Efficiency and Supply Resource Options for the Upgrade of the Plzeň District Heating System

Prepared by
Pacific Northwest National Laboratory
SEVEn
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Summary

This assessment examined options for meeting the district heating system steam and hot water heating loads associated with the Plzeň Central Heating Plant, two interconnected boilers serving the Kosutka and Bory regions, and the distributed systems in the Letna/Doubravka and Svetovar regions. The assessment methodology applied integrated resource planning principles to combine the separate supply and demand-side assessments conducted for the system.

Four system load scenarios were examined—high and low growth with and without programmatic efficiency. Hot water loads ranged from the current level of 277 megawatts thermal (MW_t) to 320 MW_t in a high growth scenario without efficiency to 253 MW_t in a low growth scenario with programmatic efficiency. The high growth scenario includes an addition of approximately 50 MW_t load from the connection of distributed boilers. An additional 250 MW_t load served by distributed boilers may provide additional potential for system expansion. Steam loads are projected to increase from 93 MW_t to 100 MW_t in the high growth scenario and decrease to 89 MW_t in the low growth scenario.

Two system expansion cases were structured for the assessment. The moderate system expansion provided for the Heat Line East I connection to serve the Letna/Doubravka region and the full system expansion case further provided for the Heat Line East II connection to serve the Svetovar region. In the moderate system expansion case, the life of the Svetovar plant is extended to continue servicing that region as a stand-alone system.

Four central plant supply configurations providing for additional cogeneration capacity were applied to the load scenarios:

Coal 2003	Life extension to the existing facilities with introduction of new coal-fired cogeneration unit in 2003.
Coal 1997	Retirement of some existing units and introduction of a new coal-fired cogeneration unit in 1997.
65 MW_t Gas	Retirement of some existing units and introduction of a new gas-fired cogeneration unit in 1997.
60 MW_t Gas	Retirement of some existing units and introduction of a new gas-fired cogeneration unit in 1997.

The central plant configurations were sized to meet the high and low demand scenarios as necessary.

Buildings sector efficiency potential was analyzed for the high and low load growth scenarios. Measures examined included weatherization, insulation, controls, and heat recovery. These measures are estimated to provide for customer level efficiency improvements of about 15% and reductions in capacity requirements of about 10%.

The supply and efficiency options were integrated and characterized by capital requirements, levelized energy cost, typical household energy bill, and emissions for the four load growth scenarios and moderate and full system expansion cases as follows (the two gas-fired options are combined for this summary):

Capital Requirements

Coal 2003	Lowest, near-term (1993-2000) requirements at 800 million Crowns (Kc), about 40% of the next highest option, Coal 1997. Lowest long-term (1993-2010) requirements at 2150 million Kc, about 3% and 30% lower than the Coal 1997 configuration for the high and low load growth scenarios, respectively.
Coal 1997	Nearly equal to the 60 MW_t gas-fired configuration and about 10% to 15% lower than the 65 MW_t gas-fired configuration in the near and long term.
Gas 1997	Highest capital requirement, ranging from 2300 to 2540 million Kc for the long term.
Efficiency	Requires about 500 million Kc in capital, 250 million Kc of it in the near term.
Full System Expansion	Requires about 54 million Kc in near term.

Levelized Energy Cost (Combined Hot Water and Steam)

Coal 2003	Lowest, about 160 Kc/gigajoule (GJ) in the moderate system expansion case.
Coal 1997	Moderate, ranging from about 170 to 180 Kc/GJ.
Gas 1997	Highest, ranging from about 200 to 215 Kc/GJ.
Efficiency	Increases price of any of the three options by approximately 20 Kc/GJ.
Full System Expansion	Increases price by approximately 5 Kc/GJ.

Residential Energy Bill

Coal 2003	Lowest, about 6800 Kc/yr in moderate system expansion case.
Coal 1997	Moderate, ranging from 7100 to 7500 Kc/yr.
Gas 1997	Highest, ranging from 9100 to 9900 Kc/yr.
Efficiency	Reduces bill about 300-400 Kc/yr for coal configurations and 500-600 Kc/yr for gas-fired configurations.
Full System Expansion	Increases bill by approximately 100-300 Kc/yr.

Emissions Reduction (Particulates, SO_2, NO_X, and CO)

The emissions reductions are based on levels expected from compliance with 1997 emissions requirements.

Coal 2003	Zero, serves as the base case, so reductions are realized only in the low load growth scenario.
Coal 1997	Low, provides for approximately 1% reduction in all emissions.
Gas 1997	Highest reduction, 17% to 20% in SO_2, 12% to 16% in NO_X, 4% in particulates, and 1% to 2% in CO.
Efficiency	Low, provides additional 3% reduction in SO_2 and NO_X, 1% to 2% in particulates, and 1% in CO.
Full System Expansion	No appreciable change.

This assessment did not optimize the amount and timing of the supply and efficiency resources for meeting load at least cost; however, it is not expected that the relative differences and effects of the resource options would change the comparisons discussed above.

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1.0 Introduction

The City of Plzeň in the Czech Republic is examining options for meeting the thermal energy requirements of its citizens, with consideration of economic and the environment factors. Major energy-related issues the City faces are

- The need to upgrade and/or replace the heat generation resources that supply the district heating system.
- The need to reduce emissions in order to comply with more stringent environmental regulations and improve air quality.
- The need to minimize consumer energy bills, particularly to accommodate the upcoming decontrol of energy prices.

The U.S. Agency for International Development, through the U.S. Department of Energy, provided technical support to assist the City with an analysis of energy supply and efficiency options for addressing these issues. The supply assessment examined heat generation alternatives with application to the central segment of the district system serving the City and limited connection of coal-fired distributed boilers. The efficiency assessment examined the efficiency resource that exists in the space and water heat end-uses for the residential and non-residential buildings sectors and all fuel types. Readers interested in detailed information are referred to these two reports (see Section 8).

This report summarizes and integrates the results and findings from the supply and demand assessments and is organized as follows:

- Assessment Scope
- System Loads
- Baseline Emissions
- Supply Resources
- Efficiency Resource
- Integrated Findings

The intent of the integrated assessment is to present the analysis of the options examined to support the City's decision-making process, not to provide specific recommendations or guidance for the City to follow.

2.0 Assessment Scope

The existing district heating system serving the City consists of four segments as shown in Figure 1. The system provides steam for industrial customers and hot water for residential and non-residential buildings and industrial customers.

The **Central System** consists of the Plzeň cogeneration plant, the Kosutka hot water peaking plant, the Pivovary (brewery) steam plant, the Railway (Zos) steam plant, and the Bory plant, which provides steam for an industrial (hospital) load and hot water. The total hot water and steam generating capacity is about 360 MW thermal (MW_t).

The major consuming entities served by the Central System are buildings in the central portion of the City, the Kosutka area to the North and the Bory area in the South, the train station and associated maintenance facilities, the brewery, and the Bory industrial facility.

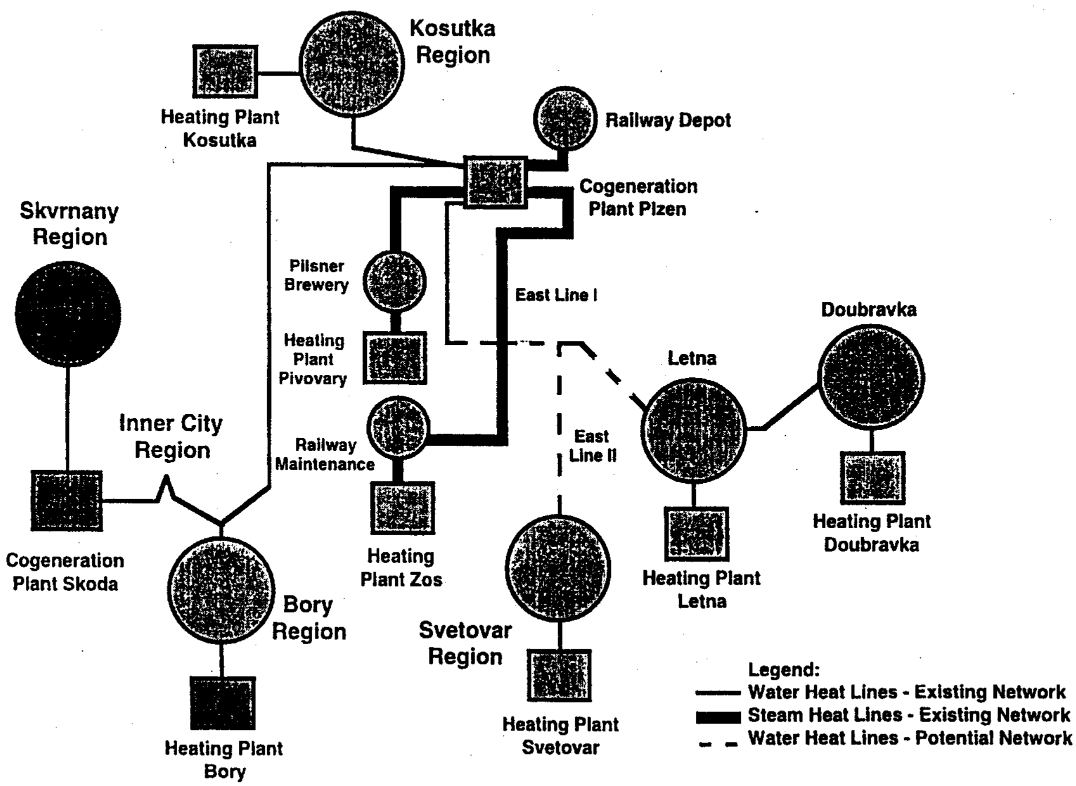

Figure 1. Plzeň District Heating System Schematic

The Central and Kosutka regions consume hot water provided by the Plzeň coal-fired cogeneration plant, supplemented by the Kosutka peaking plant. The Kosutka plant is being converted from coal to natural gas. The Plzeň cogeneration and Kosutka plants were formerly owned and operated by ZCE, West Bohemia Electric Utility, and are now 80% owned by the City, with the remainder scheduled for transfer to private ownership. The Central plan has a combined hot water and steam generating capacity of about 225 MW_t, and the Kosutka plant has hot water generating capacity of about 17 MW_t.

