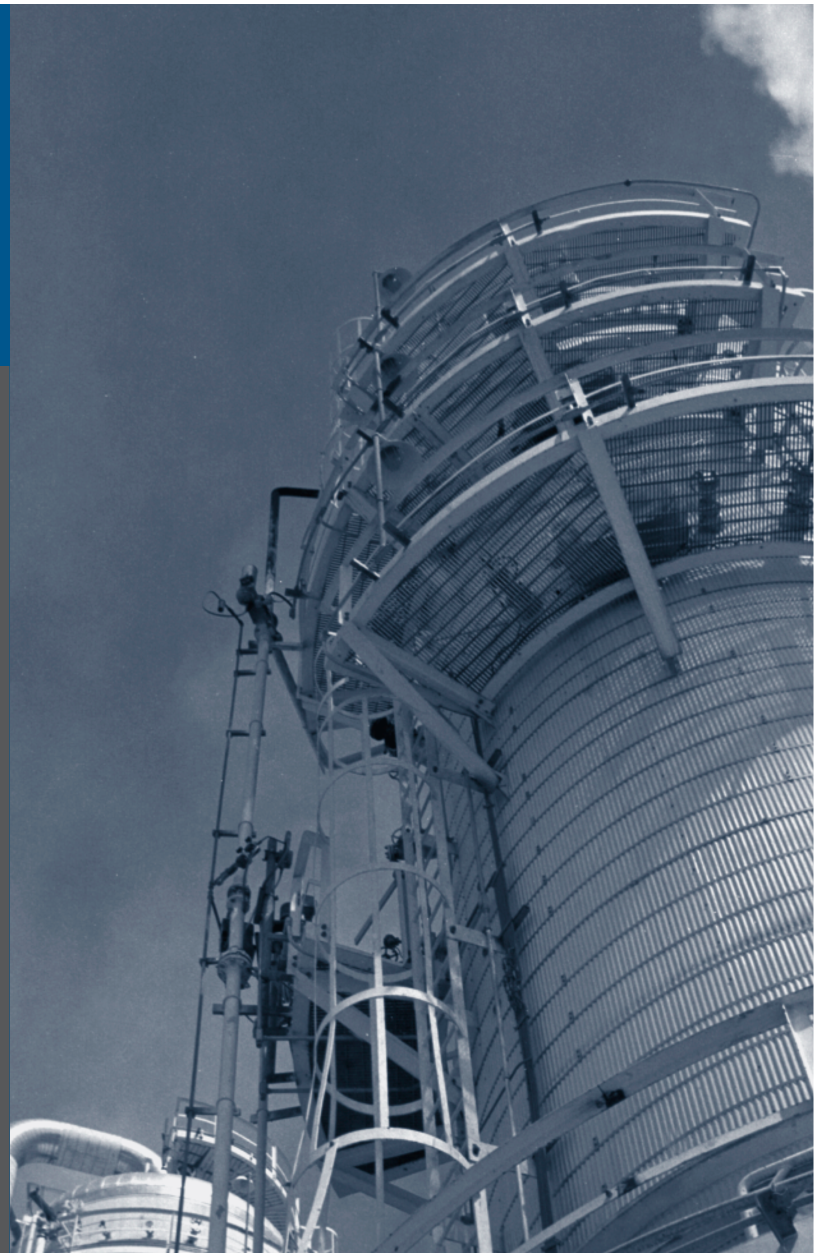
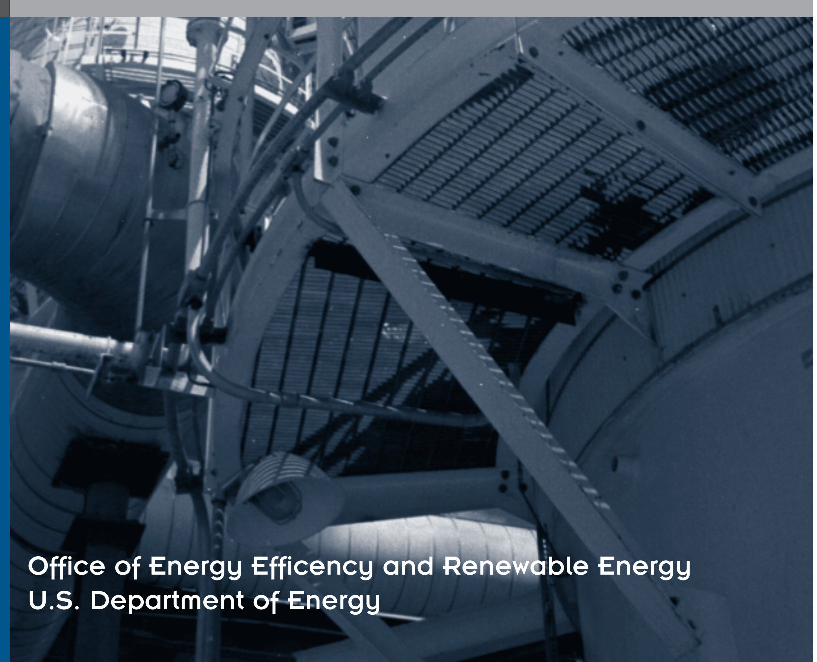
Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries



Appendices



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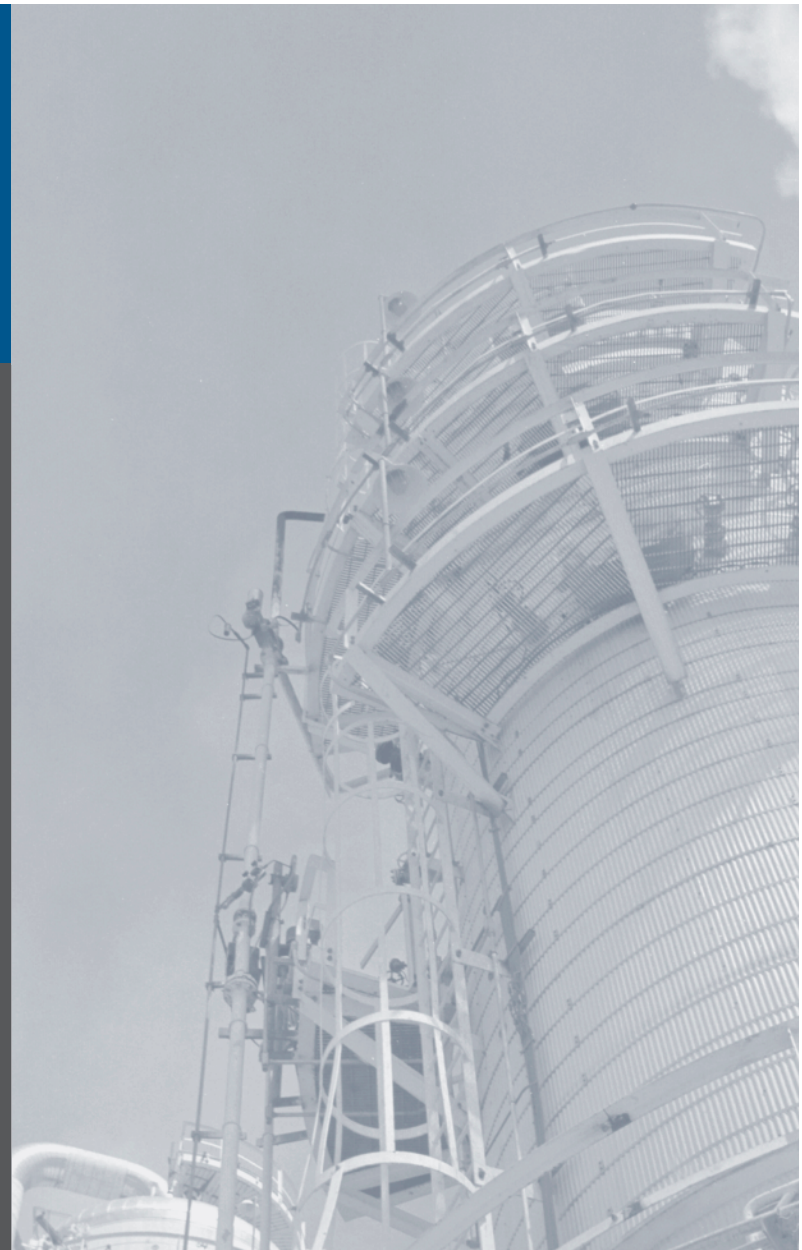

Appendices

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These appendices are part of the Steam System Opportunity Assessment for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries. The Main Report is available in print, as a PDF on this CD-ROM, or online at www.oit.doe.gov/bestpractices.

Appendices

Appendix A

MECS Data for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries

This appendix contains energy use estimates based on the *Manufacturing Energy Consumption Survey 1994* (MECS). Although much of the data was taken directly from MECS, in several cases, data that was missing or omitted had to be inferred. The process of inferring this data required making assumptions about the industry. These assumptions were developed from knowledge of the industry and from data contained in other parts of MECS.

Additionally, each industry segment has a "Calculated Boiler Fuel" entry. This represents the total of three fuel sources: indirect boiler fuel, a portion of the fuel energy in the "End Use Not Reported," and conventional electricity generation.

Another calculated result is the "Steam as a % of Total Energy." This value is determined by dividing "Calculated Boiler Fuel" by the total energy used by that industry segment.

Pulp and Paper Industry Energy Use

		Inputs (Trillion Btu)							
Industry/Process	**SIC**	**Net Electricity**	**Residual F.O.***	**Distillate F.O.***	**Natural Gas**	**LPG****	**Coal**	**Other**	**Total**
Paper and Allied Products	26								
Total Inputs		**223**	**173**	**9**	**574**	**5**	**307**	**1,343**	**2,634**
Boiler Fuel (Indirect Uses)		**5**	**138**	**5**	**401**	**1**	**299**	**0**	**849**
Total Process (Direct Uses)		**191**	**32**	**2**	**115**	**2**	**0**	**0**	
Process Heating		6	30	1	102	1	0	0	
Process Cooling and Refrigeration		3	0	0	1	0	0	0	
Machine Drive		179	1	1	10	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		3	0	0	2	0	0	0	
Total Non-Process (Direct Uses)		**24**	**2**	**2**	**51**	**3**	**0**	**0**	
Facility HVAC		11	0	0	17	0	0	0	
Facility Lighting		10	0	0	0	0	0	0	
Facility Support		2	0	0	1	0	0	0	
On-Site Transportation		0	0	2	0	2	0	0	
Conventional Electricity Generation		0	0	0	31	0	0	0	31
Other Non-Process Use		0	0	0	2	0	0	0	
End Use Not Reported		**5**	**1**	**0**	**7**	**0**	**0**	**1,343**	**1,356**
Pulp Mills	2611								
Total Inputs		**7**	**23**	**1**	**22**	**0**	**7**	**190**	**251**
Boiler Fuel (Indirect Uses)		**0**	**18**	**1**	**14**	**0**	**7**	**0**	**40**
Total Process (Direct Uses)		**6**	**4**	**0**	**7**	**0**	**0**	**0**	
Process Heating		0	4	0	7	0	0	0	
Process Cooling and Refrigeration		0	0	0	0	0	0	0	
Machine Drive		6	0	0	0	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**1**	**0**	**0**	**1**	**0**	**0**	**0**	
Facility HVAC		0	0	0	1	0	0	0	
Facility Lighting		0	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	0	0	0	0	0
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**1**	**0**	**0**	**0**	**0**	**190**	**191**

**Fuel Oil*
***Liquefied Petroleum Gas*

Table continues next page

Pulp and Paper Industry Energy Use

Industry/Process	SIC	Inputs (Trillion Btu)							
		Net Electricity	Residual F.O.	Distillate F.O.	Natural Gas	LPG	Coal	Other	Total
Paper Mills	**2621**								
Total Inputs		**117**	**94**	**4**	**271**	**2**	**195**	**609**	**1,292**
Boiler Fuel (Indirect Uses)		**1**	**76**	**2**	**195**	**0**	**185**	**0**	**459**
Total Process (Direct Uses)		**106**	**17**	**1**	**48**	**1**	**5**	**0**	
Process Heating		1	17	1	44	1	3	0	
Process Cooling and Refrigeration		1	0	0	0	0	0	0	
Machine Drive		102	1	0	0	0	3	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		2	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**8**	**0**	**1**	**26**	**1**	**5**	**0**	
Facility HVAC		4	0	0	3	0	5	0	
Facility Lighting		3	0	0	0	0	0	0	
Facility Support		1	0	0	0	0	0	0	
On-Site Transportation		0	0	1	0	1	0	0	
Conventional Electricity Generation		0	0	0	23	0	0	0	23
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**2**	**0**	**0**	**2**	**0**	**0**	**609**	**613**
Paperboard Mills	2631								
Total Inputs		**46**	**50**	**2**	**199**	**0**	**101**	**531**	**930**
Boiler Fuel (Indirect Uses)		**2**	**39**	**1**	**150**	**0**	**96**	**0**	**288**
Total Process (Direct Uses)		**40**	**9**	**0**	**36**	**0**	**3**	**0**	
Process Heating		1	0	0	31	0	0	0	
Process Cooling and Refrigeration		0	0	0	0	0	0	0	
Machine Drive		38	0	0	0	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**3**	**0**	**1**	**12**	**0**	**3**	**0**	
Facility HVAC		1	0	0	0	0	0	0	
Facility Lighting		2	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	1	0	0	0	0	
Conventional Electricity Generation		0	0	0	9	0	0	0	9
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**1**	**0**	**0**	**2**	**0**	**0**	**531**	**534**

Chemical Manufacturing Industry Energy Use

Industry/Process	SIC	Inputs (Trillion Btu)							
		Net Electricity	Residual F.O.	Distillate F.O.	Natural Gas	LPG	Coal	Other	Total
Chemicals and Allied Products	28								
Total Inputs		**520**	**60**	**13**	**1,895**	**0**	**257**	**519**	**3,273**
Boiler Fuel (Indirect Uses)		**8**	**37**	**7**	**931**	**1**	**245**	**0**	**1,229**
Total Process (Direct Uses)		**463**	**18**	**0**	**707**	**2**	**10**	**0**	
Process Heating		21	18	2	638	1	0	0	
Process Cooling and Refrigeration		32	0	0	11	0	0	0	
Machine Drive		340	0	1	39	0	0	0	
Electro-Chemical		70	0	0	0	0	0	0	
Other		1	0	0	20	0	0	0	
Total Non-Process (Direct Uses)		**43**	**0**	**3**	**230**	**1**	**0**	**0**	
Facility HVAC		21	0	0	17	0	1	0	
Facility Lighting		16	0	0	0	0	0	0	
Facility Support		4	0	0	3	0	0	0	
On-Site Transportation		0	0	2	0	1	0	0	
Conventional Electricity Generation		0	0	0	207	0	0	0	207
Other Non-Process Use		1	0	0	3	0	0	0	
End Use Not Reported		**6**	**5**	**0**	**27**	**0**	**2**	**519**	**559**
Alkalies and Chlorine	2812								
Total Inputs		**46**	**0**	**0**	**53**	**0**	**0**	**30**	**129**
Boiler Fuel (Indirect Uses)		**0**	**0**	**0**	**51**	**0**	**0**	**0**	**51**
Total Process (Direct Uses)		**45**	**0**	**0**	**2**	**0**	**0**	**0**	
Process Heating		0	0	0	0	0	0	0	
Process Cooling and Refrigeration		0	0	0	0	0	0	0	
Machine Drive		4	0	0	0	0	0	0	
Electro-Chemical		41	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Facility HVAC		0	0	0	0	0	0	0	
Facility Lighting		0	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	0	0	0	0	0
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**0**	**0**	**0**	**30**	**30**

