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Integrated Resource Plan

4 CSR 240-22.040

Supply-Side Resource Analysis

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4 CSR 240-22.040 (1)

The analysis of supply-side resources shall begin with the identification of a variety of potential supply-side resource options which the utility can reasonably expect to develop and implement solely through its own resources or for which it will be a major participant. These options include new plants using existing generation technologies; new plants using new generation technologies; life extension and refurbishment at existing generating plants; enhancement of the emission controls at existing or new generating plants; purchased power from utility sources, cogenerators or independent power producers; efficiency improvements which reduce the utility's own use of energy; and upgrading of the transmission and distribution systems to reduce power and energy losses. The utility shall collect generic cost and performance information for each of these potential resource options which shall include at least the following attributes where applicable:

This section is broken down into four sections: fossil fuels, renewable resources, nuclear, and pump storage. The following options are addressed in their respective sections:

- Existing plants 4CSR240-22.040(3) & 4CSR240-22.040(4)
- PPA 4CSR240-22.040(5)
- Transmission and Distribution 4CSR240-22.040(6) & 4CSR240-22.040 (7)

Fossil Fuel Resources

The supply-side resource analysis initially identified potential resource technology options that used the applicable fuels. The technologies were limited to those that could be reasonably developed or implemented by AmerenUE through its resources or as a major participant. The options considered were for new plants using new or existing generation technologies. Generic cost and performance data were collected for typical greenfield site conditions in Missouri.

A multi-stage approach was utilized to determine the list of technologies to be characterized in the analysis. The first stage consisted of developing a "universe" list of potential fossil fired resources. The universe list was screened to develop a "medium" list of technologies by conducting a high-level fatal flaw analysis that was based on the expertise of AmerenUE and Black & Veatch professionals. Technologies that did not pass the high-level fatal flaw analysis consisted of those technologies that could not be reasonably developed or implemented by AmerenUE. The primary constraints on technologies that did not pass the high-level fatal flaw analysis consisted of current and forecasted commercial status and market availability.

Technologies that were considered in the fossil supply-side resource analysis are provided in Tables 1 through 3. These technologies comprise the medium list of technologies that were screened as potentials for further analysis. The technologies are classified by their dispatch group as being either baseload, intermediate load, or peaking load (Table 1). The baseload technologies were further classified as either "conventional" or "advanced." The term "conventional" designates a technology that is technically mature and has been repeatedly and successfully deployed. The term "advanced" designates a technology that is less mature; such a technology may be in research and development, the demonstration stage, or early commercialization.

Technologies that did not pass the high-level fatal flaw analysis and that were part of the universe list are provided in Table 2. A brief descriptor defines why these technologies were not selected for further analysis.

A carbon capture and compression (CCC) option was considered for three of the baseload technologies. The CCC options are provided in Table 1.

For the combustion turbine generator (CTG) and reciprocating internal combustion engine (RICE) options, specific technology providers were selected as representative examples of all other major technology providers. For the integrated gasification combined cycle (IGCC) option, the Shell coal gasification process was selected as a representative example of the major entrained flow gasification technology providers with the capability to use a Powder River Basin (PRB) fuel. The intent of the supply-side resource analysis was not to compare all available technology providers within one technology option but, rather, to compare different technology options to one another. Black & Veatch experience suggests that there would be no significant difference in performance and cost between different technology providers that would adversely affect the results of the study between the different technology options.

This study refers to advanced/ultrasupercritical pulverized coal (PC) as USCPC. There is no general agreement in the industry about the definition of advanced or ultrasupercritical steam conditions. For this planning study, steam conditions were assumed to be 4,000 psia/1,100° F/1,100° F. At these temperatures and pressures, commercially available materials of construction can be used. A handful of plants around the world are operating at or near these steam conditions. As new alloys become available, these steam conditions may be increased to as high as 5,000 psia and 1,300 or 1,400° F. These conditions would certainly be considered ultrasupercritical.

Numerous attributes of the potential resource options from Table 1 were characterized. These characterizations are discussed in the following sections. 4CSR 240-22.040 Appendix A contains a copy of the Characterization Table.

Table 1 Potential Resource Option Technologies	
Conventional	**Advanced**
Baseload	
• Atmospheric Bubbling Fluidized Bed (BFB) • Atmospheric Circulating Fluidized Bed (CFB) • Subcritical PC • Supercritical PC	• Advanced/Ultrasupercritical PC • USCPC with CCC • IGCC • IGCC with CCC • Oxygen Fueled Combustion • Oxygen Fueled Combustion with CCC • Supercritical CFB • Pressurized BFB
Intermediate	
• Combined Cycle Combustion Turbine • Combined Cycle Reciprocating Engine • Cheng Cycle • Thermal Steam Boiler (TSB)	• None
Peaking	
• Simple Cycle Combustion Turbine • Simple Cycle Reciprocating Engine	• None

Table 2
Non-Potential Resource Option Technologies

Technology	Comment
Baseload	
• Stoker Boiler • Cyclone Boiler	• Technologies are no longer commercially available.
Intermediate	
• Humid Air Turbine • CHAT • Kalina Cycle • SRGT • Intercooled SRGT • Chemically Recuperated Gas Turbine • Advanced Brayton (Evap/Regen) • Advanced Brayton. Brayton (Reheat/Intercooled) • Magnetohydrodynamics • Indirect-Fired Combustion Turbine	• Technologies are not yet commercially available.
Peaking	
• Microturbine • Fuel Cell	• More applicability as distributed generation resources.

4 CSR 240-22.040 (1) (A)
Fuel Type and Feasible Variations in Fuel Type or Quality

Three primary fuel sources were considered in the fossil supply-side resource. The primary fuel sources considered consisted of the following:

- PRB Coal.
- Natural Gas.
- No. 2 Fuel Oil.

The ability of a technology to fire different fuels, its fuel flexibility, was also assessed. Each technology was assessed as being either fuel flexible or limited in its ability to be fuel flexible. Table 3 summarizes the assumed fuels for each of the potential technologies and their fuel flexibility.

Because of its low delivered cost and sulfur content, PRB coal was the primary fuel considered for the coal fueled technologies. Illinois No. 6 coal was considered next for three of the baseload technologies because of the proximity of the AmerenUE service area to the Illinois Basin coal reserves. Natural gas and No. 2 fuel oil fired technologies were selected for use with the CTG and RICE technologies.

Table 3
Selected Fuels and Fuel Flexibility

	Assumed Fuel	Fuel Flexibility
Conventional Baseload Technologies		
BFB - 50 MW	PRB	Yes
CFB - 2x250 MW	PRB	Yes
Subcritical PC - 500 MW	PRB	Limited
Supercritical PC - 500 MW	PRB	Limited
Supercritical PC - 850 MW	PRB	Limited
Supercritical PC - 850 MW - IL No. 6	IL No. 6	Limited
Advancing Baseload Technologies		
USCPC - 850 MW	PRB	Limited
USCPC - 850 MW - IL No. 6	IL No. 6	Limited
USCPC - 850 MW w/ CCC	PRB	Limited
IGCC - 2x1 600 MW, Shell	PRB	Limited
IGCC - 2x1 600 MW, Shell, IL No. 6	IL No. 6	Limited
IGCC - 2x1 600 MW, Shell w/CCC	PRB	Limited
OxyComb - 850 MW	PRB	Limited
OxyComb - 850 MW w/ CCC	PRB	Limited
Supercritical CFB - 500 MW	PRB	Yes
Pressurized BFB - 250 MW	PRB	Limited
Intermediate Load Technology		
1x1 General Electric (GE) 7EA	Natural Gas	Yes
1x1 GE 7FA	Natural Gas	Yes
2x1 GE 7FA	Natural Gas	Yes
1x1 Wartsila 12V46	No. 2 Fuel Oil	Yes
2x1 Wartsila 12V46	No. 2 Fuel Oil	Yes
1x1 Wartsila 18V46	No. 2 Fuel Oil	Yes
Cheng Cycle - 7EA	Natural Gas	Yes
TSB - 250 MW	Natural Gas	Yes
Peaking Load Technology		
GE LM6000PC	Natural Gas	Yes
GE LMS100	Natural Gas	Yes
GE 7EA	Natural Gas	Yes
GE 7FA	Natural Gas	Yes
Wartsila 12V46	No. 2 Fuel Oil	Yes
Wartsila 18V46	No. 2 Fuel Oil	Yes

4 CSR 240-22.040 (1) (B)

(1)(B) Practical Size Ranges

The selection of practical size ranges for each of the technologies was based on the reasonable capability to implement the technology. For the baseload technologies, there is typically a capacity range over which a technology could be reasonably specified. For the combustion turbine- and reciprocating engine-based technologies, a variety of specific technology provider models were used to develop a representative range of available capacity options. The practical size ranges for the baseload, intermediate load, and peaking load technologies are as follows:

- Baseload Technologies:

  BFB--BFB units are typically utilized in niche markets to take advantage of opportunity fuels. Because of this, unit availability within a wide range of capacities is limited. Generally, for capacities greater than 150 MW and when considering fluidized bed combustion technologies, CFB would be preferred over BFB.

  CFB--Like BFB, CFB technologies can be used to take advantage of opportunity fuels. They are often compared with PC technologies because of their fuel flexibility. Currently, CFB boiler technology is limited in capacity; therefore, when larger capacities are required, multiple CFB boilers would be arranged to provide main and reheat steam to a single steam turbine generator (STG). Single CFB boilers are typically constructed to support net plant output in the range of 100 to 300 MW.

  Subcritical PC--Subcritical PC boilers can be constructed in a wide range of capacities. Subcritical PC is often compared to supercritical PC for baseload capacity resource planning because both have proven high reliability. For capacities below 600 MW, subcritical PC is often more economically feasible. For larger capacities, above 600 MW, supercritical PC can have a slight economic advantage. The economic comparison is driven by thermal efficiency, capital cost, and the cost of the selected fuel.

Supercritical PC--The practical capacity of supercritical PC boilers ranges from 600 to 1,000 MW. Some supercritical PC units have been constructed that are as large as 1,300 MW. Supercritical PC can be built in smaller sizes, but that is not a common practice..

USCPC--USCPC units can be constructed in practical size ranges similar to those of supercritical PC units.

IGCC--IGCC is a CTG-based technology. Because CTGs are only available in discrete sizes, limitations exist in sizing plant capacity to a specified net output. Currently, the most economical IGCC configurations are based upon state-of-the-art conventional "F" class CTGs modified to fire syngas. In an IGCC configuration, a 1x1 "F" class combined cycle at ISO conditions would produce a nominal net output of 300 MW. Configurations with multiple CTGs can be utilized to obtain a larger net capacity. A 2x1 configuration is generally accepted as typical and has a nominal net output of 600 MW

Oxycombustion--Oxycombustion units can be constructed in practical size ranges similar to those of supercritical PC units.

Supercritical CFB--Supercritical CFB units can be constructed in practical size ranges similar to those of subcritical CFB units. The capacity may be increased to capture economies of scale. One plant in Poland has a capacity of 460 MW.

Pressurized BFB--Pressurized BFB technology capacity range is limited because only a few providers market this technology. The largest pressurized BFB demonstration project was 360 MW.

- Intermediate Load and Peaking Load Technologies:

  CTG-Based Technologies--Because combustion turbines are only available in discrete sizes, limitations apply when specifying project capacity. However, many technology providers offer a wide range of CTG sizes. CTGs can often be selected to satisfy power producer's capacity requirements, whether with single or multiple CTGs.

RICE-Based Technologies--Similar to CTG-based technologies, reciprocating engine-based technologies are only available in discrete sizes. Multiple units can be aggregated to achieve higher plant outputs.

TSB--Similar to PC or CFB technologies, TSBs can be sized to match the specified project capacity. However, the capacity range of TSBs is limited because of market availability. Most TSBs are used in industrial applications and not for utility-scale electric power generation. It is questionable whether a TSB of substantial capacity could even be procured.

For the supply-side analysis, a reasonable capacity was selected for each of the potential technologies. For the intermediate and peaking load CTG- and RICE-based technologies, several models were selected as representative examples that could be implemented. Table 4 shows the selected net capacity for each of the potential technologies.

Table 4
Selected Net Plant Output

	Selected Output, MW
Conventional Baseload Technologies(1)	
BFB - 50 MW	50
CFB - 2x250 MW	500
Subcritical PC - 500 MW	500
Supercritical PC - 500 MW	500
Supercritical PC - 850 MW	850
Supercritical PC - 850 MW - IL No. 6	850
Advancing Baseload Technologies(1)	
USCPC - 850 MW	850
USCPC - 850 MW - IL No. 6	850
USCPC - 850 MW w/ CCC(2)	850
IGCC - 2x1 600 MW, Shell	580
IGCC - 2x1 600 MW, Shell, IL No. 6	586
IGCC - 2x1 600 MW, Shell w/CCC	580
OxyComb - 850 MW	850
OxyComb - 850 MW w/ CCC	850
Supercritical CFB - 500 MW	500
Pressurized BFB - 250 MW	250
Intermediate Load Technology(3)	
1x1 GE 7EA(4)	115
1x1 GE 7FA(4)	230
2x1 GE 7FA(4)	470
1x1 Wartsila 12V46	11.4
2x1 Wartsila 12V46	22.8
1x1 Wartsila 18V46	17.7
Cheng Cycle - 7EA	96
TSB - 250 MW	247
Peaking Load Technology(5)	
GE LM6000PC(6)	33
GE LMS100(6)	92
GE 7EA(6)	74
GE 7FA(6)	151
Wartsila 12V46	10.5
Wartsila 18V46	16.3

(1)Net capacity based on a “cool day” ambient temperature of 50° F.
(2)Estimates include additional gross output to make up the increased auxiliary load requirements of the CCC process. Net capacity based on a “cool day” ambient temperature of 50° F.
(3)Net capacity based on a “hot day” ambient temperature of 85° F.
(4)Net capacity includes the effects of evaporative cooling without duct firing.
(5)Net capacity based on a “hot day” ambient temperature of 95° F.
(6)Net capacity includes the effects of evaporative cooling.

4 CSR 240-22.040 (1) (C)
Maturity of the Technology

The maturity of each of the potential technologies was qualitatively assessed. Technology maturity was assessed as either "mature" or "developing." Technologies defined as mature were those that are proven and well established within the electric power generation industry. Developing technologies consist of all other technologies that may have limited experience, have been utilized in demonstration projects, or consist of laboratory tested conceptual designs. Table 5 lists the maturity of each technology. Some of the cases are shown as "early commercial," which is more advanced than "developing," but less commercially proven in the United States than "mature."

Table 5 Technology Maturity	
Conventional Baseload Technologies	
BFB - 50 MW	Mature
CFB 2x250 MW	Mature
Subcritical PC - 500 MW	Mature
Supercritical PC - 500 MW	Mature
Supercritical PC - 850 MW	Mature
Supercritical PC - 850 MW - IL No. 6	Mature
Advancing Baseload Technologies	
USCPC - 850 MW	Early Commercial
USCPC - 850 MW - IL No. 6	Early Commercial
USCPC - 850 MW w/ CCC	Early Commercial
IGCC - 2x1 600 MW, Shell	Early Commercial
IGCC - 2x1 600 MW, Shell, IL No. 6	Early Commercial
IGCC - 2x1 600 MW, Shell w/CCC	Developing
OxyComb - 850 MW	Developing
OxyComb - 850 MW w/ CCC	Developing
Supercritical CFB - 500 MW	Developing
Pressurized BFB - 250 MW	Developing
Intermediate Load Technologies	
1x1 GE 7EA	Mature
1x1 GE 7FA	Mature
2x1 GE 7FA	Mature
1x1 Wartsila 12V46	Mature
2x1 Wartsila 12V46	Mature
1x1 Wartsila 18V46	Mature
Cheng Cycle - 7EA	Developing
TSB - 250 MW	Mature
Peak Load Technologies	
GE LM6000PC	Mature
GE LMS100	Mature
GE 7EA	Mature
GE 7FA	Mature
Wartsila 12V46	Mature
Wartsila 18V46	Mature

4 CSR 240-22.040 (1) (D)
Lead Time for Permitting, Design, Construction, Testing, and Startup

Estimates of project durations were collected for each of the technologies and were based on current permitting and market conditions as of May 2007. Information was gathered from in-house Black & Veatch data and was based on actual Black & Veatch project experience. Durations are provided for the permitting and development time and notice to proceed (NTP) to commercial operation (COD) for each of the technologies. These project durations are provided in Table 6 for each of the technologies.