The Bory region to the South consumes hot water provided by the Bory plant, supplemented by hot water from the Plzeň plant to meet peak needs. Modification of the hot water network will be necessary for the Plzeň plant to provide sufficient quantities of hot water when the Bory hot water boilers are retired. The Bory plant is owned and operated by TEZA, the municipal district heating company and has a combined hot water and steam generating capacity of about 55 MW_t.

The Bory industrial facility is served entirely by the Bory plant for steam needs and supplemented by the Plzeň plant for peak hot water needs.

Steam for the train station is provided by the Plzeň cogeneration plant. Steam for the train maintenance facilities is provided by the Zos plant in the summer months and supplemented by the Plzeň plant in the winter months.

Steam for the brewery is provided by the Pivovary plant in the summer months and supplemented by the Plzeň plant in the winter months.

The **Letna/Doubravka Segment** of the system is supplied by the Letna and Doubravka hot water plants, which consist of 8 coal-fired boilers and 1 oil-fired peaking boiler; these units are owned and operated by TEZA. These plants have hot water generating capacity of about 56 MW_t and supply buildings located in the Letna and Doubravka areas. TEZA also owns and operates the associated transmission and distribution system. The East I transmission line connecting the Plzeň plant to the Letna/Doubravka areas is under construction and planned for completion in 1997.

The **Svetovar Segment** of the system is supplied by the Svetovar hot water plant, which consists of 4 coal-fired boilers; this plant is owned and operated by TEZA. This plant has hot water generating capacity of about 23 MW_t and supplies buildings located in the Svetovar area. TEZA also owns and operates the associated transmission and distribution system. This plant is in need of upgrade or replacement or connection to the Plzeň system; proposals to connect the Svetovar region to the Plzeň system have been made, but no firm plans to do so have developed. This potential connection is referred to as the East II transmission line.

The **Skoda/Skvrnany Segment** of the system is supplied by the Skoda cogeneration plant, which consists of 3 coal-fired boilers and 2 oil-fired boilers that produce steam; these are owned and operated by Skoda Industries. This plant has combined hot water and steam capacity of about 323 MW_t and provides steam and hot water to the Skoda industrial facilities and hot water to buildings in the Skvrnany area. Skoda Industries owns and operates the transmission and distribution system for its own uses. Skoda also owns and operates the transmission lines to the Skvrnany and Bory areas; TEZA owns and operates the associated distribution systems. TEZA also owns and operates a transmission line that interconnects the Plzeň plant to the Western segment; although this interconnection exists, it is not used.

The integrated assessment scope included examining alternative efficiency and supply resource options for the Central (central cogeneration and Kosutka plants), Letna/Doubravka, and Svetovar segments. These options were characterized by amount of capital investment, cost to consumers, and emissions reduction. It was assumed that the Skoda plant would continue to operate and provide heat to the Skvrnany customers at a price consistent with that charged other customers.

3.0 System Loads

The hot water and steam loads for the system segments were developed in terms of peak thermal capacity (MW_t) in order to relate to supply capacity requirements for four load growth scenarios. The four scenarios were high and low growth with no-efficiency and high and low growth with programmatic efficiency in the buildings sector. The no-efficiency case includes metering and controls at the heat exchanger stations and/or building boundary. Although the controls do reduce energy use by about 10%, the scenarios are termed no-efficiency because the metering and controls are required by regulation. The programmatic efficiency scenarios reflect customer side efficiency improvements in the buildings sector obtained through an acquisition program.

The load growth scenarios for the three system segments are provided in Table 1.

Table 1. Hot Water and Steam Load Growth Scenarios by Peak Capacity (MW_t), 1992-1997, 2000 and 2010

Scenario/Segment	1992	1993	1994	1995	1996	1997	2000	2010	Growth (%/yr)
High Growth, No-Efficiency									
Central Segment	207	210	223	234	238	241	243	238	0.8
Letna/Doubravka	47	47	47	47	56	58	60	58	1.2
Svetovar	23	23	23	23	23	25	26	24	0.2
Total Hot Water	277	280	293	304	317	324	329	320	0.8
Total Steam	93	92	92	91	100	100	100	100	0.4
High Growth, With Efficiency									
Central Segment	207	210	222	232	232	233	228	212	0.1
Letna/Doubravka	47	47	47	47	55	56	56	52	0.6
Svetovar	23	23	23	23	23	24	24	22	-0.3
Total Hot Water	277	280	292	302	310	313	308	286	0.2
Total Steam	93	92	92	91	100	100	100	100	0.4
Low Growth, No-Efficiency									
Central Segment	207	209	213	219	221	222	217	206	0.0
Letna/Doubravka	47	47	47	47	50	52	52	51	0.5
Svetovar	23	23	23	23	23	23	22	21	-0.5
Total Hot Water	277	279	283	289	294	297	291	278	0.0
Total Steam	93	92	92	91	91	89	89	89	-0.3
Low Growth, With Efficiency									
Central Segment	207	209	212	217	216	215	203	188	-0.5
Letna/Doubravka	47	47	47	47	50	51	49	46	-0.1
Svetovar	23	23	23	23	23	22	21	19	-1.1
Total	277	279	212	287	289	288	273	253	-0.5
Total Steam	93	92	92	91	91	89	89	89	-0.3

Components of the load growth are the existing customer base, new construction/customers, and connection of local boilers. Additional data showing the load growth by component is provided in Appendix A.

A major issue is the potential for retiring coal-fired local boilers, which are a major source of emissions, and either connecting the customers served by these boilers to the district heating system or encouraging conversion to natural gas. There are approximately 590 local boilers representing about 300 MW_t of capacity, of which 230 are coal-fired with about 130 MW_t capacity. Of these, 20 have committed to connect to the district system. Economics indicate another 33 have the potential and may do so; these represent about 50 MW_t of capacity in the high load growth scenarios. The remaining 177 may have to pay the emissions penalty to continue operation, upgrade to cleaner burning coal technologies, or switch to other fuel types, which may include district heat. Additional analysis is needed to identify the economics, as well as policies and incentive programs to support these decisions.

4.0 Baseline Emissions

This section provides the estimated emissions by existing heat generation sources within the City of Plzeň. The estimates provided in Table 2 show the reductions that are expected to result by upgrading the existing district heating equipment to comply with the 1997 emissions regulations and by connecting the number of distributed boilers to the district heating system as discussed in the prior section. The emissions upgrades examined were to fuel switch to higher quality black coal and to install baghouses for particulate removal.

Expected changes in emissions levels for compliance with the 1997 regulations are

- In all cases, the quantities of emissions from home furnaces remain unchanged, as this equipment is not subject to emissions regulations. As a result, the share of total emissions for home heating equipment remains constant or increases.
- The quantity of total particulates decreases by about 30%. Particulates from district heat sources decrease from over 600 to over 230 tonnes and from 680 to 532 tonnes from local boiler sources.
- Sulfur dioxide emissions decrease by about 55% with reductions of 10,382 to 4345 tonnes from district heat sources and 540 to 421 tonnes from local boilers.
- Emissions of nitrous oxides increase by 4%. In the case of district heat sources, these emissions increase from 2443 to 2599 tonnes and decrease from 178 to 139 tonnes from local boiler sources.
- Carbon monoxide emissions decrease by 1% with an increase from 153 to 217 tonnes from district heat sources and a decrease from 400 to 312 tonnes from local boilers.

The total emissions for 1997 will serve as the baseline for comparing supply alternatives, as these represent compliance with upcoming emissions regulations for the existing supply resources.

Table 2. Emissions from Existing Generating Supply Resources (Tonnes/year), 1993 and Compliance with 1997 Regulations

	1993				1997			
Sources	Particulates	SO_2	NO_X	CO	Particulates	SO_2	NO_x	CO
Existing District Heat Plants, Including Soda	37%	92%	87%	6%	21%	85%	89%	8%
Local Boilers	41%	5%	6%	14%	47%	8%	5%	11%
Home Furnaces	22%	3%	6%	80%	32%	7%	6%	81%
Tonnes	1658	11,297	2,799	2,782	1,136	5,140	2,916	2,759

5.0 Supply Resources

The assessment of supply resources examined four alternatives to upgrade the Plzeň central heating plant. All options assume that new and existing units will comply with 1997 emissions regulations. The major distinguishing characteristics (fuel type, size, and date of introduction) of the Central Plant capacity configurations to meet the high load are

Coal 1997 — Addition of new coal-fired cogeneration capacity in 1997 with maximum thermal output of 75 MW_t and electrical output of 32 MW_e.

Coal 2003 — Addition of new 75 MW_t coal-fired cogeneration capacity in 2005 with maximum output of 75 MW_t and 32 MW_e.

65 MW Gas — Addition of new natural gas-fired cogeneration capacity in 1997 with maximum output of 65 MW_t and 89 MW_e.

60 MW Gas — Addition of new natural gas-fired cogeneration capacity in 1997 with maximum output of 60 MW_t and 73 MW_e.

The capacity configurations were downsized to meet the low load growth scenarios.

Available peak capacity for each of the Plzeň central heating plant configurations is shown in Table 3.