Table continues next page

Chemical Manufacturing Industry Energy Use

Industry/Process	SIC	Inputs (Trillion Btu) Net Electricity	Residual F.O.	Distillate F.O.	Natural Gas	LPG	Coal	Other	Total
Inorganic Pigments	2816								
Total Inputs		**8**	**0**	**0**	**26**	**0**	**0**	**5**	**40**
Boiler Fuel (Indirect Uses)		**0**	**0**	**0**	**10**	**0**	**0**	**0**	**10**
Total Process (Direct Uses)		**8**	**0**	**0**	**11**	**0**	**0**	**0**	
Process Heating		0	0	0	11	0	0	0	
Process Cooling and Refrigeration		0	0	0	0	0	0	0	
Machine Drive		5	0	0	0	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**0**	**0**	**0**	**0**	**0**	**0**	**0**	
Facility HVAC		0	0	0	0	0	0	0	
Facility Lighting		0	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	0	0	0	0	0
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**5**	**0**	**0**	**5**	**10**
Industrial Inorganic Chemicals, nec.	2819								
Total Inputs		**144**	**4**	**0**	**140**	**0**	**32**	**23**	**344**
Boiler Fuel (Indirect Uses)		**0**	**1**	**1**	**73**	**0**	**26**	**0**	**101**
Total Process (Direct Uses)		**140**	**3**	**0**	**63**	**0**	**0**	**0**	
Process Heating		7	3	0	61	0	0	0	
Process Cooling and Refrigeration		1	0	0	0	0	0	0	
Machine Drive		118	0	0	0	0	0	0	
Electro-Chemical		14	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**4**	**0**	**0**	**4**	**0**	**0**	**0**	
Facility HVAC		2	0	0	2	0	0	0	
Facility Lighting		1	0	0	0	0	0	0	
Facility Support		1	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	2	0	0	0	2
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**0**	**0**	**0**	**23**	**23**

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Chemical Manufacturing Industry Energy Use

		Inputs (Trillion Btu)							
Industry/Process	**SIC**	**Net Electricity**	**Residual F.O.**	**Distillate F.O.**	**Natural Gas**	**LPG**	**Coal**	**Other**	**Total**
Plastics Materials and Resins	2821								
Total Inputs		**56**	**3**	**1**	**188**	**0**	**19**	**50**	**319**
Boiler Fuel (Indirect Uses)		**1**	**0**	**1**	**116**	**0**	**19**	**0**	**137**
Total Process (Direct Uses)		**48**	**0**	**0**	**52**	**0**	**0**	**0**	
Process Heating		2	0	0	38	0	0	0	
Process Cooling and Refrigeration		5	0	0	0	0	0	0	
Machine Drive		36	0	0	6	0	0	0	
Electro-Chemical		6	0	0	0	0	0	0	
Other		0	0	0	8	0	0	0	
Total Non-Process (Direct Uses)		**5**	**0**	**0**	**20**	**0**	**0**	**0**	
Facility HVAC		2	0	0	1	0	0	0	
Facility Lighting		2	0	0	0	0	0	0	
Facility Support		1	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	0	0	0	0	0
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**1**	**0**	**0**	**0**	**0**	**0**	**50**	**52**
Synthetic Rubber	2822								
Total Inputs		**8**	**0**	**0**	**42**	**0**	**0**	**9**	**63**
Boiler Fuel (Indirect Uses)		**0**	**0**	**0**	**23**	**0**	**0**	**0**	**23**
Total Process (Direct Uses)		**7**	**0**	**0**	**18**	**0**	**0**	**0**	
Process Heating		0	0	0	16	0	0	0	
Process Cooling and Refrigeration		1	0	0	0	0	0	0	
Machine Drive		5	0	0	0	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	2	0	0	0	
Total Non-Process (Direct Uses)		1	0	0	0	0	0	0	
Facility HVAC		0	0	0	0	0	0	0	
Facility Lighting		0	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	0	0	0	0	0
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**0**	**0**	**0**	**9**	**9**

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Chemical Manufacturing Industry Energy Use									
		Inputs (Trillion Btu)							
Industry/Process	SIC	Net Electricity	Residual F.O.	Distillate F.O.	Natural Gas	LPG	Coal	Other	Total
Organic Fibers, Noncellulosic	2824								
Total Inputs		**24**	**9**	**1**	**41**	**0**	**35**	**4**	**114**
Boiler Fuel (Indirect Uses)		**0**	**5**	**0**	**32**	**0**	**35**	**0**	**72**
Total Process (Direct Uses)		**20**	**5**	**0**	**3**	**0**	**0**	**0**	
Process Heating		0	5	0	0	0	0	0	
Process Cooling and Refrigeration		3	0	0	0	0	0	0	
Machine Drive		13	0	0	0	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**4**	**0**	**0**	**2**	**0**	**0**	**0**	
Facility HVAC		2	0	0	0	0	0	0	
Facility Lighting		1	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	0	0	0	0	0
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**4**	**0**	**0**	**4**	**8**
Cyclic Crudes and Intermediates	2865								
Total Inputs		**16**	**14**	**1**	**98**	**1**	**0**	**25**	**155**
Boiler Fuel (Indirect Uses)		**1**	**14**	**1**	**65**	**0**	**0**	**0**	**81**
Total Process (Direct Uses)		**13**	**0**	**0**	**26**	**0**	**0**	**0**	
Process Heating		2	0	0	25	0	0	0	
Process Cooling and Refrigeration		2	0	0	0	0	0	0	
Machine Drive		9	0	0	0	0	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	0	0	0	0	
Total Non-Process (Direct Uses)		**2**	**0**	**0**	**5**	**0**	**0**	**0**	
Facility HVAC		1	0	0	0	0	0	0	
Facility Lighting		1	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	4	0	0	0	4
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**2**	**0**	**0**	**25**	**28**

Table continues next page

Chemical Manufacturing Industry Energy Use

		Inputs (Trillion Btu)							
Industry/Process	**SIC**	**Net Electricity**	**Residual F.O.**	**Distillate F.O.**	**Natural Gas**	**LPG**	**Coal**	**Other**	**Total**
Industrial Organic Chemicals, nec.	2869								
Total Inputs		**64**	**5**	**2**	**837**	**1**	**92**	**369**	**1,370**
Boiler Fuel (Indirect Uses)		**1**	**0**	**1**	**387**	**0**	**0**	**0**	**389**
Total Process (Direct Uses)		**55**	**1**	**0**	**285**	**1**	**0**	**0**	
Process Heating		0	1	0	249	0	0	0	
Process Cooling and Refrigeration		9	0	0	4	0	0	0	
Machine Drive		40	0	0	28	0	0	0	
Electro-Chemical		3	0	0	0	0	0	0	
Other		0	0	0	4	0	0	0	
Total Non-Process (Direct Uses)		**7**	**0**	**1**	**153**	**0**	**0**	**0**	
Facility HVAC		3	0	0	3	0	0	0	
Facility Lighting		3	0	0	0	0	0	0	
Facility Support		1	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	147	0	0	0	147
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**2**	**0**	**0**	**11**	**0**	**0**	**369**	**383**
Nitrogenous Fertilizers	2873								
Total Inputs		**13**	**0**	**0**	**267**	**0**	**0**	**5**	**286**
Boiler Fuel (Indirect Uses)		**0**	**0**	**0**	**72**	**0**	**0**	**0**	**72**
Total Process (Direct Uses)		**12**	**0**	**0**	**185**	**0**	**0**	**0**	
Process Heating		1	0	0	177	0	0	0	
Process Cooling and Refrigeration		1	0	0	5	0	0	0	
Machine Drive		10	0	0	2	0	0	0	
Electro-Chemical		1	0	0	0	0	0	0	
Other		0	0	0	2	0	0	0	
Total Non-Process (Direct Uses)		**1**	**0**	**0**	**2**	**0**	**0**	**0**	
Facility HVAC		0	0	0	0	0	0	0	
Facility Lighting		0	0	0	0	0	0	0	
Facility Support		0	0	0	0	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	2	0	0	0	2
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**0**	**0**	**0**	**8**	**0**	**0**	**5**	**13**

Petroleum Refining Energy Use

Industry/Process	SIC	Inputs (Trillion Btu)							
		Net Electricity	Residual F.O.	Distillate F.O.	Natural Gas	LPG	Coal	Other	Total
Petroleum and Coal Products	29								
Total Inputs		**121**	**72**	**21**	**811**	**47**	**6**	**2,179**	**3,263**
Boiler Fuel (Indirect Uses)		**0**	**37**	**2**	**255**	**10**	**0**	**0**	**304**
Total Process (Direct Uses)		**104**	**29**	**16**	**469**	**35**	**6**	**0**	
Process Heating		3	29	14	451	32	6	0	
Process Cooling and Refrigeration		6	0	0	0	0	0	0	
Machine Drive		96	0	0	12	1	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	6	0	0	0	
Total Non-Process (Direct Uses)		**9**	**0**	**2**	**81**	**1**	**0**	**0**	
Facility HVAC		4	0	0	5	0	0	0	
Facility Lighting		4	0	0	0	0	0	0	
Facility Support		1	0	0	1	0	0	0	
On-Site Transportation		0	0	2	0	0	0	0	
Conventional Electricity Generation		0	0	0	74	0	0	0	74
Other Non-Process Use		0	0	0	0	0	0	0	
End Use Not Reported		**8**	**6**	**2**	**6**	**2**	**0**	**2,179**	**2,203**
Petroleum Refining	2911								
Total Inputs		**114**	**68**	**7**	**756**	**47**	**0**	**2,161**	**3,153**
Boiler Fuel (Indirect Uses)		**7**	**35**	**1**	**243**	**9**	**0**	**0**	**295**
Total Process (Direct Uses)		**99**	**28**	**5**	**430**	**33**	**0**	**0**	
Process Heating		2	28	5	414	31	0	0	
Process Cooling and Refrigeration		6	0	0	3	1	0	0	
Machine Drive		91	0	0	10	1	0	0	
Electro-Chemical		0	0	0	0	0	0	0	
Other		0	0	0	3	0	0	0	
Total Non-Process (Direct Uses)		**8**	**0**	**0**	**78**	**0**	**0**	**0**	
Facility HVAC		4	0	0	2	0	0	0	
Facility Lighting		3	0	0	0	0	0	0	
Facility Support		1	0	0	1	0	0	0	
On-Site Transportation		0	0	0	0	0	0	0	
Conventional Electricity Generation		0	0	0	74	0	0	0	74
Other Non-Process Use		4	0	0	0	0	0	0	
End Use Not Reported		**0**	**5**	**0**	**6**	**5**	**0**	**2,161**	**1,313**

Discussion of Assumptions Used in Assessing Energy Data for the Pulp and Paper, Chemical Manufacturing, and Petroleum Refining Industries

Figures referenced in this section begin on page 15, in the order they are mentioned in the text.

Discussion of Assumptions Used in Assessing Energy Use in the Pulp and Paper Industry

To determine the amount of steam used in the pulp and paper industry, process energy data from integrated plants were combined with production data and product type data. Production data was available for 14 basic product categories from reference [1]. Each of these categories was assigned to an integrated pulp and paper plant. Where necessary, the energy associated with these product categories was adjusted with data from references [2], [3], and [4].

For example, consider unbleached kraft paper. An integrated kraft pulp and paper plant has average thermal energy requirements ranging from 16,000 to 33,000 thousand British thermal units per ton (Btu/ton). The thermal energy required to bleach kraft paper is about 3,000 thousand Btu/ton [2]. As a result, the range of energy requirements for unbleached kraft paper is estimated to be 13,000 to 30,000 thousand Btu/ton. In 1994, production of unbleached kraft paper was 2,308 thousand short tons. This results in a total thermal energy use for this product of between 30 and 69 trillion Btu. The fuel use associated with this thermal energy requirement can be determined using a reasonable fuel-to-steam conversion estimate. If this conversion is 70 percent, then the fuel use associated with unbleached kraft paper is 43 to 99 trillion Btu.

A conversion efficiency of 70 percent was calculated using boiler efficiencies for different fuel types. Reference [2] provides estimates of boiler efficiencies with respect to fuel types, as shown in Figure B-1. Using *Manufacturing Energy Consumption Survey 1994* (MECS) data, the relative fuel usage for each industry was applied against the corresponding boiler efficiency for that fuel type, resulting in the data shown in Figure B-2.

Several different references describe the energy use of pulp and paper production tasks. For each process, the minimum and maximum energy values were determined by comparing these different resources and selecting appropriate values. In several cases, the minimum and maximum values for the same process were selected from different references. For example, the thermal energy requirements for kraft pulping processes are derived from references [2] and [3]. Reference [3] provides thermal energy values and temperature parameters for both continuous and batch kraft pulping processes. The batch process energy values (3,000 to 3,500 thousand Btu/ton) agree with reference [2]; however, Reference [2] is silent with respect to continuous kraft pulping.

Similarly, temperature and steam pressure data is determined by comparing different references. In many cases, reference [4] is used for temperature data. However, because references [2] and [3] are more current, their data is considered more accurate and is given greater weight in the event of conflicts.

For the purposes of this report, for process heating applications, the steam is assumed to be saturated. This means that steam tables are used to find the pressure corresponding to the process temperature.

However, in mechanical drive applications, the steam is often superheated to protect the turbine blades. The steam supplied for mechanical drive applications can vary from plant to plant and process to process. Consequently, steam temperatures and pressures are not identified for steam-turbine driven applications.

Evaluating Pulp and Paper Industry Boiler Capacity

Boiler capacity data is largely derived from reference [5], which is a representation of a boiler population assembled by the Gas Research Institute. Several other resources including references [6] and [7] were evaluated for this part of the report; however, their inconsistencies indicated a degree of inaccuracy that discouraged their use for estimating boiler capacity. Reference [1] can be used to assemble a boiler population for the pulp and paper industry, but it does not address other industries. Reference [7] describes boiler and steam system capacity for large facilities, but is not intended to be a comprehensive representation of industry, focusing rather on the large energy users. Because reference [5] attempted to reconcile the boiler population data from several different resources, it was used to describe boiler capacity by size and fuel type.