Table 6
Project Duration

	Permitting and Development, months(1)	NTP to COD, months(1)
Conventional Baseload Technologies		
BFB - 50 MW	24 to 30	40
CFB - 2x250 MW	24 to 36	46
Subcritical PC - 500 MW	24 to 36	49
Supercritical PC - 500 MW	24 to 36	54
Supercritical PC - 850 MW	24 to 36	57
Supercritical PC - 850 MW - IL No. 6	24 to 36	59
Advancing Baseload Technologies		
USCPC - 850 MW	24 to 36	57
USCPC - 850 MW - IL No. 6	24 to 36	59
USCPC - 850 MW w/ CCC	24 to 36	63
IGCC - 2x1 600 MW, Shell	24 to 30	53
IGCC - 2x1 600 MW, Shell, IL No. 6	24 to 30	53
IGCC - 2x1 600 MW, Shell w/CCC	24 to 30	59
OxyComb - 850 MW	24 to 36	60
OxyComb - 850 MW w/ CCC	24 to 36	62
Supercritical CFB - 500 MW	24 to 36	51
Pressurized BFB - 250 MW	24 to 36	53
Intermediate Load Technologies		
1x1 GE 7EA	14 to 18	30
1x1 GE 7FA	14 to 18	30
2x1 GE 7FA	14 to 18	31
1x1 Wartsila 12V46	14 to 18	27
2x1 Wartsila 12V46	14 to 18	28
1x1 Wartsila 18V46	14 to 18	27
Cheng Cycle - 7EA	14 to 18	25
TSB - 250 MW	14 to 18	40
Peak Load Technologies		
GE LM6000PC	14 to 18	21
GE LMS100	14 to 18	24
GE 7EA	14 to 18	21
GE 7FA	14 to 18	21
Wartsila 12V46	14 to 18	18
Wartsila 18V46	14 to 18	18

(1)Project durations based on current permitting and market conditions as of May 2007.

4 CSR 240-22.040 (1) (E)
Capital Cost per Kilowatt

Generic screening-level overnight capital costs were collected for each of the technologies and were based on current market conditions as of May 2007. Capital cost estimates were gathered from in-house Black & Veatch data and were factored to be reflective of a generic Midwest US installation. The capital cost estimates were based on previous Black & Veatch estimates.

The capital costs are generic screening-level estimates appropriate for supply-side resource analyses; they were developed on a consistent basis. Source capital cost estimates were developed using an engineering, procurement, and construction (EPC) method of contracting, which is exclusive of Owner's cost. Typically, the scope of work for EPC capital costs is the base plant, which is defined as being "within the fence." The sum of the EPC capital cost and the Owner's cost equals the total project cost or the total capital requirement for the project. These costs are not usually included in the EPC estimate and should be considered by the project developer to determine the total capital requirement for the project. Owner's cost items include costs for "outside the fence" physical assets, project development, and financing costs. The order of magnitude of these costs is project-specific and can vary significantly, depending upon technology and project-unique requirements. For a screening-level analysis, the Owner's cost can be estimated as a percentage of the EPC capital cost. Typically, based on actual project financial data, Owner's costs have been found to be in the range of 20 to 60. An Owner's cost was assumed for each of the technologies.

Generic screening-level overnight capital costs for each of the technologies are provided in Tables 7 through 9. The assumed Owner's cost for each of the technologies is also provided. The unit capital costs are based on a specific net plant output (NPO), which is also provided. The NPOs listed are representative of the typical ambient conditions that would be expected for the type of dispatch. In other words, a peaking simple cycle combustion turbine would typically be dispatched during a hot day condition. Because the plant output for a combustion turbine plant is significantly affected by temperature, this is a very relevant qualification when stating capital cost in units of $/kW. It is less relevant for a Rankine cycle thermal plant.

Table 7
Baseload Technology Capital Costs

	NPO[1]	EPC Capital Cost [2]		Owner's Cost [3]	Total Project Cost [4]	
	MW	$1,000	$/kW[5]	percent	$1,000	$/kW[5]
Conventional Baseload Technologies						
BFB - 50 MW	50	161,000	3,210	40	225,000	4,500
CFB - 2x250 MW	500	949,000	1,900	40	1,329,000	2,660
Subcritical PC - 500 MW	500	894,000	1,790	40	1,252,000	2,500
Supercritical PC - 500 MW	500	922,000	1,840	40	1,291,000	2,580
Supercritical PC - 850 MW	850	1,420,000	1,670	40	1,988,000	2,340
Supercritical PC - 850 MW - IL No. 6	850	1,340,000	1,580	40	1,876,000	2,210
Advancing Baseload Technologies						
USCPC - 850 MW	850	1,464,000	1,720	40	2,050,000	2,410
USCPC - 850 MW - IL No. 6	850	1,382,000	1,630	40	1,935,000	2,280
USCPC - 850 MW w/ CCC	850	3,067,000	3,610	40	4,294,000	5,050
IGCC - 2x1 600 MW, Shell	580	1,350,000	2,330	50	2,025,000	3,490
IGCC - 2x1 600 MW, Shell, IL No. 6	586	1,300,000	2,220	50	1,950,000	3,330
IGCC - 2x1 600 MW, Shell w/CCC	580	1,822,500	3,140	50	2,734,000	4,710
OxyComb - 850 MW	850	2,554,000	3,000	50	3,831,000	4,510
OxyComb - 850 MW w/ CCC	850	2,870,000	3,380	50	4,305,000	5,060
Supercritical CFB - 500 MW	500	1,014,000	2,030	40	1,521,000	3,040
Pressurized BFB - 250 MW	250	670,000	2,680	40	1,005,000	4,020

(1)NPO based on performance at cool day baseload ambient conditions, 50° F.
(2)EPC capital costs are exclusive of Owner's costs.
(3)Owner's cost is estimated as an assumed percentage of EPC capital cost.
(4)Total project cost is the sum of the EPC capital cost and Owner's costs.
(5)Unit capital costs are based on performance at cool day baseload ambient conditions, 50° F.

Table 8 Intermediate Load Technology Capital Costs						
	NPO(1)	EPC Capital Cost (2)		Owner's Cost (3)	Total Project Cost (4)	
	MW	$1,000	$/kW(5)	percent	$1,000	$/kW(5)
1x1 GE 7EA	115	138,000	1,200	30	179,400	1,560
1x1 GE 7FA	230	183,000	796	30	237,900	1,030
2x1 GE 7FA	470	299,000	636	30	388,700	830
1x1 Wartsila 12V46	11.4	28,900	2,410	30	37,600	3,130
2x1 Wartsila 12V46	22.8	47,200	1,970	30	61,400	2,560
1x1 Wartsila 18V46	17.7	33,200	1,780	30	43,200	2,320
Cheng Cycle - 7EA	96	74,900	780	30	97,400	1,010
TSB - 250 MW	247	349,000	1,413	30	453,700	1,840

(1)NPO based on performance at hot day intermediate load ambient conditions, 85° F.
(2)EPC capital costs are exclusive of Owner's costs.
(3)Owner's costs are estimated as an assumed percentage of EPC capital cost.
(4)Total project cost is the sum of the EPC capital cost and Owner's costs.
(5)Unit capital costs are based on performance at hot day intermediated load ambient conditions, 85° F.

Table 9 Peaking Load Technology Capital Costs						
	NPO(1)	EPC Capital Cost (2)		Owner's Cost (3)	Total Project Cost (4)	
	MW	$1,000	$/kW(5)	percent	$1,000	$/kW(5)
GE LM6000PC	33	39,300	1,190	30	51,100	1,550
GE LMS100	92	63,500	690	30	82,600	900
GE 7EA	74	51,800	700	30	67,300	910
GE 7FA	151	71,900	476	30	93,500	620
Wartsila 12V46	10.5	4,900	460	30	6,400	610
Wartsila 18V46	16.3	6,400	390	30	8,300	510

(1)NPO based on performance at hot day peaking load ambient conditions, 95° F.
(2)EPC capital costs are exclusive of Owner's costs.
(3)Owner's costs are estimated as an assumed percentage of EPC capital cost.
(4)Total project cost is the sum of the EPC capital cost and Owner's costs.
(5)Unit capital costs are based on performance at hot day peaking load ambient conditions, 95° F.

4 CSR 240-22.040 (1) (F)
Annual Fixed Operations and Maintenance Costs

Generic screening-level fixed operations and maintenance (O&M) costs were collected for each of the technologies. The fixed O&M cost estimates were gathered from in-house Black & Veatch data and were factored to be reflective of a generic Midwest US installation. The fixed O&M cost estimates were based on previous Black & Veatch estimates.

The fixed O&M costs are generic screening-level estimates appropriate for screening-level supply-side resource analyses; they were gathered from estimates generated on a consistent basis. Fixed O&M costs are driven predominantly by plant personnel salaries and wage rates, and the required level of staffing. The fixed O&M cost estimates used assumed staffing levels that could effectively operate and maintain the plant. Routine fixed maintenance costs are also included. Property taxes and operating insurance have not been included.

Generic screening-level fixed O&M costs for each of the technologies are provided in Tables 10 through 12. The unit fixed O&M costs were based on a specific NPO reflective of probable unit dispatching, which is also provided. This is consistent with the NPO data used for the capital cost estimates.

Table 10 Baseload Technology Fixed O&M Costs (2007$)			
	NPO[1]	Fixed O&M Costs	
	MW	$1,000	$/kW-yr [2]
Conventional Baseload Technologies			
BFB - 50 MW	50	5,900	118
CFB - 2x250 MW	500	12,710	25.4
Subcritical PC - 500 MW	500	10,980	22.0
Supercritical PC - 500 MW	500	11,070	22.1
Supercritical PC - 850 MW	850	14,310	16.8
Supercritical PC - 850 MW - IL No. 6	850	14,840	17.5
Advancing Baseload Technologies			
USCPC - 850 MW	850	14,430	17.0
USCPC - 850 MW - IL No. 6	850	14,960	17.6
USCPC - 850 MW w/ CCC	850	22,400	26.4
IGCC - 2x1 600 MW, Shell	580	16,100	27.8
IGCC - 2x1 600 MW, Shell, IL No. 6	586	16,100	27.5
IGCC - 2x1 600 MW, Shell w/CCC	580	16,600	28.6
OxyComb - 850 MW	850	18,690	22.0
OxyComb - 850 MW w/ CCC	850	23,760	28.0
Supercritical CFB - 500 MW	500	12,810	25.6
Pressurized BFB - 250 MW	250	9,030	36.1

(1)NPO based on performance at cool day baseload ambient conditions, 50° F.
(2)Unit fixed O&M cost is based on performance at cool day baseload ambient conditions, 50° F.

Table 11 Intermediate Load Technology Fixed O&M Costs (2007$)			
	NPO(1)	Fixed O&M Costs	
	MW	$1,000	$/kW-yr (2)
1x1 GE 7EA	115	2,270	19.7
1x1 GE 7FA	230	2,560	11.1
2x1 GE 7FA	470	3,200	6.81
1x1 Wartsila 12V46	11.4	516	43.0
2x1 Wartsila 12V46	22.8	624	26.0
1x1 Wartsila 18V46	17.7	521	28.0
Cheng Cycle - 7EA	96	1,810	18.9
TSB - 250 MW	247	5,798	23.5

(1)NPO based on performance at hot day intermediate load ambient conditions, 85° F.
(2)Unit fixed O&M cost is based on performance at hot day intermediated load ambient conditions, 50° F.

Table 12 Peaking Load Technology Fixed O&M Costs (2007$)			
	NPO(1)	Fixed O&M Costs	
	MW	$1,000	$/kW-yr (2)
GE LM6000PC	33	922	27.9
GE LMS100	92	975	10.6
GE 7EA	74	962	13.0
GE 7FA	151	1,018	6.74
Wartsila 12V46	10.5	512	48.6
Wartsila 18V46	16.3	516	31.6

(1)NPO based on performance at hot day peaking load ambient conditions, 95° F.
(2)Unit fixed O&M cost is based on performance at hot day peaking load ambient conditions, 95° F.

4 CSR 240-22.040 (1) (G)

(1)(G) Annual Variable Operations and Maintenance Costs

Generic screening-level variable O&M costs were collected for each of the technologies. Variable O&M cost estimates were gathered from in-house Black & Veatch data and were factored to be reflective of a generic Midwest US installation. The variable O&M cost estimates were based on previous Black & Veatch estimates.

The variable O&M costs are generic estimates appropriate for screening-level supply-side resource analyses; they were gathered from estimates generated on a consistent basis. Source variable O&M cost estimates include key variable cost components consisting of overhaul maintenance, consumables, and applicable reagents. The estimates have assumed that additional maintenance staff and equipment required during overhaul periods would be available through contracted services. Reagent consumption was based on the technology and an estimation of the required reagent to maintain the emissions rates within reasonably expected levels when compared to recent Best Available Control Technology (BACT) analyses.

The generic screening-level variable O&M costs for each of the technologies are provided in Tables 13 through 15. The unit variable O&M costs were based on an assumed capacity factor and specific NPO, which are also provided.

Table 13 Baseload Load Technology Variable O&M Costs (2007$)				
	NPO[1]	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh[2]
Conventional Baseload Technologies				
BFB - 50 MW	50	85	1,540	4.14
CFB - 2x250 MW	500	85	8,750	2.35
Subcritical PC - 500 MW	500	85	7,150	1.92
Supercritical PC - 500 MW	500	85	7,560	2.03
Supercritical PC - 850 MW	850	85	11,840	1.87
Supercritical PC - 850 MW - IL No. 6	850	85	16,580	2.62
Advancing Baseload Technologies				
USCPC - 850 MW	850	85	12,530	1.98
USCPC - 850 MW - IL No. 6	850	85	17,550	2.77
USCPC - 850 MW w/ CCC	850	85	36,800	5.81
IGCC - 2x1 600 MW, Shell	580	80	27,680	6.81
IGCC - 2x1 600 MW, Shell, IL No. 6	586	80	32,030	7.80
IGCC - 2x1 600 MW, Shell w/CCC	580	80	29,500	7.26
OxyComb - 850 MW	850	82	29,310	4.80
OxyComb - 850 MW w/ CCC	850	82	37,240	6.10
Supercritical CFB - 500 MW	500	85	8,520	2.29
Pressurized BFB - 250 MW	250	80	14,200	8.11

(1) NPO based on performance at cool day baseload ambient conditions, 50° F.
(2) Unit variable O&M cost is based on assumed capacity factor and performance at cool day baseload ambient conditions, 50° F.