Additional information describing the make-up of each capacity configuration is provided in Appendix B.

Table 3. Peak Capacity (MW_t) for Plzeň Central Heating Plant Configuration, 1993-2000, 2005 and 2010

Configuration	1993	1994	1995	1996	1997	2000	2005	2010
High Load Growth								
Coal 1997	305	305	305	384	380	380	391	391
Coal 2003	305	305	305	384	384	384	390	390
65 MW Gas	305	305	304	384	369	369	380	380
60 MW Gas	305	305	305	384	353	353	364	364
Low Load Growth								
Coal 1997	305	305	305	384	380	380	333	333
Coal 2003	305	305	305	384	384	384	352	352
65 MW Gas	305	305	305	384	369	369	322	322
60 MW Gas	305	305	305	384	353	353	306	306

6.0 Efficiency Resource

The efficiency resource assessment developed estimates of the space and water heat energy efficiency potential in the residential and non-residential buildings sectors; limited information was collected on efficiency potential in the industrial sector. The buildings sector is estimated to account for about 60% of space and water heat energy use, with the industrial sector accounting for the balance. District heat is estimated to provide 56% of buildings sector heat and hot water energy use and 81% of industrial sector steam and hot water requirements.

Fifty measures were considered for reducing the buildings sector space and water heat consumption, of which the following 14 were determined to be cost-effective because they have a positive net present value (note: not all measures were applied to each of the 18 building types considered).

- Insulate building exterior side walls
- Weatherstrip elevator penthouse, stairway, doors and windows
- Weatherstrip windows and doors
- Install revolving or double door in vestibule
- Install storm windows
- Install zone valves on each radiator and install central thermostats with 'on time counter' in each apartment
- Install heat recovery vent system in basements
- Install heat reflectors behind each radiator or heater
- Remove draperies from radiator
- Install low-flow shower heads
- Install flow restrictors on faucets
- Insulate hot water pipes in unconditioned spaces
- Install hot water flow meters
- Install waste water heat recovery heat exchanger.

The efficiency assessment estimated a 40% reduction in buildings sector energy consumption at a levelized cost of 105 Kc/GJ. This amount was adjusted downward to provide for a 15% reduction in buildings sector energy consumption and 10% reduction in heat production for three reasons. First, experience in the U.S. has shown that engineering-based estimates, such as the one for Plzeň, typically predict greater potential than is realized and that the over-prediction can be as high as 2:1. Second, the efficiency assessment included all measures and the baseline includes the effect of metering and controls at the heat exchanger station or building boundary; these controls are estimated to reduce consumption by about 10% as noted in the system loads discussion. Third, experience in a demonstration of buildings sector energy efficiency in Krakow, Poland, for the types of measures considered indicates that a reduction of about 25% can be achieved, of which 10% is from controls at the heat exchanger station or building boundary.

The installed cost of the measures considered is estimated to be 5700 Kc/GJ for first year savings. This cost appears consistent with the costs experienced in the Krakow demonstration and with derating the efficiency potential, while keeping costs constant. *These adjustments are felt to present a conservative picture for the buildings sector efficiency resource.*

Industrial sector energy efficiency potential is reported to be on the order of 15% to 20% of base use. This estimate is based upon the findings of other studies and discussions with facility managers. The cost of acquiring this resource was not available.

7.0 Integrated Findings

This section provides the integration of the efficiency and supply resources to meet the high and low load and growth scenarios.

Moderate System Expansion. The loads on the Central System increase with the completion of Heat Line East I to include the Letna/Doubravka areas with service provided by the Plzeň Central Plant per the four capacity configurations presented in the supply discussion above. The loads are subject to high and low growth, with and without programmatic efficiency. This case considered life extension to the existing Svetovar plant and continued operation of this segment as a stand-alone system. The Supply Assessment examined three alternatives for the Svetovar heat generation plant—life extension and environmental compliance, conversion to natural gas, and replacement with a micro-cogeneration unit. Life extension was found to be the most cost-effective alternative; therefore, the other two alternatives were not considered in this integrated assessment. Within the moderate system expansion case, the Coal 2003 high load without efficiency scenario is considered the base case, and it most closely reflects the simple life extension case.

Full System Expansion. The loads on the Central System increase with the completion of Heat Lines East I and II to include the Letna/Doubravka and Svetovar areas with service provided by the Plzeň Central Plant per the four capacity configurations presented in the supply discussion above. The loads are subject to high and low growth, with and without programmatic efficiency. In this case, the Svetovar plant is retired.

The first step in integrating the efficiency and supply assessments was to identify cases where supply resources were not adequate to meet the projected loads and not consider these cases further. This step compared the peak loads with the corresponding supply capacities, considering an outage of the largest generating unit. This comparison showed significant capacity shortfalls for all supply configurations under the full system expansion case with high load growth and without programmatic efficiency. As a result, these cases were not considered further in the integration. The process and findings for load/capacity surplus/deficit comparison are contained in Appendix C.

The next step characterized the economic and environmental attributes of the cases considered. Economic attributes include the capital cost to implement the supply and efficiency resources, the levelized cost in Kc/GJ for the combined production of heat and steam, the typical residential energy bill, and the levels of emissions (particulates, SO_2, NO_X, and CO). The levelized cost was developed on a cash flow basis for the period 1994-2000. The attributes for the moderate system expansion case without and with efficiency are presented in Table 4.

In all cases, the Coal 2003 supply configuration requires the least capital investment, particularly in the 1993-2000 period at a cost of 40% of the next most expensive supply configuration. In the longer term, the differential in capital cost is on the order of 25%.

Table 4. Economic and Environmental Attributes for Moderate System Load Expansion by Plant Configuration, High and Low Load Growth Without and With Efficiency

HIGH LOAD GROWTH WITHOUT PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2003	799	2157	162	6804	BASE	BASE	BASE	BASE
Coal 1997	1978	2238	170	7140	1	-1	-1	-1
65MW Gas	2282	2542	206	8652	-4	-18	-13	-1
60MW Gas	2044	2304	199	8358	-4	-17	-12	-1

HIGH LOAD GROWTH WITH PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2003	1098	2643	181	6462	-1	-4	-3	0
Coal 1997	2276	2724	190	6783	1	-4	-4	-2
65MW Gas	2580	3027	225	8033	-4	-19	-14	-2
60MW Gas	2342	2790	220	7854	-4	-19	-14	-1

LOW LOAD GROWTH WITHOUT PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2005	688	1515	159	6678	-1	-7	-5	-1
Coal 1997	1867	2050	180	7560	0	-7	-7	-2
65MW Gas	2171	2354	216	9072	-4	-21	-16	-2
60MW Gas	1933	227	208	8736	-4	-20	-15	-2

LOW LOAD GROWTH WITH PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2003	954	1945	181	6462	-2	-9	-8	-1
Coal 1997	2132	2480	200	7140	0	-10	-10	-1
65MW Gas	NA		NA	NA	NA	NA	NA	NA
60MW Gas	NA		NA	NA	NA	NA	NA	NA

The levelized energy cost for the period 1994-2010 reflects the combined effect of the differential in capital, fuel, and other operations and maintenance costs. In the two high growth scenarios, the two coal configurations can be considered nearly equal and about 20% below the cost of the two gas-fired configurations. In the two low growth scenarios, the Coal 2003 option is about 10% less than the Coal 1997 option and about 20% less than the gas-fired options. Note that the levelized energy cost includes the Svetovar life extension, which reduces the price per GJ for the balance of the system by about 8 Kc. While the levelized energy cost increases about 10% in the efficiency scenario, the typical residential energy bill based on average consumption of 42 GJ/year is expected to decrease about 5%.

The reductions in emissions are based upon total emissions from heat generation sources in the City of Plzeň. The two gas-fired options clearly provide the greatest reduction in emissions and efficiency provides modest additional benefit over the without-efficiency case.

Table 5 provides the attribute data for the full system expansion case without and with efficiency. As noted above, the four supply options were not considered for the high load without efficiency scenario because of the deficit in supply capacity to meet the loads.

The relationships in this table are similar to those for the moderate system expansion case. The capital requirements for the coal options are less than the gas-fired options, particularly for the Coal 2003 option. The difference in the levelized energy cost narrows slightly between the coal and gas options and stays about the same between the two coal options. Emissions also show a reduction with the implementation of efficiency.

A comparison of the full system expansion to the moderate system shows the capital requirements to be about 2% higher and the levelized energy cost to be about 2% to 5% higher. Although the utilization of the central system capacity increases with the full system expansion, the production cost is still higher than that of the Svetovar plant (about 150-170 Kc/GJ).[a] As a result, the typical energy bill increases over that in the moderate system expansion case.

Emissions are estimated to increase slightly from the moderate system expansion case. The models predict that emissions associated with the increased utilization of the Central Plant more than offset the reductions achieved from not extending the life of the Svetovar Plant. While this is not intuitively obvious, the other basic relationships still hold—the gas-fired options provide significant emissions reductions for sulfur and nitrous oxides, and efficiency provides a modest additional reduction over the without efficiency scenario.

(a) The supply assessment projected a levelized energy cost for the Svetovar segment of approximately 350 Kc/GJ and a current cost of about 250 Kc/GJ, whereas the City claims the current production cost is about 125 Kc/GJ. The latter cost was escalated at a 3% real rate to provide a levelized cost of about 150 Kc/GJ, which was used in the results reported above. Had the higher cost been used, the Svetovar connection would have been economically attractive.