Reference [7] provides data regarding steam system size and pressure. To determine boiler capacity by pressure, three pressure groups were defined: less than 300 pounds per square inch gauge (psig); between 300 and 1,000 psig; and greater than 1,000 psig. Steam system capacities were distributed into the appropriate category based on their pressure. Summing the capacities for each pressure group provided a relative distribution of capacity by pressure. Applying these same proportions to the boiler capacity provided by reference [5] showed how the boiler capacity is distributed by pressure. An important assumption in this step is that boiler capacity and steam system capacity are directly proportional.

Discussion of Assumptions Used in Assessing Energy Use in the Chemical Manufacturing Industry

To find the amount of steam generated by the chemical industry, we identified the most energy-intensive chemical products. Combining the quantity of product produced with the amount of steam required to make a known quantity of that product gives an estimate of the total steam needed to produce that chemical on an industry-wide basis. Because there are over 70,000 chemical products, it is not feasible to determine the unit energy requirements of each product. Similarly, the broad range of processes that are used in chemical manufacturing make it impractical to use a process-based approach. However, by assessing the most energy-intensive chemicals, most of the steam use in the industry can be determined. Then the steam use that supports the production of these products can be evaluated more accurately.

The first step in identifying the chemical products was to rank the chemical industry segments in terms of those that use the most thermal energy. Next, the leading chemicals in each of these segments were identified. Subsequently, the energy requirements of each chemical product were assessed.

In terms of each chemical product, different assumptions were made based on the available information. Several resources were iteratively checked to determine how to allocate energy to each chemical product. References [8] and [4] provide energy use estimates for most of the energy-intensive chemical products. Because Reference [8] is a more recent effort, it was afforded higher consideration. Importantly, reference [4] was cited as a resource for reference [8]. Reference [8] was used to determine the overall steam requirement for each chemical. Reference [4] was then used to determine how this steam should be distributed among the production processes. In each case, conflicts between [8] and [4] were reconciled by assessing several factors including effects on overall energy, the relative balance among thermal energy and electrical energy, and how energy is used in products that have similar production processes.

Some chemicals, such as ethylene and ammonia, represent most of the energy use in their respective industrial segment. In these cases, references [4], [9], [10], and [11] were used to help determine various components of energy use. For example, ethylene is the largest chemical product in the Industrial Organic Chemicals NEC (SIC 2869) industrial segment. Ethylene production requires a large amount of mechanical-drive energy to compress the process stream. Much of this energy is motor driven (40 trillion Btu); however, a significant portion is natural gas (28 trillion Btu). Although some of this natural gas is consumed in combustion turbines, the steam intensive nature of ethylene production means that most of the turbine-drive energy is accounted for by steam turbines. For the purposes of this report, we assume all the natural gas in the machine-drive category for ethylene is used by steam turbines. Consequently distributing this 28 trillion Btu over the 44.5 trillion lbs of production results in a process steam value of 629 Btu/lb. The recovered steam component was determined by subtracting the process steam component.

In another example, reference [11] was used to help determine the amount of steam used in ammonia production. Reference [11] provides the amount of direct-fired fuel used in ammonia production. Normalizing this industry-wide estimate using production data provides steam energy on a per-pound basis. In this case, 5,062 Btu/lb of steam are assigned to ammonia. Reference [4] was then used to allocate this energy use among the various production processes.

Evaluating Chemical Manufacturing Industry Boiler Capacity

Boiler capacity data is largely derived from reference [5], which represents an industrial boiler population. Other resources were evaluated for this part of the report; however, they provided incomplete and/or inconsistent indications of boiler capacity. Reference [7] can be used to determine the boiler population among large manufacturing facilities. However, reference [5] recognized the differences between the various resources and attempted to reconcile them into a representative boiler population. As a result, reference [5] was selected as the resource to use for the distribution of boiler size by capacity and fuel type.

To determine boiler distribution by pressure, data from Reference [7] for the nine chemical industry segments was grouped by steam system pressure and by steam system capacity. Three categories of steam system pressures were selected: less than 300 psig; between 300 and 1,000 psig; and greater than 1,000 psig. The steam system capacity was then distributed into the appropriate pressure categories, providing a set of relative weights between these pressure groups.

Discussion of Assumptions Used to Assess Energy Data for the Petroleum Refining Industry

To determine petroleum refining steam use, reference [12] was used to determine the amount of energy required for each refining process on a per-unit basis. The production capacity for 1994 was determined by trending data from reference [13]. The total energy for the industry was then calculated by combining unit energy use for each process and the amount of production. Reference [11] was then used to deduct the direct-fired energy component from the total energy for each process. References [4] and [14] were then used to deduct the electric energy component, leaving steam as the remaining energy component.

Because the energy data for the various processes are pulled directly from the listed references, few inferences and assumptions were required in assigning the unit energy data. However, production data was supplied in terms of capacity, rather than actual output. As a result, an assumption of how much actual capacity was used in 1994 is required. For the purposes of this report, because there is uncertainty regarding how the capacity figure was determined, process output was assumed to be 100 percent of capacity. This implies that the capacity and production estimates are the same.

Evaluating Boiler Capacity

Boiler capacity data is largely derived from reference [5], which represents an industrial boiler population. Other resources were evaluated for this part of the report; however, they provided incomplete and/or inconsistent indications of boiler capacity. For example, although reference [7] can be used to estimate the boiler population among large manufacturing facilities, it does not attempt to be comprehensive. Additionally, inconsistencies among these resources indicate a level of inaccuracy that discourages their use in assembling this part of the report. Reference [5] recognized the differences between the various resources and attempted to reconcile them into a representative boiler population. As a result, reference [5] was selected as the resource to use for the distribution of boiler size by capacity and by fuel type.

To determine boiler distribution by pressure, data for the petroleum refineries in reference [7] was grouped by steam system pressure and by steam system capacity. Three categories of steam system pressures were selected: less than 300 psig; between 300 and 1,000 psig; and greater than 1,000 psig. The steam system capacity was then distributed into the appropriate pressure categories, providing a set of relative weights between these pressure groups. The boiler capacity, which was determined from reference [5], was assumed to be proportional to the steam system capacity.

References

Pulp and Paper Industry

[1] *Directory of the Pulp, Paper, and Allied Trades*, Lockwood Post, 1996.

[2] *Scoping Study Pulp and Paper Industry*, EPRI, prepared by Giese & Associates, December 1988.

[3] *Energy Efficiency and the Pulp and Paper Industry*, American Council for an Energy Efficient Economy, September 1995.

[4] *Energy Analysis of 108 Industrial Processes*, Drexel University Project Team; Brown, H.; Hamel, B.; Fairmont Press, 1985.

[5] *Analysis of the Industrial Boiler Population*, Final Report No. GRI-96/0200, Gas Technology Institute, June 1996.

[6] *Update of the American Forest & Paper Association's Recovery Boiler Program*; Grant, T.; AFPA, 1996. (Boiler capacity was calculated using AFPA estimate that recovery boilers accounted for 41 percent of industry energy use.)

[7] Major Industrial Plant Database (MIPD™), IHS Energy, June 1999.

Chemical Manufacturing Industry

[8] *Energy and Environmental Profile of the U.S. Chemical Industry*, U.S. Department of Energy, Office of Industrial Technologies, May 2000.

[9] *Manufacturing Energy Consumption Survey 1994* (MECS), U.S. Department of Energy, Energy Information Administration, 1997.

[10] *U.S. Chemical Industry Statistical Handbook 1999*, Chemical Manufacturers Association, 1999.

[11] *1992 Industrial Process Heat Energy Analysis*, Final Report no. GRI 96/0353, Gas Research Institute, September 1996.

Petroleum Refining Industry

[12] *Energy and Environmental Profile of the U.S. Petroleum Refining Industry*, December 1998, U.S. Department of Energy Office of Industrial Technologies.

[13] *Oil and Gas Journal Online*, http://ogj.pennnet.com, U.S. Refineries—State Capacities for 1995-2000.

[14] *Industry Brief*, Petroleum Refining, EPRI, 1993.

Figure B-1. Boiler Efficiency by Fuel Type

Fuel Type	Boiler Efficiency (%)
Oil	83
Natural Gas + LPG	82
Coal	81
Bark	64
Spent Liquor	65
Other (pet coke, waste oils, tars)	70

Figure B-2. Boiler Efficiency by Industry Segment

Industry Segment	Boiler Efficiency (%)
SIC 26	71.5
SIC 2611	67.9
SIC 2621	69.9
SIC 2631	70.8
Average	70.0

Steam System Performance Improvement Opportunity Descriptions

Steam system improvement opportunities are grouped into the following categories.

Generation
The first group of improvement opportunities are related primarily to the generation part of a steam system. These improvements are generally implemented in and around the boiler room.

Distribution
These improvement opportunities address the distribution part of a steam system. This part of the system consist of the piping, valves, fittings, and other components that facilitate the transport of the steam from the boiler plant to the various points of use. In most industrial facilities, the distribution system consists of multiple headers that operate at different pressures.

End Use
These improvement opportunities address large steam end uses for the pulp and paper, chemical manufacturing, and petroleum refining industries. Because steam is used in a wide range of applications, the improvement opportunities selected for this section were grouped together in broad categories, such as drying and distillation. These opportunities were intended to represent large end uses of steam where energy losses could be significantly reduced.

Recovery
These improvement opportunities target the condensate recovery part of a steam system. Condensate recovery refers to the return of condensate back to the boiler plant. The loss of condensate and flash steam represent a loss of mass and thermal energy that must be compensated for with the addition of makeup water. Optimizing condensate return can improve system efficiency.

Combined Heat and Power
This improvement opportunity addresses the potential for combined heat and power (CHP).

Generation

Minimize Boiler Combustion Loss by Optimizing Excess Air
Boilers must be fired with excess air to ensure complete combustion and to reduce the presence of carbon monoxide and unburned fuel in the exhaust gases. However, firing a boiler with too much excess air results in excessive stack gas losses. Minimizing the amount of excess air without unsafely operating the boiler can improve energy efficiency.

Improve Boiler Operating Practices

Boiler operating practices refer to general boiler operation. In multiple-boiler systems, several boilers are often operated at part load. While this practice provides some reliability benefits, there are efficiency consequences that should be considered. The particular drop off in operating efficiency during part load boiler operation depends on the design of the boiler and the amount of part load operation. Often, boiler operating practices can be improved without sacrificing steam supply reliability.

Repair or Replace Burner Parts

Design improvements in boilers, boiler components, and system controls have resulted in performance and efficiency gains. As a result, modern boiler components, especially burners, are more efficient than their older counterparts. Upgrading burners to more efficient models or replacing worn burners can improve boiler efficiency.

Install Feedwater Economizers

A feedwater economizer transfers heat from the combustion gases to the incoming feedwater. Feedwater economizers increase the amount of useful energy recovered from combusted fuel.

Install Combustion Air Preheaters

Combustion air preheaters improve efficiency by transferring available energy from the combustion gases leaving the boiler to the incoming combustion air. By heating the mass of the incoming air, less fuel energy is required to heat the combustion gases to the desired temperature.

Correct Problems from Improper Water Treatment

Water treatment is necessary to minimize fouling and corrosion in the boiler and steam system. Makeup water generally contains hardness minerals and dissolved gases such as oxygen and carbon dioxide. Chemical treatment of the feedwater reduces the presence of hardness minerals in the system. These hardness minerals can deposit on surfaces in the boiler, reducing heat transfer and promoting potential failure risks. Although a primary purpose of water treatment is system protection, systems that are not properly treated tend to operate with fouled heat transfer surfaces, which degrades system efficiency.

Clean Boiler Heat Transfer Surfaces

Deposits can form on either the water side or on the combustion gas side of boiler surfaces. Although effective water treatment can minimize waterside deposits, fouling on the combustion-gas side of the boiler generally depends on the fuel type and boiler firing practices. Cleaning these surfaces improves heat transfer, which, in turn, increases boiler efficiency.

Improve Blowdown Practices

Blowdown is important in maintaining proper boiler water properties. However, excessive blowdown results in an avoidable loss of thermal energy and an increased need for makeup water. The proper blowdown rate should be closely followed.

Install Continuous Blowdown Heat Recovery

In some applications, there is a feasible opportunity to recover thermal energy from the continuous blowdown stream. The characteristically high temperatures of blowdown water can provide an attractive opportunity to install a heat recovery device, reducing the thermal energy lost from the system.

Add/Restore Boiler Refractory

Boiler refractory is used to insulate the interior surfaces of a boiler and to channel the combustion gases in the proper path through the boiler. Degradation of the boiler refractory reduces boiler efficiency by allowing increased surfaces losses and, in some cases, increases stack losses. Restoring the boiler refractory can reduce avoidable boiler efficiency losses.

Establish the Correct Vent Rate for the Deaerator

Excessive steam used to increase the temperature of feedwater in the deaerator represents an avoidable thermal energy loss.

Reduce Steam System Generating Pressure

Generating steam at higher pressure than necessary can result in energy losses caused by the higher system surface temperatures, greater steam loss through leaks, and potentially lower boiler efficiency caused by the reduced temperature difference between the steam and the combustion gases. Although reducing steam generating pressure requires a careful assessment of the system response, where feasible, reduced steam generating pressure can provide energy savings.

Distribution

Improve Quality of Delivered Steam

Steam quality is a measure of moisture content in the steam. Poor steam quality has an adverse effect on system equipment, particularly, valves, turbines, and heat exchangers. Causes of poor steam quality include boiler water carryover. Boiler water carryover can be the result of a water treatment problem, high boiler-water level, and/or sudden drop in boiler or system pressure. A decrease in steam quality reduces the available energy in a delivered quantity of steam. Similarly, improving steam quality can reduce the amount of steam necessary to meet a particular set of end-use requirements.

Implement an Effective Steam Trap Maintenance Program

Improperly operating steam traps can cause energy losses and performance problems of the steam system and steam-using equipment. Steam traps keep steam in the steam system while allowing condensate to pass into the condensate return system. Steam traps also allow non-condensable gases to pass into the condensate system. The operating condition of a steam trap is not generally easy to detect by casual observation. Additionally, steam trap failures often create problems that are discovered far away from the failed trap. As a result, a formal management program utilizing all disciplines is generally the best way to minimize the number of failed traps at any given time in a steam system.

Ensure the Steam System Piping, Valves, Fittings, and Vessels are Well Insulated

Insulation reduces energy losses from the system surfaces. Insulation also reduces the outer surface temperature of steam piping or equipment, which decreases the risk of burns. Well-insulated piping delivers steam to end-use equipment at higher temperatures and pressures than poorly insulated piping.

Minimize Vented Steam

Most industrial steam systems have several operating pressures because of the various service requirements of end uses. Headers that have more steam than is required by the end uses on that header must send the steam to another header, store it in an accumulator, or vent it. Venting steam represents an energy loss and requires the addition of makeup water (see the discussion on improved condensate recovery). Improving system operation such that less steam needs to be vented increases energy efficiency.

Repair Steam Leaks

Steam leaks represent a direct loss of thermal energy. Steam leaks increase the amount of boiler output necessary to meet end-use requirements and increase the amount of makeup water required.