Table 14 Intermediate Load Technology Variable O&M Costs (2007$)				
	NPO[1]	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh[2]
1x1 GE 7EA	115	45	1,910	4.21
1x1 GE 7FA	230	45	4,010	4.42
2x1 GE 7FA	470	45	7,990	4.31
1x1 Wartsila 12V46	11.4	45	255	5.40
2x1 Wartsila 12V46	22.8	45	511	5.40
1x1 Wartsila 18V46	17.7	45	337	4.60
Cheng Cycle - 7EA	96	45	1,410	3.72
TSB - 250 MW	247	45	1,230	1.27

[1]NPO based on performance at hot day intermediate load ambient conditions, 85° F.
[2]Unit variable O&M cost is based on assumed capacity factor and performance at hot day intermediate load ambient conditions, 85° F.

Table 15 Peaking Load Technology Variable O&M Costs (2007$)				
	NPO[1]	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh[2]
GE LM6000PC	33	10	111	3.83
GE LMS100	92	10	238	2.95
GE 7EA	74	10	590	9.10
GE 7FA	151	10	1,830	13.8
Wartsila 12V46	10.5	10	49.9	5.40
Wartsila 18V46	16.3	10	63.0	4.40

[1]NPO based on performance at hot day peaking load ambient conditions, 95° F.
[2]Unit variable O&M cost is based on assumed capacity factor and performance at hot day peaking load ambient conditions, 95° F.

4 CSR 240-22.040 (1) (H)
Scheduled Routine Maintenance Outage Requirements

The O&M estimates were based on routine maintenance outage requirements. Applicable assumed routine maintenance outage requirements can be categorized for coal combustion, coal gasification, CTG, and RICE-based technologies. Table 16 outlines the major routine maintenance outage requirements.

Table 16 Planned Maintenance Schedule	
	Outage Pattern, week/yr(1)
Conventional Baseload Technologies	
BFB - 50 MW	3-3-3-3-3-6
CFB - 2x250 MW	3-3-3-3-3-6
Subcritical PC - 500 MW	3-3-3-3-3-6
Supercritical PC - 500 MW	3-3-3-3-3-6
Supercritical PC - 850 MW	3-3-3-3-3-6
Supercritical PC - 850 MW - IL No. 6	3-3-3-3-3-6
Advancing Baseload Technologies	
USCPC - 850 MW	3-3-3-3-3-6
USCPC - 850 MW - IL No. 6	3-3-3-3-3-6
USCPC - 850 MW w/ CCC	3-3-3-3-3-6
IGCC - 2x1 600 MW, Shell	1-3-1-4
IGCC - 2x1 600 MW, Shell, IL No. 6	1-3-1-4
IGCC - 2x1 600 MW, Shell w/CCC	1-3-1-4
OxyComb - 850 MW	3-3-3-3-3-6
OxyComb - 850 MW w/ CCC	3-3-3-3-3-6
Supercritical CFB - 500 MW	3-3-3-3-3-6
Pressurized BFB - 250 MW	1-3-1-4
Intermediate Load Technologies	
1x1 GE 7EA	1-1-2-1-1-6
1x1 GE 7FA	1-1-2-1-1-6
2x1 GE 7FA	1-1-2-1-1-6
1x1 Wartsila 12V46	1-1-2-1-1-6
2x1 Wartsila 12V46	1-1-2-1-1-6
1x1 Wartsila 18V46	1-1-2-1-1-6
Cheng Cycle - 7EA	1-2-1-2-1-6
TSB - 250 MW	
Peak Load Technologies	
GE LM6000PC	2-3-6-2
GE LMS100	2-3-6-2
GE 7EA	1-2-1-2-1-6
GE 7FA	1-2-1-2-1-6
Wartsila 12V46	1-1-2
Wartsila 18V46	1-1-2
(1)Project durations based on current permitting and market conditions as of May 2007.	

4 CSR 240-22.040 (1) (I)
Equivalent Forced Outage Rates or Full and Partial Forced Outage Rates

Generic equivalent forced outage rate (EFOR) and equivalent demand forced outage rate (EFORd) data were gathered for each of the technologies. The EFOR and EFORd data is provided in Table 17. The information was taken from the NERC GADS database and published literature to the extent that data was available. Where data was not available, they were estimated using data gathered from comparable technologies. The data is generic but representative for screening-level supply-side resource analyses.

Table 17
Forced Outage Rates

	EFOR, percent	EFORd, percent
Conventional Baseload Technologies		
BFB - 50 MW	9	9
CFB - 2x250 MW	9	9
Subcritical PC - 500 MW	7	7
Supercritical PC - 500 MW	8	8
Supercritical PC - 850 MW	8	8
Supercritical PC - 850 MW - IL No. 6	8	8
Advancing Baseload Technologies		
USCPC - 850 MW	9	9
USCPC - 850 MW - IL No. 6	9	9
USCPC - 850 MW w/ CCC	10	10
IGCC - 2x1 600 MW, Shell	13	13
IGCC - 2x1 600 MW, Shell, IL No. 6	13	13
IGCC - 2x1 600 MW, Shell w/CCC	14	14
OxyComb - 850 MW	11	11
OxyComb - 850 MW w/ CCC	12	12
Supercritical CFB - 500 MW	10	10
Pressurized BFB - 250 MW	13	13
Intermediate Load Technologies		
1x1 GE 7EA	4	3
1x1 GE 7FA	4	3
2x1 GE 7FA	4	3
1x1 Wartsila 12V46	5	4
2x1 Wartsila 12V46	5	4
1x1 Wartsila 18V46	5	4
Cheng Cycle - 7EA	4	3
TSB - 250 MW	7	6
Peak Load Technologies		
GE LM6000PC	14	5
GE LMS100	14	5
GE 7EA	17	5
GE 7FA	17	5
Wartsila 12V46	15	6
Wartsila 18V46	15	6

4 CSR 240-22.040 (1) (J)

Operational Characteristics and Constraints of Significance in the Screening Process

No additional operational characteristics or constraints were identified.

4 CSR 240-22.040 (1) (K)

Environmental Impacts, Including at Least the Following

4 CSR 240-22.040 (1)(K)1

Air emissions including at least the primary acid gases, greenhouse gases, ozone precursors, particulates and air toxics;

Probable air emissions rates were gathered for each of the technologies and were selected to be representative of current New Source Performance Standards and BACT requirements. These are presented in Table 18. The probable emissions rates are consistent with recent permitted ranges

4 CSR 240-22.040 (1) (K) 2

Waste generation including at least the primary forms of solid, liquid, radioactive and hazardous wastes;

Quantities of solid waste production were developed for each of the potential technologies. Coal fueled technologies produce large quantities of solid waste, primarily in the forms of ash and scrubber solids. Gas or liquid fueled technologies may generate some quantity of solid waste as required for raw water treatment, but compared to coal fueled options, it is negligible. Quantities of coal combustion products were estimated using the assumptions for coal composition and expected air quality control systems that were used as the basis for the characteristics included in this study. The solid waste production estimates are summarized in Table 19.

4 CSR 240-22.040 (1) (K) 3

Water impacts including direct usage and at least the primary pollutant discharges, thermal discharges and groundwater effects; and

Water consumption estimates for each of the technologies were gathered from in-house Black & Veatch data. The water consumption estimates were referenced from actual project data. All values are based on the assumption that wet, mechanical draft cooling towers would be used when cycle heat rejection is required. Because water consumption can vary from one plant to another as a result of unique plant characteristics, the estimates are considered generic but appropriate for screening-level supply-side resource analyses. A water consumption range for each of the technologies is provided in Table 20. The estimates are representative of units at full load.

Pollutant discharges could not be adequately addressed in this study because raw water quality and wastewater treatment processes could not be identified to any credible degree that allowed for valid assumptions.

4 CSR 240-22.040 (1) (K) 4

Siting impacts and constraints of sufficient importance to affect the screening process; and

No siting impacts were identified that would affect the screening results. It was assumed that fuel, transmission interconnection, raw water, and land would be sufficiently available in or around the state of Missouri to enable successful plant siting using normal engineering practices.

4 CSR 240-22.040 (1) (L)

Other characteristics that may make the technology particularly appropriate as a contingency option under extreme outcomes for the critical uncertain factors identified pursuant to 4 CSR 240-22.070(2).

No other technology characteristics were identified for inclusion in the technology screening.

Table 18
Probable Emission Rates

	Nitrogen Oxides (NO_x), lb/MBtu	Sulfur Dioxide (SO_2), lb/MBtu	PM_{10}, lb/MBtu	Carbon Dioxide (CO_2), lb/MBtu
Conventional Baseload Technologies				
BFB - 50 MW	0.06	0.1	0.015	212
CFB - 2x250 MW	0.06	0.1	0.015	212
Subcritical PC - 500 MW	0.06	0.1	0.015	212
Supercritical PC - 500 MW	0.06	0.1	0.015	212
Supercritical PC - 850 MW	0.06	0.1	0.015	212
Supercritical PC - 850 MW - IL No. 6	0.06	0.1	0.015	205
Advancing Baseload Technologies				
USCPC - 850 MW	0.06	0.1	0.015	212
USCPC - 850 MW - IL No. 6	0.06	0.1	0.015	205
USCPC - 850 MW w/ CCC	0.06	0.1	0.015	21
IGCC - 2x1 600 MW, Shell	0.06	0.015	0.015	212
IGCC - 2x1 600 MW, Shell, IL No. 6	0.06	0.1	0.015	205
IGCC - 2x1 600 MW, Shell w/CCC	0.06	0.015	0.015	21.2
OxyComb - 850 MW	0.06	0.1	0.015	212
OxyComb - 850 MW w/ CCC	0.06	0.1	0.015	4
Supercritical CFB - 500 MW	0.06	0.1	0.015	212
Pressurized BFB - 250 MW	0.06	0.1	0.015	212
Intermediate Load Technologies				
1x1 GE 7EA	0.01	0.0005	0.01	117
1x1 GE 7FA	0.01	0.0005	0.01	117
2x1 GE 7FA	0.01	0.0005	0.01	117
1x1 Wartsila 12V46	0.7	0.41	0.03	160
2x1 Wartsila 12V46	0.7	0.41	0.03	160
1x1 Wartsila 18V46	0.7	0.41	0.03	160
Cheng Cycle - 7EA	0.01	0.0005	0.01	117
TSB - 250 MW	0.06	0.0005	0.01	117
Peak Load Technologies				
GE LM6000PC	0.1	0.0005	0.01	117
GE LMS100	0.1	0.0005	0.01	117
GE 7EA	0.04	0.0005	0.01	117
GE 7FA	0.04	0.0005	0.01	117
Wartsila 12V46	0.7	0.41	0.03	160
Wartsila 18V46	0.7	0.41	0.03	160

Notes:
1. The values in this table represent typical ranges noted in recent permits and applications. A review of all BACT emissions limit determinations may show some values outside of the listed ranges.

Table 19
Solid Waste Production Estimates

	Quantity, tons/year
Conventional Baseload Technologies	
BFB - 50 MW	14,900
CFB - 2x250 MW	125,000
Subcritical PC - 500 MW	132,000
Supercritical PC - 500 MW	128,000
Supercritical PC - 850 MW	216,000
Supercritical PC - 850 MW - IL No. 6	752,000
Advancing Baseload Technologies	
USCPC - 850 MW	212,000
USCPC - 850 MW - IL No. 6	750,000
USCPC - 850 MW w/ CCC	289,000
IGCC - 2x1 600 MW, Shell	104,000
IGCC - 2x1 600 MW, Shell, IL No. 6	192,000
IGCC - 2x1 600 MW, Shell w/CCC	125,000
OxyComb - 850 MW	292,000
OxyComb - 850 MW w/ CCC	336,000
Supercritical CFB - 500 MW	121,000
Pressurized BFB - 250 MW	54,000
Intermediate Load Technologies	
1x1 GE 7EA	Negligible
1x1 GE 7FA	Negligible
2x1 GE 7FA	Negligible
1x1 Wartsila 12V46	Negligible
2x1 Wartsila 12V46	Negligible
1x1 Wartsila 18V46	Negligible
Cheng Cycle - 7EA	Negligible
TSB - 250 MW	Negligible
Peak Load Technologies	
GE LM6000PC	Negligible
GE LMS100	Negligible
GE 7EA	Negligible
GE 7FA	Negligible
Wartsila 12V46	Negligible
Wartsila 18V46	Negligible

Notes:
1. The values in this table were based on typical PRB and Illinois No. 6 ash contents. The values represent reasonably expected air quality control requirements and control efficiencies..

Table 20 Water Consumption	
	Water Consumption, gal/min
Conventional Baseload Technologies	
BFB - 50 MW	450 to 850
CFB - 2x250 MW	5,000 to 7,500
Subcritical PC - 500 MW	5,000 to 7,500
Supercritical PC - 500 MW	5,000 to 7,500
Supercritical PC - 850 MW	8,500 to 12,750
Supercritical PC - 850 MW - IL No. 6	8,500 to 12,750
Advancing Baseload Technologies	
USCPC - 850 MW	8,500 to 12,750
USCPC - 850 MW - IL No. 6	8,500 to 12,750
USCPC - 850 MW w/ CCC	13,300 to 20,000
IGCC - 2x1 600 MW, Shell	3,600 to 5,400
IGCC - 2x1 600 MW, Shell, IL No. 6	3,600 to 5,400
IGCC - 2x1 600 MW, Shell w/CCC	3,900 to 6,500
OxyComb - 850 MW	11,800 to 17,700
OxyComb - 850 MW w/ CCC	13,3000 to 20,000
Supercritical CFB - 500 MW	5,000 to 7,500
Pressurized BFB - 250 MW	3,500 to 5,250
Combined Cycle Combustion Turbine	600 to 950
1x1 GE 7EA	1,050 to 1,550
1x1 GE 7FA	2,050 to 3,050
2x1 GE 7FA	
1x1 Wartsila 12V46	Up to 100
2x1 Wartsila 12V46	Up to 100
1x1 Wartsila 18V46	
Cheng Cycle - 7EA	
TSB - 250 MW	600 to 950
Simple Cycle Combustion Turbine	
GE LM6000PC	40 to 50
GE LMS100	210 to 310
GE 7EA	70 to 110
GE 7FA	140 to 210
Wartsila 12V46	Negligible
Wartsila 18V46	Negligible

Renewable and Energy Storage Resources

The supply-side resource analysis initially identified potential resource technology options that used the applicable fuels. The technologies were limited to those that could be reasonably developed or implemented by AmerenUE through its resources or as a major participant. The options considered were for new plants using new or existing generation technologies. Generic cost and performance data were collected for typical greenfield site conditions in or around Missouri.

A multi-stage approach was utilized to determine the list of technologies to be characterized in the analysis. The first stage consisted of developing a "universe" list of potential renewable and energy storage resources. Unless specifically identified, "renewable" technologies are meant to include energy storage technologies. The universe list was screened to develop a "medium" list of technologies by conducting a high-level fatal flaw analysis that was based on the expertise of AmerenUE and Black & Veatch professionals. Technologies that did not pass the high-level fatal flaw analysis consisted of those technologies that could not be reasonably developed or implemented by AmerenUE. The primary constraints on technologies that did not pass the high-level fatal flaw analysis consisted of current and forecasted commercial status and market availability.

Renewable and energy storage technologies that were considered in the supply-side resource analysis are provided in Table 21. These technologies comprise the medium list of technologies that were screened as potentials for further analysis. The technologies are classified by their dispatch group as being baseload, intermediate load, or as-available load technologies. Energy storage technologies are as classified as "Energy Storage Technologies."

Technologies that did not pass the high-level fatal flaw analysis and that were part of the universe list are provided in Table 22. A brief descriptor defines why these technologies were not selected for further analysis.

