turbine)	4,100 BTU/KWH
Number of turbines	2
Number of compressors	3
Underground storage capacity	213,500 M^3
Power generation cycle	11 hours
Compressor cycle	11 hours
Surface reservoir	175 acre-feet
Depth of cavern	1,800-2,000 feet
Fuel	Number 2 oil
Fuel consumption	7,000 gal/hr
Heat rejected in cooling tower	5.29×10^8 Btu/hr
Cooling water flow	50,000 gpm
Blowdown	320 gpm
Evaporation/Drift Loss	1,175 gpm

Source: Gibbs and Hill, Inc., 1981.

2.2 COOLING WATER SYSTEM

A cooling water system is used to cool the air at different stages of compression, thereby decreasing the amount of power required to compress the air stored. Cooling also decreases compressed air temperature (and therefore its volume) to minimize underground reservoir storage volume.

Two separate cooling loops which would use common, as well as separate, circulating water piping are envisioned. The main loop would provide for cooling all the compressor intercoolers and aftercoolers along with minor auxiliary equipment during the compression mode of operation. The secondary loop would use its own piping and supply auxiliary equipment, which is in operation only during the power generation mode.

The cooling system could be a closed loop system rejecting heat to the atmosphere via a cooling tower. The heat load at full-load compression is approximately 5.5×10^8 Btu/hr. The temperature rise in the cooling water is planned to be about 23°F, which requires a flowrate of approximately 50,000 GPM. At full load the maximum drift and evaporation loss would be 2.35 percent (1,175 GPM) of the circulating water flow.

The anticipated design calls for keeping the dissolved solids content of the circulating water at a concentration of four times the incoming make-up water. The maximum blowdown flow would be 0.64 percent of the circulating water flow (320 GPM). Cooling water blowdown may be discharged to the surface reservoir where it is diluted. Blowdown from the reservoir would be provided with monitoring to maintain contamination level of the reservoir water within allowable limits.

2.3 PLANT LAYOUT

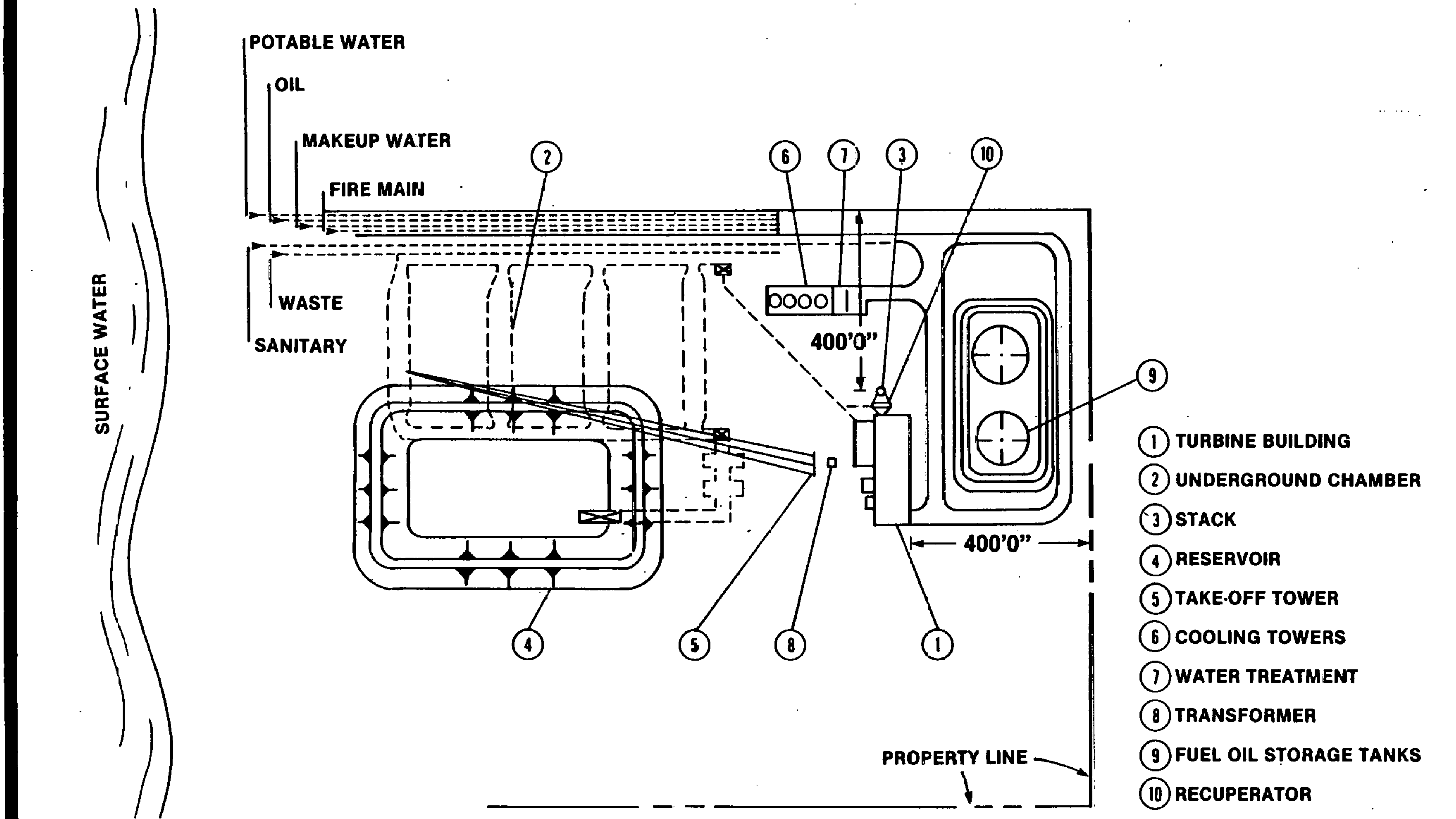
A proposed site arrangement (see Figure 2-2) is a rectangular plot of 80 acres. With this general arrangement, the actual plant facility may be laid out on an area of approximately 35 acres.

The water compensation reservoir would be designed to hold 175 acre-feet of water. With a water depth of 33 feet (10 meters) this would require a reservoir of approximately 400 by 600 feet. The reservoir would be surrounded by an earthen dike to contain the water. The dike and reservoir together use an area of about 7.5 acres. The reservoir could be located to minimize the amount of excavation necessary for construction.

The two fuel oil tanks would be adjacent to each other and surrounded by a dike. The total area would be about 450 feet by 220 feet.

The turbine building and electrical annex and recuperator would require an area of approximately 320 feet by 130 feet. The turbine building would house the turbine compressor train, the air coolers, the lubrication oil conditioning equipment, and a bridge crane for maintenance work. The electrical annex would house the on-site control room, the electrical switchgear, the diesel generator, package boiler, and locker room facilities.

A recuperator in the exhaust duct outside the turbine building and a steel stack with an exhaust silencer would be located beyond the recuperator.



SOURCE: GIBBS & HILL, INC., 1981.

Figure 2-2
TYPICAL 220-MW CAES PLANT LAYOUT

CAES TECHNOLOGY ASSESSMENT

The cooling tower and circulating water pumphouse require an area of about 240 feet by 75 feet. The cooling towers could be located away from the other site equipment and downwind of the site to ensure that the cooling tower plume does not interfere with plant operation.

The remaining area would be used to arrange required equipment and allow sufficient room for equipment construction and maintenance. Access roads would serve the turbine building and the circulating water pumphouse in addition to the general site access.

2.4 FUEL REQUIREMENTS AND FUEL STORAGE

The purpose of the fuel oil system is to receive deliveries of fuel, store the fuel, and distribute the fuel as necessary to the gas turbine and plant auxiliaries.

The envisioned fuel is Number 2 fuel oil for both the gas turbine and the boiler. Using Number 2 oil as the basis for the design eliminates the need for a fuel treatment system. Fuel would be pumped from the fuel delivery point to the storage tanks by the fuel oil unloading pumps. The two oil tanks would provide a 90-day supply of fuel at 220-MW output and 11 hours-per-day operation (approximately 7,000 gallons/hr). Each of the tanks may be approximately 3 million gallons. From the tanks the oil is pumped to the gas turbine interface, and a separate fuel oil pump would be provided to meet the needs of the auxiliary boiler.

A dike around the tanks sized to retain the oil in the event one tank fails would be constructed. Oil-water separators may be provided to treat any water collected in the dike.

2.5 WATER COMPENSATION

The water-compensated type cavern is used to control the pressure of the compressed air in the storage cavern. During the compression mode, compressed air is forced into the cavern, displacing water from the cavern and forcing the water up the water shaft and into the compensation pond. The height of water in the pond over the height of water in the cavern represents the static pressure in the cavern. Because the variations in differential water level between the cavern and the pond are small, the air pressure in the storage cavern is essentially constant and independent of the amount of air stored.

During the generation mode, air is taken from the cavern and passed into the gas turbine. As the air is taken from the cavern, water flows down the water shaft, replacing the volume of the air removed and keeping the air in the cavern at a relatively constant pressure. This allows the entire mass of air in the cavern to be used at constant pressure. The difference in water level between beginning and end of the power cycle will be about 35 feet with the planned design. This relates to a change in storage pressure of about 15 psi.

2.6 CAVERN REQUIREMENTS

The cavern is used to store the air which is compressed during the off-peak hours.

It is envisioned that the cavern may be composed of four main tunnels 400 feet long and 80 feet by 60 feet in cross section. The tunnels are cross-connected at both ends for a total cavern volume of approximately 7.5 million cubic feet (213,500 m^3).

The cavern is planned to be excavated out of the bedrock, approximately 1,800 feet (550 meters) below the surface. With water compensation this will result in a minimum cavern head pressure of 50 to 52 bar at the end of the power generation period.

A single air line will be used as both the fill and discharge for the cavern. Appropriate valving will be provided at the surface to direct the air to the gas turbine or allow compressed air to enter the cavern.

3.0 PLANT INTERFACES WITH THE ENVIRONMENT

3.1 CAES--AIR QUALITY

The design concept of a CAES system allows for the power generating mode to be operated without a compressor, which normally decreases the net power output of the gas turbine by at least 60 percent. This reduction in fuel usage results in an equivalent reduction of air pollutant emissions. This reduction, in turn, precludes the need for any special air pollution controls.

In a 220-MW net capacity gas turbine CAES plant, the fuel consumption during the peak power generating mode is approximately 100 gallons per minute of a Number 2 fuel oil. Number 2 is a light distillate oil with a maximum (A.P.I.) sulfur content of 0.7 percent by weight and negligible ash content. To provide adequate storage for up to 90 days of 11-hour-per-day operation, two tanks capable of storing 3 million gallons each will be required.

A gas turbine generation system utilizing CAES will emit the same types of pollutants as an oil-fired gas turbine generation facility. However, because a CAES gas turbine facility utilizes two-thirds less fuel than a standard gas turbine generator, the total amount of air pollutants emitted from the CAES facility will be approximately one-third of that emitted by a standard gas turbine generator. At a fuel consumption rate of 100 gallons per minute the emission rates of sulfur dioxide, nitrogen oxides, particulates, carbon monoxide, and hydrocarbons, are as shown in Table 3.1-1. The allowable emission rates for sulfur dioxide and nitrogen oxides as defined by U.S. EPA New Source Performance Standards (NSPS) are also given in Table 3.1-1.

Table 3.1-1 Air Pollutant Emission Rates* From 220-MW CAES Gas Turbine Plant

	Sulfur Dioxide	Nitrogen Oxides	Suspended Particulates	Carbon Monoxide	Hydrocarbons
Predicted Emission Rate					
lb/hr	616†	406.8	30	92.4	33.4
ppm	<140	220	--	--	--
NSPS allowable rate					
ppm	150**	250	N.S.††	N.S.††	N.S.††

* As determined from emission factors obtained in U.S. EPA document AP-42, 1973, as updated through Supplement IX, and from standard combustion calculations.

† Assumes maximum sulfur content in fuel of 0.7 percent.

** 0.015 percent by volume at 15 percent oxygen, dry basis.

†† No standard has been established.

Source: ESE, 1981.

The air quality impacts of air emissions must be evaluated in order to obtain information on the significance of these emission rates. Such factors as height of emissions release above grade (stack height), exhaust gas exit velocity, exit gas temperature, and meteorology all have a significant impact on the dispersion of these air pollutants and therefore on the resultant impact on ambient air quality.

In order to properly assess the air quality impacts of a typical 220-MW net capacity CAES gas turbine facility, dispersion modeling, employing the U.S. EPA-approved "Industrial Source Complex" (ISC) model, was employed. Screening modeling, using a full year of meteorological data representative of mid-central Illinois, was conducted employing both the normal ISC dispersion algorithm as well as the downwash algorithm. The inputs for CAES plant ISC modeling are shown in Table 3.1-2. The ISC model results are given in Table 3.1-3. Because dispersion modeling of one pollutant can be extrapolated by a simple ratio of the emission rate for the desired pollutant to that of the modeled pollutant, only the sulfur dioxide emissions were used in the ISC model.