Isolate Steam from Unused Lines

In some facilities, changes in end-use requirements eliminate the need to send steam to some headers. Continuing to supply steam to a header that does not have active end uses results in avoidable energy losses that include heat transfer to the surrounding environment and steam leaks. In many cases, isolating steam to these headers can provide significant energy savings.

Improve System Balance

Improving system balance refers to matching the amount of steam supplied to each header to the steam end-use requirements on each header. Systems that are not efficiently balanced often have avoidably high steam losses caused by venting, relief valve trips, and/or steam leaks. High steam flows through pressure-reducing valves can result in superheated steam which often must be desuperheated before it is sent into sensitive end-use equipment to prevent damage. Improving system balance can be achieved using backpressure turbines and steam accumulators.

Plant-Wide Maintenance

Plant-wide maintenance refers to general system management practices. Proactive system management often allows the discovery and resolution of problems before they worsen and cause damage or avoidably high operating costs. In general, plants that promote employee awareness regarding the indications of trouble and the costs of problems operate more efficiently and more reliably.

End Use

Optimize Steam Use in Pulp and Paper Drying Applications

Drying processes represent a significant energy use for pulp and paper facilities. Many pulp and paper facilities have opportunities to improve the efficiency of their steam use in these applications through equipment upgrades or by reducing avoidable thermal losses.

Optimize Steam Use in Pulp and Paper Air Heating Applications

Pulp and paper facilities may have opportunities to improve the efficiency of their steam use in air heating applications through equipment upgrades or by reducing avoidable thermal losses.

Optimize Steam Use in Pulp and Paper Water Heating Applications

Pulp and paper facilities may have opportunities to improve the efficiency of their steam use in water heating applications through equipment upgrades or by reducing avoidable thermal losses.

Optimize Steam Use in Chemical Product Heating Applications

Chemical manufacturing facilities may have opportunities to improve steam use efficiency in product heating applications.

Optimize Steam Use in Chemical Vacuum Production Applications

Chemical manufacturing facilities may have opportunities to improve steam use efficiency in vacuum production applications.

Optimize Steam Use in Petroleum Refining Distillation Applications

Petroleum refineries may have opportunities to improve steam use efficiency in refining distillation applications.

Optimize Steam Use in Petroleum Refining Vacuum Production Applications

Petroleum refineries may have opportunities to improve steam use efficiency vacuum production applications.

Recovery

Improved Condensate Recovery

Increasing condensate recovery results in several benefits. The loss of condensate from the system must be compensated for by adding makeup water. Because makeup water is generally much cooler than condensate and requires chemical treatment, reducing makeup water use reduces energy and treatment chemical use.

Use High-Pressure Condensate to Generate Low-Pressure Steam

In many systems, returning condensate contains significant amounts of thermal energy. Often, the condensate has enough thermal energy to provide a source of low-pressure steam. Using high-pressure condensate to supply low-pressure steam headers is often more efficient than stepping down boiler generated steam to this pressure.

Combined Heat and Power

Implement a Combined Heat and Power (Cogeneration) Project

A CHP application produces electric power and thermal energy. The feasibility of these systems depends on a wide range of factors, including the plant's requirements for electric and thermal energy, and the relative prices of fuel and electricity.

Appendix D

Steam System Performance Improvement Opportunity Questionnaire Description

To gather the data for this report, a questionnaire was sent to each of the industry experts. This appendix contains an abbreviated version of this questionnaire to provide an indication of how the queries were presented. The original questionnaire was 30 pages. A full page was devoted to each performance improvement opportunity in an attempt to make it easier for the experts to flip around and to promote marking the document with insights and comments. A standard response section was used for most of the performance improvement opportunities; as a result the questionnaire is largely repetitive.

The introductory section to the questionnaire is provided. However, instead of including the full questionnaire, the standard response sheet is provided and opportunities associated with this standard section are listed.

Several of the opportunities required a special set of queries. The questionnaire pages devoted to these opportunities are attached.

Finally, a page was devoted to steam system management practices. These queries were intended to determine how facilities make steam system management decisions. This questionnaire page is also provided.

Introduction to the Questionnaire

The questionnaire was presented to the experts as follows.

Background

BestPractices Steam is a part of the U.S. Department of Energy's strategy to increase the competitiveness of the nation's most energy-intensive industries. BestPractices Steam has sponsored many important efforts to increase awareness regarding the cost savings and performance benefits of steam system improvements. As a continuing part of this strategy, BestPractices Steam has selected three of the most steam-intensive industries—pulp and paper, chemical manufacturing, and petroleum refining—and has estimated the amount of fuel used and the amount of steam generated by each of them. The next step is the purpose of this questionnaire.

Description

This questionnaire requests information regarding steam system performance improvement opportunities. Some of the opportunities are industry specific. However, because most of the performance improvement opportunities are applicable to all three industries, we request that, if possible, you indicate how the answers differ, if at all, between each industry.

Any comments and insights are appreciated, so please provide observations and remarks. At the end of the list of opportunities, we request additional responses regarding general steam system management practices. Understanding the steam system decision-makers and the important factors that affect their management practices can help improve the effectiveness of this project. We appreciate your participation and assistance in making this important effort as useful as possible.

Organization of the Improvement Opportunities

This questionnaire is organized into five sections:

A. Generation. These opportunities relate to the boiler, its supporting systems, and operating practices.

B. Distribution. These opportunities relate to the distribution portion of the steam system.

C. Industry-Specific End Uses. These opportunities relate to end-use applications that are specific to the three targeted industries, pulp and paper, chemical manufacturing, and petroleum refining.

D. Recovery. These opportunities are associated with the condensate return system.

E. Combined Heat and Power. This opportunity addresses the potential benefits of implementing combined heat and power projects.

Standard Query Format

Typical Amount of Fuel Savings

- ☐ <1 %
- ☐ 1-2%
- ☐ 2-5%
- ☐ 5-10%
- ☐ >10%
- ☐ Specific estimate, if known

Typical Payback

- ☐ <1 month
- ☐ 1-6 months
- ☐ 6 months-1 year
- ☐ 1-2 years
- ☐ 2-3 years
- ☐ >3 years
- ☐ Specific estimate, if known

Percentage of Facilities for Which this Opportunity is Feasible

- ☐ < 5% of facilities
- ☐ 5-10% of facilities
- ☐ 10-20% of facilities
- ☐ 20-50% of facilities
- ☐ >50% of facilities
- ☐ Specific percentage, if known

Applicable Reasons for Implementing—Check if Implemented, and Rank In Order of Significance

Implemented	Rank	Reasons for Implementing
☐	☐	Energy Savings
☐	☐	Performance improvement (improved export steam quality, better system response)
☐	☐	Increased capacity
☐	☐	Improved reliability
☐	☐	Reduced maintenance
☐	☐	Safety/environmental
☐	☐	Other _______________

Remarks:

Example

To illustrate the response for a typical performance improvement opportunity, consider the following example:

A steam system auditor has found that of the chemical manufacturing plants they have assessed, 7 to 8 percent (roughly 1 out every 12 facilities) can feasibly install economizers. The average fuel savings achieved by these economizers is 3 percent and a typical payback for these installations is 9 months. The reason for installing these economizers was energy savings.

Opportunities That Were Assigned the Standard Query

The following opportunities were assigned to the format shown in the previous example. Each opportunity was assigned to a page for clarity and to encourage participants to provide comments.

A1. Minimize Boiler Combustion Loss by Optimizing Excess Air. This opportunity includes improvements to boiler efficiency by adjusting flue gas oxygen content (excess air). Examples include changing automatic oxygen control set points, periodic tuning of single set point control mechanisms, installing automatic flue gas monitoring and control, fixing broken baffles, and repairing air leaks into the boiler.

Example Query

Typical Amount of Fuel Savings

- [ ] <1 %
- [ ] 1-2%
- [x] 2-5%
- [ ] 5-10%
- [ ] >10%
- [3%] Specific estimate, if known

Typical Payback

- [ ] <1 month
- [ ] 1-6 months
- [x] 6 months-1 year
- [ ] 1-2 years
- [ ] 2-3 years
- [ ] >3 years
- [9 mo] Specific estimate, if known

Percentage of Facilities for Which this Opportunity is Feasible

- [ ] <5% of facilities
- [x] 5-10% of facilities
- [ ] 10-20% of facilities
- [ ] 20-50% of facilities
- [ ] >50% of facilities
- [ ] Specific percentage, if known

Applicable Reasons for Implementing—Check if Implemented, and Rank In Order of Significance

Implemented	Rank	Reasons for Implementing
✓	1	Energy Savings
		Performance improvement (improved export steam quality, better system response)
		Increased capacity
		Improved reliability
		Reduced maintenance
		Safety/environmental
		Other _______________

Remarks:

About 75 percent of the chemical manufacturing facilities already have economizers. In most of the other cases the exhaust gas temperature is too low to justify the investment.

A2. Improve Boiler Operating Practices. Examples include increasing individual boiler efficiency in multiple boiler systems by operating it at a higher load; reducing boiler cycling (standby losses) and purge losses; and/or increasing turndown ratio.

A3. Repair or Replace Burner Parts. Examples include installing more efficient burners or replacing worn parts.

A4. Install Feedwater Economizers. Install heat exchangers to transfer available thermal energy in the exhaust gases to boiler feedwater.

A5. Install Combustion Air Preheaters. Install a heat exchanger to transfer thermal energy from the exhaust gases to the incoming combustion air.

A6. See diagram page 29 of this section.

A7. Clean Boiler Heat Transfer Surfaces. Remove deposits on waterside and/or fireside heat transfer surfaces.

A8. Improve Blowdown Practices. Reduce excessive blowdown rate.

A9. Install Continuous Blowdown Heat Recovery. This opportunity involves the installation of a flash steam recovery tank and/or a heat exchanger in the continuous blowdown stream line, reducing thermal energy loss.

A10. Add/Restore Boiler Refractory. Reduce shell losses from the boiler.

A11. Establish the Correct Vent Rate for Deaerator. Reduce excessive steam flow from the deaerator without allowing O_2 content to exceed specifications.

A12. Reduce Steam System Generating Pressure. This opportunity addresses the benefits of reducing steam pressure where feasible. This can result in reduced energy lost from the piping surfaces and reduced steam and condensate losses from leaks. Systems with steam turbines do not benefit from reducing supply steam pressure. However, they do experience an improvement in performance as exhaust pressure is decreased.

B1-B3. See diagrams on pages 30 to 32 of this section.

B4. Minimize Vented Steam. This opportunity refers to improvements that reduce the amount of steam released caused by an oversupply. Steam oversupply generally results from poor boiler steam output control, insufficient boiler turndown, erratic steam demand, excessive numbers (capacity) of back-pressure turbines operating, and failed steam traps discharging live steam into lower pressure steam systems. Common methods used to eliminate vent steam include replacing steam turbines with electric motor drives, improving boiler controls, installing steam accumulators, and replacing failed traps.

B5. Repair Steam Leaks. Keeps thermal energy and steam in the system. (Note: vented steam is addressed in another opportunity.)

B6. Isolate Steam from Unused Lines. This opportunity addresses the benefit of isolating unused lines, both in terms of the reduced heat loss from the piping surface and the loss of steam and condensate through leaks.

B7. Improve System Balance. This opportunity addresses changes in operating practices that result in benefits, such as a reduced amount of steam vented from a system header or higher power generation from a steam turbine (reducing purchased power costs).

B8. See diagram on page 38 of this section.

C1. Optimize Steam Use in Pulp and Paper Drying Applications. The pulp and paper industry uses large amounts of steam for drying. An example of improving this steam use includes replacing a single-effect dryer with a multiple-effect dryer.

C2. Optimize Steam Use in Pulp and Paper Air Heating Applications. This opportunity includes improvements in the equipment or the operation of steam air heat exchangers.

C3. Optimize Steam Use in Pulp and Paper Water Heating Applications. This opportunity includes improvements in the equipment or the operation of steam-supplied process water heat exchangers.

C4. Optimize Steam Use in Chemical Product Heating Applications. This opportunity includes improvements in the equipment or the operation of steam-supplied product heating services.

C5. Optimize Steam Use in Chemical Vacuum Production Applications. This opportunity includes improvements in the equipment or the operation of steam ejectors.

C6. Optimize Steam Use in Petroleum Refining Distillation Applications. This opportunity includes improvements in the equipment or the operation of steam-supplied end uses.

C7. Optimize Steam Use in Petroleum Refining Vacuum Production Applications. This opportunity includes improvements in the equipment or the operation of steam ejectors.

D1. Optimize Condensate Recovery. This opportunity refers to the improvements that allow more condensate to be returned to the boiler. Examples include installing condensate recovery piping, reducing condensate leaks, and correcting sources of condensate contamination.

D2. Use High-Pressure Condensate to Make Low-Pressure Steam. This opportunity addresses improvements that allow the recovery of useful energy from condensate, such as installing flash steam separators in a condensate line that results in supplying low-pressure steam for space heating.

E1. Implement Combined Heat and Power (Cogeneration) Project. This opportunity includes a wide range of cogeneration alternatives, including the installation of backpressure turbines to generate electricity or to displace electricity in mechanical-drive applications, and/or the installation of a heat recovery steam generator (HRSG) on a combustion turbine.

Opportunities That Required a Special Format

Several of the opportunities require a different response format. These opportunities have one or more characteristics—the way the improvements are normally implemented or the way the system benefits are realized—that require a unique approach to gathering data about their effects on system performance or efficiency. For example, improving the water treatment program usually does not result in an efficiency increase; rather, such an improvement reduces the factors that create degrade system efficiency over time. As a result, although steam systems that have effective water treatment programs will operate more efficiently than those with poor water treatment programs, improving water treatment will not result in an immediate efficiency gain.

Another example is steam trap management. Steam traps serve in a wide range of systems and applications. There are differences in trap types and trap sizes and a very wide range of trap service requirements. Although the energy losses associated with repairing a failed trap can be calculated if enough data about that trap's service can be gathered, the variations in trap failure costs across industry, and even across a single steam system, complicate getting a representative fuel savings estimate. However, seeking input regarding the differences in facility approach to steam trap management can provide an indication of the improvement potential for this opportunity.

The opportunities that required a special response format included:

- Correct Problems from Improper Water Treatment
- Improve Quality of Delivered Steam
- Implement an Effective Steam Trap Maintenance Program
- Ensure that Steam System Piping, Valves, Fittings, and Vessels are Well Insulated
- Improve Plant-Wide Testing/Maintenance Practice.

A6. Correct Problems from Improper Water Treatment

Water treatment is a broad category that has an effect on many types of operating practices. However, we are trying to determine the fuel savings that can be associated with effective water treatment practices in contrast to plants that do not adhere to effective water treatment programs. We have selected three categories of water treatment and are looking for estimates of the fuel savings associated with improving poor water treatment practices.