Some technologies, such as wind turbines, were not specifically characterized according to available manufacturer's products. They were generalized to be representative of the technology as a whole. The intent of the supply-side resource analysis was not to compare all available technology providers within one technology option but, rather, to compare different technology options to one another. Black & Veatch experience suggests that there would be no significant difference in performance and cost between different technology providers that would adversely affect the results of the study between the different technology options.

Table 21 Potential Resource Option Technologies
Baseload Technologies
Biomass Combustion – Standalone Biomass Combustion – Combined Heat and Power (CHP) Biomass Combustion – Cofiring Landfill Gas (LFG) – Reciprocating Engine LFG – Combustion Turbine Biomass Integrated Gasification Combined Cycle (IGCC) Waste-to-Energy – Mass Burn Waste-to-Energy – Refuse Derived Fuel (RDF) Waste-to-Energy – Plasma Arc
Intermediate / Peaking Technologies
Hydroelectric – Run of River Hydroelectric – Dam
As Available Load Technologies
Solar Photovoltaic – Commercial Parabolic Trough w/o Storage Parabolic Trough w/ 3 hr Storage Parabolic Dish Wind Farm (Tranche 1) Wind Farm (Tranche 2) Wind Farm (Tranche 3)
Energy Storage Technologies
Battery Energy Compressed Air Energy Storage (CAES)

Table 22 Non-Potential Resource Option Technologies	
Technology	**Comment**
Baseload Technologies	
• Geothermal – conventional • Geothermal – hot dry rock	• Lack of resources
Intermediate / Peaking Load Technologies	
None	
As Available Load Technologies	
• Solar thermal – compact linear Fresnel reflector • Solar thermal – central receiver • Solar thermal – chimney • Ocean energy (all technologies)	• Developmental status of solar technologies • Lack of resources for ocean energy
Energy Storage Technologies	
• Flywheel • Super conducting magnet • Ultra capacitor	• Developmental status / not energy application

Numerous attributes of the resource options from Table 22 were characterized. These characterizations are discussed in the following sections. 4 CSR 240-22.040 Appendix B contains a copy of the characterization table.

4 CSR 240-22.040 (1) (A)

Fuel Type and Feasible Variations in Fuel Type or Quality

There are five primary fuel or energy sources that were considered in the renewable and energy storage supply-side resource. The primary fuel sources considered consisted of the following:

- Biomass – which generally includes forest residues, urban wood waste, and forest product industry residues.
- Wind.
- Solar.
- Geothermal.
- Water – as run-of-river and impound.

The ability of a technology to utilize different fuels, its fuel flexibility, was also assessed. Only biomass technologies have fuel flexibility. Their flexibility is constrained to types of biomass or possible fossil fuel firing for startup or other purposes. LFG is a biomass derived fuel. Table 23 summarizes the assumed fuels for each of the potential technologies and their fuel flexibility.

Table 23
Fuels and Fuel Flexibility

	Assumed Fuel	Fuel Flexibility
Baseload Technologies		
Biomass Combustion – Standalone	Wood	Yes
Biomass Combustion – CHP	Wood	Yes
Biomass Combustion – Cofiring	Wood	Yes
LFG – Reciprocating Engine	LFG	No
LFG – Combustion Turbine	LFG	No
Biomass IGCC	Wood	Yes
Waste-to-Energy – Mass Burn	MSW	No
Waste-to-Energy – RDF	RDF	No
Waste-to-Energy – Plasma Arc	MSW	No
Intermediate / Peaking Load Technologies		
Hydroelectric – Run of River	Water	n/a
Hydroelectric – Dam	water	n/a
As Available Load Technologies		
Solar Photovoltaic – Commercial	Solar	n/a
Parabolic Trough w/o Storage	Solar	n/a
Parabolic Trough w/ 3 hr Storage	Solar	n/a
Parabolic Dish	Solar	n/a
Wind Farm (Tranche 1)	Wind	n/a
Wind Farm (Tranche 2)	Wind	n/a
Wind Farm (Tranche 3)	Wind	n/a
Energy Storage Technologies		
Battery Energy	none	n/a
CAES	Natural Gas	Limited

4 CSR 240-22.040 (1) (B)

(1)(B) Practical Size Ranges

The selection of practical size ranges for each of the renewable and energy storage technologies was based on the reasonable capability to implement the technology. Typical sizes were selected to preclude having to evaluate first of a kind size issues. These sizes are as follows and summarized in Table 24:

- Biomass – Biomass fueled plants are commonly limited in capacity because of the cost of fuel resource. Larger plant sizes require larger fuel supply areas that increase the delivered cost of fuel. Plant sizes up to 50 to 100 MW have been built or proposed. Many of the most successful plants have been in the 25 to 35 MW range. A capacity of 35 MW was selected to be representative of likely plant sizes that could be implemented. WTE capacity sizing was assumed to the same as biomass.
- Wind – Wind plants are quite variable in size. Plants could be a single turbine or dozens of turbines. A plant size of 100 MW was selected to be representative of a utility scale wind plant located in the Midwest.
- LFG – The size of a LFG fired power plant can vary widely. The supply of LFG produced by a source is typically the limiting factor on the electrical generation capacity. Single unit capacity for reciprocating engine technology is limited to smaller capacities. Combustion turbines firing LFG are available in larger capacities compared to reciprocating engines. In both situations, multiple units could be arranged to allow for larger firing rates to consume the LFG supply. Plant sizes of 3 MW and 5 MW for reciprocating engine and combustion turbine, respectively, were characterized as representative sizes.
- Solar Thermal – Solar thermal systems are modular and scalable. The largest facilities currently in operation have generation capacities of roughly 80 MW. Recently proposed facilities utilizing either parabolic trough or dish Sterling technologies have ranged in capacity from 100 MW to 200 MW to take advantage of economies of scale. Therefore, a representative size of 100 MW was selected for dish sterling and parabolic trough systems with no storage capacity, while for

parabolic trough systems with 3 hours of storage capacity, a representative size of 200 MW was selected.

- Solar PV – Like wind, solar PV plant size is very modular. Large utility scale plants in the US have recently been built in the range of 1MW to 8 MW. For this study, a 500 kW capacity was characterized to be representative of a possible Midwestern plant.
- Geothermal – Geothermal is not a viable renewable energy resource in the Midwestern US, and therefore no size was selected.
- Water – Hydro plants are quite variable in size based on the water resources available at the plant location. Plant size was selected as an average of the published capacities of existing plants in Missouri based on data available from the Idaho National Energy Efficiency Laboratory.

Table 24
Net Plant Output

	Selected Output, MW
Baseload Technologies	
Biomass Combustion – Standalone	35
Biomass Combustion – CHP	35
Biomass Combustion – Cofiring	35
LFG – Reciprocating Engine	3
LFG – Combustion Turbine	5
Biomass IGCC	35
Waste-to-Energy – Mass Burn	35
Waste-to-Energy – RDF	35
Waste-to-Energy – Plasma Arc	35
Intermediate / Peaking Load Technologies	
Hydroelectric – Run of River	25
Hydroelectric – Dam	25
As Available Load Technologies	
Solar Photovoltaic – Commercial	0.5
Parabolic Trough w/o Storage	100
Parabolic Trough w/ 3 hr Storage	200
Parabolic Dish	100
Wind Farm (Tranche 1)	100
Wind Farm (Tranche 2)	100
Wind Farm (Tranche 3)	100
Energy Storage Technologies	
Battery Energy	10
CAES	202

4 CSR 240-22.040 (1) (C)

Maturity of the Technology

The maturity of each of the potential technologies was qualitatively assessed. Technology maturity was assessed as either "mature" or "developing." Technologies defined as mature were those that are proven and well established within the electric power generation industry. Developing technologies consist of all other technologies that may have limited experience, have been utilized in demonstration projects, or consist of laboratory tested conceptual designs. Table 25 lists the maturity of each technology.

Table 25 Technology Maturity	
Baseload Technologies	
Biomass Combustion – Standalone	Mature
Biomass Combustion – CHP	Mature
Biomass Combustion – Cofiring	Mature
LFG – Reciprocating Engine	Mature
LFG – Combustion Turbine	Mature
Biomass IGCC	Developing
Waste-to-Energy – Mass Burn	Mature
Waste-to-Energy – RDF	Mature
Waste-to-Energy – Plasma Arc	Developing
Intermediate / Peaking Load Technologies	
Hydroelectric – Run of River	Mature
Hydroelectric – Dam	Mature
As Available Load Technologies	
Solar Photovoltaic – Commercial	Mature
Parabolic Trough w/o Storage	Mature
Parabolic Trough w/ 3 hr Storage	Developing
Parabolic Dish	Developing
Wind Farm (Tranche 1)	Mature
Wind Farm (Tranche 2)	Mature
Wind Farm (Tranche 3)	Mature
Energy Storage Technologies	
Battery Energy	Mature
CAES	Developing

4 CSR 240-22.040 (1) (D)
Lead Time for Permitting, Design, Construction, Testing, and Startup

Estimates of project durations were collected for each of the technologies and were based on current permitting and market conditions as of May 2007. Information was gathered from published literature, in-house Black & Veatch data, and actual Black & Veatch project experience. Durations are provided for the permitting and development time and notice to proceed (NTP) to commercial operation (COD) for each of the technologies. These project durations are provided in Table 26 for each of the technologies.

Table 26
Project Durations

	Permitting and Development, months[1]	NTP to COD, months[1]
Baseload Technologies		
Biomass Combustion – Standalone	18 to 24	24
Biomass Combustion – CHP	18 to 24	24
Biomass Combustion – Cofiring	12 to 18	12
LFG – Reciprocating Engine	12 to 18	15
LFG – Combustion Turbine	12 to 18	15
Biomass IGCC	18 to 24	30
Waste-to-Energy – Mass Burn	21 to 27	30
Waste-to-Energy – RDF	21 to 27	30
Waste-to-Energy – Plasma Arc	21 to 27	30
Intermediate / Peaking Load Technologies		
Hydroelectric – Run of River	21 to 27	24
Hydroelectric – Dam	21 to 27	24
As Available Load Technologies		
Solar Photovoltaic – Commercial	9 to 15	12
Parabolic Trough w/o Storage	9 to 15	20
Parabolic Trough w/ 3 hr Storage	9 to 15	20
Parabolic Dish	9 to 15	14
Wind Farm (Tranche 1)	18 to 36	12
Wind Farm (Tranche 2)	18 to 36	12
Wind Farm (Tranche 3)	18 to 36	12
Energy Storage Technologies		
Battery Energy	9 to 15	6
CAES	14 to 18	21

[1] Project durations based on current permitting and market conditions as of May 2007.

4 CSR 240-22.040 (1) (E)
Capital Cost per Kilowatt

Generic screening-level overnight capital costs were collected for each of the technologies and were based on current market conditions as of May 2007. Capital cost estimates were gathered from published literature and in-house Black & Veatch data, and actual Black & Veatch project experience. Cost estimates were factored to be reflective of a generic Midwest US installation.

The capital costs are generic screening-level estimates appropriate for supply-side resource analyses; they were developed on a consistent basis, to the best extent that available information allowed. Capital cost estimates were developed assuming an engineering, procurement, and construction (EPC) method of contracting, which is exclusive of Owner's cost. Typically, the scope of work for EPC capital costs is the base plant, which is defined as being "within the fence." The sum of the EPC capital cost and the Owner's cost equals the total project cost or the total capital requirement for the project. These costs are not usually included in the EPC estimate and should be considered by the project developer to determine the total capital requirement for the project. Owner's cost items include costs for "outside the fence" physical assets, project development, and financing costs. The order of magnitude of these costs is project-specific and can vary significantly, depending upon technology and project-unique requirements. For a screening-level analysis, the Owner's cost can be estimated as a percentage of the EPC capital cost. An Owner's cost was assumed for each of the technologies.

The generic screening-level capital cost estimates are provided in Tables 27 through 30 for each of the technologies.

Table 27
Baseload Technology Capital Costs

	NPO	EPC Capital Cost (1)		Owner's Cost (2)	Total Project Cost (3)	
	MW	$1,000	$/kW	percent	$1,000	$/kW
Biomass Combustion–Standalone	35	105,300	3,010	30	137,000	3,910
Biomass Combustion – CHP	35	110,800	3,160	30	144,000	4,110
Biomass Combustion – Cofiring(4)	35	14,000	400	30	18,000	510
LFG – Reciprocating Engine	3	4,400	1,470	30	6,000	2,000
LFG – Combustion Turbine	5	7,400	1,480	30	10,000	2,000
Biomass IGCC	35	145,700	3,990	40	204,000	5,830
Waste-to-Energy – Mass Burn	35	148,500	4,240	40	208,000	5,940
Waste-to-Energy – RDF	35	178,200	5,090	40	249,000	7,110
Waste-to-Energy – Plasma Arc	35	142,900	4,080	40	200,000	5,710

(1)EPC capital costs are exclusive of Owner's costs.

(2)Owner's cost is estimated as an assumed percentage of EPC capital cost.

(3)Total project cost is the sum of the EPC capital cost and Owner's costs.

(4) Costs shown are incremental and assume that existing coal fired assets can host the cofiring

Table 28
Intermediate / Peaking Load Technology Capital Costs

	NPO	EPC Capital Cost (1)		Owner's Cost (2)	Total Project Cost (3)	
	MW	$1,000	$/kW	percent	$1,000	$/kW
Hydroelectric – Run of River	25	42,170	1,690	15	48,500	1,940
Hydroelectric – Dam	25	73,370	2,930	15	84,375	3,375

(1)EPC capital costs are exclusive of Owner's costs.

(2)Owner's cost is estimated as an assumed percentage of EPC capital cost.

(3)Total project cost is the sum of the EPC capital cost and Owner's costs.

Table 29
As Available Load Technology Capital Costs

	NPO	EPC Capital Cost [1]		Owner's Cost [2]	Total Project Cost [3]	
	MW	$1,000	$/kW	percent	$1,000	$/kW
Solar Photovoltaic – Commercial	0.5	4,000	8,000	5	4,200	8,400
Parabolic Trough w/o Storage	100	385,000	3,850	15	443,000	4,430
Parabolic Trough w/ 3 hr Storage	200	913,900	4,570	15	1,051,000	5,260
Parabolic Dish	100	297,000	2,970	15	342,000	3,420
Wind Farm (Tranche 1)	100	190,000	1,900	9	208,000	2,080
Wind Farm (Tranche 2)	100	210,000	2,100	11	232,000	2,320
Wind Farm (Tranche 3)	100	210,000	2,100	30	272,000	2,720

(1)EPC capital costs are exclusive of Owner's costs.

(2)Owner's cost is estimated as an assumed percentage of EPC capital cost.

(3)Total project cost is the sum of the EPC capital cost and Owner's costs.

Table 30
Energy Storage Technology Capital Costs

	NPO	EPC Capital Cost [1]		Owner's Cost [2]	Total Project Cost [3]	
	MW	$1,000	$/kW	percent	$1,000	$/kW
Battery Energy	10	900 to 1,700	90 to 170	10	990 to 1,870	99 to 187
CAES	202	222,200	1,100	40	311,000	1,540

[1] EPC capital costs are exclusive of Owner's costs.

[2] Owner's cost is estimated as an assumed percentage of EPC capital cost.

[3] Total project cost is the sum of the EPC capital cost and Owner's costs.

4 CSR 240-22.040 (1) (F)

Annual Fixed Operations and Maintenance Costs

Generic screening-level fixed operations and maintenance (O&M) costs were collected for each of the technologies. The fixed O&M cost estimates were gathered from in-house Black & Veatch data and were factored to be reflective of a generic Midwest US installation. The fixed O&M cost estimates were based on previous Black & Veatch estimates.