As shown in Table 3.1-3, ISC model results predict the highest, second highest concentrations of sulfur dioxide emissions to be below Prevention of Significant Deterioration (PSD) significance levels for both the 3-hour and 24-hour averaging periods when normal dispersion conditions are considered. The emissions are also below the 3-hour and only slightly above the 24-hour averaging periods when the downwash option is considered. These predicted values are below the levels established as Ambient Air Quality Standards (AAQS), which are shown in Table 3.1-3.

The heat input to the 220-MW CAES plant (846×10^6 Btu/hr) qualifies this facility as a major new source as defined by the U.S. EPA Regulations for the Prevention of Significant Deterioration. Under

Table 3.1-2. ISC Model Input Parameters for SO_2

Emission Rate (grams/sec)	Stack Height (m)	Exit Velocity (m/sec)	Stack Diameter (m)	Exit Temp. (°K)	Building Height (m)	Building Length (m)	Building Width (m)
77.68	28.96	13.40	6.10	449.8	26	85	28

Source: ESE, 1981.

Table 3.1-3. Maximum Air Quality Impact for a 220-MW CAES Gas Turbine Plant

Concentration Period	Highest 2nd-Highest SO_2 Concentrations (ug/m^3)	Downwind Distance(m)	AAQS Primary (ug/m^3)	AAQS Secondary (ug/m^3)	PSD Significance Level (ug/m^3)
Without Downwash					
3-hr	16.6	1.3	N/A†	1300*	25
24-hr	2.45	1.3	365*	N/A†	5
With Downwash					
3-hr	21.0	2.3	N/A†	1300*	25
24-hr	5.7	2.3	365*	N/A†	5

† N/A = No standard exists.
* Maximum concentration not to be exceeded more than once per year.

Source: ESE, 1981.

these regulations, no new major source or major modification can utilize more than a specified incremental level of available air quality as measured in terms of pollutant concentration for sulfur dioxide and particulate matter. The maximum allowable increase (increment consumption) in sulfur dioxide and particulate matter air quality levels by area classification is given in Table 3.1-4. Most areas of the country are designated as Class II for air quality, while national parks and national wilderness areas are designated as Class I. As may be observed from this table and the modeling results given in Table 3.1-3, the CAES facility will consume a small fraction of the available PSD increment in Class II Areas. Due to the location of the highest and second highest impact concentrations, it should be easy to locate the CAES facility far enough from any Class I areas in order to effect minimal PSD increment consumption.

In summary, it may be concluded that the impacts of air pollutant emissions from a 220-MW net capacity gas turbine power generating plant on ambient air quality are much less than AAQS or PSD increments.

Table 3.1-4. Federal Prevention of Significant Deterioration Increments (ug/m^3)

Pollutant/Averaging Time	Class I	Class II	Class III
Particulate Matter			
Annual Geometric Mean	5	19	37
24-hour Maximum*	10	37	75
Sulfur Dioxide			
Annual Arithmetic Mean	2	20	40
24-hour Maximum*	5	91	182
3-hour Maximum*	25	512	700

*Increment can be exceeded once per year for each class.

Sources: Public Law 95-95, Clean Air Amendments of 1977.
Federal Register, Vol. 43, No. 118, June 19, 1978.

3.2 WATER SUPPLY AND DISCHARGES

3.2.1 WATER SUPPLY--GENERAL CAES FACILITY

CAES facilities require water for compression cooling, a water compensation system, air quality control, water treatment, sanitary water supply, and other miscellaneous uses.

Cooling water will be the major operational water use for a CAES facility. The amount of water needed will vary depending upon cooling method chosen, and in the case of cooling towers, quality of water source. The water compensation system needs will consist of an initial filling of the reservoir and evaporation makeup to the reservoir. The need for makeup water to the reservoir will depend on the balance between rainfall and evaporation and seepage losses from the reservoir. Water may be required for nitrogen dioxide control of the gas turbine exhaust. The need for control of nitrogen dioxide will depend mainly upon the size of the facility. Water will also be required for operations such as filter backwash and resin rinse. These needs will be based upon water quality design needs and the quality of the water source. Sanitary water and other miscellaneous uses will be extremely small due to the limited manpower needed to operate a CAES facility.

The water source for a CAES facility may be either surface water or ground water. Permits for constructing a surface water intake structure may be required from the U.S. Army Corps of Engineers. State permits may be required for surface water or groundwater withdrawals.

3.2.1.1 SOYLAND CAES PROJECT

The 220-MW CAES facility planned for Illinois by Soyland may use mechanical cooling towers. The average flow rate through the cooling system will be approximately 50,000 gpm. The maximum drift and evaporation losses from the cooling system will be 1,100 to 1,200 gpm. Blowdown from the system, based upon keeping the dissolved solids in the circulating water at four times the incoming concentration, will be about 300 to 350 gpm. Therefore, the maximum makeup to the cooling system will be approximately 1,400 to 1,550 gpm.

The water compensation system will require an initial 57 million gallons of water to fill the reservoir. Assuming seepage losses from the reservoir are negligible, makeup water to the reservoir will not be needed except in cases of extreme drought.

Other water needs will probably amount to less than 10 gpm. Water injection for nitrogen dioxide control is not expected to be required for the Soyland facility. Water for treatment needs such as filter backwash and resin regeneration will vary depending on water source quality, but likely will average less than 10 gpm. Sanitary and miscellaneous water needs will be minimal.

Surface water will likely be the primary water source. However, in areas where average well yields are expected to exceed 500 gpm, ground water may be an option. Permits from the U.S. Army Corps of Engineers and the Illinois Department of Transportation (DOT) will be required for the surface water intake structure. Water withdrawal permits may be required from the Illinois DOT, Division of Water Resources.

3.2.2 WATER DISCHARGES--GENERAL CAES FACILITY

Possible sources of water discharges from a CAES facility include:

1. Blowdown from cooling systems. This could be blowdown from cooling towers, overflow from cooling ponds, or once-through cooling.

2. Overflow and/or blowdown from the water-compensating reservoir. Overflow will occur periodically in areas where rainfall is greater than evaporation. Blowdown will occur if the reservoir needs to be emptied for maintenance reasons.
3. Discharge from water treatment operations. This could include filter backwash, resin rinse water, sludge dewatering, etc.
4. Sewage plant discharges.
5. Oily wastes from fuel storage and plant service drains.

All discharges must meet general effluent standards under the National Pollution Discharge Elimination System (NPDES) permit system.

3.2.2.1 CAES PROJECT

The 220-MW CAES facility planned by Soyland will have water discharges averaging 350 to 400 gpm. The major discharge, blowdown from the cooling tower, will be approximately 300 to 350 gpm. Total dissolved solids, sulfates, chlorides, chemicals for biological control (probably chlorine), and thermal discharge are pollutants likely to exist in this source.

Overflow from the water-compensating reservoir may be an occasional discharge depending on local hydrological conditions. Rainfall exceeds lake evaporation in Illinois by 0 to 10 inches. Discharges from the reservoir source will probably average less than 5 gpm annually and will have little potential for carrying pollutants.

Discharge from the demineralizer plant will vary depending on water source and water quality requirements and will likely average less than 10 gpm. This discharge will contain salts removed in the demineralizer and regeneration chemicals.

Sewage plant discharges will be extremely small because of the limited manpower needs. Oil and grease from fuel storage and plant service drains will also be minimal.

In addition to meeting effluent standards under the NPDES permit system, these discharges must not violate Illinois water quality standards as established by the Illinois EPA. The water quality standards are based upon an allowable mixing zone assuming a 7-day, 10-year low flow in the receiving stream. Therefore, quality and mixing characteristics of the receiving stream are major factors in meeting permit requirements.

3.3 AIR STORAGE SYSTEMS

CAES systems can use either a subsurface cavern or a saturated, porous geologic formation for storage of compressed air. Storage of compressed air in a porous geologic formation, such as a groundwater aquifer, is currently a subject of research and development.

There are two basic types of air storage cavities or caverns: (1) the uncompensated, constant-volume cavern, and (2) the water-compensated, constant-pressure cavern. In the uncompensated cavern, air must be stored at greater-than-demand pressure and released during power generation. In the compensated cavern, a water reservoir feeds water into the bottom of the cavern as air is released, maintaining a relatively constant cavern pressure. The compensated caverns operate at a lower storage pressure than the uncompensated caverns and can usually be constructed in equilibrium with the fluid pressure in the surrounding rock matrix.

3.3.1 AIR STORAGE CAVERNS

Caverns for storage of compressed air can be constructed in either salt or hard rock formations. A salt dome is currently being used in Germany for storage of compressed air as part of the Huntorf CAES facility. Salt domes have the necessary structural and geohydrological properties to contain the compressed air and can be mined by solution rather than tunnel mining. The Huntorf salt dome cavern was constructed using solution mining techniques. A feasibility study and environmental assessment have been completed for Middle South Services in Louisiana for a salt dome CAES facility. In Kansas, a geological assessment of a mined cavern in salt was conducted by EPRI, and Alabama Electric Cooperative is currently investigating the use of a salt dome for a CAES system.

Salt formations are well suited for the uncompensated type of air storage caverns. The Huntorf CAES facility uses an uncompensated air storage cavern. Salt formations are relatively easy to mine compared to hard rock caverns. The uncompensated type of cavern can be constructed economically in salt.

Salt formations are not always available for construction of an air storage cavern. As a result, a number of utilities are investigating the use of hard rock air storage caverns for CAES facilities. Potomac Electric Power Company (PEPCO), in Maryland, recently completed a feasibility study for a CAES facility using a water-compensated hard rock cavern. Soyland's planned CAES facility will also use a hard rock water-compensated storage cavern.

3.3.2 HARD ROCK WATER-COMPENSATED CAVERNS

The water-compensated cavern stores compressed air at slightly greater-than-required turbine pressure. As air is released from the storage cavern, water enters from the bottom and displaces the air. The proposed Soyland CAES facility will require a water-compensated cavern at a depth of 1,700 to 2,000 feet to provide sufficient hydraulic head to balance approximately 800 psia of air pressure in the cavern. In order to meet CAES design criteria for the 220-MW Soyland CAES facility, the rock strata must conform to three parameters:

1. The formation must be massive, relatively impermeable, and capable of supporting underground mining. Precambrian granites, massive dolomites, and massive limestones are most likely to satisfy these criteria.
2. The stratigraphic unit must be at least 100 feet thick to allow excavation.
3. The strata must occur between 1,700 and 2,500 feet below ground surface because of the required hydraulic gradient of the compensation pond.

A review of Illinois geology determined that five major geological units have the potential to conform to the previously-listed parameters:

Age	Rock Unit
Precambrian	All granites
Cambrian	Lombard Dolomite of Eau Claire Formation
Cambrian	Knox Dolomite Megagroup
Ordovician	Ottawa Limestone Megagroup
Silurian and Devonian	Hinton Limestone Megagroup

Based upon the Siting Selection Study conducted by ESE (1981) Soyland's planned CAES facility will probably be constructed in western Illinois. The geologic formations at a depth of 1,800 to 2,000 feet in this part of Illinois appear to have the necessary rock properties for construction of the air storage cavern. The rock must have a strength greater than 15,000 psia and must be fairly massive. The Cambrian dolomites and Precambrian crystalline rocks, at a depth of 1,800 to 2,000 feet, meet these requirements.

The air storage cavern for the Soyland CAES facility would be expected to operate at approximately 800 psia. This pressure is greater than the required inlet pressure for the CAES system turbine, which allows for line, fitting, and cavern losses. Line storage volume of the underground reservoir would be approximately 7.5 million cubic feet (213,500 m^3). A workable concept would be four inter-connected tunnels, each approximately 400 feet long. A diagram of such a cavern system is shown in Figure 3.3-1. The final cross-sectional area, tunnel length, and design would depend on the structural properties of the rock being mined. The tunnels of the storage cavern would be arch-shaped, 80 feet high in the center, and approximately 60 feet wide at the base. The optimal design depth of the underground storage reservoir for Soyland's proposed CAES system is 1,800 to 2,000 feet below land surface. This depth range allows flexibility in the type of rock mined.