Table 5. Economic and Environmental Attributes for Full System Load Expansion by Central Plant Configuration, High and Low Load Growth Without and With Efficiency

HIGH LOAD GROWTH WITH PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2003	1136	2699	185	6605	0	0	0	0
Coal 1997	2315	2780	194	6926	1	-1	-2	-2
65MW Gas	2619	3084	231	8247	-4	-18	-14	-1
60MW Gas	2381	2846	225	8033	-4	-17	-14	-1

LOW LOAD GROWTH WITHOUT PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2003	731	1557	168	7056	-1	-4	-5	-1
Coal 1997	2020	2280	187	7854	1	-4	-6	-2
65MW Gas	2324	2584	224	9408	-4	-19	-16	-2
60MW Gas	2086	2346	219	9198	-4	-19	-15	-2

LOW LOAD GROWTH WITH PROGRAMMATIC EFFICIENCY

SUPPLY SCENARIO	Capital Requirement (X10-6Kc) 1993-2000	Capital Requirement (X10-6Kc) 1993-2010	Energy Cost Levelized Kc/GJ (1993-2010)	Energy Cost Residential Energy Bill Kc/Year	% Change in Average Annual Emissions (1997-2010) Particulates	SO2	NOX	CO
Coal 2003	991	1995	178	6355	-1	-7	-5	-1
Coal 1997	2169	2530	205	7319	0	-7	-9	-2
65MW Gas	2473	2834	244	8711	-4	-21	-17	-2
60MW Gas	2235	2596	236	8425	-4	-20	-17	-2

The integration of the supply and efficiency assessments did not optimize the amount and timing of the addition of the efficiency and supply resources; had this been done, it is expected that the costs (capital and levelized) and emissions would be somewhat lower. However, it is not likely that optimizing the resources would change the relationships evidenced in the integration among the resource options considered—life extension to the existing system, early coal upgrade, or heavier reliance on natural gas with an early upgrade.

8.0 Related Publications

This report is one of four containing an energy assessment of options for upgrading the district heating system for the City of Plzeň, Czech Republic:

An Evaluation of the Supply-Side Options for the Plzeň District Heating System (Gilbert/Commonwealth)

Assessment of the Buildings Sector Efficiency Resource for the City of Plzeň (Pacific Northwest National Laboratory)

Efficiency and Supply Resource Options for the Upgrade of the Plzeň District Heating System (Pacific Northwest National Laboratory)

Heat Supply in Plzeň: Final Report (SEVEn, Pacific Northwest National Laboratory)

All of these reports were published by

Pacific Northwest National Laboratory
901 D Street S.W., Suite 900
Washington, DC 20024-2115.

Appendix A

System Loads

Appendix A

System Loads

Tables A.1 through A.4 provide the load projections associated with the system segments for the four growth scenarios: high demand without efficiency; high demand with efficiency; low demand without efficiency; and low demand with efficiency. Within each segment, the loads are shown by area of contribution—existing customers connected to the system, customers currently served by boilers that have either promised to or have indicated they will connect to the system, and new construction.

As noted in the system loads section, the no-efficiency scenarios reflect about a 10% reduction due to the pending installation of metering and controls required by regulation. This equipment will be installed at heat exchanger stations and/or the building boundary. The programmatic efficiency scenarios reflect an additional 10% reduction that is obtained through customer-side efficiency improvements. These improvements reflect combinations of weatherization, insulation, radiator controls, and heat exchangers.

Tables A.5 and A.6 provide the load projections for the system configurations examined. The moderate system expansion case comprises the combined load from the Central, Kosutka, and Letna/Doubravka areas. The full system expansion case further includes the Svetovar segment.

Table A.1. High Demand Without Programmatic Efficiency

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Hot Water									
Kosutka									
Existing Customers	133.0	133.0	133.0	133.0	131.7	130.3	126.4	119.7	119.7
Distributed Boilers									
Promised			0.5	0.7	0.7	2.5	2.5	2.5	2.5
Expressed Interest				4.4	4.4	4.4	4.4	4.4	4.4
New Customers				1.9	2.9	4.0	12.5	15.1	17.1
Subtotal	133.0	133.0	133.5	140.0	139.7	141.2	145.8	141.7	143.7
Bory									
Existing Customers	74.0	74.0	74.0	74.0	73.3	72.5	70.3	66.6	66.6
Distributed Boilers									
Promised		3.0	12.8	14.8	16.7	17.8	17.8	17.8	17.8
Expressed Interest			2.9	5.4	7.8	9.5	9.5	9.5	9.5
Subtotal	74.0	77.0	89.7	94.2	97.8	99.8	97.6	93.9	93.9
Letna/Doubravka									
Existing Customers	46.5	46.5	46.5	46.5	46.0	45.6	44.2	41.9	41.9
Distributed Boilers									
Promised					5.6	7.1	7.1	7.1	7.1
Expressed Interest					4.5	5.1	8.8	8.8	8.8
Subtotal	46.5	46.5	46.5	46.5	56.1	57.8	60.1	57.8	57.8
Svetovar									
Existing Customers	23.2	23.2	23.2	23.2	23.0	22.7	22.0	20.9	20.9
Distributed Boilers									
Promised						2.0	3.5	3.5	3.5
Subtotal	23.2	23.2	23.2	23.2	23.0	24.7	25.5	24.4	24.4
Steam	93.0	92.3	91.7	91.1	99.8	100.0	100.0	99.6	99.6

Notes:
Source Data is Gilbert/Commonwealth Report, Appendix E, Table A.1.
Regulations requiring system side metering and controls are assumed to provide a 10% efficiency improvement in the existing customer base between 1996 and 2005.
New customer data reflects efficiency improvement resulting from regulated metering and controls.

Table A.2. High Demand With Programmatic Efficiency

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Hot Water									
Kosutka									
Existing Customers	133.0	133.0	133.0	133.0	130.3	127.7	119.7	106.4	106.4
Distributed Boilers									
Promised			0.5	0.6	0.6	2.3	2.3	2.3	2.3
Expressed Interest				4.0	4.0	4.0	4.0	4.0	4.0
New Customers				1.7	2.6	3.6	11.3	13.6	15.4
Subtotal	133.0	133.0	133.5	139.3	137.5	137.5	137.2	126.2	128.0
Bory									
Existing Customers	74.0	74.0	74.0	74.0	72.5	71.0	66.6	59.2	59.2
Distributed Boilers									
Promised		2.7	11.5	13.3	15.0	16.0	16.0	16.0	16.0
Expressed Interest			2.6	4.9	7.0	8.6	8.6	8.6	8.6
Subtotal	74.0	76.7	88.1	92.2	94.6	95.6	91.2	83.8	83.8
Letna/Doubravka									
Existing Customers	46.5	46.5	46.5	46.5	45.6	44.6	41.9	37.2	37.2
Distributed Boilers									
Promised					5.0	6.4	6.4	6.4	6.4
Expressed Interest					4.1	4.6	7.9	7.9	7.9
Subtotal	46.5	46.5	46.5	46.5	54.7	55.6	56.2	51.5	51.5
Svetovar									
Existing Customers	23.2	23.2	23.2	23.2	22.7	22.3	20.9	18.6	18.6
Distributed Boilers									
Promised						1.8	3.2	3.2	3.2
Subtotal	23.2	23.2	23.2	23.2	22.7	24.1	24.0	21.7	21.7
Steam	93.0	92.3	91.7	91.1	99.8	100.0	100.0	99.6	99.6

Notes:
Source Data is Gilbert/Commonwealth Report, Appendix E, Table A.1.
Regulations requiring system side metering and controls are assumed to provide a 10% efficiency improvement in the existing customer base between 1996 and 2005.
New customer data reflects efficiency improvement resulting from regulated metering and controls.

Table A.3. Low Demand Without Programmatic Efficiency

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Hot Water									
Kosutka									
Existing Customers	133.0	133.0	133.0	133.0	131.7	130.3	126.4	119.7	119.7
Distributed Boilers									
Promised			0.4	0.5	0.5	1.9	1.9	1.9	1.9
Expressed Interest				3.5	3.5	3.5	3.5	3.5	3.5
New Customers				1.0	1.0	1.0	1.0	1.0	1.0
Subtotal	133.0	133.0	133.4	138.0	136.7	136.7	132.8	126.1	126.1
Bory									
Existing Customers	74.0	74.0	68.0	66.5	67.3	66.6	64.6	61.2	61.2
Distributed Boilers									
Promised		2.3	9.6	11.1	12.5	13.4	13.4	13.4	13.4
Expressed Interest			1.7	3.2	4.7	5.7	5.7	5.7	5.7
Subtotal	74.0	76.3	79.3	80.8	84.5	85.7	83.7	80.3	80.3
Letna/Doubravka									
Existing Customers	46.5	46.5	46.5	46.5	46.0	45.6	44.2	41.9	41.9
Distributed Boilers									
Promised					4.2	5.3	5.3	5.3	5.3
Expressed Interest						0.6	2.2	3.4	3.4
Subtotal	46.5	46.5	46.5	46.5	50.2	51.5	51.7	50.6	50.6
Svetovar									
Existing Customers	23.2	23.2	23.2	23.2	23.0	22.7	22.0	20.9	20.9
Distributed Boilers									
Promised									
Subtotal	23.2	23.2	23.2	23.2	23.0	22.7	22.0	20.9	20.9
Steam	93.0	92.3	91.7	91.1	90.5	88.9	88.9	88.9	88.9

Notes:
Source Data is Gilbert/Commonwealth Report, Appendix E, Table A.2.
Regulations requiring system side metering and controls are assumed to provide a 10% efficiency improvement in the existing customer base between 1996 and 2005.
New customer data reflects efficiency improvement resulting from regulated metering and controls.