The fixed O&M costs are generic screening-level estimates appropriate for screening-level supply-side resource analyses; they were gathered from estimates generated on a consistent basis. Fixed O&M costs are driven predominantly by plant personnel salaries and wage rates, and the required level of staffing. The fixed O&M cost estimates used assumed staffing levels that could effectively operate and maintain the plant. Routine fixed maintenance costs are also included. Property taxes and operating insurance have not been included.

Generic screening-level fixed O&M costs for each of the technologies are provided in Table 31 through 34.

Table 31
Baseload Technology Fixed O&M Costs (2007$)

	NPO	Fixed O&M Costs	
	MW	$1,000	$/kW-yr
Biomass Combustion– Standalone	35	3,730	106.7
Biomass Combustion – CHP	35	3,800	108.6
Biomass Combustion – Cofiring	35	330	9.6
LFG – Reciprocating Engine	3	300	100.5
LFG – Combustion Turbine	5	200	40.3
Biomass IGCC	35	5,160	141.2
Waste-to-Energy – Mass Burn	35	5,720	163.3
Waste-to-Energy – RDF	35	7,800	222.7
Waste-to-Energy – Plasma Arc	35	6,970	199.0

Table 32
Intermediate / Peaking Load Technology Fixed O&M Costs (2007$)

	NPO	Fixed O&M Costs	
	MW	$1,000	$/kW-yr
Hydroelectric – Run of River	25	343	13.7
Hydroelectric – Dam	25	318	12.7

Table 33 As Available Load Technology Fixed O&M Costs (2007$)			
	NPO	**Fixed O&M Costs**	
	MW	**$1,000**	**$/kW-yr**
Solar Photovoltaic – Commercial	0.5	10	20.0
Parabolic Trough w/o Storage	100	5,430	54.3
Parabolic Trough w/ 3 hr Storage	200	9,600	48.0
Parabolic Dish	100	5,600	56.0
Wind Farm (Tranche 1)	100	3,500	35.0
Wind Farm (Tranche 2)	100	3,500	35.0
Wind Farm (Tranche 3)	100	3,500	35.0

Table 34 Energy Storage Technology Fixed O&M Costs (2007$)			
	NPO	**Fixed O&M Costs**	
	MW	**$1,000**	**$/kW-yr**
Battery Energy	10	50 to 150	5 to 15
CAES	202	2,220	11

4 CSR 240-22.040 (1) (G)

(1)(G) Annual Variable Operations and Maintenance Costs

Generic screening-level variable O&M costs were collected for each of the technologies. Variable O&M cost estimates were gathered from published literature and in-house Black & Veatch data and were factored to be reflective of a generic Midwest US installation.

The variable O&M costs are generic estimates appropriate for screening-level supply-side resource analyses; they were gathered from estimates generated on a consistent basis. Source variable O&M cost estimates include key variable cost components consisting of overhaul maintenance, consumables, and applicable reagents.

The generic screening-level variable O&M costs for each of the technologies are provided in Tables 35 through 38. The unit variable O&M costs were based on an assumed capacity factor and specific NPO, which are also provided.

Table 35
Baseload Technology Variable O&M Costs (2007$)

	NPO	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh
Biomass Combustion– Standalone	35	83	1,890	7.4
Biomass Combustion – CHP	35	81	1,940	7.8
Biomass Combustion – Cofiring	35	85	260	1.0
LFG – Reciprocating Engine	3	95	240	11.2
LFG – Combustion Turbine	5	95	370	9.9
Biomass IGCC	35	80	1,940	7.6
Waste-to-Energy – Mass Burn	35	80	13,530	55.2
Waste-to-Energy – RDF	35	80	11,730	47.8
Waste-to-Energy – Plasma Arc	35	80	12,800	52.2

Table 36
Intermediate / Peaking Load Technology Variable O&M Costs (2007$)

	NPO	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh
Hydroelectric – Run of River	25	40	377	4.3
Hydroelectric – Dam	25	40	359	4.1

Table 37
As Available Load Technology Variable O&M Costs (2007$)

	NPO	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh
Solar Photovoltaic – Commercial	0.5	21	13	23.0
Parabolic Trough w/o Storage	100	14	0	0
Parabolic Trough w/ 3 hr Storage	200	17	0	0
Parabolic Dish	100	12	0	0
Wind Farm (Tranche 1)	100	33	0	0
Wind Farm (Tranche 2)	100	35	0	0
Wind Farm (Tranche 3)	100	39	0	0

Table 38
Energy Storage Technology Variable O&M Costs (2007$)

	NPO	Capacity Factor	Variable O&M Cost	
	MW	percent	$1,000	$/MWh
Battery Energy	10	5	44 to 175	10 to 40
CAES	202	10	265	1.50

4 CSR 240-22.040 (1) (H)
Scheduled Routine Maintenance Outage Requirements

The source O&M estimates are based on routine maintenance outage requirements. Applicable assumed routine maintenance outage requirements can be categorized for the various renewable and energy storage technologies. Table 39 outlines the major routine maintenance outage requirements.

Table 39
Planned Maintenance Schedule

	Outage Pattern, week/yr
Baseload Technologies	
Biomass Combustion – Standalone	3-3-3-3-3-8
Biomass Combustion – CHP	3-3-3-3-3-8
Biomass Combustion – Cofiring	3-3-3-3-3-6
LFG – Reciprocating Engine	1-1-3
LFG – Combustion Turbine	3-3-6-3
Biomass IGCC	1-4-1-5
Waste-to-Energy – Mass Burn	3-3-3-3-3-8
Waste-to-Energy – RDF	3-3-3-3-3-8
Waste-to-Energy – Plasma Arc	3-3-4-3-3-10
Intermediate / Peaking Load Technologies	
Hydroelectric – Run of River	1
Hydroelectric – Dam	1
As Available Load Technologies	
Solar Photovoltaic – Commercial	Negligible
Parabolic Trough w/o Storage	0-0-3-0-0-6
Parabolic Trough w/ 3 hr Storage	0-0-3-0-0-6
Parabolic Dish	Negligible
Wind Farm (Tranche 1)	0-0-1
Wind Farm (Tranche 2)	0-0-1
Wind Farm (Tranche 3)	0-0-1
Energy Storage Technologies	
Battery Energy	Negligible
CAES	2-3-6-2

4 CSR 240-22.040 (1) (I)

Equivalent Forced Outage Rates or Full and Partial Forced Outage Rates

Generic equivalent forced outage rate (EFOR) and equivalent demand forced outage rate (EFORd) data were gathered for each of the technologies. The EFOR and EFORd data is provided in Table 40. The information was taken from the NERC GADS database and published literature to the extent that data was available. Where data was not available, they were estimated using data gathered from comparable technologies. The data are generic but representative for screening-level supply-side resource analyses.

Table 40
Forced Outage Data

	EFOR, percent	EFORd, percent
Baseload Technologies		
Biomass Combustion – Standalone	10	10
Biomass Combustion – CHP	10	10
Biomass Combustion – Cofiring	8	8
LFG – Reciprocating Engine	8	7
LFG – Combustion Turbine	7	6
Biomass IGCC	14	14
Waste-to-Energy – Mass Burn	10	10
Waste-to-Energy – RDF	10	10
Waste-to-Energy – Plasma Arc	12	12
Intermediate / Peaking Load Technologies		
Hydroelectric – Run of River	3	3
Hydroelectric – Dam	3	3
As Available Load Technologies		
Solar Photovoltaic – Commercial	NA	NA
Parabolic Trough w/o Storage	2	NA
Parabolic Trough w/ 3 hr Storage	2	NA
Parabolic Dish	NA	NA
Wind Farm (Tranche 1)	5	NA
Wind Farm (Tranche 2)	5	NA
Wind Farm (Tranche 3)	5	NA
Energy Storage Technologies		
Battery Energy	NA	NA
CAES	3	5

4 CSR 240-22.040 (1) (J)

Operational Characteristics and Constraints of Significance in the Screening Process

No additional operational characteristics or constraints were identified.

4 CSR 240-22.040 (1) (K)

Environmental Impacts, Including at Least the Following

4 CSR 240-22.040 (1) (K) 1

Air emissions including at least the primary acid gases, greenhouse gases, ozone precursors, particulates and air toxics;

Probable air emissions rates were gathered for each of the technologies, as applicable, and were selected to be representative of current New Source Performance Standards and BACT requirements. Only biomass, LFG, and CAES produce air emissions. These are presented in Table 41. The probable emissions rates are consistent with recent permitted ranges.

Table 41
Probable Emission Rates

	Nitrogen Oxides (NO_x), lb/MBtu	Sulfur Dioxide (SO_2), lb/MBtu	PM_{10}, lb/MBtu	Carbon Dioxide (CO_2), lb/MBtu
Baseload Technologies				
Biomass Combustion – Standalone	0.15	<0.1	0.015	Carbon neutral
Biomass Combustion – CHP	0.15	<0.1	0.015	Carbon neutral
Biomass Combustion – Cofiring	0.15	<0.1	0.015	Carbon neutral
LFG – Reciprocating Engine	0.2	Note 2	0.03	Carbon neutral
LFG – Combustion Turbine	0.2	Note 2	0.01	Carbon neutral
Biomass IGCC	0.15	<0.1	0.015	Carbon neutral
Waste-to-Energy – Mass Burn	0.34	0.05	0.015	200
Waste-to-Energy – RDF	0.32	0.05	0.015	200
Waste-to-Energy – Plasma Arc	0.2	0.05	0.015	200
Intermediate / Peaking Load Technologies				
Hydroelectric – Run of River	0	0	0	0
Hydroelectric – Dam	0	0	0	0
As Available Load Technologies				
Solar Photovoltaic – Commercial	0	0	0	0
Parabolic Trough w/o Storage	0	0	0	0
Parabolic Trough w/ 3 hr Storage	0	0	0	0
Parabolic Dish	0	0	0	0
Wind Farm (Tranche 1)	0	0	0	0
Wind Farm (Tranche 2)	0	0	0	0
Wind Farm (Tranche 3)	0	0	0	0
Energy Storage Technologies				
Battery Energy	0	0	0	0
CAES	0.1	0.0005	0.01	117

Notes:
1. The values in this table represent typical ranges noted in recent permits and applications. A review of all BACT emissions limit determinations may show some values outside of the listed ranges.
2. SO_2 emissions are highly variable. Sulfur in bio-gas can range from 100 to 12,000 ppmvd.

4 CSR 240-22.040 (1) (K) 2

Waste generation including at least the primary forms of solid, liquid, radioactive and hazardous wastes;

Quantities of solid waste production were developed for each of the potential technologies, as applicable. Only biomass and waste-to-energy plants generate a significant amount of solid waste among the renewable and energy storage technologies. Quantities of biomass and waste-to-energy combustion products were estimated using assumptions for an expected average biomass and waste-to-energy composition. The solid waste production estimates are summarized in Table 42.

Table 42
Solid Waste Production Estimates

	Quantity, tons/year
Baseload Technologies	
Biomass Combustion – Standalone	1,900
Biomass Combustion – CHP	2,000
Biomass Combustion – Cofiring	1,400
LFG – Reciprocating Engine	Negligible
LFG – Combustion Turbine	Negligible
Biomass IGCC	1,500
Waste-to-Energy – Mass Burn	65,400
Waste-to-Energy – RDF	69,500
Waste-to-Energy – Plasma Arc	60,100
Intermediate / Peaking Load Technologies	
Hydroelectric – Run of River	0
Hydroelectric – Dam	0
As Available Load Technologies	
Solar Photovoltaic – Commercial	0
Parabolic Trough w/o Storage	0
Parabolic Trough w/ 3 hr Storage	0
Parabolic Dish	0
Wind Farm (Tranche 1)	0
Wind Farm (Tranche 2)	0
Wind Farm (Tranche 3)	0
Energy Storage Technologies	
Battery Energy	0
CAES	0

4 CSR 240-22.040 (1) (K) 3

Water impacts including direct usage and at least the primary pollutant discharges, thermal discharges and groundwater effects; and

Water consumption estimates for each of the technologies were gathered from in-house Black & Veatch data, as applicable. The water consumption estimates were referenced from published literature and actual Black & Veatch project data. Where consumptive water use is a result of cycle heat rejection, values are based on the assumption that wet, mechanical draft cooling towers would be used. Because water consumption can vary from one plant to another as a result of unique plant characteristics, the estimates are considered generic but appropriate for screening-level supply-side resource analyses. A water consumption range for each of the technologies is provided in Table 43. The estimates are representative of units at full load.

Pollutant discharges could not be adequately addressed in this study because raw water quality and wastewater treatment processes could not be identified to any credible degree that allowed for valid assumptions.

Table 43 Water Consumption	
	Water Consumption, gal/min
Baseload Technologies	
Biomass Combustion – Standalone	300 to 400
Biomass Combustion – CHP	300 to 400
Biomass Combustion – Cofiring	200 to 400
LFG – Reciprocating Engine	0
LFG – Combustion Turbine	0
Biomass IGCC	250 to 350
Waste-to-Energy – Mass Burn	300 to 400
Waste-to-Energy – RDF	300 to 400
Waste-to-Energy – Plasma Arc	NA
Intermediate / Peaking Load Technologies	
Hydroelectric – Run of River	0
Hydroelectric – Dam	0
As Available Load Technologies	
Solar Photovoltaic – Commercial	0
Parabolic Trough w/o Storage	1,500
Parabolic Trough w/ 3 hr Storage	1,500
Parabolic Dish	0
Wind Farm (Tranche 1)	0
Wind Farm (Tranche 2)	0
Wind Farm (Tranche 3)	0
Energy Storage Technologies	
Battery Energy	0
CAES	0

4 CSR 240-22.040 (1) (K) 4

Siting impacts and constraints of sufficient importance to affect the screening process; and

No siting impacts were identified that would affect the screening results. It was assumed that fuel, transmission interconnection, raw water, and land would be sufficiently available in or around the state of Missouri to enable successful plant siting using normal engineering practices.

4 CSR 240-22.040 (1) (L)

Other characteristics that may make the technology particularly appropriate as a contingency option under extreme outcomes for the critical uncertain factors identified pursuant to 4 CSR 240-22.070(2).

No other technology characteristics were identified for inclusion in the technology screening.

Nuclear

The nuclear industry is very active in developing plans for the start of construction of a new generation of nuclear plants. The 2005 Energy Policy Act required the United States Government's Secretary of Energy (Secretary of Energy) to execute the Nuclear Power 2010 Program. The Nuclear Power 2010 Program has three objectives:

- Demonstrate the Early Site Permit (ESP) regulatory process which pre-approves plant sites.
- Demonstrate the NRC's combined Construction and Operating Licensing (COL) process.
- Certification of state-of the art (Generation III) design for nuclear power plants.

The Nuclear Power 2010 Program is structured as a 50/50 cost-shared arrangement to address regulatory and financial uncertainties surrounding new plant construction. The U.S. Department of Energy ("DOE") has committed $1.25 billion to this effort. DOE has agreed to support work of two consortiums and two technologies:

- NuStart Energy LLC: AP1000 (Bellefonte site).
- NuStart Energy LLC: ESBWR (Grand Gulf site) and Dominion Energy: ESBWR (North Anna site)

The Energy Policy Act also offers incentives in the form of production tax credits of up to $125 million annually estimated at 1.8 cents/kWh during the first eight years of operation for the first 6,000 MW of capacity (prorated to actual MW capacity if more than 6,000 MW). New nuclear power plants would be eligible for federal loan guarantees of up to 80 percent of construction costs. In addition, the Secretary of Energy could pay up to $500 million per project in cost resulting from NRC delays for the first two new reactors and up to $250 million per project for the next four reactors.