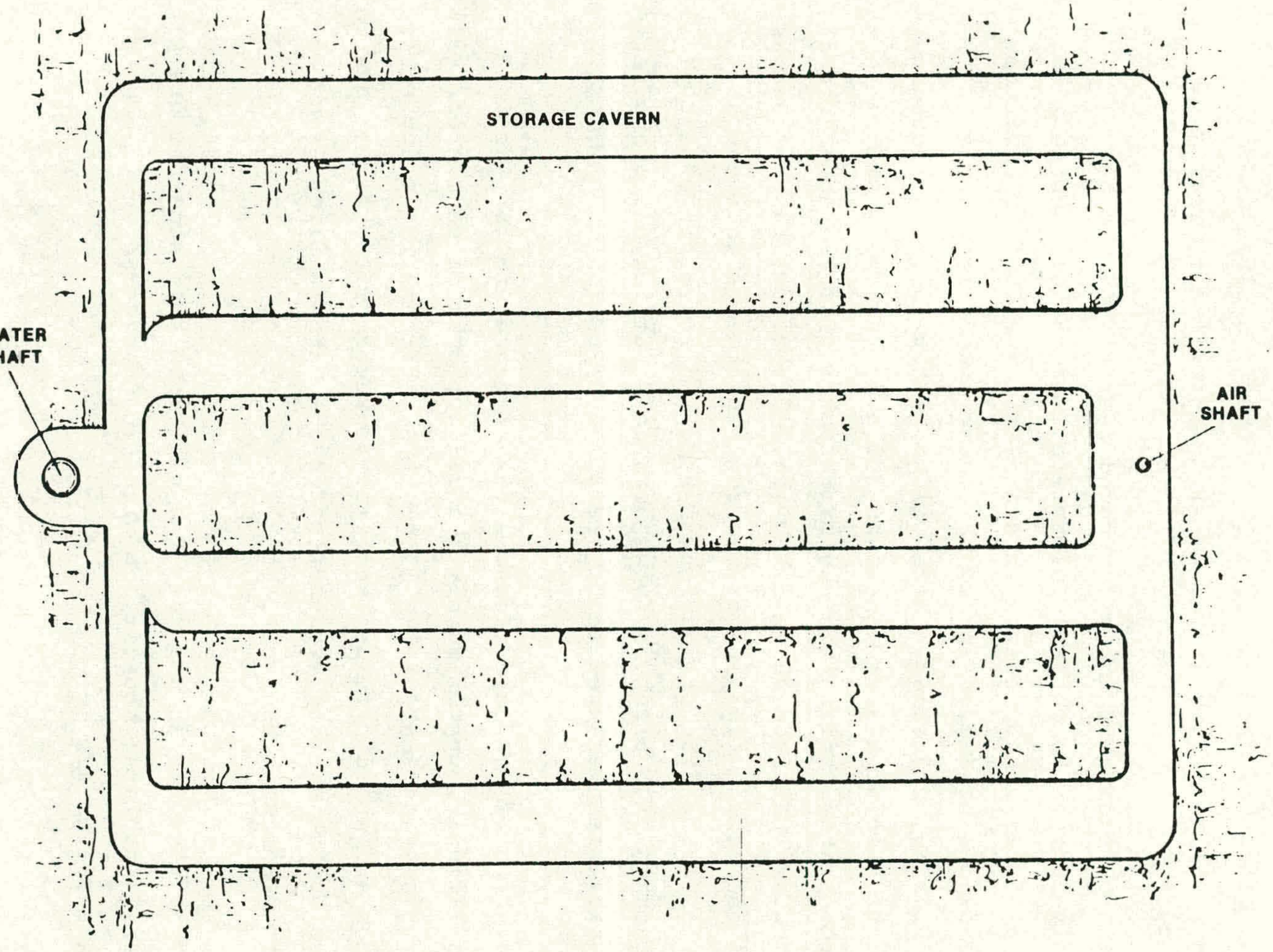


Figure 3.3-1

CONCEPTUAL DESIGN OF WATER-COMPENSATED AIR STORAGE CAVERNS

SOURCE: WILKINSON, 1978.

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and provides sufficient hydraulic head to maintain the reservoir at approximately 800 psia. The actual hydraulic head in the surrounding rock will also be important in determining the optimal design depth. Construction of an underground storage reservoir in close hydraulic equilibrium with the surrounding rock will minimize air loss.

The water shaft leading to the underground reservoir would be approximately 16 feet (5 meters) in diameter and the air shaft approximately 5 feet (1.5 meters) in diameter. The 16-foot shaft would provide access during excavation of the underground air storage reservoir. During excavation, there will be water in the surrounding rock at hydrostatic pressures less than 800 psia that will seep into the mined cavern. Water influx into the mined portion of the underground reservoir could range from 50 to 5,000 gpm. The actual rate of seepage will depend on the permeability of the rock and the effectiveness of grouting or other sealing procedures if used. A schematic of a typical, water-compensated CAES plant, showing both construction and operating characteristics, is presented in Figure 3.3-2.

During excavation of the underground air storage cavern for the CAES facility in Illinois, approximately 7.5 million cubic feet of rock will be removed. This rock material will be either Precambrian dolomite or Cambrian rock and would provide excellent aggregate material for use in construction of the surface structures for the CAES facility, such as the water compensation reservoir.

Construction of the air storage caverns will result in some temporary dust and noise problems; however, no significant adverse environmental effects are anticipated.

During operation of the Soyland CAES system, air and water will cycle in and out of the air storage cavern. In a water compensation system, the "champagne effect" can occur. The champagne effect is caused by

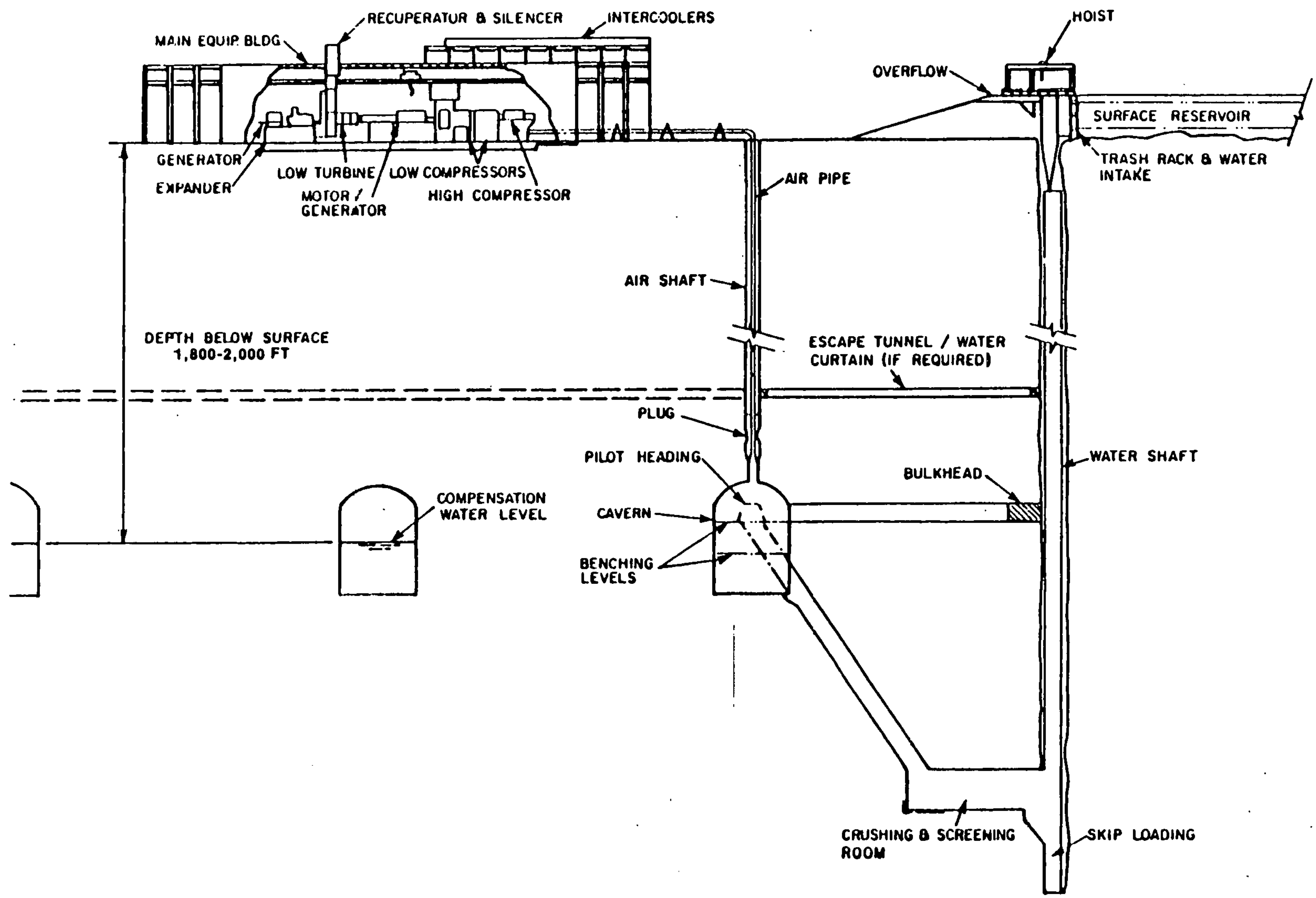

Figure 3.3-2

TYPICAL WATER-COMPENSATED CAES PLANT DESIGN AND CONSTRUCTION

SOURCE: GILL, 1978.

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water in the cavern becoming saturated with air. The air then works its way through the U-tube (shown in Figure 3.3-3) and up the water shaft. If enough bubbles form and rise, the air-water mixture with its lower density will cause loss of hydraulic weight. The air-water mixture with its lower density will cause a loss of hydraulic head on the compressed air mass. This can result in stable or unstable flow transfers. The Department of Energy and EPRI have conducted on-going experimental studies and concluded that the champagne effect can be controlled to a minor operational transient with proper engineering.

The Soyland system will be constructed to control the champagne effect. By oversizing the air storage cavern slightly, increasing friction in the water compensation system, and having a sufficiently deep U-tube, the champagne effect can be controlled.

During the charging cycle, three compressors in series would charge air into the storage cavern at 800 psia. The compressors can produce 5.29×10^8 Btu/hr of heat. This heat would be removed by a series of intercoolers and aftercoolers that cool both the compressors and the compressed air. Cooling the compressed air reduces the required storage volume. The cooling system would probably be a closed-loop mechanical cooling tower with 5.5×10^8 Btu/hr capacity.

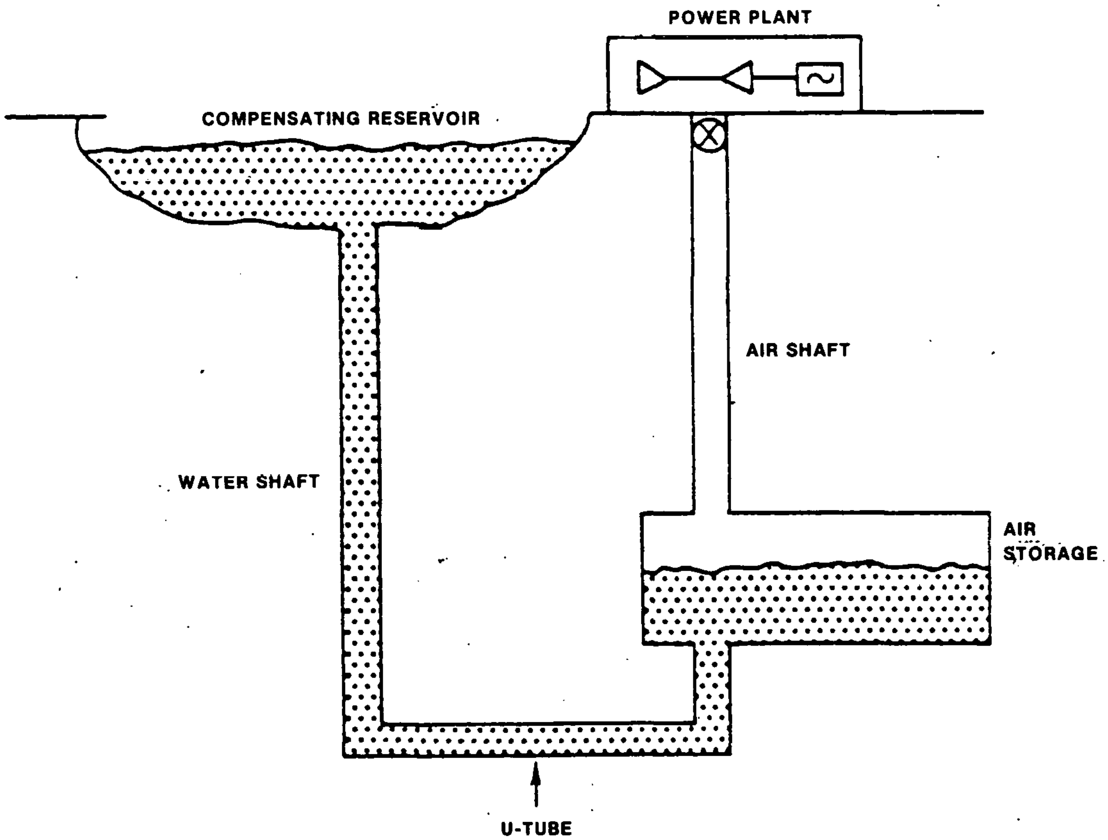

Figure 3.3-3

UNDERGROUND CROSS SECTION OF WATER COMPENSATION SYSTEM

SOURCE: BLECHER, 1978.

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3.4 CAES NOISE CONSIDERATIONS

The air quality impacts of a 220-MW CAES power plant have been shown to be relatively insignificant; however, the noise levels generated by the same facility are an important consideration. Whereas the source of air pollutant emissions is only the turbine exhaust at the stack, the major sources of noise generation are numerous:

1. Air intake (for the compressor),
2. Compressor,
3. Blow-off valve,
4. Turbine exhaust (stack),
5. Gas turbine, and
6. Cooling tower(s).

Each of these sources generates a different noise intensity and frequency pattern, which singly or in combination can create a high level if left unabated. Through incorporation of appropriate design features the intensity of generated noise can be reduced to an acceptable level.