Table A.4. Low Demand With Programmatic Efficiency

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Hot Water									
Kosutka									
Existing Customers	133.0	133.0	133.0	133.0	130.3	127.7	119.7	106.4	106.4
Distributed Boilers									
Promised			0.4	0.5	0.5	1.7	1.7	1.7	1.7
Expressed Interest				3.2	3.2	3.2	3.2	3.2	3.2
New Customers				0.9	0.9	0.9	0.9	0.9	0.9
Subtotal	133.0	133.0	133.4	137.5	134.8	133.4	125.5	112.2	112.2
Bory									
Existing Customers	74.0	74.0	74.0	74.0	72.5	71.0	66.6	59.2	59.2
Distributed Boilers									
Promised		2.1	8.6	10.0	11.3	12.1	12.1	12.1	12.1
Expressed Interest			1.5	2.9	4.2	5.1	5.1	5.1	5.1
Subtotal	74.0	76.1	84.2	86.9	88.0	88.2	83.8	76.4	76.4
Letna/Doubravka									
Existing Customers	46.5	46.5	46.5	46.5	45.6	44.6	41.9	37.2	37.2
Distributed Boilers									
Promised					4.2	5.3	5.3	5.3	5.3
Expressed Interest						0.6	2.2	3.4	3.4
Subtotal	46.5	46.5	46.5	46.5	49.8	50.5	49.4	45.9	45.9
Svetovar									
Existing Customers	23.2	23.2	23.2	23.2	22.7	22.3	20.9	18.6	18.6
Distributed Boilers									
Promised									
Subtotal	23.2	23.2	23.2	23.2	22.7	22.3	20.9	18.6	18.6
Steam	93.0	92.3	91.7	91.1	90.5	88.9	88.9	88.9	88.9

Notes:
Source Data is Gilbert/Commonwealth Report, Appendix E, Table A.2.
Regulations requiring system side metering and controls are assumed to provide a 10% efficiency improvement in the existing customer base between 1996 and 2005.
New customer data reflects efficiency improvement resulting from regulated metering and controls.

Table A.5. Moderate System Expansion (Kosutka, Bory, and Letna Doubravka)

	1992	1993	1994	1995	1996	1997	2000	2005	2010
				High Demand Without Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.5	140.0	139.7	141.2	145.8	141.7	143.7
Bory	74.0	77.0	89.7	94.2	97.8	99.8	97.6	93.9	93.9
Letna/Doubravka					56.1	57.8	60.1	57.8	57.8
Hot Water Total	207.0	210.0	223.2	234.2	293.6	298.8	303.4	293.4	295.4
Steam	93.0	92.3	91.7	91.1	99.8	100.0	100.0	99.6	99.6
				High Demand With Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.5	139.3	137.5	137.5	137.2	126.2	128.0
Bory	74.0	76.7	88.1	92.2	94.6	95.6	91.2	83.8	83.8
Letna/Doubravka					54.7	55.6	56.2	51.5	51.5
Hot Water Total	*207.0*	*209.7*	*221.6*	*231.5*	*286.8*	*288.7*	*284.5*	*261.5*	*263.3*
Steam	93.0	92.3	91.7	91.1	99.8	100.0	100.0	99.6	99.6
				Low Demand Without Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.4	138.0	136.7	136.7	132.8	126.1	126.1
Bory	74.0	76.3	79.3	80.8	84.5	85.7	83.7	80.3	80.3
Letna/Doubravka					50.2	51.5	51.7	50.6	50.6
Hot Water Total	207.0	209.3	212.7	218.8	271.4	274.0	268.1	257.0	257.0
Steam	93.0	92.3	91.7	91.1	90.5	88.9	88.9	88.9	88.9
				Low Demand With Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.4	137.5	134.8	133.4	125.5	112.2	112.2
Bory	74.0	76.1	84.2	86.9	88.0	88.2	83.8	76.4	76.4
Letna/Doubravka					49.8	50.5	49.4	45.9	45.9
Hot Water Total	207.0	209.1	217.5	224.4	272.6	272.2	258.6	234.5	234.5
Steam	93.0	92.3	91.7	91.1	90.5	88.9	88.9	88.9	88.9

Note:
Assumes connection of Letna/Doubravka load in 1996

Table A.6. Full System Expansion (Kosutka, Bory, Letna Doubravka, and Svetovar)

	1992	1993	1994	1995	1996	1997	2000	2005	2010
				High Demand Without Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.5	140.0	139.7	141.2	145.8	141.7	143.7
Bory	74.0	77.0	89.7	94.2	97.8	99.8	97.6	93.9	93.9
Letna/Doubravka					56.1	57.8	60.1	57.8	57.8
Svetovar						24.7	25.5	24.4	24.4
Hot Water Total	207.0	210.0	223.2	234.2	293.6	323.6	329.0	317.7	319.7
Steam	93.0	92.3	91.7	91.1	99.8	100.0	100.0	99.6	99.6
				High Demand With Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.5	139.3	137.5	137.5	137.2	126.2	128.0
Bory	74.0	76.7	88.1	92.2	94.6	95.6	91.2	83.8	83.8
Letna/Doubravka					54.7	55.6	56.2	51.5	51.5
Svetovar						24.1	24.0	21.7	21.7
Hot Water Total	207.0	209.7	221.6	231.5	286.8	312.8	308.5	283.2	285.0
Steam	93.0	92.3	91.7	91.1	99.8	100.0	100.0	99.6	99.6
				Low Demand Without Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.4	138.0	136.7	136.7	132.8	126.1	126.1
Bory	74.0	76.3	79.3	80.8	84.5	85.7	83.7	80.3	80.3
Letna/Doubravka					50.2	51.5	51.7	50.6	50.6
Svetovar						22.7	22.0	20.9	20.9
Hot Water Total	207.0	209.3	212.7	218.8	271.4	296.7	290.2	277.8	277.8
Steam	93.0	92.3	91.7	91.1	90.5	88.9	88.9	88.9	88.9
				Low Demand With Programmatic Efficiency					
Hot Water									
Kosutka	133.0	133.0	133.4	137.5	134.8	133.4	125.5	112.2	112.2
Bory	74.0	76.1	84.2	86.9	88.0	88.2	83.8	76.4	76.4
Letna/Doubravka					49.8	50.5	49.4	45.9	45.9
Svetovar						22.3	20.9	18.6	18.6
Hot Water Total	207.0	209.1	217.5	224.4	272.6	294.5	279.5	253.0	253.0
Steam	93.0	92.3	91.7	91.1	90.5	88.9	88.9	88.9	88.9

Assumes connection of Letna/Doubravka load in 1996 and Svetovar load in 1997

Appendix B

Supply Resources

Appendix B

Supply Resources

Table B.1 provides summary information on the existing and alternative heat supply resources. The summary information provides the name, type of output (hot water or steam), number of units, capacity of each unit, year constructed, and action applicable to the alternative capacity configurations.

Tables B.2 through B.5 provide the combinations of generating capacities that were configured for the high and low load growth scenarios in the moderate system expansion case. These tables show the total capacity available and total capacity reduced by the largest unit to reflect a worst case outage.

Table B.1. Supply Resource Description

Unit	Type	Fuel	Number Units	Size (MW)	Year Built	Action
Plzen 1 (Ia-Ic)	Hot Water	Coal	3	35	1977	Switch to Black Coal and Retrofit for 1997 Emissions Compliance
Plzen II (2a & 2b)	Steam	Coal	2	95	1983	Switch to Black Coal and Retrofit for 1997 Emissions Compliance
Plzen III	Steam	Gas	1	43		Not Considered
Plzen IV Alternatives						
65MW Gas	Steam	Gas	1	65	1997	New Unit
60MW Gas	Steam	Gas	1	60	1997	New Unit
Coal 1997	Steam	Coal	1	75	1997	New Unit
Coal 2005	Steam	Coal	1	75	2003	New Unit
Coal 2005, Low Demand	Steam	Coal	1	37.5	2003	New Unit
Plzen V	Hot Water	Oil/Gas	2	58	2005	New Unit
Kosutka	Hot Water	Gas	2	17.4	1981	Switch from Coal to Gas in 1997
Bory						
Hot Water	Hot Water	Coal	2	11.6	1965	Retire in 1997; Switch to Black Coal and Retrofit for 1997 Emissions Compliance in Coal 2005 Case
Steam	Steam	Coal	2	5.4	1965	Switch to Black Coal and Retrofit for 1997 Emissions Compliance
Steam	Steam	Coal	1	10.7	1965	Switch to Black Coal and Retrofit for 1997 Emissions Compliance
Steam	Steam	Oil	1	9.8	1973	Continue Operation
Letna						
Hot Water	Hot Water	Coal	4	5.8	1963	Retire in 1997; Switch to Black Coal and Retrofit for 1997 Emissions Compliance in Coal 2005 Case
Hot Water	Hot Water	Oil	1	9.8	1974	Continue Operation
Doubravka -- HW	Hot Water	Coal	4	5.8	1963-66	Retire in 1997; Switch to Black Coal and Retrofit for 1997 Emissions Compliance in Coal 2005 Case
Brewery						
K4	Steam	Gas	1	15.7	1974	Continue Operation
K5	Steam	Gas	1	7.8	1973	Continue Operation
K6	Steam	Gas	2	16.3	1985/89	Continue Operation
K7	Hot Water	Gas	1	25	1995	New Unit
ZOS -- Steam	Steam	Coal	2	8.5	Unknown	Retire - date unknown

Table B.2. 65 MW Gas Supply Configuration

HIGH DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35		
Plzen Ib	35	35	35	35	35	35	35		
Plzen Ic	35	35	35	35	35	35	35		
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2				
Letna I-IV					23.2				
Letna V					9.8				
Doubravka I-IV					23.2				
Plzen III									
Plzen IV						64.3	64.3	64.3	64.3
Plzen Va								58	58
Plzen Vb								58	58
Total	304.8	304.8	304.8	304.8	384.2	369.1	369.1	380.1	380.1
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	286.6	286.6	297.6	297.6