	% of Facilities	Typical Amount of Fuel Savings (%)
A. Water treatment practices are excellent, cannot be improved with economically attractive projects	☐	
B. Water treatment practices are good; some improvement is possible, but the incremental benefit is small	☐	☐
C. Water treatment practices are inadequate	☐	☐
	100% Total	

Facilities often improve water treatment practices to avoid the onset of system problems rather than to reduce fuel use. Please indicate the typical significance of the problems that facilities seek to avoid when implementing water treatment improvement.

Problem	Rank in Terms of Significance
Waterside fouling	☐
System corrosion	☐
Increased blowdown requirements	☐
Wet steam generation	☐
Other ______________________	☐

Remarks:

B1. Improve Quality of Delivered Steam

Steam quality can be improved in several ways, including optimizing boiler operation/controls and better water treatment.

Typical Amount of Fuel Savings

- ☐ <1 %
- ☐ 1-2%
- ☐ 2-5%
- ☐ 5-10%
- ☐ >10%
- ☐ Specific estimate, if known

Typical Payback

- ☐ <1 month
- ☐ 1-6 months
- ☐ 6 months-1 year
- ☐ 1-2 years
- ☐ 2-3 years
- ☐ >3 years
- ☐ Specific estimate, if known

Percentage of Facilities for Which this Opportunity is Feasible

- ☐ <5% of facilities
- ☐ 5-10% of facilities
- ☐ 10-20% of facilities
- ☐ 20-50% of facilities
- ☐ >50% of facilities
- ☐ Specific percentage, if known

Applicable Reasons for Implementing—Check if Implemented, and Rank In Order of Significance

Implemented	Rank	Reasons for Implementing
☐	☐	Energy savings
☐	☐	Performance improvement (improved export steam quality, better system response)
☐	☐	Increased capacity
☐	☐	Improved reliability
☐	☐	Reduced maintenance
☐	☐	Safety/environmental
☐	☐	Other _______________

Remarks:

Poor steam quality can have many effects on a system in addition to increased fuel use. Based on your experience, please rank the significance of the problems caused by poor steam quality.

	Rank in Terms of Significance
Reduced equipment life	☐
Decreased process heat transfer	☐
Steam trap failure	☐
Other ______________________	☐

Remarks:

B2. Implement an Effective Steam Trap Maintenance Program

A facility that follows a formal steam trap maintenance program will operate more efficiently than one that does not. Key characteristics of an effective trap maintenance program include selection, testing, recording, and maintaining. Although effective steam trap maintenance provides other important benefits, such as better steam quality and decreased risk of water hammer, we are requesting estimates of the available fuel savings.

	% of Facilities	Typical Amount of Fuel Savings (%)
A. The facility has an effective formal trap maintenance program	☐	
B. Traps are maintained informally, and a more effective program can be feasibly implemented.	☐	☐
C. The facility does not maintain their traps	☐	☐
	100% Total	

Where steam trap maintenance can be improved, please indicate the payback period associated with the improvement and the reasons for the implementation.

Typical Payback

- ☐ <1 month
- ☐ 1-6 months
- ☐ 6 months-1 year
- ☐ 1-2 years
- ☐ 2-3 years
- ☐ >3 years
- ☐ Specific estimate, if known

Applicable Reasons for Implementing—Check if Implemented, and Rank In Order of Significance

Implemented	Rank	Reasons for Implementing
☐	☐	Energy savings
☐	☐	Performance improvement (improved export steam quality, better system response)
☐	☐	Increased capacity
☐	☐	Improved reliability
☐	☐	Reduced maintenance
☐	☐	Safety/environmental
☐	☐	Other _______________

Remarks:

B3. Ensure that Steam System Piping, Valves, Fittings, and Vessels are Well-Insulated

If the steam system insulation is condition C or D (as described below), the system will operate less efficiently than facilities with insulation at condition A or B. The data we seek is the efficiency difference that can be explained between the two conditions. The efficiency gain is the best estimate that can be made by moving from a C facility or D facility respectively to one that has a feasible level of insulation.

	% of Facilities	Typical Amount of Fuel Savings (%)
A. Insulation is excellent, cannot be improved	☐	
B. Insulation is good. Although it can be improved, the benefits don't satisfy hurdle rate	☐	☐
C. Insulation is inadequate in many places and improvement opportunities exceed hurdle rate	☐	☐
D. The steam system is essentially uninsulated	☐	☐
	100% Total	

Where insulation can be improved, please indicate a typical payback period associated with implementing the improvement and the reasons for the implementation.

Typical Payback

- ☐ <1 month
- ☐ 1-6 months
- ☐ 6 months-1 year
- ☐ 1-2 years
- ☐ 2-3 years
- ☐ >3 years
- ☐ Specific estimate, if known

Applicable Reasons for Implementing—Check if Implemented, and Rank In Order of Significance

Implemented	Rank	Reasons for Implementing
☐	☐	Energy savings
☐	☐	Performance improvement (improved export steam quality, better system response)
☐	☐	Increased capacity
☐	☐	Improved reliability
☐	☐	Reduced maintenance
☐	☐	Safety/environmental
☐	☐	Other _______________

Remarks:

B8. Improve Plant-Wide Testing/Maintenance Practices

This opportunity addresses the benefits available from better testing/maintenance practices.

	% of Facilities	Typical Amount of Fuel Savings (%)
A. Practices are excellent, cannot be improved	☐	
B. Practices are good; some improvement is possible, but the incremental benefit is small	☐	☐
C. Practices are inadequate	☐	☐
	100% Total	

A facility that has C category testing/maintenance practices will operate less efficiently and less reliably than facilities with A or B category testing/maintenance practices. We are requesting the efficiency increase that can be expected by improving a facility from C to B or A. Another way to view the question is how much more efficient is a steam system that is properly maintained than one that is not. "Proper maintenance" is up to the judgment of the reviewer. Although improvements in maintenance practices often result in benefits, such as reduced risk of failure and avoided cost of downtime, we are specifically looking for the energy savings.

Where maintenance practices can be improved, please indicate a typical payback period associated with the improvement and the reasons for the implementation.

Typical Payback

- ☐ <1 month
- ☐ 1-6 months
- ☐ 6 months-1 year
- ☐ 1-2 years
- ☐ 2-3 years
- ☐ >3 years
- ☐ Specific estimate, if known

Applicable Reasons for Implementing—Check if Implemented, and Rank In Order of Significance

Implemented	Rank	Reasons for Implementing
☐	☐	Energy savings
☐	☐	Performance improvement (improved export steam quality, better system response)
☐	☐	Increased capacity
☐	☐	Improved reliability
☐	☐	Reduced maintenance
☐	☐	Safety/environmental
☐	☐	Other _______________

Remarks:

General Steam System Management Practices

The last query of the questionnaire addressed general steam management practices. This query was used to determine who makes steam system management decisions and how these decisions are made. The format of this query is shown below.

The following four questions address general steam system management practices. Understanding the important factors that affect how plant operators, engineers, and managers develop their steam system management practices can help improve the effectiveness of this study. Consequently, any insights regarding the awareness and prioritization of best practices and opportunity improvements among steam system stakeholders would be helpful.

Query of General Steam Management Practices

Who in the facility or organization makes steam system decisions?

What criteria do these people use to make these decisions?

To what extent are facility management and staff aware of the elements of good steam system operations and improvement opportunities?

What barriers inhibit facility managers and engineering staff from implementing steam system improvements?

Appendix E

Steam System Performance Opportunity Data Tables

This appendix contains all the data tables generated by the expert elicitation effort described in Section 4. Each opportunity has four listings, including the results for each industry and the combined results for all the experts. The results for each industry were developed by grouping the experts into categories based on their responses to industry-specific, end-use opportunities.

In addition, the results from alternative statistical approaches are presented. These alternative approaches include arithmetic mean, median, and geometric mean. A discussion of these statistical methods is presented in Appendix F.

Fuel Saving Statistical Data

Opportunity	Industry Group	Fuel Savings (%) Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A01. Minimize Boiler Combustion Loss by Optimizing Excess Air	Pulp & Paper	3.0	0.4	2.3	2.0	3.2	2.3	1.9	2.6
	Chemical Manufacturing	2.7	0.4	2.1	1.9	2.6	2.3	2.1	2.6
	Petroleum Refining	2.9	0.5	2.2	1.8	2.8	2.4	2.0	2.8
	Combined	2.8	0.3	1.9	1.6	2.0	2.2	1.8	2.5
A02. Improve Boiler Operating Practices	Pulp & Paper	2.8	0.5	1.4	1.1	1.8	1.3	0.9	1.7
	Chemical Manufacturing	3.8	0.7	1.7	1.3	1.9	1.8	1.3	2.3
	Petroleum Refining	3.4	0.8	1.8	1.3	2.0	1.9	1.2	2.4
	Combined	3.4	0.6	1.5	1.1	1.9	1.5	1.1	1.9
A03. Repair or Replace Burner Parts	Pulp & Paper	2.4	0.3	1.8	1.4	2.0	1.7	1.3	2.1
	Chemical Manufacturing	2.1	0.3	1.5	1.1	1.9	1.3	0.9	1.7
	Petroleum Refining	2.2	0.4	1.5	1.1	1.8	1.4	0.9	1.8
	Combined	2.2	0.3	1.7	1.3	1.9	1.5	1.1	1.8
A04. Install Feedwater Economizers	Pulp & Paper	3.6	0.6	3.1	2.4	4.0	2.8	2.3	3.2
	Chemical Manufacturing	3.5	0.6	2.9	2.3	3.8	2.6	2.2	3.1
	Petroleum Refining	3.8	0.8	2.7	2.1	3.8	2.5	1.9	3.0
	Combined	3.5	0.5	3.0	2.4	3.8	2.7	2.3	3.1
A05. Install Combustion Air Preheaters	Pulp & Paper	2.4	0.4	1.8	1.4	2.0	1.6	1.1	2.0
	Chemical Manufacturing	2.4	0.3	1.9	1.4	2.0	1.6	1.1	2.0
	Petroleum Refining	2.3	0.4	1.5	1.1	1.9	1.3	0.7	1.7
	Combined	2.4	0.3	1.9	1.5	2.0	1.7	1.2	2.0
A07. Clean Boiler Heat Transfer Surfaces	Pulp & Paper	1.9	0.3	1.6	1.3	1.9	1.5	1.2	1.8
	Chemical Manufacturing	2.0	0.3	1.6	1.3	1.9	1.7	1.3	1.9
	Petroleum Refining	2.1	0.4	1.7	1.4	2.0	1.9	1.5	2.2
	Combined	1.8	0.3	1.5	1.2	1.8	1.4	1.0	1.6
A08. Improve Blowdown Practices	Pulp & Paper	1.1	0.2	1.1	0.9	1.4	0.8	0.6	1.1
	Chemical Manufacturing	1.0	0.2	1.0	0.7	1.3	0.8	0.5	1.0
	Petroleum Refining	1.0	0.2	1.0	0.6	1.4	0.8	0.5	1.1
	Combined	1.0	0.1	1.0	0.7	1.3	0.8	0.5	1.0
A09. Install Continuous Blowdown Heat Recovery	Pulp & Paper	1.2	0.2	1.1	0.8	1.4	0.8	0.6	1.1
	Chemical Manufacturing	1.3	0.2	1.2	1.0	1.5	0.9	0.6	1.2
	Petroleum Refining	1.3	0.3	1.1	0.8	1.6	0.9	0.6	1.3
	Combined	1.2	0.2	1.1	0.8	1.4	0.8	0.5	1.1

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Fuel Saving Statistical Data

Opportunity	Industry Group	Fuel Savings (%) Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A10. Add/Restore Boiler Refractory	Pulp & Paper	1.3	0.3	0.7	0.4	0.9	0.7	0.4	1.0
	Chemical Manufacturing	1.2	0.2	0.7	0.4	0.9	0.6	0.4	0.9
	Petroleum Refining	0.9	0.2	0.6	0.3	0.9	0.5	0.3	0.8
	Combined	1.2	0.2	0.7	0.4	0.9	0.6	0.4	0.9
A11. Establish the Correct Vent Rate for the Deaerator	Pulp & Paper	1.1	0.2	0.7	0.4	0.9	0.6	0.4	0.9
	Chemical Manufacturing	1.1	0.2	0.7	0.4	0.9	0.7	0.4	0.9
	Petroleum Refining	0.9	0.3	0.6	0.3	0.9	0.6	0.3	0.9
	Combined	1.1	0.2	0.7	0.4	0.9	0.6	0.4	0.9
A12. Reduce Steam System Generating Pressure	Pulp & Paper	3.0	0.6	1.5	1.1	1.9	1.4	0.8	1.8
	Chemical Manufacturing	3.1	0.6	1.6	1.2	1.9	1.5	1.0	1.9
	Petroleum Refining	3.6	1.0	2.0	1.4	2.9	1.9	1.2	2.4
	Combined	2.7	0.5	1.3	1.1	1.8	1.3	0.8	1.7
B01. Improve Quality of Delivered Steam	Pulp & Paper	1.6	0.3	1.3	1.1	1.7	1.0	0.7	1.4
	Chemical Manufacturing	1.4	0.3	1.2	1.0	1.6	0.9	0.6	1.3
	Petroleum Refining	1.2	0.3	1.0	0.7	1.3	0.8	0.5	1.2
	Combined	1.6	0.3	1.3	1.1	1.7	1.0	0.7	1.4
B04. Minimize Vented Steam	Pulp & Paper	3.9	0.7	2.3	1.7	3.7	2.6	2.0	3.0
	Chemical Manufacturing	5.2	1.0	3.0	2.1	4.4	3.4	2.9	3.9
	Petroleum Refining	4.2	1.1	2.4	1.5	3.9	2.8	2.3	3.4
	Combined	4.7	0.8	2.7	2.0	3.9	2.9	2.3	3.4
B05. Repair Steam Leaks	Pulp & Paper	2.1	0.4	1.7	1.3	1.9	1.6	1.2	1.9
	Chemical Manufacturing	2.0	0.4	1.6	1.3	1.9	1.5	1.1	1.8
	Petroleum Refining	2.5	0.6	1.8	1.4	2.0	2.1	1.7	2.5
	Combined	1.9	0.4	1.5	1.2	1.8	1.4	1.0	1.7
B06. Isolate Steam from Unused Lines	Pulp & Paper	1.5	0.2	1.2	1.0	1.5	1.0	0.6	1.3
	Chemical Manufacturing	1.5	0.3	1.2	1.0	1.6	1.0	0.6	1.3
	Petroleum Refining	1.5	0.3	1.2	1.0	1.7	1.0	0.5	1.3
	Combined	1.4	0.2	1.1	1.0	1.5	0.9	0.6	1.2
B07. Improve System Balance	Pulp & Paper	2.2	0.4	1.6	1.3	1.9	1.6	1.1	1.9
	Chemical Manufacturing	1.7	0.3	1.5	1.2	1.8	1.3	0.8	1.6
	Petroleum Refining	1.4	0.3	1.4	1.1	1.7	1.2	0.7	1.5
	Combined	2.1	0.3	1.5	1.2	1.9	1.4	1.0	1.8

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Fuel Saving Statistical Data