Tables 3.4-1 and 3.4-2 show the daytime and nighttime sound pressure levels, respectively, that cannot be exceeded in Illinois. When noise is emitted to any receiving Class A land from any property- line noise source that is located on either Class A, B, or C land, it must be measured at any point within such receiving Class A land. However, no measurement of sound pressure levels are to be made less than 25 feet from such a property-line source. A property-line noise source is defined as "any equipment or facility, or combination thereof, which operates within any land use as specified by Rule 201 of Chapter 8 of the Illinois Pollution Control Board Rules and Regulations. Such equipment or facility, or combination thereof, must be capable of emitting sound beyond the property line of the land on which it is operated." Land Class designations are based on the Standard Land Use

Table 3.4-1. Sound Emitted to Class A Land During Daytime Hours

Octave Band Center Frequency (Hertz)	Allowable Octave Band Sound Pressure Levels (dB) of Sound Emitted to any Receiving Class A Land from Class C Land	Class B Land	Class A Land
31.5	75	72	72
63	74	71	71
125	69	65	65
250	64	57	57
500	58	51	51
1000	52	45	45
2000	47	39	39
4000	43	34	34
8000	40	32	32

Source: Illinois EPA, 1981.

Table 3.4-2. Sound Emitted to Class A Land During Nighttime Hours

Octave Band Center Frequency (Hertz)	Allowable Octave Band Sound Pressure Levels (dB) of Sound Emitted to any Receiving Class A Land from Class C Land	Class B Land	Class A Land
31.5	69	63	63
63	67	61	61
125	62	55	55
250	54	47	47
500	47	40	40
1000	41	35	35
2000	36	30	30
4000	32	25	25
8000	32	25	25

Source: Illinois EPA, 1981.

Coding Manual (SLUCM) (1969) as developed by the U.S. Departmemt of Transportation, Federal Highway Administration.

Table 3.4-3 shows the CAES noise levels by source. As observed from Table 3.4-3, the two most significant sources of noise emissions are the air intake (suction pipe) to the compressor and the blow-off valves. The blow-off valves can produce a maximum level of 155 dB measured 3 feet from the source. Some attenuation would normally be realized by increased measurement distance from the source. Since compliance with the levels given in Tables 3.4-1 and 3.4-2 is determined at a distance of no greater than 25 feet from the source property line, the location of each separate source with respect to the property line can effect a significant reduction in noise level at the measurement point. However, unless these distances are great, meeting the desired sound pressure levels at the property line (or up to 25 feet out past the property line) may be difficult without special design consideration. Figure 3.4-1 illustrates noise reduction as a function of distance from the source.

Measures that can be taken to attenuate the noise level reaching the property-line measurement point and, more importantly, sensitive receptors such as dwellings (Class A Land) or places of business (Class B Land) are varied. These include dampers, insulation, silencers, baffles, design features such as air inlet structure size and shape, orientation of air inlet structure and blow-off valve exhaust, the use of deflecting earth berms, and noise-absorbing vegetation cover. None of these measures will totally eliminate noise generation levels, but they may aid in the attenuation of noise emitted to an acceptable level.

The assessment of specific noise abatement methods is beyond the scope of this document, since the level of detail required to properly make

Table 3-4.3. Raw Noise Levels by Source for a 220-MW CAES Facility

SUCTION NOISE, SUCTION OPENING, COMPRESSOR OPERATION

(Hz)	32	64	125	250	500	1k	2k	4k	8k	dB-A
(dB)	120	120	120	128	135	140	140	135	130	145

BLOW-OFF VALVES

(Hz)	125	250	500	1000	2000	4000	8000	16000
(dB)	145	150	155	155	155	147	138	130

GAS EXHAUST NOISE, STACK (TURBINE OPERATION)

(Hz)	32	64	125	250	500	1k	2k	4k	8k	dB-A
(dB)	103	105	107	103	102	100	90	80	65	107

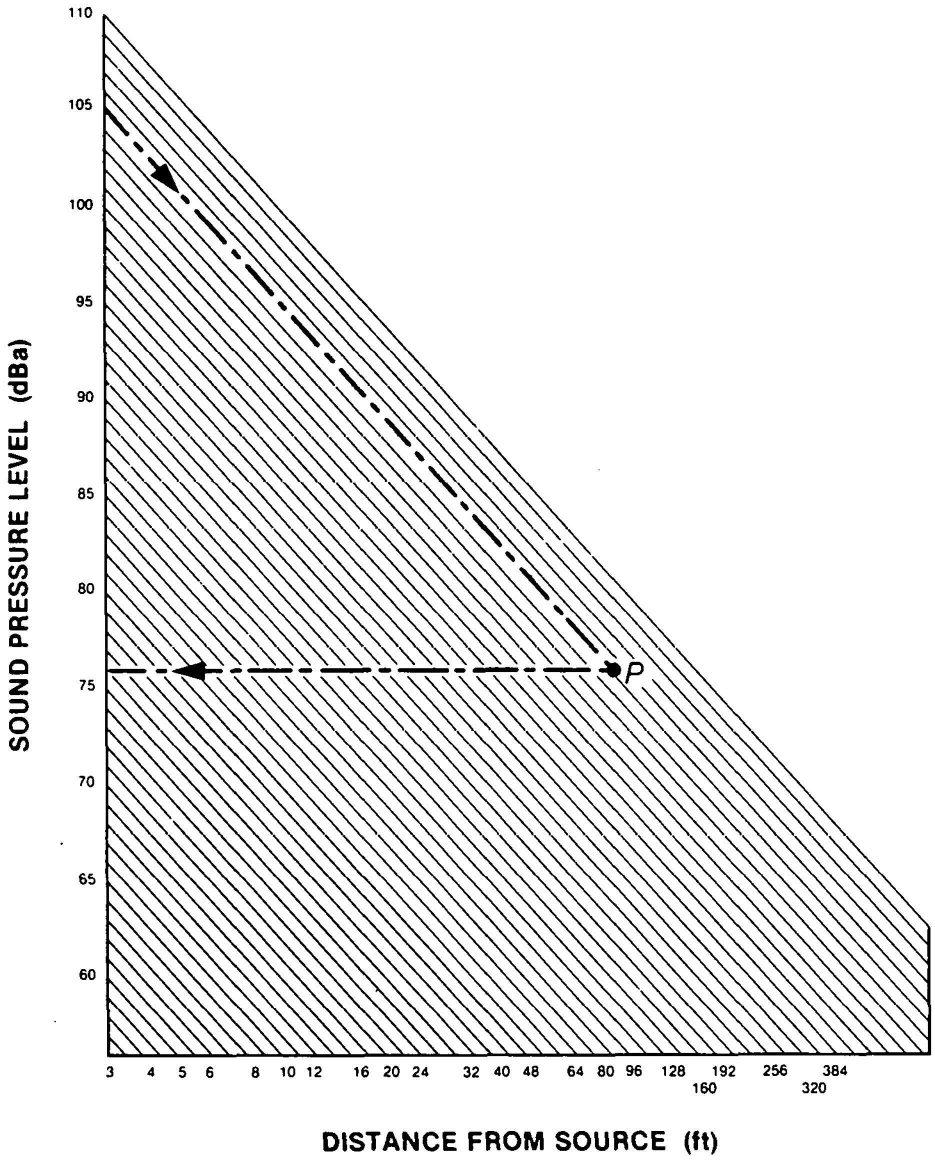
NOISE RADIATION OF THE BUILDING (INCLUDING TURBINE, VALVES, PIPING AND COMPRESSION)

(Hz)	32	64	125	250	500	1k	2k	4k	8k
(dB)	90	95	100	100	100	100	105	100	95

COOLING PLANT

(Hz)	32	64	125	250	500	1k	2k	4k	8k	dB-A
(dB)	110	110	110	102	102	102	102	100	97	110

Source: Illinois EPA, 1981.



If the sound pressure level SPL_1 of a point source at a distance d_1 is known, the sound pressure level SPL_2 at a second distance d_2 can be found by using this formula:

$$SPL_2 = SPL_1 - 20 \times \log_{10}(d_2/d_1)$$

This calculation is incorporated in the graph above, which assumes that the sound level is measured at a point 3 feet from the piece of equipment generating the noise.

Figure 3.4-1
SOUND PRESSURE LEVEL WITH RESPECT TO DISTANCE FROM NOISE SOURCE

SOURCE: *POWER* JOURNAL, JANUARY 1973.

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such an assessment involves a case-by-case and source-by-source study of available alternative noise abatement methods. Such factors as plant site elevation with respect to neighboring land areas, surrounding topographical relief, and occurrence of other naturally-occurring noise deflecting or otherwise attenuating features either singly or in combination can have a dramatic effect on the level of noise attenuation required at the source in order to meet both property-line and receiving land sound pressure levels.

4.0 CAES COMPARISON WITH OTHER GENERATION OPTIONS

4.1 FINANCIAL COMPARISONS

Three alternative peaking power options are compared in this analysis:

1. Simple cycle combustion turbines,
2. Combined cycle combustion turbines, and
3. Compressed air energy storage (CAES).

Non-peaking energy sources assumed in this analysis are a 97-MW share of a nuclear facility (Clinton I) available in 1983, a 450-MW coal-fired facility available in 1987, and a second 450-MW coal-fired facility available in 1997. Energy purchases from Central Illinois Public Service and Illinois Power Company are used as required to meet projected load and reserve requirements.

Load projections used in this study are based on estimates of future loads by the 15 member systems of the Soyland Power Cooperative, using 11 years of historical data (1967 to 1977). An additional 5 percent was added to account for transmission losses in the system. The resulting projections are shown in Table 4.1-1.

Based on data from a representative portion of Soyland's service area during 1979, it was determined that severe winter loads represent a 45-day period; severe summer loads represent a 45-day period; the balance (275 days) can be considered mild. Variation in day-to-day peaks was found to be greater than variation between weekday and weekend peaks; therefore, no special treatment is required for weekend periods.

A previous study (Reynolds, Smith and Hills, 1981) showed that Soyland needs approximately 200 MW of peaking capacity during the mid-1980's to achieve the lowest power supply cost. Others (Arthur D. Little, 1979; showed that Soyland could meet its own peaking power needs with a CAES facility more economically than purchasing firm power.

Table 4.1-1. Demand and Energy Consumption Projections

Year	System Coincident Demand Including Transmission Losses (MW)	System Energy Consumption Including Transmission Losses (GWH)
1977	323	1,632
1978	352	1,779
1979	384	1,940
1980	419	2,114
1981	457	2,305
1982	498	2,513
1983	527	2,658
1984	557	2,811
1985	589	2,973
1986	623	3,144
1987	659	3,325
1988	695	3,507
1989	733	3,688
1990	773	3,900
1991	815	4.112
1992	860	4,339
1993	907	4,577
1994	956	4,824
1995	1,009	5,091
1996	1,064	5,369
1997	1,122	5,661
1998	1,184	5,974
1999	1,248	6,297
2000	1,316	6,640
2001	1,389	7,009

Source: Reynolds, Smith and Hills, 1981.

4.1.1 CAPITAL COSTS

4.1.1.1 NON-PEAKING ENERGY SUPPLY SOURCES

Soyland's share of the Clinton I nuclear field facility was initially expected to cost $148 million ($1,526 per kilowatt), but recent estimates have increased this cost to $230 million. Fortunately, the installed cost does not affect the selection of peaking alternatives. The availability of the nuclear unit on an annual basis is projected to be 70 percent.

The 450-MW coal-fired facility is currently under design. The current estimate of its total cost is $589.4 million ($1,310 per kilowatt). Availability of the coal unit on an annual basis is projected to be 74 percent.

The cost of the second 450-MW coal-fired facility is estimated to be a 1997 cost of $1,259.7 million ($2,800 per kilowatt).

4.1.1.2 SIMPLE CYCLE COMBUSTION TURBINES

For purposes of this analysis the 210-MW simple cycle combustion turbine facility is assumed to be sited on a 50-acre plot. The facility consists of three 70-MW simple cycle combustion turbines, a fuel oil storage system, a 1,500-square-foot office building, a switch yard, and asphalt access roads.

The total capital cost of 1981 construction of this option was determined to be $52,992,000. Escalation at 8 percent per year plus interest during construction would result in a 1986 installation cost of $84,870,000.

4.1.1.3 COMBINED CYCLE COMBUSTION TURBINES

For purposes of this analysis the combined cycle facility is also assumed to be sited on a 50-acre plot. The facility consists of two 70-MW combustion turbines, each with its own heat recovery steam generator, a 170-MW steam turbine, feed water heating system, condensing system, supporting auxiliary fuel oil storage system, mechanical cooling tower, 1,500-square foot office building, switch yard, and asphalt access roads. Capital costs for this facility if constructed in 1981 were estimated to be $89,900,000. Escalation at 8 percent per year plus interest during construction would result in a 1986 installation cost of $156,940,000.

4.1.1.4 COMPRESSED AIR ENERGY STORAGE FACILITY

This 220-MW facility is assumed to be sited on a 100-acre plot. The facility consists of a 220-MW compressor-motor/generator-turbine train with a recuperator, intercoolers and aftercoolers, compressed air storage cavern, fuel oil storage system, mechanical cooling tower, office building, maintenance building, switch yard, and asphalt access roads. Total capital costs for this facility based on a June 1986 operating date are estimated to be $171,371,000, excluding interest during construction. Including the latter, the total 1986 installed cost is $203,600,000.