LOW DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35		
Plzen Ib	35	35	35	35	35	35	35		
Plzen Ic	35	35	35	35	35	35	35		
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2				
Letna I-IV					23.2				
Letna V					9.8				
Doubravka I-IV					23.2				
Plzen III									
Plzen IV						64.3	64.3	64.3	64.3
Plzen Va								58	58
Plzen Vb									
Total	304.8	304.8	304.8	304.8	384.2	369.1	369.1	322.1	322.1
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	286.6	286.6	239.6	239.6

Table B.3. 60 MW Gas Supply Configuration

HIGH DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35		
Plzen Ib	35	35	35	35	35	35	35		
Plzen Ic	35	35	35	35	35	35	35		
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2				
Letna I-IV					23.2				
Letna V					9.8				
Doubravka I-IV					23.2				
Plzen III									
Plzen IV						48.2	48.2	48.2	48.2
Plzen Va								58	58
Plzen Vb								58	58
Total	304.8	304.8	304.8	304.8	384.2	353	353	364	364
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	270.5	270.5	281.5	281.5

LOW DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35		
Plzen Ib	35	35	35	35	35	35	35		
Plzen Ic	35	35	35	35	35	35	35		
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2				
Letna I-IV					23.2				
Letna V					9.8				
Doubravka I-IV					23.2				
Plzen III									
Plzen IV						48.2	48.2	48.2	48.2
Plzen Va								58	58
Plzen Vb									
Total	304.8	304.8	304.8	304.8	384.2	353	353	306	306
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	270.5	270.5	223.5	223.5

Table B.4. Coal 1997 Supply Configuration

HIGH DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35		
Plzen Ib	35	35	35	35	35	35	35		
Plzen Ic	35	35	35	35	35	35	35		
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2				
Letna I-IV					23.2				
Letna V					9.8				
Doubravka I-IV					23.2				
Plzen III									
Plzen IV						75	75	75	75
Plzen Va								58	58
Plzen Vb								58	58
Total	304.8	304.8	304.8	304.8	384.2	379.8	379.8	390.8	390.8
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	297.3	297.3	308.3	308.3

LOW DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35		
Plzen Ib	35	35	35	35	35	35	35		
Plzen Ic	35	35	35	35	35	35	35		
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2				
Letna I-IV					23.2				
Letna V					9.8				
Doubravka I-IV					23.2				
Plzen III									
Plzen IV						75	75	75	75
Plzen Va								58	58
Plzen Vb									
Total	304.8	304.8	304.8	304.8	384.2	379.8	379.8	332.8	332.8
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	297.3	297.3	250.3	250.3

Table B.5. Coal 2005 Supply Configuration

HIGH DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35	35	35
Plzen Ib	35	35	35	35	35	35	35	35	35
Plzen Ic	35	35	35	35	35	35	35	35	35
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2	23.2	23.2		
Letna I-IV					23.2	23.2	23.2		
Letna V					9.8	9.8	9.8	9.8	9.8
Doubravka I-IV					23.2	23.2	23.2		
Plzen III									
Plzen IV								75	75
Plzen Va									
Plzen Vb									
Total	304.8	304.8	304.8	304.8	384.2	384.2	384.2	389.6	389.6
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	301.7	301.7	307.1	307.1

LOW DEMAND

	1992	1993	1994	1995	1996	1997	2000	2005	2010
Plzen Ia	35	35	35	35	35	35	35	35	35
Plzen Ib	35	35	35	35	35	35	35	35	35
Plzen Ic	35	35	35	35	35	35	35	35	35
Plzen IIa	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Plzen IIb	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5	82.5
Kosutka	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8	34.8
Bory I & II					23.2	23.2	23.2		
Letna I-IV					23.2	23.2	23.2		
Letna V					9.8	9.8	9.8	9.8	9.8
Doubravka I-IV					23.2	23.2	23.2		
Plzen III									
Plzen IV								37.5	37.5
Plzen Va									
Plzen Vb									
Total	304.8	304.8	304.8	304.8	384.2	384.2	384.2	352.1	352.1
Total w/o Largest	222.3	222.3	222.3	222.3	301.7	301.7	301.7	269.6	269.6

Appendix C

Load/Supply Capacity Margins

Appendix C

Load/Supply Capacity Margins

The analysis to integrate the supply and efficiency resource options is based upon the ability to meet system loads. Following the methodology used in the supply assessment, the load scenarios are matched to the alternative supply resource configurations to provide the net capacity surplus or deficit for each combination. A modest capacity surplus provides for future system expansion with existing capacity, and a significant surplus would indicate that the investment in resources may be deferred. A deficit situation indicates that additional capacity may be required to serve the load if reliability and service are important.

The four load scenarios from Tables A.5 and A.6, the moderate and full system expansion cases, are matched to the capacity configurations in Tables B.2 - B.5. The high demand portions of the load tables are matched to the high demand capacity scenario; this is repeated for the low demand portions of the tables. A conservative approach is taken in this process to ensure system reliability and service as follows:

1. On the load side, the hot water and steam loads are increased by 10% and 5%, respectively, over the values shown to account for an extraordinary peak, and this adjusted load is then reduced by 15% to reflect a short term reduction in quality of service in a peak period. In fact, Czech regulations permit a service reduction of about 20%. So, in the moderate system expansion case (Table A.5), high demand without programmatic efficiency, the 295.4 MW_t hot water load in the year 2010 is adjusted to 276.2 MW_t and the 99.6 MW_t steam load is adjusted to 88.9 MW_t. The total load for the net capacity calculation is then 365.1 MW_t.

2. On the supply side, the total capacity without the largest unit is used to reflect the ability of the system to meet load with the largest unit out of service. In addition, 56.1 MW_t of capacity assumed to be available from the brewery is added. So, in the case of the 65 MW gas supply configuration for the high load, the available capacity is 353.7 MW_t.

For the above example, a deficit of about 11 MW_t of capacity exists in the 65 MW gas supply option in the year 2010 to meet the projected system load. The net capacities for all 32 load and capacity combinations are shown in Table C.1.

The integrated analysis did not attempt to adjust the capacity configurations to reduce significant surpluses or deficits. However, in some cases, the capacity configuration and load scenarios

Table C.1. Heat Supply Peak Capacity Surplus/Deficit by Supply and Load Combination

	BORY, KOSUTKA, AND LETNA/DOUBRAVKA							
	1993		1997		2005		2010	
SUPPLY CAPACITY SCENARIO	WITHOUT EFFICIENCY	WITH EFFICIENCY	WITHOUT EFFICIENCY	WITH EFFICIENCY	WITHOUT EFFICIENCY	WITH EFFICIENCY	WITHOUT EFFICIENCY	WITH EFFICIENCY
HIGH DEMAND								
CP Plzen – 65MW Gas (A2)	-0.3	0.0	-26.0	-16.5	-9.5	20.3	-11.3	18.6
CP Plzen – 60MW Gas (A3)	-0.3	0.0	-42.1	-32.6	-25.6	4.2	-27.4	2.5
CP Plzen – Coal 1997 (B1)	-0.3	0.0	-15.3	-5.8	1.2	31.0	-0.6	29.3
CP Plzen – Coal 2005 (C1)	-0.3	0.0	-10.9	-1.4	0.0	29.8	-1.8	28.1
LOW DEMAND								
CP Plzen – 65MW Gas (A2)	0.3	0.5	7.2	8.8	-23.9	-2.9	-23.9	-2.9
CP Plzen – 60MW Gas (A3)	0.3	0.5	-8.9	-7.3	-40.0	-19.0	-40.0	-19.0
CP Plzen – Coal 1997 (B1)	0.3	0.5	17.9	19.5	-13.2	7.8	-13.2	7.8
CP Plzen – Coal 2005 (C1)	0.3	0.5	22.3	23.9	6.1	27.1	6.1	27.1

	BORY, KOSUTKA, LETNA/DOUBRAVKA, AND SVETOVAR							
	1993		1997		2005		2010	
SUPPLY CAPACITY SCENARIO	WITHOUT EFFICIENCY	WITH EFFICIENCY	WITHOUT EFFICIENCY	WITH EFFICIENCY	WITHOUT EFFICIENCY	WITH EFFICIENCY	WITHOUT EFFICIENCY	WITH EFFICIENCY
HIGH DEMAND								
CP Plzen -- 65MW Gas (A2)	-0.3	0.0	-49.1	-39.0	-32.3	0.0	-34.1	-1.7
CP Plzen -- 60MW Gas (A3)	-0.3	0.0	-65.2	-55.1	-48.4	-16.1	-50.2	-17.8
CP Plzen – Coal 1997 (B1)	-0.3	0.0	-38.4	-28.3	-21.6	10.7	-23.4	9.0
CP Plzen -- Coal 2005 (C1)	-0.3	0.0	-34.0	-23.9	-22.8	9.5	-24.6	7.8
LOW DEMAND								
CP Plzen -- 65MW Gas (A2)	0.3	0.5	-14.0	-12.0	-43.4	-20.2	-43.4	-20.2
CP Plzen -- 60MW Gas (A3)	0.3	0.5	-30.1	-28.1	-59.5	-36.3	-59.5	-36.3
CP Plzen – Coal 1997 (B1)	0.3	0.5	-3.3	-1.3	-32.7	-9.5	-32.7	-9.5
CP Plzen -- Coal 2005 (C1)	0.3	0.5	1.1	3.1	-13.4	9.8	-13.4	9.8

Net capacity is calculated as follows:
Total supply capacity (Appendix B) without the largest unit plus 56.1MWt capacity available from the brewery.
Minus hot water load (App. A) increased by 10% to reflect extraordinary demand and reduced by 15% to reflect high demand service reduction.
Minus steam load (App. A) increased by 5% to reflect extraordinary demand and reduced by 15% to reflect high demand service reduction.

combinations were not analyzed because of the magnitude of the deficit. The selection for the supply/load combinations follows, with the discussion focusing on the values in the 2005-2010 time period.