Opportunity	Industry Group	Fuel Savings (%) Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
C01. Optimize Steam Use in Pulp and Paper Drying Applications	Pulp & Paper	7.2	1.0	5.2	3.5	7.8	5.0	4.3	5.7
C02. Optimize Steam Use in Pulp and Paper Air Heating Applications	Pulp & Paper	2.0	0.4	1.1	0.9	1.4	1.1	0.7	1.4
C03. Optimize Steam Use in Pulp and Paper Water Heating Applications	Pulp & Paper	2.5	0.6	1.2	1.0	1.8	1.2	0.7	1.5
C04. Optimize Steam Use in Chemical Product Heating Applications	Chemical Manufacturing	3.2	0.6	1.7	1.4	1.9	2.0	1.6	2.4
C05. Optimize Steam Use in Chemical Vacuum Production Applications	Chemical Manufacturing	3.6	0.8	1.7	1.3	1.9	2.0	1.3	2.4
C06. Optimize Steam Use in Petroleum Refining Distillation Applications	Petroleum Refining	2.3	0.5	2.0	1.5	2.8	1.9	1.3	2.3
C07. Optimize Steam Use in Petroleum Refining Vacuum Production Applications	Petroleum Refining	3.4	1.0	1.6	1.2	1.9	1.7	1.0	2.2
D01. Optimize Condensate Recovery	Pulp & Paper	3.9	0.8	1.5	1.2	1.9	1.8	1.3	2.2
	Chemical Manufacturing	5.1	1.1	1.7	1.2	1.9	2.3	1.5	2.7
	Petroleum Refining	4.9	1.3	1.7	1.2	1.9	2.3	1.6	2.9
	Combined	4.7	0.9	1.6	1.3	1.9	2.1	1.5	2.5
D02. Use High-Pressure Condensate to Make Low-Pressure Steam	Pulp & Paper	2.9	0.6	1.5	1.2	1.9	1.6	1.1	1.9
	Chemical Manufacturing	3.2	0.6	1.7	1.3	2.0	1.8	1.3	2.2
	Petroleum Refining	3.7	1.0	2.0	1.4	2.9	2.2	1.5	2.8
	Combined	2.8	0.5	1.5	1.2	1.9	1.5	1.1	1.9
E01. Implement Combined Heat and Power (Cogeneration) Project	Pulp & Paper	10.5	1.8	11.5	9.9	14.7	5.2	4.0	6.2
	Chemical Manufacturing	11.2	1.9	12.0	10.4	15.6	6.0	4.8	7.1
	Petroleum Refining	12.0	2.4	13.0	10.5	17.6	5.7	4.2	7.0
	Combined	10.5	1.8	11.5	9.9	14.7	5.2	4.0	6.2

Percentage of Facilities Statistical Data

Opportunity	Industry Group	Percent of Facilities (%)							
		Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A01. Minimize Boiler Combustion Loss by Optimizing Excess Air	Pulp & Paper	32.8	3.3	32.0	24.0	41.5	28.0	25.1	31.3
	Chemical Manufacturing	35.2	3.7	35.1	27.3	43.2	30.7	27.5	34.5
	Petroleum Refining	30.7	4.4	30.6	23.0	40.5	26.1	22.6	30.1
	Combined	34.3	3.2	33.7	25.6	42.3	29.4	26.5	32.5
A02. Improve Boiler Operating Practices	Pulp & Paper	18.6	1.8	8.3	6.8	9.4	10.8	9.4	12.2
	Chemical Manufacturing	19.9	1.9	9.2	7.9	9.9	12.8	11.2	14.0
	Petroleum Refining	18.0	2.0	8.2	6.5	9.6	10.8	9.0	12.3
	Combined	18.2	1.7	8.8	7.4	9.7	11.2	9.8	12.5
A03. Repair or Replace Burner Parts	Pulp & Paper	13.9	2.1	10.2	9.0	12.3	9.5	7.4	11.1
	Chemical Manufacturing	12.9	2.1	10.2	8.8	12.2	8.8	6.6	10.6
	Petroleum Refining	10.8	2.2	7.9	5.7	9.6	7.1	4.8	9.0
	Combined	14.0	2.0	11.0	10.0	14.6	9.8	7.7	11.4
A04. Install Feedwater Economizers	Pulp & Paper	18.7	2.1	14.2	11.1	18.0	14.0	12.4	15.5
	Chemical Manufacturing	17.2	1.9	12.2	10.3	16.3	12.6	11.2	14.1
	Petroleum Refining	13.7	2.2	10.5	9.0	13.2	10.6	8.9	12.3
	Combined	17.6	1.9	12.6	10.4	16.6	13.0	11.6	14.4
A05. Install Combustion Air Preheaters	Pulp & Paper	9.7	1.6	3.5	2.1	4.6	3.6	2.7	4.5
	Chemical Manufacturing	5.2	1.3	3.0	1.9	4.1	2.6	1.9	3.3
	Petroleum Refining	6.4	1.9	3.2	1.8	4.4	2.7	1.8	3.6
	Combined	8.9	1.4	3.4	2.2	4.4	3.4	2.6	4.3
A07. Clean Boiler Heat Transfer Surfaces	Pulp & Paper	11.2	1.2	7.5	5.8	9.1	6.8	5.6	8.1
	Chemical Manufacturing	11.8	1.2	8.1	6.0	9.6	7.3	5.9	8.7
	Petroleum Refining	13.4	1.6	8.2	6.3	9.7	8.0	6.2	9.8
	Combined	10.7	1.1	6.9	5.4	8.9	6.4	5.2	7.6
A08. Improve Blowdown Practices	Pulp & Paper	20.2	1.8	12.3	10.3	15.9	12.1	10.2	13.7
	Chemical Manufacturing	25.0	2.1	15.1	11.7	18.5	15.6	13.4	17.4
	Petroleum Refining	18.2	1.9	8.5	6.6	9.7	10.3	8.3	12.1
	Combined	23.2	1.9	14.2	11.2	17.6	14.0	12.1	15.7
A09. Install Continuous Blowdown Heat Recovery	Pulp & Paper	20.3	2.4	13.6	10.6	17.5	12.2	10.1	14.2
	Chemical Manufacturing	21.1	2.5	15.0	11.5	18.3	13.9	11.9	15.9
	Petroleum Refining	21.7	2.8	11.6	8.9	14.4	11.9	9.0	14.4
	Combined	19.1	2.2	12.8	10.5	16.6	12.0	10.1	13.7

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Percentage of Facilities Statistical Data

		Percent of Facilities (%)							
Opportunity	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A10. Add/Restore Boiler Refractory	Pulp & Paper	4.6	0.8	4.1	2.7	4.9	3.7	2.8	4.7
	Chemical Manufacturing	4.6	0.7	4.2	2.9	4.9	3.7	2.9	4.7
	Petroleum Refining	4.2	0.8	3.6	2.3	4.7	3.3	2.4	4.5
	Combined	4.6	0.7	4.2	2.9	4.9	3.7	2.9	4.7
A11. Establish the Correct Vent Rate for the Deaerator	Pulp & Paper	14.8	2.1	7.9	5.8	9.6	7.9	6.0	9.6
	Chemical Manufacturing	16.4	2.3	9.1	6.7	10.0	9.3	7.3	11.2
	Petroleum Refining	12.4	1.8	5.1	2.8	8.9	6.1	4.2	8.1
	Combined	15.6	2.1	8.4	6.3	9.7	8.6	6.7	10.3
A12. Reduce Steam System Generating Pressure	Pulp & Paper	17.8	2.0	10.4	8.8	12.8	9.9	8.0	11.7
	Chemical Manufacturing	14.2	1.9	8.6	6.6	9.8	8.5	6.9	10.2
	Petroleum Refining	16.1	2.4	10.5	8.6	13.5	9.6	7.5	11.8
	Combined	16.3	1.8	8.6	6.6	9.8	8.9	7.3	10.4
B01. Improve Quality of Delivered Steam	Pulp & Paper	19.6	3.1	11.3	8.3	14.3	9.7	7.5	11.9
	Chemical Manufacturing	16.0	3.2	7.5	5.1	9.9	8.2	6.3	10.3
	Petroleum Refining	15.5	3.7	5.8	4.2	7.2	7.5	5.4	9.8
	Combined	19.6	3.1	11.3	8.3	14.3	9.7	7.5	11.9
B04. Minimize Vented Steam	Pulp & Paper	16.6	2.2	6.4	3.6	9.7	7.7	5.4	9.5
	Chemical Manufacturing	15.7	2.3	4.1	2.7	4.9	6.2	4.3	8.0
	Petroleum Refining	16.4	3.4	4.1	2.0	5.0	6.6	3.8	9.3
	Combined	14.8	1.9	4.5	3.1	5.0	6.5	4.9	8.2
B05. Repair Steam Leaks	Pulp & Paper	25.6	2.7	16.8	12.8	19.5	16.4	14.0	18.6
	Chemical Manufacturing	28.1	2.7	17.2	13.5	19.5	17.1	14.3	19.5
	Petroleum Refining	27.4	2.9	15.1	11.0	19.0	16.3	13.5	18.7
	Combined	26.2	2.5	16.8	12.8	19.5	15.7	13.3	17.9
B06. Isolate Steam from Unused Lines	Pulp & Paper	12.5	1.7	7.7	5.9	9.3	7.5	5.7	8.9
	Chemical Manufacturing	13.5	1.9	8.2	6.2	9.7	8.1	6.1	9.8
	Petroleum Refining	12.5	1.9	6.8	4.7	9.3	6.7	4.5	8.7
	Combined	12.6	1.6	8.1	6.1	9.6	7.8	6.1	9.2
B07. Improve System Balance	Pulp & Paper	12.3	1.4	8.1	6.4	9.4	8.3	6.9	9.6
	Chemical Manufacturing	11.7	1.4	7.5	6.0	9.1	7.4	6.0	8.6
	Petroleum Refining	14.2	2.2	7.5	5.8	9.2	8.2	6.2	9.9
	Combined	11.2	1.2	7.4	5.9	9.1	7.2	5.9	8.4

Table continues next page

Percentage of Facilities Statistical Data

Opportunity	Industry Group	Percent of Facilities (%)							
		Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
C01. Optimize Steam Use in Pulp and Paper Drying Applications	Pulp & Paper	18.0	2.0	8.4	6.1	9.8	9.4	7.5	11.2
C02. Optimize Steam Use in Pulp and Paper Air Heating Applications	Pulp & Paper	15.0	2.4	6.8	5.3	8.8	7.5	5.8	9.2
C03. Optimize Steam Use in Pulp and Paper Water Heating Applications	Pulp & Paper	15.0	2.2	7.4	5.5	9.4	7.9	6.2	9.5
C04. Optimize Steam Use in Chemical Product Heating Applications	Chemical Manufacturing	27.9	2.5	16.3	12.2	19.3	17.6	15.4	19.7
C05. Optimize Steam Use in Chemical Vacuum Production Applications	Chemical Manufacturing	11.5	2.9	6.1	5.0	8.6	6.4	4.8	8.1
C06. Optimize Steam Use in Petroleum Refining Distillation Applications	Petroleum Refining	18.8	3.2	8.5	6.4	9.8	11.7	9.8	13.5
C07. Optimize Steam Use in Petroleum Refining Vacuum Production Applications	Petroleum Refining	10.1	2.3	6.8	5.4	8.8	6.5	5.0	8.1
D01. Optimize Condensate Recovery	Pulp & Paper	31.2	3.0	27.5	21.4	37.6	23.6	21.3	26.0
	Chemical Manufacturing	36.2	3.7	36.5	27.0	45.9	29.1	26.0	32.6
	Petroleum Refining	31.0	4.2	29.3	21.9	40.1	23.5	20.4	27.0
	Combined	31.5	3.0	28.7	21.7	38.5	24.2	21.8	26.8
D02. Use High Pressure Condensate to Make Low Pressure Steam	Pulp & Paper	15.1	2.2	8.8	6.5	9.9	8.6	7.0	10.3
	Chemical Manufacturing	16.0	2.4	10.0	7.4	12.6	9.4	7.5	11.3
	Petroleum Refining	19.6	3.6	12.6	6.9	19.2	10.6	7.7	13.4
	Combined	14.4	2.0	8.8	6.5	9.9	8.2	6.6	9.8
E01. Implement Combined Heat and Power (Cogeneration) Project	Pulp & Paper	20.8	2.3	14.6	11.5	18.1	14.7	12.4	16.9
	Chemical Manufacturing	17.6	2.2	13.8	11.3	17.2	13.1	10.6	15.2
	Petroleum Refining	18.2	2.6	13.5	10.7	17.1	12.8	9.9	15.1
	Combined	20.8	2.3	14.6	11.5	18.1	14.7	12.4	16.9

Payback Period Statistical Data

Opportunity	Industry Group	Payback Period (Months)							
		Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A01. Minimize Boiler Combustion Loss by Optimizing Excess Air	Pulp & Paper	8.9	1.4	5.3	3.9	5.9	5.6	4.5	6.7
	Chemical Manufacturing	9.3	1.5	5.5	3.9	6.0	5.8	4.6	7.0
	Petroleum Refining	8.1	1.8	4.3	2.6	5.5	4.5	3.3	5.8
	Combined	9.4	1.3	6.4	5.4	7.9	6.1	5.1	7.2
A02. Improve Boiler Operating Practices	Pulp & Paper	5.9	0.9	4.2	2.5	5.5	3.3	2.6	4.0
	Chemical Manufacturing	5.7	0.8	4.7	2.8	5.8	3.4	2.7	4.1
	Petroleum Refining	5.4	1.1	3.9	2.2	5.4	3.1	2.3	4.0
	Combined	6.3	0.8	4.9	3.1	5.8	3.7	3.0	4.4
A03. Repair or Replace Burner Parts	Pulp & Paper	19.7	2.1	11.1	8.4	12.0	12.4	10.7	14.2
	Chemical Manufacturing	17.7	1.9	10.3	8.1	11.7	11.2	9.6	13.0
	Petroleum Refining	16.4	2.2	9.0	6.6	11.3	9.8	7.9	11.7
	Combined	19.0	1.9	11.3	8.8	12.0	12.4	10.8	14.0
A04. Install Feedwater Economizers	Pulp & Paper	23.4	1.9	24.7	22.1	28.5	19.7	17.7	21.7
	Chemical Manufacturing	24.7	2.0	25.7	24.1	29.8	22.3	20.3	24.2
	Petroleum Refining	24.5	2.6	25.1	21.0	30.4	21.4	19.0	23.9
	Combined	23.4	1.8	24.6	22.2	28.1	20.0	18.2	22.0
A05. Install Combustion Air Preheaters	Pulp & Paper	30.4	2.7	29.3	25.1	33.8	25.9	23.7	28.4
	Chemical Manufacturing	33.2	2.8	32.2	27.2	35.4	29.3	26.7	31.9
	Petroleum Refining	29.0	3.4	24.0	17.9	32.8	24.8	21.9	27.8
	Combined	31.5	2.5	30.7	26.3	34.4	27.2	24.9	29.4
A07. Clean Boiler Heat Transfer Surfaces	Pulp & Paper	10.7	1.2	7.7	6.3	10.2	6.6	5.4	7.7
	Chemical Manufacturing	10.4	1.2	8.4	6.4	10.8	6.6	5.5	7.8
	Petroleum Refining	8.6	1.4	7.3	6.0	10.3	6.6	5.2	8.1
	Combined	11.2	1.2	8.4	6.4	10.8	7.0	5.9	8.1
A08. Improve Blowdown Practices	Pulp & Paper	6.1	1.1	4.0	2.1	5.5	3.1	2.4	3.9
	Chemical Manufacturing	9.4	1.5	4.0	2.1	5.5	3.5	2.7	4.5
	Petroleum Refining	7.2	1.6	4.1	1.9	5.7	3.9	2.8	5.2
	Combined	8.7	1.3	4.0	2.1	5.5	3.2	2.6	4.1
A09. Install Continuous Blowdown Heat Recovery	Pulp & Paper	21.9	1.9	22.9	18.6	25.9	19.0	17.0	21.1
	Chemical Manufacturing	22.3	2.1	21.2	17.2	23.5	19.0	16.8	21.0
	Petroleum Refining	21.1	2.6	21.3	16.1	23.9	18.0	15.1	20.5
	Combined	23.3	1.9	23.1	19.2	25.9	20.1	18.1	22.0