The significant tax credits available are the Federal Government's attempt to offset the first of a kind costs and risks that the first plants will face. The potential benefits can outweigh the potential costs if the risks are understood and careful attention is paid to selecting a technology vendor who can manage and minimize the risks. One of the first risks to overcome is the technology risk. The best technologies should have a proven, reliable, licensable design ready for construction.

The NRC is responsible for Design Certification (DC) of new reactor technologies. Table 44 lists the new reactor technologies and their NRC DC status.

These 12 nuclear technologies were chosen to be evaluated based on AmerenUE's potential need for new nuclear generation. In light of the current status of the nuclear industry, AmerenUE has identified the following three general factors associated with their need for additional nuclear generation.

- The reactor technology must be US licensable. Exotic Generation IV technologies that will not be ready for commercialization for another 25 years and are not appropriate for AmerenUE consideration. Similarly, foreign reactor designs that would have great trouble meeting US licensing criteria are also not attractive to AmerenUE.
- Low generation cost consistent with safety and reliability. Several factors contribute to low cost generation as discussed below.
  - Economies of scale in construction and operation.
  - Extended refueling cycle periods to maximize availability.
  - Low fuel cycle costs.
  - High efficiency.
  - Able to take advantage of government incentives.
- The reactor technology must provide a clear link to proven technology. AmerenUE is interested in safe, reliable, efficient technology that has a long history of evolution and provides a high level of confidence of reliable operation. Exotic, unproven reactor technology will expose AmerenUE to greater risk.

Table 44
Nuclear Technologies Screened

Reactor Design	Vendor	App. Capacity (MWe)	Reactor Type	NRC DC Status
US-EPR	AREVA NP	1600	PWR	Pre-Certification, Target 2009
US-APWR	Mitsubishi	1700	PWR	Undergoing Certification, Target 2011
AP-1000	Westinghouse	1117	PWR	Certified (January 2006)
ABWR	GEH	1350	BWR	Certified (May 1997)
ESBWR	GEH	1520	BWR	Undergoing Certification, Target 2010
AP-600	Westinghouse	650	PWR	Certified (December 1999)
System 80+	Westinghouse	1300	PWR	Certified (May 1997)
ACR Series	AECL Technologies	700- 1200	PHWR Modified	Pre-Certification, application apparently withdrawn
PBMR	Westinghouse, Eskom	180	HTGR	Pre-Certification, No Target
IRIS	Westinghouse et. al.	360	PWR	Pre-Certification, Target 2010
GT-MHR	General Atomics	325	HTGR	Research Prototype planned
4S	Toshiba	10 – 50	Sodium Cooled	Inactive Review

There are currently eight designs from four vendors which have either completed or are in the process of completing the NRC DC process. Of these eight designs, five are actively being marketed in the United States. These include the US-EPR, the US-APWR, the AP1000, the ABWR and the ESBWR. A brief introduction to each technology follows.

Areva US-EPR

The US-EPR is a four-loop Pressurized Water Reactor (PWR) with rated thermal power of 4590 MWt, designed by Areva NP. Areva NP is a jointly-owned subsidiary of Areva and Siemens. While Areva NP has never built a PWR in the United States, it has extensive experience throughout the world. While the firm's initial expertise was developed while both Siemens and Areva were licensees to Westinghouse Electric Corporation (Westinghouse) in the 1970's and 1980's, their more recent N4, four-loop design was entirely developed in-house. An EPR is currently being constructed at the Olkiluoto site in Finland and the Flamanville site in France. This is a notable advantage in that design details and bills of material will be finalized well in advance of AmerenUE's scheduled needs.

The US-EPR is an evolutionary design with active safety features. The Reactor Coolant System (RCS), loop configuration and main component are similar to currently operating PWRs. The US-EPR RCS includes a reactor vessel housing the fuel assemblies, a pressurizer, one Reactor Coolant Pump (RCP) per loop, one Steam Generator (SG) per loop, associated piping and related control and protection systems. This fundamental design is identical to operating PWRs.

The RCS is housed within a concrete containment building which is internally lined with steel. The containment building is then enclosed in a Shield Building, with an annular space between the two buildings. The Shield Building is an additional safeguard not found in currently licensed US PWRs.

The plant is designed with four trains of safety systems. These systems are physically separated into four Safeguards Buildings. The Reactor Building, Fuel Building and two of the four Safeguards Buildings are entirely protected against aircraft hazards and external explosions. These levels of redundancy and separation of safety systems are advanced beyond that found in any currently operating US PWR.

Each safety train has a dedicated Emergency Diesel Generator (EDG) in the event of loss of off-site power. Two additional diesel generators provide further protection against a simultaneous loss of off-site power and all four EDGs.

The US-EPR design philosophy is based upon improving upon the design of currently operating PWRs in the areas of increased redundancy and separation, reducing core damage frequency, reducing large radioactivity release frequency, mitigating the effects of severe accidents, protecting critical systems from external events, improved man-machine interface and allowing more time for operator actions.

Key US-EPR design parameters include the following:

- Design life- 60 years
- Thermal power- 4,590 MW
- Net average electrical power- 1,600 MW
- Efficiency- 36 percent
- Number of fuel assemblies- 241
- Fuel lattice- 17 x 17
- Active Fuel Length- 13.78 ft
- Rods per Assembly- 265
- Refueling Frequency- Up to 24 months
- Areva NP formally requested a pre-application review of the US-EPR on February 8, 2005.

Mitsubishi US-APWR

The Mitsubishi Heavy Industries (Mitsubishi) US-APWR is another advanced, active four-loop PWR design based on conventional technology. Like Areva, Mitsubishi's roots in nuclear technology come from experience gained as a licensee of Westinghouse. The US-APWR has evolved from a joint Mitsubishi-Westinghouse design effort in the 1980's for the Advanced Pressurized Water Reactor (APWR). The design was certified by the United States NRC and selected for several Japanese sites. Four units are currently under planning or licensing in Japan, with Japan Atomic Power Company's Tsuruga Units 3 & 4 the lead plants. No APWRs have yet been built. Following the selection of Toshiba for the purchase of Westinghouse, Mitsubishi decided to enter the US market directly as a competitor. They are currently supporting one COLA application for TXU.

Mitsubishi is in a unique position in the global nuclear industry in that the corporation includes fabrication and heavy manufacturing infrastructure that allows it to fabricate the large components for a PWR, including the Reactor Vessel and SGs. Mitsubishi directly controls the companies that would supply approximately 33 percent of the Reactor Protection Systems (RPS).

The basic design of the US-APWR is similar to the APWR. It is the largest of the available technologies at 1,700 MWe output. As stated above, it is an active design which relies primarily on larger heat transfer surfaces, turbine blades and nuclear fuel improvements. Examples include the last stage low pressure turbine blades, which are 70 inches long verses 54 inches for the APWR; the SG heat transfer area is 91,500 ft2/SG verses 70,000 ft2/SG for the APWR and a higher density fuel pellet. The reactor also includes a neutron reflector to support a more even fuel burnout and improved plant efficiency. The design includes full four safety trains for both electrical and mechanical systems and has completely digital control and protection systems. The US-APWR utilizes a digital architecture that has been built and is operating in earlier generation Japanese PWRs, making it the only design under NRC certification with an operating digital control system. The Reactor Coolant Pumps (RCPs) are similar to those already used in conventional PWRs, except that the seal designs have been improved.

Key US-APWR design parameters include the following:

- Design life- 60 years
- Thermal power- 4,451 MW
- Net electrical power- 1,700 MW
- Efficiency- 39 percent
- Number of fuel assemblies- 257
- Fuel lattice- 17 x 17
- Active Fuel Length- 14 ft
- Rods per Assembly- 264
- Refueling Frequency- Up to 24 months

Mitsubishi is the most recent nuclear vendor to request Design Certification. They formally requested a pre-application review of the US-APWR on August 31, 2006. They are utilizing a two-pronged, parallel path approach, which includes both submittal of Topical Reports and the phased submittal of the Design Certification Document (DCD). NRC DCD is scheduled to be complete in mid- 2011.

Westinghouse AP1000

The Westinghouse AP1000 is a passive two-loop, 1,117 MWe PWR design which is a significant departure from conventional technology. Based on a design initially intended for secure, stationary military power plants the AP1000 is the culmination of over fifteen years design effort in passive technology by Westinghouse. Westinghouse has been the leader in PWR technology, with nearly 50 percent of the worlds' nuclear plants being based on designs by either Westinghouse or its licensees.

The AP1000 relies on the thermodynamic principle that as water is heated it becomes less dense. This along with gravity and compressed gas provide post-accident circulation. Even with no operator action and a complete loss of all on-site and off-site ac power, the AP1000 will safety shut down. The first commercial design, the AP600 was a smaller, 600MW plant which was ultimately determined to be too small for the US marketplace. Both the AP600 and AP1000 have received NRC Design Certification and Westinghouse was recently awarded a contract for the supply of four AP1000 plants in China at the Sanmen and Haiyang sites. Civil construction has begun on one of these sites with commercial operation scheduled for 2013.

By relying on passive technology, the AP1000 utilizes considerably less infrastructure than a conventional PWR. For example, the AP1000 has 180 pumps verses 280 for a conventional PWR; 1,400 safety class valves verses 2,800; 19,000 ft of safety class piping verses 110,000 ft; 1.2 million ft of cable verses 9.1 million and a Seismic Building volume of 5.6 million ft3 verses 12.7 million ft3. The plant has one SG per loop, which is a similar design to current PWRs but with a much larger heat transfer surface area than typical for two loop plants. The RCPs are completely different than conventional PWRs, although they are based on a military design manufactured by Westinghouse for decades. They are variable speed, canned motor pumps directly mounted to the SG and inverted. There are two RCPs/loop for a total of four. This design eliminates the RCP seal assemblies that are maintenance intensive in the current operating PWRs. Like the other Generation III/III+ designs, the plant has four safety trains and is entirely digital in control and protection. It has the smallest output of the Generation III/III+ designs at 1,117 MWe. It also has an eighteen month refueling frequency. Due to the neutron physics associated with this particular core design the fuel would require considerable enrichment to support a twenty-four month refueling cycle, which Westinghouse has determined to be an economic disadvantage.

Key AP1000 design parameters include the following:

- Design life- 60 years
- Thermal power- 3,400 MW
- Net electrical power- 1,117 MW
- Efficiency- 35 percent (estimate)
- Number of fuel assemblies- 157
- Fuel lattice- 17 x 17
- Active Fuel Length- 14 ft
- Rods per Assembly- 264
- Refueling Frequency- Up to 18 months

The NRC has reviewed Westinghouse's request for final design approval (FDA) and standard design certification for the AP1000. The AP1000 standard plan design is based closely on the AP600 design that NRC certified on December 16, 1999. The final design certification rule was signed by the Secretary of the Commission on January 23, 2006, and issued in the Federal Register on January 27, 2006. A revised FDA based on Revision 15 of Westinghouse's DCD was issued on March 10, 2006.

GEH ABWR

The General Electric (GE) Advanced Boiling Water Reactor (ABWR) is one of two Generation III/III+ offerings from GE Hitachi (GEH), a recently formed joint venture between the two firms. GEH is 60 percent owned by GE and 40 percent by Hitachi and is the sole global nuclear contacting company, except for Japan. In Japan, the organization is primarily owned by Hitachi. A Boiling Water Reactor (BWR) differs from a PWR in that it has no SG, but rather transfers the steam directly from the reactor to the steam turbine, returning it through the condensate and feed system. This design has the advantage of being more thermally efficient and simple (no SGs) but has the disadvantage of contaminating more of the plant, typically exposing the plant staff to higher radiation doses. A BWR also has a smaller containment building, does not rely on chemical poison (boron) for plant shutdown and is simpler to operate in emergency conditions.

The ABWR nuclear plant was developed in cooperation with the Tokyo Electric Power Company and GE's partners Hitachi and Toshiba. The ABWR is an evolutionary design from previous BWRs, improving on design, modular construction, full four train safety systems and digital instrumentation and control. Seven ABWRs have been constructed in Asia, with Lungmen 1& 2 in Taiwan and Shimane 3 in Japan currently under construction. The ABWR has been proven to be constructed in as little as 37 months in Japan. It has the distinction of being the first Generation III to be commercially operating. The ABWR is an active design which has a larger Containment than the BWR/6 (180 m3/MWe verses 170), more safety system pumps (18 verses 9), more recirculation pumps (10 verses 2) and more fuel bundles (872 verses 800). It has three safety diesel generators, the same number as in the BWR/6.

Key ABWR design parameters include the following:

- Design life- 60 years
- Thermal power- 3,926 MW
- Net electrical power- 1,350 MW
- Efficiency- 35 percent
- Number of fuel assemblies- 872

- Fuel lattice – 10 x 10
- Rods per Assembly – 92
- Active Fuel Length- 12.5 ft
- Refueling Frequency- Up to 24 months

The Nuclear Regulatory Commission amended its regulations to certify the U.S. Advanced Boiling Water Reactor (ABWR) design developed by GE Nuclear Energy in May 1997. The certification was the first to be issued under the NRC's new licensing process for standard design certification.

GEH ESBWR

The GEH Evolutionary Simplified BWR (ESBWR) is a passive design that relies on natural circulation much like the AP1000. Also like the AP1000, it has a significantly simplified design resulting in less components and materials of construction. Both the ABWR and EWSBWR have fine motion control rods. On the ESBWR these rods and the natural circulation design allow for reactivity control without the use of recirculation pumps. There are no recirculation pumps, safety system pumps, or safety diesel generators in the ESBWR design. There are 25 percent fewer pumps, motors and valves than any previous BWR design, including the ABWR. The ESBWR has approximately 15 percent less concrete and 10 percent less steel than currently operating BWRs. These design enhancements significantly improve the radiation exposure of plant workers. An independent review of the design has suggested O&M costs will be approximately 20 percent less than current technology. The passive design requires no operator action for the first 72 hours following a severe accident. As with all other Generation III/III+ designs the ESBWR has four safety trains and a fully digital instrumentation and control system.

The ESBWR utilizes the 1,600 MW GE steam turbine generator, which GE advertises as the world's largest output 60 Hz machine.

Key ESBWR design parameters include the following:

- Design life- 60 years
- Thermal power- 4,500 MW
- Net electrical power- 1,520 MW
- Efficiency- 34.7 percent
- Number of fuel assemblyies- 1132
- Fuel lattice- 10 x 10
- Active Fuel Length- 10 ft

- Rods per Assembly – 92
- Refueling Frequency- Up to 24 months

GEH formally requested a pre-application review of the ESBWR on August 25, 2005. DCD submittals commenced in mid- 2006 and all modules are to be submitted by mid- 2008. The current schedule for NRC approval of the DCD is December 2009.

The designs listed above are currently in various stages of development by global nuclear suppliers. During Phase I of the screening, the above technologies (Table 44) were identified, evaluated, and screened to five viable generation III/III+ technologies that are actively being marketed in the United States. These technologies are shown below.

- Areva US-EPR
- Mitsubishi US-APWR
- Westinghouse AP1000
- GEH ABWR
- GEH ESBWR

The five viable Generation III/III+ technologies were screened along with the ACR-1000 and the PBMR in accordance with AmerenUE's needs. The ACR-1000 and PBMR were included in the screening since they represented technologies that were a marked departure from the light water technologies. Although the ACR-1000 and PBMR are not licensable in the United States in the near future, their inclusion in the screening analysis ensures that consideration of technologies other than light water reactors do not present significant potential for use by AmerenUE. Brief descriptions of the ACR-1000 and PBMR technologies follow. Table 3 presents the screening criteria.