4.1.2 OPERATING COSTS

4.1.2.1 SIMPLE CYCLE COMBUSTION TURBINES

Operation and maintenance costs for this facility were estimated on the basis of 25 cents per installed kilowatt capacity per year for fixed costs and $2.70 per 1,000 KWH produced for variable costs in 1978 dollars. Based on an annual usage of 565 hours and an escalating factor of 8 percent, this results in a total operation and maintenance charge of $470,000 for 1981.

4.1.2.2 COMBINED CYCLE COMBUSTION TURBINES

Fixed operation and maintenance costs are estimated to be $4.40 per installed kilowatt capacity per year and variable costs at $1.10 per 1,000 KWA in 1978 dollars. Based on an annual usage of 565 hours and an escalation factor of 8 percent, this would result in the total operation and maintenance charge of $1,328,000 for 1981.

4.1.2.3 COMPRESSED AIR ENERGY STORAGE (CAES)

Operation and maintenance costs are estimated to be $480,000 in 1981, based upon 565 hours of equivalent full-power operation.

Table 4.1.2-1 summarizes capital and operating costs of each peaking alternative. Table 4.1.2-2 summarizes operating costs from 1986 through 2001 for each alternative study. These data show that capital costs of the compressed air energy storage option are significantly higher than combustion turbine options, and operating costs are significantly lower than combustion turbine options.

4.1.3 LEVELIZED COSTS

A detailed economic analysis of peaking options was developed which includes all fixed components of investment and all variable costs. The analysis has two parts. In the first part each unit of generated or purchased capacity is allocated and dispatched each year against the load duration curve according to its economic priority to meet system demand. From the resulting dispatch the energy provided and the fuel consumed by each source is determined. Fuel consumption at part load is determined from heat rate data for each unit. Results from the first part or dispatch portion of the program are then combined with the associated economic parameters in the second part of the program to provide the detailed economic output.

Two complicating factors were encountered in the course of this study. The first is the result of having an alternative which is an energy storage device requiring a daily recharge cycle. To assure acceptable simulation, unit dispatch was based upon seasonal load duration curves instead of the annual load duration curves normally used. The second complicating factor involved accounting for outages of all generating units supplying power. Peaking utilization is dependent upon the operational status of the base load unit. If one or more base load units are unavailable due to forced outage, energy that would normally

Table 4.1.2-1. Fixed and Operating Costs of Peaking Alternatives

FIXED COST OF PEAKING ALTERNATIVES

	Total Investment (M$ for 210 MW)	Annual Ownership Cost (M$ for 210 MW)
Combustion Turbine	84.87	11.37
Combined Cycle	156.94	21.03
Compressed Air Energy Storage	203.60	27.28

OPERATING COSTS OF PEAKING ALTERNATIVES FOR 1986

	Heat Rate at 80-Percent Power [Btu/KWH(HHV)]	Fuel Cost if Operated at Full Power ($/Hr)	O&M Cost if Operated at Full Power ($/Hr)	Cost per Hour if Operated at Full Power ($/H4)
Combustion Turbine	11,888	31,040	1,222	32,260
Combined Cycle	8,658	22,610	3,452	26,060
Compressed Air Energy Storage	4,430*	15,460	1,247	16,710

* The CAES System also uses 0.72 KWH of electrical power for each KWH produced. The "energy" component of purchased power is expected to have a value of $25.75 per MWH in 1986.

Source: Reynolds, Smith and Hills, 1981.

Table 4.1.2-2. Operating Cost Peaking Alternatives for Years 1986 Through 2001

	Cost Per Hour if Operated at Full Power			
	1986	1991	1996	2001
Combustion Turbine	32,260	56,500	99,040	173,770
Combined Cycle	26,060	44,920	77,670	134,700
Compressed Air Energy Storage	16,710	27,680	46,290	78,030

Source: Reynolds, Smith and Hills, 1981.

be produced must be provided by units lower in the dispatch order. This generally results in an increased usage of peaking capacity. To provide an accurate estimate of peaking facility use, it is necessary to use probabilistic methods for determining dispatch. This was done by performing a dispatch for each possible combination of unit outages. The expected value of energy produced by each unit was then determined by weighing each dispatch by the probability of its occurrence. Peaking facilities were assigned a forced outage rate of 8 percent.

The results of this analysis for the three peak generating options show that the compressed air energy storage provides the lowest cost over the study period. The present worth value of all power supply expenses over the 16 years when expressed in millions of 1986 dollars is:

	Peaking Power Cost
Combustion Turbine	452
Combined Cycle	467
Compressed Air Energy System	415

The total annual cost for each alternative is presented in Table 4.1.3-1. These data show that the CAES provides the lowest annual power supply for all years except the initial 2-year period. The annual economic advantage of the CAES facility is compared to other alternatives in Table 4.1.3-2. Towards the end of the study period the advantage of the CAES system over the other two options increases yearly. Extending the study period beyond 2001 would result in increasing the financial advantage of the CAES facility.

In summary, financial analyses of three options for meeting peaking power demands show that the CAES system has a $37 million advantage over the simple combustion turbine option and a $52 million advantage over the combined cycle combustion turbine option. On a year-by-year basis, the CAES facility provides a lower power supply cost for all years

Table 4.1.3-1. Annual Peaking Power Supply Cost

Year	Combustion Turbine Alternative	Combined Cycle Alternative	Compressed Air Energy Storage Alternative
1986*	25.6 M$	32.5 M$	34.6 M$
1987	40.7	44.6	42.3
1988	42.8	46.2	43.1
1989	44.9	47.8	44.0
1990	47.0	49.4	44.9
1991	49.2	51.1	45.8
1992	51.4	52.8	46.6
1993	43.0	53.9	47.2
1994	54.3	54.9	47.6
1995	55.4	55.6	47.9
1996	56.1	56.1	48.1
1997	64.2	62.3	51.5
1998	68.0	65.2	53.2
1999	72.0	68.2	54.8
2000	76.2	71.3	56.4
2001	80.4	74.5	58.0
Present Worth for Period 1986-2001	452 M$	467 M$	415 M$

* Cost for 1986 reflects 12 months of peaking unit availability.

Source: Reynolds, Smith and Hills, 1981.

Table 4.1.3-2. Annual Economic Advantage of CAES Facility Compared to Other Alternatives

Year	Additional Cost of Combustion Turbine Facility (Millions of Dollars)	Additional Cost of Combined Cycle Facility (Millions of Dollars)
1986*	(0)†	(2)
1987	(2)	2
1988	0	3
1989	1	4
1990	2	4
1991	3	5
1992	5	6
1993	6	7
1994	7	7
1995	7	8
1996	8	8
1997	13	11
1998	15	12
1999	17	13
2000	20	15
2001	22	17
Present Worth for Period 1986-2001	37	52

* Cost for 1986 reflects 12 months of peaking unit availability.
† Parentheses indicate that designated alternative has lower cost than does the CAES for the specified year.

Source: Reynolds, Smith and Hills, 1981.

except the first three. For years 1986 through 1987 a combustion turbine facility would provide the lowest cost. After 1988, the advantage of the CAES facility increases each year. The economic advantage of the CAES facility continues to increase after 2001.

4.2 ENVIRONMENTAL CONSIDERATIONS

4.2.1 ECOLOGY

Impacts to ecological systems resulting from construction and operation of a CAES power plant can be broadly grouped as follows: air emissions, habitat loss, noise, human activity, waste handling, and water use.

4.2.1.1 POTENTIAL IMPACTS TO AQUATIC ECOSYSTEMS

CAES systems impact or may impact aquatic ecosystems in the following manner:

1. Sedimentation and siltation during construction,
2. Entrainment/impingement of aquatic organisms during water withdrawal,
3. Discharges of blowdown and other wastes, and
4. Leachates and runoff from waste and raw material storage areas.

The degree of impact associated with each of the above is determined in general by the size and capacity of the CAES facility, techniques utilized in construction of the facility, and the design and operation of waste handling or treatment facilities, and water intake structures. Impact is also determined by characteristics of the aquatic systems on or near the site.

Sedimentation and Siltation

During construction of any power generation facility a certain amount of land must be disturbed. This can result in erosion producing turbidity and sedimentation in watershed streams and can influence the hydrology of those streams. Impact of land disturbance depends primarily upon:

1. Amount of land disturbed,
2. Soil and topographic characteristics,
3. Soil erosion control techniques utilized during construction, and
4. Size and characteristics of watershed streams.

Entrainment/Impingement

Whenever water is withdrawn from a surface water, organisms will be withdrawn as well. CAES systems require water withdrawal for cooling purposes and possibly as makeup to the compensation reservoir. The water requirements depend upon the type of cooling system utilized and the size of the compensation reservoir. Once-through cooling systems require several times the water requirement of a recirculating system.

The number of organisms entrained or impinged by a CAES facility depends on the intake volume and velocity, the intake screen system, and characteristics of the aquatic habitat providing the water. A well-designed intake structure located in a non-prime biological area generally minimizes entrainment/impingement losses.

Waste Discharge

The major wastes which may be generated by CAES systems are blowdown from the cooling system and compensation reservoir, oily wastes, and demineralizer sludge. Discharges from cooling systems may periodically contain residual biocides (e.g., chlorine) utilized in biofouling control. Most wastes can be stored or treated on site with little discharge to surface waters. Often blowdown is discharged into surface waters, and once-through cooling systems return significant quantities of water at higher temperatures to surface waters.

Thermal and chemical discharges can significantly impact aquatic biota depending on quantities and constituents of the discharges, the dilution potential of the receiving water, and the sensitivity of biota present.

Leachates and Runoff

CAES systems may generate some solid wastes that may be stored or treated on site. Those wastes associated with using oils have a toxic potential for aquatic organisms (Dvorak et al., 1978). In most cases, the wastes can be disposed on site.

Given the previously-mentioned impact sources, a number of parameters must be considered with regard to aquatic ecosystems in Illinois and specific CAES site evaluation. The volume and hydrologic regime of the aquatic systems is an important determinant of impact. Larger rivers should not be seriously affected by water withdrawals or discharges, assuming a closed-cycle cooling system and a properly designed intake structure. Many small streams carry a relatively small volume of water, especially during summer dry periods. In addition, smaller streams often have greater habitat diversity and assemblages of fauna more sensitive to environmental stresses, relative to the larger rivers.

There are no federal threatened or endangered fish species known in Illinois; but a number of state threatened, endangered, or otherwise sensitive species are known, primarily from the Illinois and Mississippi Rivers and several smaller rivers. A number of federally listed mussels occur in Illinois, primarily in the upper Mississippi and Wabash Rivers. The full projection of impact of the CAES facility in Illinois requires a complete assessment of aquatic habitats and biota on the specific site.

Because the power at a CAES plant is generated by compressed fuel oil or natural gas, direct emissions from the plant are relatively low. Emission rates of all pollutants are far below levels considered harmful to plants or animals.

CAES facilities are highly automated and thus little human activity occurs around the plant site. Energy entering the plant is in the form of electricity, fuel oil, or natural gas, and little waste is generated. Consequently, little activity is required to facilitate fuel delivery and waste storage. Because of the low levels of human activity, few animals will be disturbed by people and machines moving around the plant site. Noise from operation of the turbines, particularly when compression is initiated, can be significant. This impact can be reduced considerably by carefully siting the plant and incorporating sound dampening elements into plant construction.

Intake and discharge of water will have little effect upon terrestrial systems. Even with a once-through cooling system little water is used, and unless the plant is located in an area with a severe water shortage, terrestrial organisms should not be affected.

Cumulative Effects

The severity of potential impacts associated with a CAES plant will be determined by the sensitivity of the local environment to disturbances and the measures taken to mitigate impacts. None of the predicted CAES impacts are considered to have critical or severe effects upon ecological systems. However, the cumulative effect of the impacts might be significant.

Because all CAES plants require another generating facility to provide energy for compressing air, impacts from that facility should be evaluated with direct impacts from the CAES plant. In most instances the plant that supports the CAES plant will be the primary generating unit providing base load electricity needs. As such, that unit will create impacts separate from those of the CAES plant. However, operation of the CAES plant will require that the primary plant generate more electricity more efficiently, and impacts, particularly noise and water and air emissions, may be higher.

4.2.1.2 POTENTIAL IMPACTS TO TERRESTRIAL ECOSYSTEMS

A CAES facility can be constructed on less than 100 acres of land; therefore, loss of significant habitat for terrestrial organisms is not a major impact. When such a small land area is required, important habitats can be avoided through careful siting. Only when the entire region being considered for siting is composed of relatively undisturbed land (e.g., in some portions of the western United States) will habitat loss be a major CAES impact.

Potential Impacts from a Proposed CAES Plant in Illinois

Impacts of CAES systems vary with specific characteristics of individual systems. Primary factors determining impact upon terrestrial ecosystems include:

1. Output of system,
2. Land requirement of system,
3. Fuel utilized,
4. Water requirements, and
5. Ecological characteristics of the site.