Moderate System Expansion

High Demand Without and With Efficiency. It would appear that the load could reasonably be met with the 65 MW gas configuration either with or without efficiency because the deficit of 11 MW_t (surplus of 19 MW_t) is about only about 3% (5%) of the projected load. However, in the case of the 60 MW gas supply configuration, the deficit accounts for about 7% of the projected load and the surplus in the efficiency scenario is near zero. In the two coal configurations, the deficit is minimal without efficiency and increases to about 8% of the projected load when programmatic efficiency is introduced.

While it would have been desirable to adjust the system configurations to analyze a closer match of capacity to load in both load scenarios (without and with programmatic efficiency), program constraints did not allow for this. All eight cases were analyzed with the surplus or deficit as shown.

Low Demand Without and With Efficiency. Again, the two gas supply configurations exhibit deficits even when programmatic efficiency is considered. Of the two coal options, the 1997 configuration appears to be an acceptable match to the load either without or with programmatic efficiency, and the 2003 configuration exhibits a surplus in both load scenarios.

In this case, the high demand capacity configurations for the two gas supply configurations were analyzed for the load scenario without efficiency—this produced capacity surpluses of 34 MW_t and 18 MW_t for the 65 MW_t and 60 MW_t gas configurations, respectively. The low demand capacity configurations were retained for the load scenario with efficiency, but not analyzed because of project constraints.

Full System Expansion

High Demand Without and With Efficiency. In all without-efficiency combinations, a significant capacity deficit exists. In the with-efficiency cases, the deficit is reduced for the two gas supply configurations and becomes a slight surplus for the two coal-fired configurations.

Given the size of the deficits in the without-efficiency load scenario, no cases were analyzed as this would have required adding additional supply capacity. All four high demand capacity configurations were analyzed for the load scenario with efficiency, with the net capacities as shown.

Low Demand Without and With Efficiency. Again, a significant capacity deficit exits for all four of the low demand capacity configurations paired with the load scenario without efficiency. The deficits exist for all but the 2003 coal supply configuration in the load scenario with efficiency.

In the load scenario without efficiency, the high load capacity configurations were selected for analysis. This provides a surplus of 15 MW_t for the 65 MW_t gas configuration, a deficit of 2 MW_t

Low Demand Without and With Efficiency. Again, a significant capacity deficit exits for all four of the low demand capacity configurations paired with the load scenario without efficiency. The deficits exist for all but the 2003 coal supply configuration in the load scenario with efficiency.

In the load scenario without efficiency, the high load capacity configurations were selected for analysis. This provides a surplus of 15 MW_t for the 65 MW_t gas configuration, a deficit of 2 MW_t for the 6 MW_t gas configuration, and creates surpluses of 9 MW_t and 8 MW_t for the 1995 and 2003 coal supply configurations, respectively. In the case of the load scenario with efficiency, the high load gas supply configurations were again analyzed; this provides surpluses of 38 MW_t and 22 MW_t for the 65 and 60 MW_t gas supply configurations. The low demand coal configurations were retained with the net capacities as shown.

A critical ending note is that the authors believe the analyses conducted are sufficient to indicate the relative merits of the supply and efficiency resources. Although it would be desirable from a standpoint of completeness to have examined each supply and load combination for a zero capacity deficit/surplus and examined the six missing pairs, it is not felt that the additional information would change the relative merits of the combinations examined.

Appendix D

Analysis Assumptions

Appendix D

Analysis Assumptions

Most of the analysis and assumptions supporting the integrated analysis were drawn from the supply and efficiency assessments. Discussions with staff from the City of Plzeň resulted in the following revisions:

- Electricity production from the existing 55 MW_e unit was set at about 160,000 MWh/year and sales were set at about 130,000 MWh/year. These agree historical levels and are felt to be the best the unit could achieve.

- Steam production levels were set at about 240,000 MWh/year. These are in line with historical production and sales levels and with the supply assessment data after removing steam purchases from the brewery.

- The cost streams for the four alternatives are shown in Tables D.1 through D.8. Major additions reflect the cost of retirements, ash disposal, and heat line extension for the Letna/Doubravka and Svetovar connections.

- The efficiency potential is set to reduce heat production by 10% and end-use consumption by 15% at the cost developed in the efficiency assessment. This is felt to be a conservative estimate of the customer-side potential and is based upon results of the demonstration and evaluation of similar measures being conducted in Krakow, Poland.

The combined steam and heat price calculation is structured as follows:

- Annual revenue is set equal to the sum of principal, interest, change in working capital, operations and maintenance, return on equity/investment, and taxes; where taxes equal the tax rate times revenue minus operations and maintenance, depreciation, and interest. The revenue is then reduced by the loan receipts and the after-tax electricity revenue to provide the revenue needed from steam and heat sales for operation.

- Adjusted revenue is then divided by the combined steam and heat sales to provide the price needed for operation.

Table D.1. Cost Stream for System Upgrade, Moderate System Expansion (Million Kc,) Coal 2003

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1993-2000
Bory			4.1	4.1									28.3						36.5	8.2
Letna			5.8	5.8									35.1						46.7	11.6
Doubravka			4.1	4.1									35.1						43.3	8.2
Svetovar			5.8	5.8															11.6	11.6
Kosutka				10.6															10.6	10.6
East I Extension			25.0	50.0															75.0	75.0
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7															21.4	21.4
Plzen II			225.0	225.0															450.0	450.0
Ash Disposal			10.0	15.0	25.0														50.0	50.0
Plzen III																			0.0	0.0
Plzen IV									534.0	534.0									1068.0	0.0
Plzen IV*									307.0	307.0									614.0	0.0
Plzen V											91.5	91.5							183.0	0.0
Plzen V*											56.4	56.4							112.8	0.0
Total -- Kc	5.3	23.5	351.3	358.6	38.8	7.2	7.2	7.2	534.9	534.9	92.4	92.4	99.4	0.7	0.7	0.7	0.7	0.7	2156.6	799.1
Total -- $	0.19	0.84	12.55	12.81	1.39	0.26	0.26	0.26	19.10	19.10	3.30	3.30	3.55	0.03	0.03	0.03	0.03	0.03	77.02	28.54
Total -- Kc*	1.7	7.1	313.4	336.4	28.7	0.4	0.4	0.4	307.2	307.2	56.6	56.6	98.7	0.0	0.0	0.0	0.0	0.0	1514.8	688.5
Total -- $*	0.06	0.25	11.19	12.01	1.03	0.01	0.01	0.01	10.97	10.97	2.02	2.02	3.53	0.00	0.00	0.00	0.00	0.00	54.10	24.59

* Notes cost streams for low demand scenario.

Table D.2. Cost Stream for System Upgrade, Moderate System Expansion (Million Kc,) Coal 1997

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1994-2000
Bory					28.3														28.3	28.3
Letna					35.1														35.1	35.1
Doubravka					35.1														35.1	35.1
Svetovar			5.8	5.8															11.6	11.6
Kosutka				10.6															10.6	10.6
East I Extension			25.0	50.0															75.0	75.0
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7										68.9					90.3	21.4
Plzen II			225.0	225.0															450.0	450.0
Ash Disposal			10.0	15.0	25.0														50.0	50.0
Plzen III																			0.0	0.0
Plzen IV			554.0	554.0															1108.0	1108.0
Plzen V											91.5	91.5							183.0	0.0
Plzen V*											56.4	56.4							112.8	0.0
Total -- Kc	5.3	23.5	891.3	898.6	137.3	7.2	7.2	7.2	0.9	0.9	92.4	92.4	0.9	69.6	0.7	0.7	0.7	0.7	2237.5	1977.6
Total -- $	0.19	0.84	31.83	32.09	4.90	0.26	0.26	0.26	0.03	0.03	3.30	3.30	0.03	2.49	0.03	0.03	0.03	0.03	79.91	70.63
Total -- Kc*	1.7	7.1	853.4	876.4	127.2	0.4	0.4	0.4	0.2	0.2	56.6	56.6	0.2	68.9	0.0	0.0	0.0	0.0	2049.7	1867.0
Total -- $*	0.06	0.25	30.48	31.30	4.54	0.01	0.01	0.01	0.01	0.01	2.02	2.02	0.01	2.46	0.00	0.00	0.00	0.00	73.20	66.68

* Notes cost streams for low demand scenario.

Table D.3. Cost Stream for System Upgrade, Moderate System Expansion (Million Kc), 65MW Gas

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1994-2000
Bory					28.3														28.3	28.3
Letna					35.1														35.1	35.1
Doubravka					35.1														35.1	35.1
Svetovar			5.8	5.8															11.6	11.6
Kosutka				10.6															10.6	10.6
East I Extension			25	50															75	75
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7										68.9					90.3	21.4
Plzen II			225	225															450	450
Ash Disposal			10	15	25														50	50
Plzen III																			0	0
Plzen IV			706	706															1412	1412
Plzen V											91.5	91.5							183	0
Plzen V*											56.4	56.4							112.8	0
Total -- Kc	5.3	23.5	1043.3	1050.6	137.3	7.2	7.2	7.2	0.9	0.9	92.4	92.4	0.9	69.6	0.7	0.7	0.7	0.7	2541.5	2281.6
Total -- $	0.19	0.84	37.26	37.52	4.90	0.26	0.26	0.26	0.03	0.03	3.30	3.30	0.03	2.49	0.03	0.03	0.03	0.03	90.77	81.49
Total -- Kc*	1.7	7.1	1005.4	1028.4	127.2	0.4	0.4	0.4	0.2	0.2	56.6	56.6	0.2	68.9	0.0	0.0	0.0	0.0	2353.7	2171.0
Total -- $*	0.06	0.25	35.91	36.73	4.54	0.01	0.01	0.01	0.01	0.01	2.02	2.02	0.01	2.46	0.00	0.00	0.00	0.00	84.06	77.54

* Notes cost streams for low demand scenario.