AECL ACR Series

The Advanced CANDU Reactor (ACR) is a heavy water moderated reactor designed by Atomic Energy of Canada, Limited (AECL). The ACR is a third-generation reactor. While retaining the low-pressure heavy water moderator, it incorporates some features of the pressurized water reactor. Adopting light water cooling and a more compact core reduces capital cost, and because the reactor is run at higher temperature and coolant pressure, it has higher thermal efficiency. The ACR also uses slightly enriched uranium fuel, computer-controlled operation, and on-power fueling.

On June 19, 2002, Atomic Energy of Canada, Limited (AECL) requested pre-application review of their ACR-700 for licensing in the United States. The ACR-700 is a 700 MWe light-water-cooled reactor with two steam generators and four heat transport pumps. Initially selected as one of several designs under consideration for development by Dominion Energy, it was removed form consideration when the NRC notified AECL that certification would take longer than average because of the unique features associated with the ACR design. AECL apparently has withdrawn their DC application and is currently focusing on design of the ACR-1000 and certification in Canada and the UK.

PBMR

South Africa's Pebble Bed Modular Reactor (PBMR) is being developed by a consortium led by the utility Eskom with assistance from Westinghouse, and drawing on German expertise. It represents a dramatic improvement in safety and passive control as compared to current US light-water designs. Production units will be 165 MWe, will have a direct-cycle gas turbine generator and thermal efficiency about 42 percent. Up to 450,000 fuel pebbles will recycle through the reactor continuously (about six times each) until they are expended.

Exelon requested that the NRC commence design certification of the PBMR in 2000, but the review was terminated in 2002 when Exelon withdrew from the consortium. There has been no further interest in the PBMR by US utilities and the consortium has informed the NRC that they do not plan to request further review until prototypes are built in South Africa to demonstrate the design on a larger scale.

Screening Methodology

In conducting an IRP, it is not important that individual generating unit alternatives are completely optimized because the IRP considers a large number of alternatives and it is not prudent to spend large amounts on developing each of those alternatives. It is, however, important that a consistent amount of effort be spent to develop each alternative. The purpose of the IRP is to select the technology, size, and timing of generating unit additions in conjunction with consideration of other factors such as conservation and demand-side management and emissions. Thus for a technology such as nuclear, it is appropriate to evaluate a single specific nuclear technology. That said, it is important that the specific technology be a relatively good technology for the utility. The screening process presented in this section is designed to select specific nuclear technologies (two to three) which are well suited for AmerenUE's general needs. In the next phase of the study, AmerenUE's more specific needs will be used to select a single nuclear technology to characterize in more detail to evaluate with other generating technologies.

Cost considerations limit the amount of work that can be expended upon each individual alternative. As a result existing publicly available literature from credible sources is heavily relied upon to obtain details relative to the individual technologies to be screened.

The screening methodology used involves identifying categories that are relevant to AmerenUE's general needs. For each of the category's selected, criteria and their corresponding relative weights are selected. Finally scoring bases are identified. The screening methodology and results are presented in Table C-1 and Table C-2 of4 CSR 240-22.040 Appendix C.

Every attempt is made to develop a screening methodology which is definitive in all aspects. Unfortunately, there is no escaping requiring some level of judgment in the screening process. The selection of the categories, the criteria, the weighting, and the scoring basis all will be viewed somewhat differently by different individuals. For this screening process, a team of three Black & Veatch experts were used. The first team member was a nuclear engineer experienced in capital and O&M costs for various nuclear feasibility studies. The second team member was the Vice President in charge of group which does nuclear study work. He has over 14 years of nuclear engineering experience. He is a certified Chief Engineer by US Naval Sea Systems Command and a Chartered Nuclear Engineer in the United Kingdom. The third team member was a nuclear engineer that has focused on IRP's for the last several years. Black & Veatch has successfully used this team approach in similar studies requiring quantification of judgment.

The screening resulted in the following ranking:

[redacted]

These three technologies were evaluated in more detail in Phase II in accordance with AmerenUE's needs and the US-EPR was ultimately selected for detailed characterization.

4 CSR 240-22.040 (1) (A)

Fuel Type and Feasible Variations in Fuel Type or Quality

The technologies evaluated in Table 44 are capable of burning a range of fuels including enriched uranium (UO2), mixed oxide, and natural uranium. Fuel costs and other fuel specifics are separately provided by AmerenUE.

4 CSR 240-22.040 (1) (B)

(1)(B) Practical Size Ranges

The reactor sizes in Table 44 range from 10 MW(e) to 1,700 MW(e). Based on AmerenUE's need for adequate economies of scale, options outside of the 1,100 MW(e) to 1,700 MW(e) range were eliminated, leaving 7 possible options.

4 CSR 240-22.040 (1) (C)

Maturity of the Technology

Since the nuclear technologies evaluated in Phase I and II are new nuclear generation technologies, criteria were created to evaluate the development risks associated with new generation technologies. Table 45 presents the criteria associated with the maturity of each technology.

Table 45
Technology Maturity

	Detailed Design Complete	Technology Under Construction	Technology Currently Operating
ABWR	Yes	Yes	Yes
ACR-1000	No	No	No
AP1000	DCD Approved	Yes	No
ESBWR	DCD in US NRC review	No	No
PBMR	No	No	No
US-APWR	DCD in US NRC review	No	No
US-EPR	DCD in US NRC review	Yes	No

4 CSR 240-22.040 (1) (D)

Lead Time for Permitting, Design, Construction, Testing, and Startup

There are currently 19 proposed applications comprising 28 units that are expected to submit combined Construction and Operating License Applications (COLAs) from 2007 through 2009 as shown in Table 46. Details of the expected COLA application are presented in Table C-3 of 4CSR 240-22.040 Appendix C. The technologies were also evaluated on the completeness of detailed design as shown above in Table 45.

Table 46
US Nuclear Power Plant Applications 2007-2009

Technology	Number of Applications	Number of Units
AP-1000	6	12
US-EPR	5	6
ESBWR	3	3
ABWR	1	2
US-APWR	1	2
To Be Determined	3	3
Total	**19**	**28**

The technologies were also evaluated based on their Design Certification status as shown in Table 47.

Table 47 Design Certification Status	
	Design Certification Status
ABWR	Certified
ACR-1000	No Target Date
AP1000	Certified
ESBWR	Target 2010
PBMR	No Target Date
US-APWR	Target 2011
US-EPR	Target 2009

The technologies were further evaluated based on construction schedule as shown in Table 48.

Table 48 Construction Schedule			
Contract Effective Date to Commercial Operation			
	CED to CO (months)	**FC to FL (months)**	**FL to CO (months)**
ABWR	72	36	7
ACR-1000	70	42	8
AP1000	69	36	6
ESBWR	N/A	39	N/A
PBMR	70	40	6
US-APWR	70	40	6
US-EPR	70	40	6

Notes:

CED – Contract Effective Date
FC – First safety-related concrete pour
FL – Fuel load
CO – Commercial operation

4 CSR 240-22.040 (1) (E)

Capital Cost per Kilowatt

Engineering, Procurement, and Construction (EPC) costs were developed for the nuclear technologies being screened from publicly available data. The publicly available data was escalated at 6 percent annually to place all technologies in 2007 dollars. The costs are presented in Table 49.

Stakeholders commented during the Phase I stakeholder meeting that the AP1000 technology appeared to be very competitive. Unfortunately, much of the publicly available capital cost information is dated. Nuclear technologies as well as other generating technologies have undergone significant recent escalation. [redacted]

Table 49
Capital Cost

	Reported Capital Cost ($/kW-net)	Year Reported	2007 Capital Cost ($/kW-net)	Notes
ABWR	[redacted]	2005	[redacted]	Ref. 1
ACR-1000		2004		Ref. 2,
AP1000		2004		Ref. 2, 3
ESBWR		2004		Ref. 2
PBMR		2003		Ref. 2
US-APWR		2004		Ref. 2
US-EPR		2007		Ref. 4,

References:

1. Toshiba Corporation, General Electric Company, USEC, Bechtel Power Corporation, and Global Nuclear Fuel - America, (2005) New Nuclear Power Plant Licensing Demonstration Project, ABWR Cost/Schedule/COL Project at TVA's Bellefonte Site, Tennessee Valley Authority, August; http://www.ne.doe.gov/np2010/reports/mainReportAll5.pdf
2. Tolley, George S., Jones, Donald W., University of Chicago, (2004) The Economic Future of Nuclear Power, University of Chicago, August; http://www.ne.doe.gov/np2010/reports/NuclIndustryStudy.pdf
3. Westinghouse, (2004) Westinghouse - AP1000, Technology Fact Sheet, Westinghouse; http://www.energetics.com/pdfs/nuclear/ap1000.pdf
4. Turnage, Joe, Massachusetts Institute of Technology (MIT), (2007) A Strategic Analysis of the Investment Opportunity for Advanced Nuclear Generation, Constellation Energy, March 12; http://mit.edu/ans/www/documents/seminar/S07/turnage.pdf

4 CSR 240-22.040 (1) (F)
Annual Fixed Operations and Maintenance Costs

Annual fixed operation and maintenance costs were included with variable O&M costs and are presented on an annual $/MWh basis in Table 50.

Table 50 O&M Cost		
Annual Cost per MWh		
	O&M Cost	Notes
ABWR	[redacted]	Ref. 1
ACR-1000		Ref. 2
AP1000		Ref. 1
ESBWR		Ref. 1
PBMR		Ref. 2
US-APWR		Ref. 2
US-EPR		Ref. 2

References:

5. Dominion Energy, Bechtel Power Corporation, TLG, Inc., and MPR Associates, (2004) NP2010 Improved Construction Technologies, O&M Staffing and Cost, Decommissioning Costs, and Funding Requirements Study, Volume 1: Study of Construction Technologies and Schedules, O&M Staffing and Cost, Decommissioning Costs and Funding Requirements for Advanced Reactors Designs, Cooperative Agreement DE-FC07-03ID14492, Washington D.C.: U.S. Department of Energy (DOE), May 27; http://www.ne.doe.gov/np2010/reports/1DominionStudy52704.pdf
6. Turnage, Joe, Massachusetts Institute of Technology (MIT), (2007) A Strategic Analysis of the Investment Opportunity for Advanced Nuclear Generation, Constellation Energy, March 12; http://mit.edu/ans/www/documents/seminar/S07/turnage.pdf

4 CSR 240-22.040 (1) (G)

(1)(G) Annual Variable Operations and Maintenance Costs

Annual variable operation and maintenance costs were included with fixed O&M costs and presented on an annual $/MWh basis in Table 50 above.

4 CSR 240-22.040 (1) (H)

Scheduled Routine Maintenance Outage Requirements

The refueling cycle requirements control the scheduled routine and maintenance outage requirements for nuclear units. Current enrichment limits of 5 percent prevent fuel cycle lengths longer than 24 months. Increased fuel cycle lengths allow increased flexibility in optimizing fuel cycle costs. Continuously refueled technologies will require periodic outages for equipment maintenance. Fuel cycle lengths are presented in Table 51.

Table 51
Fuel Cycle Lengths

	Fuel Cycle (months)	Notes
ABWR	24	Ref. 1
ACR-1000	Continuous Refueling	Ref. 2
AP1000	18	Ref. 3
ESBWR	24	Ref. 3
PBMR	Continuous Refueling	Ref. 4
US-APWR	24	Ref. 5
US-EPR	24	Ref. 3

References:

1. General Electric Company (GE), (2000) Advanced Boiling Water Reactor Plant General Description, GE; http://www.ftj.agh.edu.pl/~cetnar/ABWR/Advanced%20BWR%20 General%20Description.pdf
2. Atomic Energy of Canada Limited (AECL), (2007), *ACR-1000: An Excerpt from "ACR-1000 Technical Summary,"* AECL; http://www.aecl.ca/Assets/Publications/ACR-Excerpt.pdf
3. Dominion Energy, Bechtel Power Corporation, TLG, Inc., and MPR Associates, (2004) NP2010 Improved Construction Technologies, O&M Staffing and Cost, Decommissioning Costs, and Funding Requirements Study, Volume 1: Study of Construction Technologies and Schedules, O&M Staffing and Cost, Decommissioning Costs and Funding Requirements for Advanced Reactors Designs, Cooperative Agreement DE-FC07-03ID14492, Washington D.C.: U.S. Department of Energy (DOE), May 27; http://www.ne.doe.gov/np2010/reports/1DominionStudy52704.pdf
4. PBMR (Pty) Ltd. and Exelon (2001), *PBMR Design Description,* PBMR; US NRC Adams Accession #ML022320906.
5. Mitsubishi Heavy Industries, Ltd. (MHI), (2006) *US-APWR Design Description,* MHI; US NRC Adams Accession #ML063030474

4 CSR 240-22.040 (1) (I)

Equivalent Forced Outage Rates or Full and Partial Forced Outage Rates

Equivalent forced-outage rates or full and partial-forced outage rates were not explicitly developed for the seven technologies included in the Phase I screening in part due to the difficulty of estimating those values for technologies that are not yet operating. Overall availability of the technologies was considered in the Phase I screening primarily through the fuel cycle length presented in Table 51.

In Phase II, where the top three ranked technologies were evaluated in greater detail relative to AmerenUE's specific needs, availability estimates were developed as shown below.

- US-EPR – 94%
- ABWR – 90%
- AP1000- 93%

For the US-EPR, which was characterized in detail during Phase II, an estimate of a 2 percent forced outage rate was developed.

4 CSR 240-22.040 (1) (J)

Operational Characteristics and Constraints of Significance in the Screening Process

The only operational characteristics and constraints of significance identified in the screening analysis pertained to the technologies' ability to be licensed and built in a reliable and timely manner especially with respect to their ability to meet the requirements necessary to obtain the production tax credits associated with the 2005 Energy Policy Act. Tables 45, 47, and 52 present criteria for screening in these areas.

Table 52
Ability to License

	US NRC Design Certification	US NRC Experience
ABWR	Yes	Similar features to existing BWRs.
ACR-1000	Not yet submitted.	CANDU's operating in Canada, Korea
AP1000	Yes	No US NRC experience regulating PWR's with passive safety systems, but certified by US NRC.
ESBWR	In review.	No US NRC experience regulating BWR's with passive safety systems.
PBMR	Not yet submitted.	No experience since Ft. St. Vrain
US-APWR	In review.	Similar features to existing PWRs.
US-EPR	In review.	Similar features to existing PWRs.

4 CSR 240-22.040 (1) (K)

Environmental Impacts, Including at Least the Following

4 CSR 240-22.040 (1) (K) 1

Air emissions including at least the primary acid gases, greenhouse gases, ozone precursors, particulates and air toxics;

The nuclear technologies do not produce primary acid gases, greenhouse gases, ozone precursors, particulates, or air toxics other than through operation of the emergency diesel generators (EDGS).

4 CSR 240-22.040 (1) (K) 2

Waste generation including at least the primary forms of solid, liquid, radioactive and hazardous wastes;

For technology screening purposes, the following two radioactive waste streams were considered:

- Spent Fuel
- Intermediate and Low-Level Waste

Spent fuel wastes were considered similar for each of the technologies. Estimated intermediate and low-level waste volumes are presented in Table 53.