Aquatic Impacts

The CAES system planned by Soyland will have a design output of 220 MW and will require a permanent site of 35 to 50 acres with up to 100 acres disturbed during construction. Provided that significant ecological habitats are avoided and that sound revegetation and erosion control techniques are utilized, impacts from land disturbance should be low.

The proposed CAES system could withdraw a daily average of 750 gpm with a maximum withdrawal of 1,200 gpm. Assuming that withdrawal would be from a major waterway such as the Mississippi or Illinois River, this volume would represent less than 1 percent of the river flow during 7-day, 10-year low flows. Entrainment/impingement impacts on existing fish populations should not be significant.

Fuel oil would be utilized to heat compressed air during the generation phase. The utilization of oil will produce minimal air emissions and waste generation. Some oily wastes will be created, but oil will be contained in tanks or transported off site.

Demineralizer sludge blowdown will result from the closed-cycle cooling system. Demineralizer sludge has limited toxic potential and can be stored on site. Blowdown, heated and periodically containing biocide residuals, will probably be discharged to surface waters. Such discharge must meet Illinois EPA mixing zone standards. The zone in which blowdown levels will exceed standards should be limited to an area less than 1 acre in size and should therefore have minimal impact on a major water body.

Terrestrial Impacts

The Illinois Department of Conservation has created an inventory of all significant natural areas within the state, and this information can be used in siting the Soyland CAES plant so that the identified areas can be avoided. Areas known to support federal threatened and endangered species will be avoided during siting. In Illinois the primary federal species of concern are the bald eagle, Indiana bat, and gray bat.

Minimal waste will be generated by the Soyland plant because diesel fuel oil will be used to fire the turbines. The volumes of intake and discharge water will be relatively low. Because waste generation and water consumption are relatively minor operations of the proposed plant, impacts associated with them are not expected to be ecologically significant.

Air emissions from the 220-MW Soyland CAES facility should not have measurable effects upon terrestrial organisms. Because fuel oil is being burned, sulfur dioxide emissions will be low. All ambient air quality standards can be met as long as the plant is located outside designated nonattainment areas (i.e., localities that currently have significant air pollution problems).

The Soyland unit will be highly automated and thus will require little human activity. Subsequently, little disturbance to adjacent wildlife will occur. The noise associated with the compression of air and operation of turbines may, however, be great enough to affect animals in the nearby vicinity of the plant. The creatures most susceptible to noise would be those dependent upon sound to find prey, to attract mates, or to avoid predators. Animals which are particularly wary of man would also likely be disturbed by noise at the CAES plant.

The cumulative effects of impacts from the Soyland CAES plant should not be significant, but firm conclusions cannot be drawn until the plant site is selected and site-specific impacts are defined more clearly. The base load electrical generating station supporting the Soyland CAES plant will operate at a higher capacity factor than if it were not supporting a CAES plant. All impacts of the base load plant except habitat loss may increase because of this higher factor.

4.2.1.3 COMPARISON OF ECOLOGICAL IMPACTS FROM DIFFERENT FACILITIES

The following discussion compares potential ecological impacts of a CAES facility with those of a gas turbine facility and a conventional coal-fired facility of equal output. Table 4.2.1-1 summarizes impact sources discussed.

Aquatic Ecosystems

Potential impacts of power generation upon aquatic systems include:

1. Withdrawal of water from natural aquatic systems,
2. Thermal/chemical discharges to surface waters,
3. Leaching and runoff from waste and raw material storage areas, and
4. Disturbance of natural soil and ground-cover systems.

Water Intake Structures and Withdrawals

The withdrawal of water from natural surface sources provides a potential for significant impacts upon aquatic ecosystems via entrainment and impingement of aquatic organisms, especially fish. Entrainment/impingement of fish is of greatest concern and the number of fish impacted depends upon several factors, the most important of which are the ratio of withdrawal volume to source volume, the location of the intake structure, and characteristics of fish populations present.

Gas turbine systems utilize minimal water except for domestic use (which can be supplied by ground water). Therefore, the gas turbine facility presents no potential for impact due to entrainment/impingement.

Both the CAES and coal-fired facility would utilize withdrawal from a surface source. The CAES facility requires one-half to one-third the water required by the coal-fired facility (see Table 4.2.1-1), therefore entrainment/impingement impacts would be less for the CAES facility.

Table 4.2.1-1. Comparative Summary of Ecological Impact Sources for Three Types of Electrical Generating Facilities

	CAES	Coal-Fired	Gas Turbine
Land Required	100 acres	400 to 500 acres (Dvorak et al., 1978)	25 to 35 acres
Water Intake from Surface Source	750 gpm Daily Average 1,200 gpm Maximum	2,200 gpm Daily Average 2,700 gpm Maximum	No appreciable use except domestic consumption
Waste Generation	Demineralizer sludge Blowdown	Fly Ash/Bottom Ash Scrubber sludge Water treatment wastes FGD sludge Blowdown	No appreciable waste except domestic
Raw Material Storage	Fuel Oil (Tanks and/or Pipeline)	Open coal storage	Light oil or LNG (tanks and/or pipeline)
Air Emissions	See Text Table 4.2.2-1	See Text Table 4.2.2-1	See Text Table 4.2.2-1
Noise	High noise levels during compressor startup and turbine operation	Lower noise levels than CAES and turbine facilities	Constant high noise level due to turbine operation

Source: ESE, 1981.

Land Requirements

All three load facilities will disturb and permanently alter existing habitats. The coal-fired facility will utilize several times the acreage utilized by the other systems. The gas-turbine facility would utilize the least acreage.

Greater land requirements increase the potential for perturbation of aquatic systems due to siltation and sedimentation during construction. Sound construction techniques and erosion safeguards can minimize erosional inputs.

The increase in land acreage committed to a power facility may also produce hydrologic changes in watershed streams. Holding stormwater on the site could reduce overall water levels in streams and possibly reduce wetland habitats during reduced flow periods.

Neither the gas-turbine or CAES facility would have appreciable ecological effect considering the acreages involved.

Waste Generation

The generation and disposal of waste products are significant from an aquatic standpoint when a potential for contamination of aquatic systems by toxic materials exists. With proper methods of treatment and disposal this should not be a significant impact source with any of the three generation facilities.

The CAES facility is a low (relative to a coal-fired facility) generator of wastes, producing primarily blowdown from the cooling system and compensation reservoir, demineralizer sludge from any water pretreatment system, and oily wastes. All have some toxic potential. The gas-turbine system produces no appreciable waste products other than sanitary and domestic wastes, which have limited toxic potential.

The coal-fired facility would produce a number of wastes in appreciable quantities and with toxic potential (Dvorak et al., 1978), including fly ash, bottom ash, and scrubber sludges as well as wastes from the boiler water treatment system and cooling system blowdown. These wastes are of limited impact if handled properly. Waste generated in the coal-fired facility, notably the ashes and sludges, have toxic potential for aquatic organisms in the form of heavy metals and other trace elements. Especially sensitive are fish and benthic invertebrate communities.

Blowdown from cooling water systems (not a component of the gas-turbine facility) periodically contains residual chlorine or other biocide utilized to control biofouling. The biocides, being toxic to aquatic biota, can have adverse impacts when discharged into aquatic systems. The probable blowdown volumes should have negligible impact when discharged into major waterways.

Raw Material Storage

Uncontrolled surface runoff or leaching from coal piles at a coal-fired plant can result in heavy metals and other trace elements as well as low pH solution entering aquatic systems and producing potentially toxic situations. Coal-fired facilities will utilize open coal storage.

Only liquid fuels are utilized at the CAES and gas-turbine facilities, and these fuels are contained in tanks or pipelines. No other potentially toxic materials are stored on site.

Air Emissions

Emissions from fossil fuel facilities are not usually of major concern in terms of impacts on aquatic environments. Regional problems such as acid deposition are of concern in the northeastern United States, but individual facilities have not been identified as having significant impacts on aquatic systems on or near sites. A more detailed discussion of air emission impacts is provided in Section 4.2.1.2.

Terrestrial Ecosystems

Fossil fuel electric generation facilities impact or potentially impact terrestrial ecosystems more than aquatic ecosystems. To estimate impacts upon terrestrial ecosystems it is necessary to evaluate the following:

1. Habitat alteration and disturbance,
2. Effects of air emissions upon terrestrial biota,
3. Effects of waste and raw material storage and handling, and
4. Noise/activity impacts.

Land Required/Land Use

A major impact of power facility development on terrestrial ecosystems is the alteration of habitats and land use patterns.

Gas-turbine facilities utilize the least land and CAES facilities only slightly more, so these facilities would have the least impact from a land use standpoint. Coal-fired facilities require four to eight times the land required by other facilities and, therefore, represent a more significant impact from habitat alteration or loss.

Neither the CAES nor the gas-turbine facility causes a significant degree of habitat alteration or loss. The coal-fired facility does represent a potentially significant land use. Ultimate impacts, of course, depend on the habitat types lost or altered.

Water Intake

The withdrawal of water from surface sources does not impact terrestrial systems.

Waste Generation

Waste generation may impact terrestrial ecosystems via: (1) habitat loss or alteration, and (2) toxic substances (heavy metals and other trace elements).

Neither CAES nor gas-turbine facilities produce appreciable quantities of wastes potentially toxic to terrestrial biota. In coal-fired facilities these wastes must be handled and contained properly if they are not to adversely impact terrestrial ecosystems.

Leachates or runoff from ash and sludge storage areas contain metals and other trace elements which can be accumulated in plant tissues to potentially toxic levels. Potential toxins can enter faunal food chains via plant tissues (Dvorak *et al.*, 1978).

Raw Material Storage

Open storage of raw materials is of concern only with coal-fired facilities, which require open storage of large coal volumes. Neither CAES nor gas-turbine facilities require open storage of materials; the major raw material required is liquid fuel, which will be stored in tanks and/or supplied via pipelines.

Open coal storage presents the same impact potential for terrestrial ecosystems as the handling and disposal of wastes discussed previously (Dvorak *et al.*, 1978).

Air Emissions

The burning of fossil fuels produces several products (notably sulfur dioxide, nitrogen oxides, and particulate matter) that are potentially toxic to or may have an adverse impact upon terrestrial organisms.

The three facilities may be ranked as follows in terms of increasing air emission levels; (1) CAES, (2) gas-turbine, and (3) coal-fired. Gas-turbine facilities produce about three times the emissions of a CAES facility, and coal-fired facilities produce several times the emissions of gas turbine facilities. Table 4.2.2-1 presents comparative emission information for the two facilities.

Table 4.2.2-1. Comparative Emissions Data* for Two Types of 220-MW Electrical Generating Facilities

	Sulfur Dioxide	Nitrogen Oxide	Partic-ulate Matter	Carbon Mon-oxide	Hydro-Carbons
CAES Facility	616	406.8	30	92.4	33.4
Gas-Turbine Facility	1,850	1,220	90	275	100

* Uncontrolled Emissions (lb/hr).

† All emissions based on emission factors from U.S. EPA documents AP-42, Table 1.2-1, April 1977, and Standard Combustion Calculations.

Source: ESE, 1981.

Sulfur dioxide emissions are of concern as they can be acutely or chronically toxic to plant tissues given sufficient exposure. CAES facilities are not projected to produce sulfur dioxide levels sufficient to result in adverse impacts upon vegetation. Emissions from gas turbine facilities may have some adverse impact, while coal-fired facilities have the greatest potential. Emissions from all facilities can be controlled to minimize potentially toxic conditions.

Comparatively, emissions from a coal-fired 220-MW facility increase the potential for impact upon terrestrial communities on or near site, especially those frequently fumigated.

Projections from air quality modeling for the three facilities indicate the following highest 3-hour concentrations of emissions:

CAES	25 ug/m^3
Gas-Turbine	75 ug/m^3
Coal-fired	219 ug/m^3

Comparing these concentrations to literature values (Dvorak et al., 1978) for chronic or acute toxicity suggests that, by themselves, none of the facilities presents a significant toxicity potential. However, ultimate impact depends upon the sensitivity of habitats on or near site.

Toxicity of air emissions to animals is low relative to that for vegetation, and projected emissions are well below levels of toxicity to animal life.

Noise

Elevated noise levels can have adverse impact on terrestrial wildlife. The major impact of noise is to disrupt or alter natural behavior patterns resulting in the eventual displacement of wildlife populations or individuals.

Of the three facilities being considered, the gas turbine and CAES facilities probably have a greater noise potential than the coal-fired facility due to the utilization of turbines and compressors. The gas turbine facility would produce higher continuous noise levels than either of the other two types, but the CAES facility produces periodic elevations of noise during compressor startup and turbine operation.

Wildlife may acclimate more quickly to constant noise levels than to fluctuating noise levels. Therefore, the CAES facility may have the greatest noise impact potential.

4.2.2 LAND USE/SOCIOECONOMICS

Socioeconomic parameters surrounding a CAES system include existing and planned land uses; site land requirements; demographic, economic, housing and fiscal impacts together with community services and facilities; transportation and electric transmission accessibility; and archaeological and historical impact considerations. The proposed 220-MW compressed air energy storage system will require a site of approximately 100 acres, a construction labor force averaging 80 to 85 workers (maximum of 120 workers at one time), with 15 to 20 professionals, and an ideal operating work force of one technician per shift, generating total populated impact, primary and secondary, of less than 25 people new to the region. The construction duration is short; therefore the construction workers will tend to commute rather than relocate, with resultant secondary socioeconomic impacts being small.