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Payback Period Statistical Data

Opportunity	Industry Group	Payback Period (Months)							
		Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A10. Add/Restore Boiler Refractory	Pulp & Paper	18.0	2.1	11.2	8.8	12.0	11.1	9.4	12.7
	Chemical Manufacturing	20.0	2.1	14.1	12.1	19.9	12.6	10.9	14.3
	Petroleum Refining	15.9	2.3	10.3	7.9	11.8	9.3	7.6	11.0
	Combined	20.0	2.1	14.1	12.1	19.9	12.6	10.9	14.3
A11. Establish the Correct Vent Rate for the Deaerator	Pulp & Paper	9.2	1.6	6.4	4.9	8.2	4.9	3.9	5.9
	Chemical Manufacturing	7.9	1.5	4.0	1.9	5.6	3.3	2.5	4.0
	Petroleum Refining	10.0	2.2	6.9	4.9	8.7	5.5	4.1	7.0
	Combined	8.0	1.4	4.6	2.7	5.7	3.5	2.7	4.2
A12. Reduce Steam System Generating Pressure	Pulp & Paper	4.9	0.9	2.8	1.4	4.9	2.1	1.6	2.6
	Chemical Manufacturing	5.2	0.8	3.5	1.5	5.5	2.3	1.8	2.9
	Petroleum Refining	6.0	1.2	4.2	2.3	5.7	3.1	2.3	4.1
	Combined	4.8	0.8	2.8	1.4	4.9	2.1	1.6	2.6
B01. Improve Quality of Delivered Steam	Pulp & Paper	17.3	1.9	15.7	12.7	21.1	14.2	12.3	16.1
	Chemical Manufacturing	16.1	2.1	14.2	12.1	20.0	13.2	11.4	15.2
	Petroleum Refining	17.7	2.6	17.2	12.9	22.5	14.2	11.6	16.6
	Combined	17.3	1.9	15.7	12.7	21.1	14.2	12.3	16.1
B04. Minimize Vented Steam	Pulp & Paper	8.1	2.1	5.2	3.1	6.0	4.2	3.2	5.2
	Chemical Manufacturing	12.4	2.4	7.2	6.1	10.3	6.4	5.0	7.8
	Petroleum Refining	8.4	3.1	5.0	2.5	6.0	4.4	3.1	5.9
	Combined	11.4	2.2	6.2	5.0	7.8	5.1	4.0	6.3
B05. Repair Steam Leaks	Pulp & Paper	9.1	1.9	5.5	3.6	6.0	5.2	4.2	6.4
	Chemical Manufacturing	12.5	2.1	7.1	6.0	9.9	6.5	5.3	7.8
	Petroleum Refining	10.7	2.6	5.4	3.4	6.0	6.5	4.9	8.3
	Combined	11.9	2.0	6.2	5.2	7.7	6.1	5.0	7.4
B06. Isolate Steam from Unused Lines	Pulp & Paper	4.4	0.8	1.6	1.0	3.6	1.7	1.3	2.1
	Chemical Manufacturing	7.7	1.2	3.0	1.6	4.9	2.6	2.1	3.3
	Petroleum Refining	6.0	1.2	3.5	1.8	5.3	2.7	2.0	3.5
	Combined	6.9	1.1	2.3	1.2	4.2	2.1	1.7	2.6
B07. Improve System Balance	Pulp & Paper	14.2	2.8	7.7	6.1	10.8	6.2	4.9	7.7
	Chemical Manufacturing	15.4	3.0	8.9	6.7	11.1	7.7	6.2	9.5
	Petroleum Refining	15.1	5.4	8.9	6.7	11.1	6.9	4.7	9.2
	Combined	15.8	2.6	7.7	6.1	10.8	6.8	5.5	8.3

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Payback Period Statistical Data

Opportunity	Industry Group	Payback Period (Months)							
		Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
C01. Optimize Steam Use in Pulp and Paper Drying Applications	Pulp & Paper	29.8	3.0	28.7	24.9	33.5	26.4	23.8	29.2
C02. Optimize Steam Use in Pulp and Paper Air Heating Applications	Pulp & Paper	25.0	2.6	20.3	15.4	23.3	19.4	16.9	21.9
C03. Optimize Steam Use in Pulp and Paper Water Heating Applications	Pulp & Paper	25.1	2.4	27.1	24.5	31.9	15.9	13.5	18.0
C04. Optimize Steam Use in Chemical Product Heating Applications	Chemical Manufacturing	24.3	2.0	26.3	24.4	30.3	16.9	14.9	18.7
C05. Optimize Steam Use in Chemical Vacuum Production Applications	Chemical Manufacturing	26.1	3.9	25.1	16.8	32.6	22.9	19.5	26.3
C06. Optimize Steam Use in Petroleum Refining Distillation Applications	Petroleum Refining	27.9	3.0	29.5	25.5	33.6	18.0	14.8	20.6
C07. Optimize Steam Use in Petroleum Refining Vacuum Production Applications	Petroleum Refining	25.1	2.7	27.0	24.5	31.5	22.9	20.2	25.6
D01. Optimize Condensate Recovery	Pulp & Paper	19.0	2.5	15.0	12.1	21.3	12.9	11.0	15.0
	Chemical Manufacturing	21.4	2.9	19.2	13.3	23.7	15.1	12.9	17.6
	Petroleum Refining	20.7	3.5	20.4	13.4	26.0	15.7	13.1	18.5
	Combined	21.1	2.5	17.2	12.8	22.1	14.1	12.2	16.3
D02. Use High-Pressure Condensate to Make Low-Pressure Steam	Pulp & Paper	18.2	1.8	16.1	13.1	20.4	14.8	13.1	16.5
	Chemical Manufacturing	19.4	1.7	17.0	13.4	21.5	16.6	15.1	18.2
	Petroleum Refining	21.0	2.3	18.0	13.2	23.0	17.5	15.7	19.6
	Combined	18.4	1.6	16.1	13.1	20.4	15.0	13.4	16.5
E01. Implement Combined Heat and Power (Cogeneration) Project	Pulp & Paper	38.8	3.0	42.5	37.4	49.6	33.7	30.7	36.5
	Chemical Manufacturing	37.7	3.4	42.0	37.3	49.1	32.5	29.2	35.4
	Petroleum Refining	40.4	4.3	43.7	38.0	51.3	36.3	32.0	40.6
	Combined	38.8	3.0	42.5	37.4	49.6	33.7	30.7	36.5

Industry Fuel Savings, Results from Statistical Data

		Total Savings (%)							
Opportunity	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A01. Minimize Boiler Combustion Loss by Optimizing Excess Air	Pulp & Paper	1.09	0.20	0.74	0.53	1.03	0.64	0.51	0.77
	Chemical Manufacturing	0.96	0.18	0.78	0.60	1.00	0.71	0.60	0.84
	Petroleum Refining	0.93	0.24	0.56	0.36	0.79	0.62	0.49	0.76
	Combined	1.05	0.18	0.73	0.54	0.96	0.64	0.52	0.76
A02. Improve Boiler Operating Practices	Pulp & Paper	0.73	0.16	0.11	0.07	0.17	0.14	0.10	0.20
	Chemical Manufacturing	0.89	0.18	0.23	0.15	0.33	0.24	0.17	0.31
	Petroleum Refining	0.66	0.18	0.20	0.12	0.32	0.21	0.13	0.27
	Combined	0.79	0.16	0.18	0.12	0.27	0.17	0.12	0.23
A03. Repair or Replace Burner Parts	Pulp & Paper	0.46	0.13	0.23	0.16	0.33	0.16	0.11	0.21
	Chemical Manufacturing	0.40	0.12	0.17	0.12	0.23	0.13	0.08	0.17
	Petroleum Refining	0.42	0.17	0.12	0.08	0.16	0.10	0.05	0.14
	Combined	0.44	0.12	0.20	0.13	0.30	0.15	0.11	0.20
A04. Install Feedwater Economizers	Pulp & Paper	0.59	0.12	0.38	0.28	0.51	0.39	0.32	0.47
	Chemical Manufacturing	0.53	0.11	0.32	0.24	0.42	0.33	0.27	0.40
	Petroleum Refining	0.37	0.11	0.27	0.19	0.37	0.26	0.19	0.33
	Combined	0.55	0.10	0.34	0.27	0.45	0.36	0.29	0.42
A05. Install Combustion Air Preheaters	Pulp & Paper	0.32	0.12	0.06	0.03	0.11	0.08	0.05	0.11
	Chemical Manufacturing	0.23	0.12	0.05	0.03	0.08	0.06	0.04	0.08
	Petroleum Refining	0.32	0.17	0.05	0.02	0.08	0.06	0.03	0.09
	Combined	0.29	0.11	0.06	0.04	0.10	0.08	0.05	0.11
A07. Clean Boiler Heat Transfer Surfaces	Pulp & Paper	0.28	0.10	0.13	0.09	0.18	0.11	0.08	0.14
	Chemical Manufacturing	0.30	0.11	0.15	0.12	0.20	0.13	0.10	0.16
	Petroleum Refining	0.37	0.16	0.18	0.12	0.27	0.17	0.13	0.21
	Combined	0.27	0.09	0.12	0.09	0.16	0.09	0.07	0.12
A08. Improve Blowdown Practices	Pulp & Paper	0.27	0.06	0.12	0.08	0.17	0.10	0.07	0.13
	Chemical Manufacturing	0.29	0.06	0.14	0.09	0.22	0.12	0.08	0.16
	Petroleum Refining	0.24	0.07	0.09	0.06	0.14	0.08	0.04	0.11
	Combined	0.27	0.05	0.14	0.09	0.21	0.11	0.07	0.14
A09. Install Continuous Blowdown Heat Recovery	Pulp & Paper	0.28	0.06	0.16	0.11	0.23	0.10	0.06	0.14
	Chemical Manufacturing	0.30	0.07	0.21	0.15	0.30	0.13	0.08	0.17
	Petroleum Refining	0.32	0.09	0.22	0.12	0.37	0.11	0.06	0.16
	Combined	0.27	0.06	0.15	0.11	0.21	0.10	0.06	0.14

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Industry Fuel Savings, Results from Statistical Data

		Total Savings (%)							
Opportunity	**Industry Group**	**Arithmetic Mean (AM)**	**Uncertainty on AM (±)**	**Median**	**Lower Uncertainty on Median**	**Upper Uncertainty on Median**	**Geometric Mean (GM)**	**Lower Uncertainty on GM**	**Upper Uncertainty on GM**
A10. Add/Restore Boiler Refractory	Pulp & Paper	0.07	0.02	0.03	0.01	0.04	0.03	0.01	0.04
	Chemical Manufacturing	0.06	0.02	0.02	0.01	0.04	0.02	0.01	0.04
	Petroleum Refining	0.05	0.02	0.02	0.01	0.03	0.02	0.01	0.03
	Combined	0.06	0.02	0.02	0.01	0.04	0.02	0.01	0.04
A11. Establish the Correct Vent Rate for the Deaerator	Pulp & Paper	0.16	0.07	0.05	0.03	0.09	0.05	0.03	0.07
	Chemical Manufacturing	0.19	0.07	0.06	0.03	0.10	0.06	0.04	0.09
	Petroleum Refining	0.07	0.04	0.04	0.02	0.07	0.03	0.02	0.06
	Combined	0.18	0.06	0.06	0.03	0.09	0.05	0.03	0.08
A12. Reduce Steam System Generating Pressure	Pulp & Paper	0.93	0.33	0.22	0.15	0.31	0.13	0.08	0.20
	Chemical Manufacturing	0.91	0.32	0.19	0.13	0.27	0.13	0.08	0.18
	Petroleum Refining	1.29	0.55	0.23	0.17	0.32	0.18	0.10	0.26
	Combined	0.82	0.29	0.17	0.10	0.26	0.11	0.07	0.16
B01. Improve Quality of Delivered Steam	Pulp & Paper	0.49	0.14	0.14	0.09	0.20	0.10	0.06	0.14
	Chemical Manufacturing	0.35	0.12	0.05	0.02	0.09	0.08	0.04	0.11
	Petroleum Refining	0.30	0.12	0.04	0.02	0.07	0.06	0.03	0.10
	Combined	0.49	0.14	0.14	0.09	0.20	0.10	0.06	0.14
B04. Minimize Vented Steam	Pulp & Paper	0.97	0.31	0.14	0.08	0.21	0.20	0.13	0.26
	Chemical Manufacturing	1.06	0.37	0.14	0.08	0.21	0.23	0.16	0.32
	Petroleum Refining	0.95	0.51	0.11	0.05	0.21	0.19	0.10	0.28
	Combined	0.93	0.29	0.16	0.09	0.24	0.20	0.14	0.27
B05. Repair Steam Leaks	Pulp & Paper	0.69	0.26	0.29	0.20	0.38	0.27	0.20	0.34
	Chemical Manufacturing	0.71	0.27	0.28	0.19	0.40	0.27	0.19	0.34
	Petroleum Refining	0.86	0.41	0.26	0.16	0.36	0.32	0.24	0.40
	Combined	0.63	0.23	0.26	0.17	0.36	0.22	0.15	0.28
B06. Isolate Steam from Unused Lines	Pulp & Paper	0.23	0.08	0.09	0.05	0.14	0.07	0.04	0.10
	Chemical Manufacturing	0.24	0.08	0.09	0.04	0.14	0.08	0.05	0.11
	Petroleum Refining	0.19	0.07	0.09	0.03	0.17	0.06	0.03	0.10
	Combined	0.22	0.07	0.09	0.04	0.14	0.07	0.04	0.10
B07. Improve System Balance	Pulp & Paper	0.27	0.07	0.15	0.11	0.21	0.13	0.09	0.17
	Chemical Manufacturing	0.20	0.06	0.13	0.09	0.17	0.10	0.07	0.14
	Petroleum Refining	0.17	0.08	0.11	0.08	0.15	0.09	0.06	0.13
	Combined	0.25	0.07	0.14	0.09	0.18	0.11	0.07	0.14