Table 53
Intermediate and Low-Level Waste Volumes

	ILW plus LLW Radwaste (m^3)	Notes
ABWR	25,638	Ref. 1, 2
ACR-1000	1,430	Ref. 1, 2, Adj. 2
AP1000	1,035	Ref. 1, 2
ESBWR	14,025	Ref 1, 2, Adj. 2
PBMR	2,376	Ref 1, 2, Adj. 1
US-APWR	2,210	Ref 1, 2, Adj. 2
US-EPR	2,080	Ref. 1, 2

References:

1. Committee on Radioactive Waste Management (CoRWM) (2005) CoRWM's Radioactive Waste and Materials Inventory -- July 2005, CoRWM Document No. 1279, Attachment to CoRWM Document 700; http://www.corwm.org.uk/pdf/InventoryReport.pdf
2. Nuclear Decommissioning Authority (NDA), (2006) Potential Waste Volumes Arising from New Build, NDA, October, Appendix to NexiaSolutions Report (07) 8446; http://www.dti.gov.uk/files/file39386.pdf

Adjustments:

1. PBMR unpackaged volumes increased by factor of 2 to obtain packaged volumes.
2. Extrapolated from published values.

4 CSR 240-22.040 (1) (K) 3

Water impacts including direct usage and at least the primary pollutant discharges, thermal discharges and groundwater effects; and

For the screening analysis, water impacts were evaluated through the thermal efficiency of the technologies. Table 54 presents the estimated thermal efficiencies of the technologies.

Table 54
Thermal Efficiency

	Efficiency (%)
ABWR	35
ACR-1000	37
AP1000	35
ESBWR	34.7
PBMR	42
US-APWR	39
US-EPR	36

The water impacts for the US-EPR were evaluated in detail as discussed below.

Consumptive use of water is primarily attributable to evaporation losses from the natural-draft cooling towers. The US-EPR will utilize two natural-draft cooling towers with evaporative losses of approximately 22,000 gpm.

Blowdown from the new cooling towers will be approximately 5,500 gpm. each, or a total of 11,000 gpm. The unit will consume a total of approximately 27,600 gpm including estimated cooling tower drift. In comparison to average annual flow of the Missouri River over 60 years, such losses are estimated to require less than 0.1 percent of river flow. The water resources so committed for plant operating will have no effect on other users downstream from the plant.

In connection with the construction of the proposed US-EPR, Callaway will replace it's current surface water intake structure (grade elevation 525 MSL), located on the Missouri River at River Mile 115.4, about 3,500 feet upstream of the confluence of Logan Creek with the Missouri River, with two new Collector Well systems. The Collector Wells will be located along the Missouri River, drawing from the river's aquifer, on new land to be acquired. The existing access roadway will be extended to the each of the Collector Well sites. Collector Wells will utilize natural filtration to provide the following environmental and economic benefits:

- Eliminates the need for surface water intake upgrades to address 316b regulations;
- Provides pre-filtered, sediment free makeup water, eliminating the need for sedimentation pond and it's dredging and spoil disposal issues;
- Eliminates the need for operator action for periodic large flows of flotsam and jetsam that overwhelm the intake racks, automatic traveling screens, and backwashes;
- Eliminates the need for periodic dredging of the surface water intake bays and approaches, permitting sediment to naturally migrate along the river banks;
- Reduces visual impact on riverbank, since the new structures will be set back from the shoreline;
- Eliminates susceptibility to macro-fouling from mollusks (e.g. zebra muscles);
- Eliminates low river level and winter ice formation (e.g. ice flows, frazil ice) concerns;
- Eliminates loose barge excursion impact and security concerns.

Natural Filtration occurs as water moves down through the earth, eventually collecting in an underground pool called an aquifer. This process reduces or eliminates suspended materials and potentially harmful microbiological organisms that may be present in the water. The term riverbank filtration is used when describing natural filtration near rivers or streams.

Natural filtration replenishes the water in the aquifer as it is being pumped out by wells. As the collector well pumps water, a cone of depression forms around the central caisson, causing ground water to flow toward the laterals. During pumping, water from the aquifer moves toward the well to replace the pumped water, in this case, at an average rate of 28 million gallons per day (mgd) and with peaks up to 45 mgd.

Fourteen 12-inch diameter stainless steel well screens (laterals) are installed, like spokes on a wheel, in a highly permeable soil more than 100 feet below the ground surface, and guide water to the 20-foot diameter reinforced concrete caisson cylinder (wet well). Using large, high efficiency pumps and longer lengths (about 2,800 feet) of well screens permits the collector well to produce higher volumes of water more economically.

The new Collector Well Pumphouses are designed to withstand the 200 year flood elevation 539 MSL, and remain operational.

Water is supplied to the site through a five-mile long 48-inch diameter pipeline from the intake structure and pumping station at the Missouri River. The piping is routed (above-grade/below-grade), across steadily rising terrain, with an 315 feet overall elevation increase from the Pumphouse (elevation 525 MSL) to the plant site (elevation 840 MSL). This water replaces water lost by evaporation, drift and blowdown from the cooling towers and supplies other uses inside the power blocks. This intake structure will be replaced with a series of Collector Well Systems, separated from one another by 1500 feet, located along the river bank. The existing pipeline will be extended to the new location.

The existing intake structure and pumphouse will be retired in place after the new Collector Well systems become operational.

In addition to the normal heat rejection system, the US-EPR includes four Ultimate Heat Sink Cooling Towers (UHS) for cooling four-trains of the essential service water system (ESW). The ESW consists of four separated safety-classified trains that provide cooling of the component cooling water system (CCW) heat exchangers with water from the UHS during all normal plant operating conditions, transients, and accidents. The ESW also includes two additional trains of dedicated cooling for the severe accident mitigation system (SAHRS). Each UHS will be a 2-cell mechanical-draft cooling tower. A makeup water pond, constructed to seismic class-1 standards will provide makeup water to each UHS cooling tower basin. The UHS & makeup pond configuration can be accommodated at the Callaway site, and does not add significant acreage or cost impacts.

The circulating water system (CW) supplies cooling water from the plant's cooling water source to the main condenser to condense the steam that discharges from the exhaust of the turbine or the turbine bypass system. The US-EPR will utilize two large natural draft cooling towers for its source of cooling.

The essential service water system (ESW) provides cooling water from the ultimate heat sink (cooling towers) for plant components which require cooling for safe shutdown of the reactor following an accident and/or loss of offsite power. These components are the component cooling water heat exchangers, containment air coolers, diesel generator coolers, safety injection pump room coolers, RHR pump room coolers, containment spray pump room coolers, centrifugal charging pump room coolers, component cooling water pump room coolers, auxiliary feedwater pump room coolers, control room air conditioning condensers, Class IE switchgear air-conditioning condensers, and penetration room coolers.

During normal plant operation, the service water system (SW) supplies cooling water to the turbine building closed cooling water heat exchangers, turbine building chiller condensers, steam jet air ejectors, steam packing exhauster, generator stator coolers, generator hydrogen cooler, turbine-generator lube oil coolers, steam generator blowdown heat exchanger, letdown chiller condenser, and air compressor

The essential service water system provides emergency makeup to the fuel pool and component cooling water systems. It is also the backup water supply to the auxiliary feedwater system. The heat rejection system utilizes two (60% each) hyperbolic, natural-draft, counter-flow, wet-cooling towers. The system design is shown in Table 55.

Table 55
Cooling Tower Design

		Qty	Rating Each	Description	Heat Rejection Rate[1] (MMBtu/hr)	Flow (gpm)	Cycles of Conc.	Blowdown Rate (gpm)	Duty
US-EPR	Main Tower/ CW & SW	2	60%	Hyperbolic, natural-draft, counter-flow, wet cooling tower	6,600 (incl. 130 for SW)	440,000 (incl. 27,000 for SW)	5	5,500	Cont.
	UHS/ ESW	4	50%	Two-cell, mechanical-draft	175 per Cell	15,000 per Cell	5	100 per Cell	Stby

Notes:
1. Ambient air temperature of 79 F wet bulb and 95 F dry bulb.

Natural- and Mechanical-draft towers have traditionally been the alternative to once through cooling systems at large base-loaded power stations. Evaporative cooling consumes quantities of water through evaporation, drift, and blowdown requirements, totaling nearly 4% of circulating water flow. Blowdown, a continuous discharge of circulating water, is necessary in order to limit the buildup of dissolved solids in the circulating water.

Makeup water is supplied from the Missouri river. Existing surface water intake for Callaway unit 1 will be replaced with Collector Well System sized for the new and existing units. The Collector Well will also draw from the Missouri river. Requirements for the US-EPR are shown in Table 56.

Table 56
Makeup Water Requirements

Unit		Qty	Evaporation (gpm)	Blowdown (gpm)	Makeup (gpm)	Unit Totals	
						Blowdown (gpm)	Makeup (gpm)
Proposed US-EPR	Main Tower	2	22,000	5,500	27,505	5,500	27,505
	DWM	1	N/A	50	50	50	50
	UHS Cooling Tower Basins	4	Max. 60 acre-ft inventory loss per 30 day period		4000[1]	1000	4000
					Proposed US-EPR Total	***6550***	***31,555***

Notes:
1. Maximum makeup rate when automatic system used.
2. Represents an update of design information from the Phase Ii Stakeholder Meeting.

Detailed design of the demineralizer system has not been completed. It is assumed it will be similar to the existing condensate demineralizer system which consists of six 20-percent capacity demineralizer units (one on standby) with deep-bed regenerable mixed strong acid cation/strong base anion resins. The system is installed with full flow bypass to limit pressure drop across the cleanup polisher on loss of heater drain pumps or for standby service when water chemistry can be kept below normal design limits by steam generator blowdown.

Water is currently discharged from the Callaway site into the Missouri river through a 24-inch diameter pipeline paralleling the intake water pipeline. This pipeline will be replaced with a new 36-inch diameter pipeline, sized to handle the larger flows, and set below the 1-day, 30-year low-flow surface elevation of 489 MSL. Discharge velocity will be maintained at approximately 7.4 feet-per-second. The current discharge rate of 4,685 gpm (of which 99 percent is cooling tower blowdown), will increase to 10,335 gpm when the new US-EPR comes online. Blowdown from the three natural-draft cooling towers will still comprise at least 98 percent of the new Callaway station discharge flow.

The Callaway station currently has a three cell lagoon type Sewage Treatment Plant that processes all the sanitary wastes generated onsite. When the second unit is constructed, the Sewage Treatment Plant has sufficient capacity to handle the increased flows .

The oily waste separator handles an intermittent and variable amount of oily waste discharge from the Callaway station. The waste is treated by skimming and concentrating the oil. The concentrate is trucked away to an oil reclamation plant. The water effluent from the separator treatment meets the State of Missouri Effluent Standards of less than 15 mg/l oil content and is discharged with the blowdown from the cooling towers into the Missouri river.

The oily waste water storage tank is used to store the first hour of runoff (1,500 gpm), should a fire occur at the plant. The tank capacity is 90,000 gallons. The tank also serves as an equalization basin and contains part of the flow during separator cleaning operations.

The US-EPR oily waste system will be slightly larger than the existing Unit 1 system, with a similar layout.

4 CSR 240-22.040 (1) (K) 4

Siting impacts and constraints of sufficient importance to affect the screening process; and

No additional siting impacts and constraints of sufficient importance that affected the screening analysis were identified.

4 CSR 240-22.040 (1) (L)

Other characteristics that may make the technology particularly appropriate as a contingency option under extreme outcomes for the critical uncertain factors identified pursuant to 4 CSR 240-22.070(2).

No other characteristics that make the technology particularly appropriate as a contingency option under extreme outcomes for the critical uncertain factors identified pursuant to 4 CSR 240-22.070(2).

Pump Storage

A pumped storage technology was considered in AmerenUE's 2005 IRP filing and was revisited and considered for the 2008 IRP filing. Paul C. Rizzo Associates, Inc. was engaged to update their prior study on this supply-side technology (4CSR 240-22.040 Appendix L) to include changes requested by AmerenUE and to include an upper reservoir that would be constructed of Roller Compacted Concrete similar to the new Taum Sauk design. The responses to the various sections of the rule were completed and included at the end of this section and as listed in Appendix C of the Rizzo report (4CSR 240-22.040 Appendix L).

4 CSR 240-22.040 (1) (A)

Fuel Type and Feasible Variations in Fuel Type or Quality

The generation fuel is water. There are no feasible variations.

4 CSR 240-22.040 (1) (B)

Practical Size Ranges

Nominal generating capacities ranging from 200 MW to 800 MW were evaluated. The 600 MW and 800 MW generating capacities were selected as the most practical.

4 CSR 240-22.040 (1) (C)

Maturity of the Technology

Pumped storage is a mature technology. Facilities with similar technology have been in service for more than 40 years.

4 CSR 240-22.040 (1) (D)

Lead Time for Permitting, Design, Construction, Testing, and Startup

The projected lead time from the Notice of Intent to Startup is 10 years.

4 CSR 240-22.040 (1) (E)

Capital Cost per Kilowatt

A summary of the estimated capital costs for the 800 MW Base Scheme and the 600 MW Modified Scheme is given in the Table 57.

Table 57: SUMMARY OF ESTIMATED COSTS (Millions of $US)

	800 MW BASE SCHEME	600 MW MODIFIED SCHEME
Construction Costs	[redacted]	
Contingency		
Other (Engineering, Legal, AmerenUE Costs, AFUDC, Taxes, and usage fees, etc.)		
Escalation		
Total Cost		
Cost Per Kilowatt ($/kW)		

Note: 1 Based on Generating Capacity at Minimum Head.

4 CSR 240-22.040 (1) (F)

Annual Fixed Operations and Maintenance Costs

4 CSR 240-22.040 (1) (G)

Annual Variable Operations and Maintenance Costs

Assuming a Notice of Intent issued in 2007 and 10 years for a design, permitting, and construction period, the projected annual expenses for the first year of operation, 2017, are in the Table 58.

Table 58: ANNUAL PROJECT EXPENSES (Millions of $US)

	600 MW	800 MW
Pumping Costs	39.7	54.5
Fixed O & M Costs	1.8	2.4
Variable O & M Costs	4.0	5.3
Property Taxes, Insurance, Misc. Overhead	9.2	13.5
Total Expenses	**$54.7**	**$75.7**

4 CSR 240-22.040 (1) (H)

Scheduled Routine Maintenance Outage Requirements

Scheduled routine maintenance outage requirements have not been developed at this stage of the study. A 25 percent capacity factor, which assumes some maintenance outages, has been used for evaluation of the projects.

4 CSR 240-22.040 (1) (I)

Equivalent Forced Outage Rates or Full and Partial Forced Outage Rates

Equivalent forced-outage rates or full and partial-forced-outage rates have not been developed at this stage of the study. A 25 percent capacity factor, which assumes some forced outages, has been used for evaluation of the projects.

4 CSR 240-22.040 (1) (J)

Operational Characteristics and Constraints of Significance in the Screening Process

No additional operational characteristics or constraints were identified. The evaluated project is a pumped storage facility with a few operational characteristics and constraints that will have to be considered.

- Since it is a pumped storage facility it is a net user of electricity. The maximum projected cycle efficiency is 80 percent.
- The project is limited to a maximum of eight hours of operation per day.

4 CSR 240-22.040 (1)

(K) Environmental impacts, including at least the following:

1. Air emissions including at least the primary acid gases, greenhouse gases, ozone precursors, particulates and air toxics;

2. Waste generation including at least the primary forms of solid, liquid, radioactive and hazardous wastes;

3. Water impacts including direct usage and at least the primary pollutant discharges, thermal discharges and groundwater effects; and

4. Siting impacts and constraints of sufficient importance to affect the screening process; and

The evaluated project has not been developed to the point where the noted environmental impacts can be determined at this time.

4 CSR 240-22.040 (1)

(L) Other characteristics that may make the technology particularly appropriate as a contingency option under extreme outcomes for the critical uncertain factors identified pursuant to 4 CSR 240-22.070(2).

The project has not been developed sufficiently to make a proper determination.