Table D.4. Cost Stream for System Upgrade, Moderate System Expansion (Million Kc), 60MW Gas

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1994-2000
Bory					28.3														28.3	28.3
Letna					35.1														35.1	35.1
Doubravka					35.1														35.1	35.1
Svetovar			5.8	5.8															11.6	11.6
Kosutka				10.6															10.6	10.6
East I Extension			25	50															75	75
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7										68.9					90.3	21.4
Plzen II			225	225															450	450
Ash Disposal			10	15	25														50	50
Plzen III																			0	0
Plzen IV			587.1	587.1															1174.2	1174.2
Plzen V											91.5	91.5							183	0
Plzen V*											56.4	56.4							112.8	0
Total -- Kc	5.3	23.5	924.4	931.7	137.3	7.2	7.2	7.2	0.9	0.9	92.4	92.4	0.9	69.6	0.7	0.7	0.7	0.7	2303.7	2043.8
Total -- $	0.19	0.84	33.01	33.28	4.90	0.26	0.26	0.26	0.03	0.03	3.30	3.30	0.03	2.49	0.03	0.03	0.03	0.03	82.28	72.99
Total -- Kc*	1.7	7.1	886.5	909.5	127.2	0.4	0.4	0.4	0.2	0.2	56.6	56.6	0.2	68.9	0.0	0.0	0.0	0.0	2115.9	1933.2
Total -- $*	0.06	0.25	31.66	32.48	4.54	0.01	0.01	0.01	0.01	0.01	2.02	2.02	0.01	2.46	0.00	0.00	0.00	0.00	75.57	69.04

* Notes cost streams for low demand scenario.

Table D.5. Cost Stream for System Upgrade, Full System Expansion (Million Kc,) Coal 2003

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1993-2000
Bory			4.1	4.1									28.3						36.5	8.2
Letna			5.8	5.8									35.1						46.7	11.6
Doubravka			4.1	4.1									35.1						43.3	8.2
Kosutka				10.6															10.6	10.6
East I Extension			25.0	50.0															75.0	75.0
East II Extension			27.0	27.0															54.0	54.0
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7															21.4	21.4
Plzen II			225.0	225.0															450.0	450.0
Ash Disposal			10.0	15.0	25.0														50.0	50.0
Plzen III																			0.0	0.0
Plzen IV									534.0	534.0									1068.0	0.0
Plzen IV*									307.0	307.0									614.0	0.0
Plzen V											91.5	91.5							183.0	0.0
Plzen V*											56.4	56.4							112.8	0.0
Total -- Kc	5.3	23.5	372.5	379.8	38.8	7.2	7.2	7.2	534.9	534.9	92.4	92.4	99.4	0.7	0.7	0.7	0.7	0.7	2199.0	841.5
Total -- $	0.19	0.84	13.30	13.56	1.39	0.26	0.26	0.26	19.10	19.10	3.30	3.30	3.55	0.03	0.03	0.03	0.03	0.03	78.54	30.05
Total -- Kc*	1.7	7.1	334.6	357.6	28.7	0.4	0.4	0.4	307.2	307.2	56.6	56.6	98.7	0.0	0.0	0.0	0.0	0.0	1557.2	730.9
Total -- $*	0.06	0.25	11.95	12.77	1.03	0.01	0.01	0.01	10.97	10.97	2.02	2.02	3.53	0.00	0.00	0.00	0.00	0.00	55.61	26.10

* Notes cost streams for low demand scenario.

Table D.6. Cost Stream for System Upgrade, Full System Expansion (Million Kc,) Coal 1997

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1994-2000
Bory					28.3														28.3	28.3
Letna					35.1														35.1	35.1
Doubravka					35.1														35.1	35.1
Kosutka				10.6															10.6	10.6
East I Extension			25.0	50.0															75.0	75.0
East II Extension			27.0	27.0															54.0	54.0
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7										68.9					90.3	21.4
Plzen II			225.0	225.0															450.0	450.0
Ash Disposal			10.0	15.0	25.0														50.0	50.0
Plzen III																			0.0	0.0
Plzen IV			554.0	554.0															1108.0	1108.0
Plzen V											91.5	91.5							183.0	0.0
Plzen V*											56.4	56.4							112.8	0.0
Total -- Kc	5.3	23.5	912.5	919.8	137.3	7.2	7.2	7.2	0.9	0.9	92.4	92.4	0.9	69.6	0.7	0.7	0.7	0.7	2279.9	2020.0
Total -- $	0.19	0.84	32.59	32.85	4.90	0.26	0.26	0.26	0.03	0.03	3.30	3.30	0.03	2.49	0.03	0.03	0.03	0.03	81.43	72.14
Total -- Kc*	1.7	7.1	874.6	897.6	127.2	0.4	0.4	0.4	0.2	0.2	56.6	56.6	0.2	68.9	0.0	0.0	0.0	0.0	2092.1	1909.4
Total -- $*	0.06	0.25	31.24	32.06	4.54	0.01	0.01	0.01	0.01	0.01	2.02	2.02	0.01	2.46	0.00	0.00	0.00	0.00	74.72	68.19

* Notes cost streams for low demand scenario.

Table D.7. Cost Stream for System Upgrade, Full System Expansion (Million Kc,) 65MW Gas

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1994-2000
Bory					28.3														28.3	28.3
Letna					35.1														35.1	35.1
Doubravka					35.1														35.1	35.1
Kosutka				10.6															10.6	10.6
East I Extension			25	50															75	75
East II Extension			27	27															54	54
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7										68.9					90.3	21.4
Plzen II			225	225															450	450
Ash Disposal			10	15	25														50	50
Plzen III																			0	0
Plzen IV			706	706															1412	1412
Plzen V											91.5	91.5							183	0
Plzen V*											56.4	56.4							112.8	0.0
Total -- Kc	5.3	23.5	1064.5	1071.8	137.3	7.2	7.2	7.2	0.9	0.9	92.4	92.4	0.9	69.6	0.7	0.7	0.7	0.7	2583.9	2324
Total -- $	0.19	0.84	38.02	38.28	4.90	0.26	0.26	0.26	0.03	0.03	3.30	3.30	0.03	2.49	0.03	0.03	0.03	0.03	92.28	83.00
Total -- Kc*	1.7	7.1	1026.6	1049.6	127.2	0.4	0.4	0.4	0.2	0.2	56.6	56.6	0.2	68.9	0.0	0.0	0.0	0.0	2396.1	2213.4
Total -- $*	0.06	0.25	36.66	37.49	4.54	0.01	0.01	0.01	0.01	0.01	2.02	2.02	0.01	2.46	0.00	0.00	0.00	0.00	85.58	79.05

* Notes cost streams for low demand scenario.

Table D.8. Cost Stream for System Upgrade, Full System Expansion (Million Kc,) 60MW Gas

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	Total	1994-2000
Bory					28.3														28.3	28.3
Letna					35.1														35.1	35.1
Doubravka					35.1														35.1	35.1
Kosutka				10.6															10.6	10.6
East I Extension			25	50															75	75
East II Extension			27	27															54	54
System Improvement	5.3	23.5	60.8	27.5	13.8	7.2	7.2	7.2	0.9	0.9	0.9	0.9	0.9	0.7	0.7	0.7	0.7	0.7	160.5	152.5
System Improvement*	1.7	7.1	22.9	5.3	3.7	0.4	0.4	0.4	0.2	0.2	0.2	0.2	0.2						42.9	41.9
Plzen I			10.7	10.7										68.9					90.3	21.4
Plzen II			225	225															450	450
Ash Disposal			10	15	25														50	50
Plzen III																			0	0
Plzen IV			587.1	587.1															1174.2	1174.2
Plzen V											91.5	91.5							183	0
Plzen V*											56.4	56.4							112.8	0.0
Total -- Kc	5.3	23.5	945.6	952.9	137.3	7.2	7.2	7.2	0.9	0.9	92.4	92.4	0.9	69.6	0.7	0.7	0.7	0.7	2346.1	2086.2
Total -- $	0.19	0.84	33.77	34.03	4.90	0.26	0.26	0.26	0.03	0.03	3.30	3.30	0.03	2.49	0.03	0.03	0.03	0.03	83.79	74.51
Total -- Kc*	1.7	7.1	907.7	930.7	127.2	0.4	0.4	0.4	0.2	0.2	56.6	56.6	0.2	68.9	0.0	0.0	0.0	0.0	2158.3	1975.6
Total -- $*	0.06	0.25	32.42	33.24	4.54	0.01	0.01	0.01	0.01	0.01	2.02	2.02	0.01	2.46	0.00	0.00	0.00	0.00	77.08	70.56

* Notes cost streams for low demand scenario.

The following assumptions were used in the price calculation:

- Values are expressed in real terms.
- Capital and efficiency are debt financed.
- Capital is depreciated on a straight line basis over 25 years.
- Efficiency is expensed in the current year.
- Efficiency is implemented over a 10-year period.
- Real annual interest rate of 7%.
- Loan term of 8 years.
- Real annual discount rate of 10%.
- Tax rate of 45%.