In comparison, a coal-fired electric generating plant of similar size would require several hundreds of acres, 400 to 600 construction workers and 40 to 50 operations personnel, generating around 200 new residents for the affected region. Construction of a coal-fired plant takes longer than a CAES plant. Therefore, construction workers may tend to relocate. Secondary impacts, therefore, will be greater than with a CAES plant.

A 220-MW combustion turbine peaking unit requires 25 to 35 acres, 50 to 80 (maximum) construction workers, and 3 to 5 operating personnel on a less than 24 hour basis. Construction of a combustion turbine is short-term, generating few or no primary or secondary impacts.

Regionally, Illinois is a heavily farmed state. Densely populated, large urbanized areas are also located throughout Illinois. As large tracts of land suitable for coal-fired generating plants are less available, the smaller land requirements of a combustion turbine or a CAES system result in a greater number of socioeconomically-acceptable sites. The combustion turbine, however, is generally located adjacent to an electric generating plant, thus narrowing preferred site selections. Adverse impacts from a CAES system are therefore more readily avoided.

Transportation and electrical transmission accessibilities are increased significantly with the lower acreage requirement and greater site selection. The CAES plant will be more easily located in proximity to highways and rail lines, with decreasing equipment and fuel transportation costs, and closer to existing appropriate-voltage power lines for electrical transmission. Fuel transport for a combustion turbine or a CAES plant is by road and rail. Bulk handling facilities are necessary for coal-fired plants (barges, loading/unloading, etc.). Storage facilities are significantly larger for a coal-fired plant and include requirements for disposal of sludge and ash in addition to simple storage.

Overall, above-ground land and storage requirements and facilities for a combustion turbine or a 220-MW CAES plant are significantly less than for a coal-fired electric generating plant of similar size. Prime farmland avoidance is facilitated by the lower land requirement, as is possible avoidance ot archaeological and historical sites. The small labor force requirements of the combustion turbine and the CAES plant will effect fewer demographic changes and housing impacts. Demands placed upon community services and facilities are expected to be less than those of a coal-fired plant.

Combustion turbines, CAES, and coal-fired generating plants generate positive economic and fiscal impacts which should more than offset any fiscal constraints placed upon local jurisdiction with regard to increased services and possible capital improvements. Because a coal-fired generating plant has more land and facility requirements, the *ad valorem* tax generated should be significantly higher than for the combustion-turbine or CAES facility.

4.3 REGULATORY CONSIDERATION

The primary federal acts, regulations, and policies governing the licensing and permitting of a CAES facility are similar to policies governing other power generation facilities. A listing of major federal and state regulatory programs associated with CAES permitting and licensing is presented in Table 4.3-1.

The major prerequisites for permitting and licensing activities for CAES facilities can be found in the body of environmental law initiated with passage of the National Environmental Policy Act (NEPA) of 1969, and the Council of Environmental Quality (CEQ) Regulations for the implementation of NEPA procedures. Subsequent regulatory programs which exert an influence on the licensing procedure for CAES facilities are described in this section.

4.3.1 POWER PLANT AND INDUSTRIAL FUEL USE ACT OF 1978

In response to the oil embargo initiated in the early and mid 1970's, the Power Plant and Industrial Fuel Use Act was implemented in 1978. Its main objective is to minimize utilization of natural gas and petroleum as primary energy sources. Since a number of CAES designs are for the utilization of one or more of these fuels in the generation cycle, a special exemption from the fuel use prohibitions must be obtained. Based on current economic and energy supply conditions, however, exemptions have been granted for a number of combustion-turbine as well as conventional gas-burning power facilities. Section 212 of the Fuel Use Act (FUA) provides several alternatives for fuel use exemption.

As a preliminary step to the development of a 220-MW CAES facility, Soyland has applied for and obtained a permanent fuel mixture exemption from the Act. It is therefore considered that future CAES development should not be hampered by the FUA requirements.

Table 4.3-1. Federal, State, and Local Permits and Reviews Associated with CAES Licensing

Federal Permits/Studies	Associated Laws
EIS Review	National Environmental Policy Act of 1969 (PL 42 USC 4321 et seq.), Executive Orders 11514 and 11991 and CEQ Regulations of 11/29/78
EIS Review	Rural Electrification Administration Bulletin 20-21
FUA Exemption	Power Plant and Industrial Fuel Use Act
NPDES Permit (EPA; 316 Studies)	Federal Water Pollution Control Act, 1972 (FL 92-500)
Sections 401 & 404 Permits (COE)	Federal Water Pollution Control Act, Sections 401 & 404, 1972 (PL 92-500), Executive Order 11990 (Wetlands), 1977
SDWA/UIC	Underground Injection Control Permit 40 CFR 146--Also Provides for Class V well classification
Section 10 Permit (COE)	Rivers and Harbors Act of 1899 (33 USC 401-413)
SPCC Plan	EPA Spill Prevention Counter Measure Control Plan--Section 311(b) (3) CWA
EIS Review	Flood Disaster Protection Act, 1973 (PL 93-234)
EIS Review	Executive Order 11988 (Floodplains)
EIS Review	Safe Drinking Water Act, 1974 (PL 93-523)
EIS Review	National Historic Preservation Act, 1974

Table 4.3-1. Federal, State, and Local Permits and Reviews Associated with CAES Licensing (Continued Page 2 of 3)

Federal Permits/Studies	Associated Laws
EIS Review	Archaeological and Historical Preservation Act, 1974 (PL 93-291)
EIS Review	Executive Order 11593 (Historic Places), 1971
EIS Review	USDA Secretary's Memo 1827, revised 1978 (Land Use Policy)
EIS Review	CEQ's Memorandum for Heads of Agencies, 1976
Section 7 Consultation: Biological Assessment	Endangered Species Act of 1973, amended 1978 (PL 93-205)
NSPS	40 CFR 60, Subpart GG, Sept. 10, 1979, and as amended Dec. 5, 1980
PSD/BACT	Clean Air Act Amendments, 1977 (42 USC 7476(C))
Tall Structures Permit	Federal Aviation Regulation, Part 77

State Permits/Studies	Associated Laws
Water Supply	Illinois Statute 111 1/2; Illinois Department of Public Health
Water Pollution	Illinois Statute 111 1/2; Illinois EPA Rules and Regulations, Chapter 3
Solid Waste	Illinois Statute 111 1/2; Illinois EPA Rules and Regulations, Chapter 7
Noise	Illinois Statute 111 1/2; Illinois EPA Rules and Regulations, Chapter 8
Mining	Illinois Statute 111 1/2; Illinois EPA Rules and Regulations, Chapter 4

Table 4.3-1. Federal, State, and Local Permits and Reviews Associated with CAES Licensing (Continued Page 3 of 3)

State Permits/Studies	Associated Laws
Air	Illinois Statute 111 1/2; Illinois EPA Rules and Regulations, Chapter 1
Administrative Procedures	Illinois Statute 111 1/2; Illinois EPA Rules and Regulations, Chapter 1
Canals and Waterways	Illinois Statute 19; Illinois Department of Transportation
Drainage	Illinois Statute 42; Illinois Department of Transportation
Roads and Bridges	Illinois Statute 121; Illinois Department of Transportation
Wells	Illinois Department of Mines and Minerals
Nature Preserves	Illinois State Park and Nature Preserves Act of 1925

Local Permits	Associated Laws
Zoning Permits, Variances, and Special Permits	Zoning Ordinances Comprehensive Plans

Source: ESE, 1981.

4.3.2 AIR PERMITTING CONSIDERATIONS

Air emissions produced during the generation phase are released via a chimney structure (stack) as on conventional power facilities. Such emissions from a CAES facility must be in compliance with the requirements of the Clean Air Act of 1970 as amended. Under the Clean Air Act power generation facilities are required to meet specific standards of performance as well as the requirements for prevention of significant deterioration, if applicable.

On September 10, 1979, EPA promulgated New Source Performance Standards (NSPS) for Stationary Gas Turbines. These standards, as originally promulgated and later amended on December 5, 1980, are defined in Title 40, Part 60, Subpart GG, of the Code of Federal Regulations. NSPS for stationary gas turbines with greater than 100 million Btu per hour heat input are given in Table 4.3-2. Since the CAES facility utilizes gas-turbine technology (it is a gas-turbine plant adapted with facilities to store compressed air for use during the normal peak period power generating mode), NSPS for stationary gas turbines will be applicable.

As presented in Table 3.1-1 (Section 3 of this document), the emission rates for a 220-MW net capacity oil-fired CAES gas turbine facility fall below NSPS limits established for both sulfur dioxide and nitrogen oxides. These limits are attainable without the need for any special air pollution controls. Proper burner design coupled with good operating practice is all that is necessary to meet NSPS limits. It should be noted, however, that for CAES gas-turbine plants with higher output capacities this observation may not be wholly valid. That is, some form of added "control" (water injection for nitrogen oxides control, for example) may be required to meet NSPS limits as a result of higher fuel rates, combustion zone temperatures, and potentially different excess air rates. In addition, the turbine exhaust gas release height (stack height) may have to be increased in order to maintain a minimal impact on ambient air quality.

Table 4.3-2. Federal New Source Performance Standards for Stationary Gas Turbines (>100 million Btu per hour)

Pollutant	Existing Standards
Sulfur Dioxide	(a) $\leq$0.015 percent by volume at 15-percent oxygen, on a dry basis, or (b) Fuel sulfur content $\leq$0.8 percent by weight
Nitrogen Oxides	$0.0075 \frac{(14.4)}{Y^{(1)}} + F^{(2)}$

(1) Y = manufacturer's rated heat rate at manufacturer's rated load (kilojoules per watt hour); Y shall not exceed 14.4 kilojoules per watt hour.

(2) F = NO_x emission allowance for fuel-bound nitrogen.

Sources: Code of Federal Regulations, Title 40, Part 60, Subpart D.
Federal Register, Vol. 44, No. 113, June 11, 1979.

Although larger capacity CAES plants may be required to include some form of air pollution control in the plant design in order to meet NSPS requirements, little difficulty should be encountered in meeting Ambient Air Quality Standards (AAQS) and Prevention of Significant Deterioration (PSD) increment limits. The impact levels predicted for the 220-MW net capacity gas turbine CAES plant are at or below PSD significance levels and therefore clearly indicate that the air pollutant emissions of larger facilities would generate a minor impact on AAQS and only minimal impact on PSD increment consumption. A CAES gas turbine plant that is ten times the capacity of the 220-MW plant would consume only about one-half to two-thirds of the available PSD increments for sulfur dioxide in a Class II area and only 15 to 20 percent of the total AAQS limits.

4.3.2.1 PREVENTION OF SIGNIFICANT DETERIORATION (PSD)

On December 5, 1974, U.S. EPA, under 40 CFR, Part 52, promulgated PSD air quality regulations. Revised PSD regulations promulgated by U.S. EPA in June 1978 incorporated the requirements of the Clean Air Act Amendment of 1977 (Public Law 95-95). Specifically, Section 52.21 (and various subsections) require that U.S. EPA review certain new source categories to ensure compliance with air quality increments, ambient air quality standards, and Best Available Control Technology (BACT).

4.3.2.2 FEDERAL PSD REGULATIONS APPLIED TO CAES

Revised federal PSD regulations promulgated in the *Federal Register* on August 7, 1980, and incorporated into the Code of Federal Regulations, Title 40, Part 52, will be applicable to CAES facilities. The definition of a "major stationary source" includes plants larger than 250 million Btu-per-hour input which also emit more than 100 tons per year or more of any air pollutant subject to regulation under the Clean Air Act.

4.3.2.3 AMBIENT AIR QUALITY STANDARDS

As a result of requirements of the 1970 Amendments of the Clean Air Act, U.S. EPA enacted Primary and Secondary National Ambient Air Quality

Standards (AAQS) (Federal Register, 1971) for six air pollutants. Primary National AAQS protect the public health, and Secondary National AAQS protect the public welfare from any known or anticipated adverse effects associated with the presence of pollutants in ambient air. Table 4.3-2 presents existing applicable National AAQS. Pollutants for which AAQS have been established are termed "criteria" pollutants. Areas of the country shown to be in violation of any AAQS are designated as nonattainment areas, and new or modified sources to be located in or near these areas may be subject to more stringent air permitting requirements.

Under PSD review requirements, all major new sources of air pollutants regulated under the Clean Air Act must be reviewed and approved by U.S. EPA (or by the state, if review authority has been delegated to the state). A "major stationary source" is defined as any one of 28 named source categories which has an emissions potential of 100 tons per year or more, or any other stationary source with an emissions potential of 250 tons per year or more of any pollutant regulated under the Clean Air Act. "Potential to emit" means the capability at maximum design capacity to emit a pollutant after application of control equipment.

Congress, in promulgating the 1977 Clean Air Act Amendments, and U.S. EPA by implementing this legislative requirement, specified that certain increases above an air quality "baseline" level of sulfur dioxide and total suspended particulate concentrations would constitute significant deterioration. The exact increment cannot be exceeded and depends upon the classification of the area impacted by a new plant (or major modification). Three classifications were designated depending on the criteria established in the Clean Air Act. Initially, Congress promulgated areas as Class I (international parks, national wilderness areas, and memorial parks larger than 5,000 acres, and national parks larger than 6,000 acres) or Class II (all other areas not designated as Class I). No Class III areas, which allow greater deterioration than Class II areas, were designated. Table 4.3-3 presents PSD increments.

Table 4.3-3. Ambient Air Quality Standards (AAQS) and Prevention of Significant Deterioration (PSD) Allowable Increments

Pollutant	Averaging Time	AAQS Primary Standard	AAQS Secondary Standard	Class I	Class I	Class III
Suspended Particulate Matter	Annual Geometric Mean	75 ug/m^3	60 ug/m^3	5	19	37
	24-Hour Maximum*	260 ug/m^3	150 ug/m^3	10	37	75
Sulfur Dioxide	Annual Arithmetic Mean	80 ug/m^3		2	20	40
	24-Hour Maximum*	365 ug/m^3		5	91	182
	3-Hour Maximum*	NA†	1,300 ug/m^3	25	512	700
Carbon Monoxide	8-Hour Maximum*	10 mg/m^3	10 mg/m^3	†	†	†
	1-Hour Maximum*	40 mg/m^3	40 mg/m^3	†	†	†
Hydrocarbons	3-Hour Maximum* (6 to 9 a.m.)	160 ug/m^3	160 ug/m^3	†	†	†
Nitrogen Dioxide	Annual Arithmetic Mean	100 ug/m^3	100 ug/m^3	†	†	†
Ozone	1-Hour Maximum*	235 ug/m^3	235 ug/m^3	†	†	†
Lead	Calendar Quarter Arithmetic Mean	1.5 ug/m^3	1.5 ug/m^3	†	†	†

* Maximum concentration not to be exceeded more than once per year.
† No standard exists.

Source: U.S. Environmental Protection Agency, 1979.

In accordance with requirements of 40 CFR 52.21(m), any application for a PSD permit must contain, for each pollutant regulated under the Clean Air Act, an analysis of continuous (up to 1 year) ambient air quality data in the area the proposed major stationary source or major modification would affect. For a new source, the affected pollutants are those that the source would potentially emit in a significant amount. For a modification, the affected pollutants are those which would have a net increase by a greater-than-significant amount.

The regulations, however, include an exemption which excludes or limits the pollutants requiring an air quality analysis. This exemption states that the monitoring requirements of 40 CFR 52.21(m) shall not apply to a proposed major stationary source or major modification with respect to a particular pollutant if the emissions increase of the pollutant from the source or modification would cause, in any area, air quality impacts less than certain de minimis levels.

PSD regulations specifically require using atmospheric dispersion models to perform impact analysis, estimate baseline and future air quality levels, and determine compliance with AAQS and allowable PSD increments. Designated U.S. EPA models usually must be used. Specific applications for other than U.S. EPA-approved models require U.S. EPA's consultation and prior approval.

The 1977 Clean Air Act Amendments specify that the degree of emission limitation required for control of any pollutant cannot be affected by a stack height exceeding good engineering practice (GEP) or any other dispersion technique. U.S. EPA promulgated proposed stack height regulations on January 12, 1979. GEP stack height is defined as 30 meters, or as the height of the nearby structure plus 1.5 times the lesser dimension of the height or width, whichever is greater.

4.3.2.4 BEST AVAILABLE CONTROL TECHNOLOGY

Determining the Best Available Control Technology (BACT) is required by U.S. EPA pursuant to PSD regulations for all new major sources of any pollutant. U.S. EPA requires that the owner of the source, or a representative for each different point emission source, prepare a form which evaluates the environmental, energy, and economic impacts of selected and alternative control techniques.

4.3.2.5 ATMOSPHERIC DISPERSION MODELING IMPACT ANALYSIS

An atmospheric dispersion modeling impact analysis of ambient air quality levels is required under PSD regulations. The air quality impact analysis must demonstrate that the proposed source will not cause or contribute to a violation of either maximum allowable PSD increments or AAQS. U.S. EPA modeling guidelines must be followed in performing the analysis for respective review agencies, or prior approval must be obtained for significant deviations from these guidelines.

In addition to air quality impact analyses, federal PSD regulations require additional analyses on impairment to visibility and impacts upon soils and vegetation which would occur as a result of the source. This analysis is to be conducted primarily for Class I PSD areas. Impacts due to general commercial, residential, industrial, and other growth associated with the source must also be addressed.

De minimis emission levels have been promulgated to define when a "net emissions increase" is "significant." The de minimis levels are listed in Table 4.3-4. Since emissions from a CAES facility can exceed certain de minimis levels, the proposed CAES system can be designated "major" and, therefore may have to undergo federal PSD review.

4.3.3 WATER SUPPLY AND DISCHARGES

The CAES cooling water system is primarily used to cool storage air during various stages of the compression cycle. In addition, smaller cooling streams are use to provide cooling to auxiliary equipment during power generation. As a result, approximately 1,500 gpm is required to compensate for cooling tower drift, evaporation loss, and blowdown at

Table 4.3-4. Significant Levels for Net Emissions Increase or Potential to Emit

	Emissions Levels (tons per year)
Carbon Monoxide	100
Nitrogen Oxides	400
Sulfur Dioxide	40
Particulate Matter	25
Ozone	40 (volatile organic compounds)
Lead	0.6
Asbestos	0.007
Beryllium	0.0004
Mercury	0.1
Vinyl Chloride	1
Fluorides	4
Sulfuric Acid Mist	7
Hydrogen Sulfide (H_2S)	10
Total Reduced Sulfur (including H_2S)	10
Reduced Sulfur Compounds (including H_2S)	10

Source: ESE, 1981.

full load operation for a 220-MW CAES. Although water withdrawals are relatively modest, local-or state-level permits are required. For the planned 220-MW CAES facility in Illinois, water withdrawal permitting is governed by the Department of Transportation (Illinois Statute 19).

Water discharges from CAES facilities to waters of the United States (40 CFR 122.3) will also require appropriate authorizations under the National Pollutant Discharge Elimination System (NPDES) as defined in Section 402 of the Clean Water Act (CWA). As such, CAES facilities will be required to meet appropriate water quality standards of the receiving body of water consistent with Sections 301 (Effluent Limitations), 302 (Water Quality Related Effluent Limitations), and 304 (Information and Guidelines) of the CWA. In addition, effluent limitations for point sources for all pollutants identified pursuant to Section 304(a)(4) of the CWA will require the application of best conventional pollutant control technology (e.g., biological oxygen demand, total suspended solids, pH, fecal coliform, oil and grease).

4.3.3.1 INTAKE AND DISCHARGE STRUCTURES

The development of CAES installations may require the placement of structures for intake cooling water and discharge systems as well as associated dredge-and-fill activities which may take place in navigable waters.

The U.S. Army Corps of Engineers (COE) is responsible for regulating disposal of dredge-and-fill materials in the navigable waters of the United States (PL 92-500, Section 404). As of July 1, 1977, COE's jurisdiction has been expanded to include tributaries of navigable waters with flows of more than 5 cubic feet per second and adjacent wetlands. It is probable that granting of COE permits may also in some cases constitute a "major federal action" and will require an Environmental Assessment for determination of pollutant impacts (40 CFR 230).

The Rivers and Harbors Act of 1899 grants control of structures in navigable waters to the Secretary of the Army and, by delegation, to COE. For example, construction of a cooling water intake or discharge structure for a CAES facility will require authorization from COE. This authorization is usually combined with the dredge and fill permit.

4.3.3.2 FUEL STORAGE

The planned 220-MW CAES facility will utilize two fuel oil tanks to provide up to 90 days of storage. The tanks (each 120 feet by 35 feet) will hold a total of 6,000,000 gallons of Number 2 fuel oil. As a result, this and other CAES facilities with any significant oil storage must comply with oil spill prevention regulations codified in 40 CFR 112. In essence, it will be necessary to provide both design and operating considerations to minimize the effect of potential oil spills and a countermeasures plan in the event of such an occurrence.

4.3.3.3 UNDERGROUND INJECTION CONSIDERATIONS

Section 1421(d)(1) of the Safe Drinking Water Act (SDWA) of 1974 requires that the well injection of fluids be controlled by permit to protect the integrity of groundwater resources. Although the classification of air injection as a fluid may be more questionable, the utilization of a water compensation system would also constitute a well injection. Therefore, the SDWA has substantial implications in the development of CAES facilities, especially aquifer-based systems.

4.3.4 ENVIRONMENTAL IMPACT STATEMENT REQUIREMENTS

Primary EIS considerations stem from the requirements of the National Environmental Policy ACT (NEPA) of 1969 and the Council of Environmental Quality (CEQ) regulations for the implementation of NEPA procedures (effective July 30, 1979). As a result of applicable regulatory programs previously discussed, the potential for the approval process requiring a major federal action is probable.

In addition, judgments regarding CAES development as having significant environmental impacts will tend to be more conservative based on the newness of the technology.

Because of Soyland's position as a cooperative utility, the Rural Electrification Administration (REA) procedures for implementing NEPA (REA Bulletin 20-21:320-21) will apply. REA will most likely be assigned lead agency status as a result of an interagency scoping meeting. The major federal action supporting this status is the anticipation of a loan guarantee to Soyland Power Cooperative, Inc., for construction of the CAES facility, by the REA.

Lead agency status is in accordance with NEPA and subsequent CEQ guidelines. As such, REA would be responsible for overseeing the conduct of environmental studies, preparation of an environmental analysis and an environmental impact statement (if required), and public participation.

4.3.5 STATE AND LOCAL PERMITTING

The State of Illinois has been delegated primacy for all major federal permit programs. As such, Soyland's planned 220-MW CAES will receive overview from the following agencies:

Illinois Environmental Protection Agency--Illinois Environmental Protection Agency (EPA) is responsible for the issuance of both construction and operating permits for the proposed CAES. Under a coordinated permit review program, several permit applications are combined into one submittal. Included in the agency's permit program are provisions for water pollution (EPA Rules and Regulations, Chapter 3), solid waste (Chapter 7), air quality (Chapter 2), and noise (Chapter 8). The planned CAES facility will need approval from Illinois EPA prior to initiation of construction at the site.

Illinois Department of Transportation--Illinois Department of Transportation (DOT) has enforcement responsibilities for the state's bridges and highways, canals and waterways, and drainage (Illinois Statutes 121, 19, and 42, respectively).

Illinois Department of Public Health--Illinois Department of Public Health governs the construction, operation, and quality of water from public water supplies. During the operational phase of any ground- or surface water potable water source, the department requires routine monitoring of bacteriological and other water quality parameters.

Illinois Department of Conservation--The Illinois Department of Conservation (DOC) has the responsibility of maintaining the quality and integrity of the state's natural biological systems and cultural and historical heritage. Hence, Illinois DOC reviews all major projects for impacts on these features. The Division of Historical Sites has the responsibility to recommend, when necessary, measures to assure the protection or mitigation of the state's archaeological and historical resources. These measures can range from preliminary surveys to detailed excavations.

Local Permits and Reviews--The local County Zoning Administrator has responsibility for reviewing and issuing requested zoning variances and changes, and issuing building permits.

BIBLIOGRAPHY

Acres American, Inc. 1980. Preliminary Design Study of Underground Pumped Hydro and Compressed Air Energy Storage in Hard Rock. Prepared for Potomac Electric Power Company. Washington, D.C.

Arthur D. Little Co., Inc. 1979. The Relative Economic Merits of Building a Compressed Air Energy Storage System to Meet Soyland Power Cooperative's Need for Peaking Capacity. 83890-04. Cambridge, Massachusetts

Brown Boveri, Inc. 1981. Proposed Air Storage Power Plant for Soyland Power Cooperative, Inc. Decatur, Illinois.

Dvorak, A.J. et al. 1978. Impacts of Coal-Fired Power Plants on Fish, Wildlife and Their Habitats. Prepared for U.S. Fish and Wildlife Service, Biological Services Program. INS/OBS-78/29. Washington, D.C.

Hobson, M.J. 1980. CAES Plant Design. Paper presented at CAES/UPH Seminar. Washington, D.C.

Illinois Department of Conservation. 1980. Natural Areas Inventory. Springfield, Illinois.

Murray, J.S. 1980. Recuperators in the CAES Cycle. Presented at the CAES/UPH Seminar. Washington, D.C.

Newman, R.B. and F.W. Gettler. 1980. Compressed Air Energy Storage--Economic Peaking and Reserve Capacity for Soyland Power Cooperative. Presented at the Thrid Miami International Conference on Alternate Energy Sources. Miami, Florida.

Reynolds, Smith and Hill, Inc. 1981. Evaluation of Peaking Power Alternatives for Soyland Power Cooperative, Inc. Decatur, Illinois.

United Engineers. 1980. Compressed Air Energy Storage for the Middle South Utilities System. New Orleans, Louisiana.

U.S. Department of Transportation. 1969. Standard Land Use Coding Manual (SLUCM). Washington, D.C.

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