Table continues next page

Industry Fuel Savings, Results from Statistical Data

		Total Savings (%)							
Opportunity	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
C01. Optimize Steam Use in Pulp and Paper Drying Applications	Pulp & Paper	1.98	0.42	0.37	0.23	0.61	0.46	0.36	0.58
C02. Optimize Steam Use in Pulp and Paper Air Heating Applications	Pulp & Paper	0.46	0.16	0.08	0.04	0.12	0.08	0.05	0.11
C03. Optimize Steam Use in Pulp and Paper Water Heating Applications	Pulp & Paper	0.85	0.35	0.09	0.04	0.14	0.09	0.05	0.13
C04. Optimize Steam Use in Chemical Product Heating Applications	Chemical Manufacturing	1.59	0.52	0.26	0.17	0.37	0.34	0.25	0.41
C05. Optimize Steam Use in Chemical Vacuum Production Applications	Chemical Manufacturing	0.46	0.20	0.13	0.08	0.20	0.13	0.07	0.18
C06. Optimize Steam Use in Petroleum Refining Distillation Applications	Petroleum Refining	0.43	0.15	0.18	0.12	0.25	0.19	0.13	0.24
C07. Optimize Steam Use in Petroleum Refining Vacuum Production Applications	Petroleum Refining	0.21	0.08	0.15	0.10	0.22	0.11	0.06	0.16
D01. Optimize Condensate Recovery	Pulp & Paper	1.66	0.49	0.35	0.23	0.52	0.40	0.28	0.51
	Chemical Manufacturing	2.33	0.66	0.42	0.27	0.63	0.62	0.42	0.78
	Petroleum Refining	2.43	0.79	0.38	0.24	0.59	0.55	0.36	0.72
	Combined	1.92	0.52	0.39	0.27	0.55	0.48	0.34	0.60
D02. Use High-Pressure Condensate to Make Low-Pressure Steam	Pulp & Paper	0.87	0.33	0.12	0.08	0.17	0.12	0.08	0.16
	Chemical Manufacturing	0.96	0.36	0.14	0.09	0.21	0.16	0.10	0.21
	Petroleum Refining	1.33	0.57	0.22	0.10	0.37	0.20	0.12	0.28
	Combined	0.79	0.29	0.12	0.08	0.17	0.11	0.07	0.15
E01. Implement Combined Heat and Power (Cogeneration) Project	Pulp & Paper	1.94	0.54	1.13	0.68	1.71	0.85	0.61	1.09
	Chemical Manufacturing	1.87	0.52	1.13	0.68	1.72	0.83	0.60	1.07
	Petroleum Refining	1.98	0.62	1.14	0.65	1.80	0.80	0.54	1.05
	Combined	1.94	0.54	1.13	0.68	1.71	0.85	0.61	1.09

Special Opportunities Statistical Data

Opportunity	Question	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
A06. Correct Problems from Improper Water Treatment	a. Excellent, no improvement (% facilities)	Pulp & Paper	36.8	14.5	25.0	10.0	70.0	24.5	14.9	41.5
		Chemical Manufacturing	30.6	13.2	20.0	10.0	42.5	20.9	13.3	33.5
		Petroleum Refining	38.7	19.1	30.0	10.0	75.0	26.7	14.2	50.2
		Combined	34.6	12.9	20.0	10.0	70.0	23.5	14.6	35.9
	b. Good, improvement possible (% facilities)	Pulp & Paper	34.3	8.0	40.0	20.0	50.0	30.1	23.1	39.6
		Chemical Manufacturing	37.8	9.4	42.5	20.0	50.0	33.2	24.6	43.8
		Petroleum Refining	32.0	10.4	23.0	20.0	50.0	27.8	19.5	39.0
		Combined	35.5	8.2	40.0	20.0	50.0	30.8	23.8	39.2
	c. Inadequate (% facilities)	Pulp & Paper	27.6	9.8	25.0	10.0	45.0	14.0	4.1	31.3
		Chemical Manufacturing	30.3	11.2	27.5	12.5	45.0	14.9	3.8	34.5
		Petroleum Refining	26.6	13.8	20.0	2.0	40.0	9.2	1.2	33.6
		Combined	28.8	10.4	25.0	10.0	45.0	14.9	4.3	31.4
	d. Savings from b to a (%)	Pulp & Paper	1.8	0.7	1.0	1.0	2.0	1.4	1.0	2.0
		Chemical Manufacturing	2.5	1.5	1.0	1.0	2.0	1.7	1.2	2.7
		Petroleum Refining	2.1	1.0	1.0	1.0	2.0	1.7	1.2	2.6
		Combined	2.3	1.4	1.0	1.0	2.0	1.6	1.1	2.4
	e. Savings from c to a (%)	Pulp & Paper	4.9	2.6	3.0	2.0	5.3	2.6	1.0	5.2
		Chemical Manufacturing	7.3	5.5	3.0	2.0	5.5	2.9	0.9	6.4
		Petroleum Refining	5.7	3.6	3.0	2.0	10.0	2.6	0.5	6.8
		Combined	6.7	4.8	3.0	2.0	6.3	2.9	1.1	6.0
	f. Total savings b to a (%)	Pulp & Paper	0.6	0.3	0.5	0.3	0.6	0.4	0.3	0.7
		Chemical Manufacturing	0.8	0.3	0.5	0.4	1.0	0.6	0.4	0.9
		Petroleum Refining	0.6	0.4	0.5	0.2	0.6	0.5	0.3	0.8
		Combined	0.7	0.3	0.5	0.4	0.7	0.5	0.3	0.7
	g. Total savings c to a (%)	Pulp & Paper	1.8	1.5	0.6	0.4	2.0	0.6	0.3	2.1
		Chemical Manufacturing	3.7	3.5	0.6	0.3	3.5	0.7	0.2	3.2
		Petroleum Refining	2.3	2.2	0.6	0.1	5.0	0.6	0.2	2.0
		Combined	3.3	2.8	0.6	0.3	3.2	0.7	0.3	2.4
B02. Implement an Effective Steam Trap Maintenance Program	a. Has effective trap maintenance program (% facilities)	Pulp & Paper	19.6	7.3	15.0	10.0	30.0	15.2	10.6	21.9
		Chemical Manufacturing	14.5	4.6	10.0	7.5	20.0	11.1	6.8	16.2
		Petroleum Refining	18.2	5.5	17.5	10.0	30.0	15.7	10.8	21.6
		Combined	18.0	6.2	10.0	10.0	20.0	12.9	8.3	18.8

Table continues next page

Special Opportunities Statistical Data

Opportunity	Question	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
(B02. continued)	b. Traps maintained informally, improvement possible (% facilities)	Pulp & Paper	46.1	8.6	50.0	30.0	60.0	41.7	32.7	51.5
		Chemical Manufacturing	47.8	10.8	55.0	30.0	60.0	41.2	29.3	54.8
		Petroleum Refining	47.1	12.1	55.0	27.5	65.0	41.9	28.7	56.9
		Combined	45.9	9.2	50.0	30.0	60.0	40.1	30.3	50.7
	c. Does not maintain traps (% facilities)	Pulp & Paper	34.4	11.1	30.0	20.0	40.0	25.2	14.2	38.7
		Chemical Manufacturing	37.9	12.7	30.0	20.0	55.0	30.0	21.3	43.2
		Petroleum Refining	34.7	14.4	27.5	18.8	51.3	27.6	18.1	42.0
		Combined	36.0	11.5	30.0	20.0	40.0	25.5	15.4	39.2
	d. Savings from b to a (%)	Pulp & Paper	3.6	1.2	3.0	2.0	5.0	2.9	1.9	4.0
		Chemical Manufacturing	4.8	2.3	4.0	2.0	5.0	3.5	2.4	5.3
		Petroleum Refining	3.7	1.0	4.0	2.5	5.0	3.3	2.3	4.5
		Combined	4.4	2.1	3.0	2.0	5.0	3.0	2.0	4.5
	e. Savings from c to a (%)	Pulp & Paper	8.5	3.3	5.0	4.0	10.0	6.7	5.0	9.3
		Chemical Manufacturing	11.5	5.9	10.0	5.0	10.0	7.9	5.3	11.9
		Petroleum Refining	10.7	4.8	10.0	5.0	15.0	8.8	5.7	13.4
		Combined	10.7	5.5	5.0	4.0	10.0	7.2	4.9	10.7
	f. Total savings b to a (%)	Pulp & Paper	1.8	0.7	1.5	0.8	3.0	1.3	0.8	2.0
		Chemical Manufacturing	1.9	0.6	1.5	1.0	2.4	1.5	1.1	2.2
		Petroleum Refining	1.8	0.7	1.5	0.8	3.0	1.5	1.0	2.3
		Combined	1.8	0.6	1.5	0.8	2.4	1.3	0.9	2.0
	g. Total savings c to a (%)	Pulp & Paper	2.5	1.1	2.0	0.9	3.0	1.5	0.8	2.6
		Chemical Manufacturing	5.5	5.4	2.0	1.3	4.0	2.2	1.2	4.2
		Petroleum Refining	3.1	1.6	2.0	0.9	6.0	2.3	1.2	3.8
		Combined	4.8	4.7	2.0	0.9	3.8	1.7	0.8	3.4
	h. Typical payback period (months)	Pulp & Paper	12.6	1.9	8.9	6.9	11.0	8.7	7.2	10.2
		Chemical Manufacturing	11.0	1.4	7.8	6.3	10.3	7.1	6.0	8.3
		Petroleum Refining	12.2	2.0	9.0	6.6	11.4	8.7	6.9	10.5
		Combined	11.7	1.7	8.4	6.7	10.4	7.6	6.4	8.9
B03. Ensure that Steam System Piping, Valves, Fittings, and Vessels are Well Insulated	a. Insulation excellent, no improvement (% facilities)	Pulp & Paper	11.4	3.4	10.0	5.0	20.0	7.1	2.7	12.8
		Chemical Manufacturing	11.3	3.8	10.0	5.0	20.0	6.4	2.1	12.0
		Petroleum Refining	10.5	4.1	10.0	5.0	17.5	5.4	1.1	13.0
		Combined	11.4	3.4	10.0	5.0	20.0	6.9	2.8	12.2

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Special Opportunities Statistical Data

Opportunity	Question	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
(B03 continued)	b. Insulation is good, does not exceed hurdle rate (% facilities)	Pulp & Paper	40.2	9.7	49.0	20.0	50.0	32.8	22.5	44.9
		Chemical Manufacturing	39.1	11.1	49.5	15.0	52.5	28.9	17.5	44.9
		Petroleum Refining	37.7	14.9	47.0	12.5	55.0	28.0	15.4	46.5
		Combined	39.1	10.0	49.0	20.0	50.0	29.7	19.2	43.7
	c. Insulation inadequate, exceeds hurdle rate (% facilities)	Pulp & Paper	44.1	10.6	40.0	25.0	60.0	37.2	25.9	50.0
		Chemical Manufacturing	44.7	12.0	40.0	25.0	60.0	37.3	25.8	52.2
		Petroleum Refining	47.2	15.1	45.0	30.0	69.5	38.7	21.4	58.1
		Combined	45.3	10.3	40.0	25.0	60.0	37.8	28.2	50.2
	d. System is uninsulated (% facilities)	Pulp & Paper	5.6	2.3	5.0	1.0	10.0	1.3	0.3	4.8
		Chemical Manufacturing	4.3	2.3	3.5	0.5	7.5	0.7	0.2	2.7
		Petroleum Refining	4.7	3.1	3.0	0.0	10.0	0.8	0.1	3.9
		Combined	5.2	2.1	5.0	1.0	10.0	1.1	0.3	3.7
	e. Typical savings c to b (%)	Pulp & Paper	3.2	1.0	3.5	1.0	4.0	2.5	1.7	3.6
		Chemical Manufacturing	3.3	1.0	3.5	1.0	5.0	2.7	1.8	3.8
		Petroleum Refining	3.3	1.3	3.0	1.0	5.0	2.7	1.7	3.9
		Combined	3.2	0.9	3.5	1.0	5.0	2.5	1.7	3.5
	f. Typical savings d to b (%)	Pulp & Paper	10.2	4.7	7.5	3.5	17.5	1.8	0.3	7.6
		Chemical Manufacturing	10.6	4.9	10.0	0.0	20.0	1.2	0.2	5.9
		Petroleum Refining	11.8	6.1	10.0	0.0	25.0	2.8	0.3	14.9
		Combined	10.2	4.5	7.5	0.0	20.0	1.6	0.3	6.7
	g. Total savings c to b (%)	Pulp & Paper	1.4	0.7	0.9	0.3	2.1	0.9	0.5	1.5
		Chemical Manufacturing	1.6	0.8	0.9	0.3	2.1	1.0	0.6	1.6
		Petroleum Refining	1.6	1.0	0.8	0.5	2.1	1.0	0.5	1.9
		Combined	1.6	0.7	0.9	0.3	2.1	0.9	0.5	1.5
	e. Total savings d to b (%)	Pulp & Paper	0.5	0.3	0.3	0.0	0.6	0.2	0.1	0.4
		Chemical Manufacturing	0.5	0.3	0.3	0.0	0.8	0.2	0.1	0.5
		Petroleum Refining	0.5	0.5	0.2	0.0	1.0	0.1	0.0	0.5
		Combined	0.5	0.3	0.4	0.0	0.8	0.2	0.1	0.4
	g. Typical payback period (months)	Pulp & Paper	18.6	2.3	15.2	11.7	20.5	14.5	12.4	16.6
		Chemical Manufacturing	17.6	1.8	14.0	12.1	19.0	13.9	12.3	15.5
		Petroleum Refining	21.4	2.5	18.0	13.3	22.6	17.6	15.5	19.7
		Combined	17.8	2.0	14.5	11.7	19.3	14.1	12.3	15.9

Table continues next page

Special Opportunities Statistical Data

Opportunity	Question	Industry Group	Arithmetic Mean (AM)	Uncertainty on AM (±)	Median	Lower Uncertainty on Median	Upper Uncertainty on Median	Geometric Mean (GM)	Lower Uncertainty on GM	Upper Uncertainty on GM
B08. Improve Plant-Wide Testing & Maintenance Practices	a. Practices excellent, no improvement (% facilities)	Pulp & Paper	11.9	6.2	5.0	3.5	20.0	2.8	0.6	9.6
		Chemical Manufacturing	10.6	6.7	5.0	2.0	20.0	2.2	0.5	8.1
		Petroleum Refining	15.7	9.6	10.0	5.0	25.0	10.3	5.4	19.4
		Combined	11.3	6.0	5.0	3.5	20.0	3.0	0.8	8.9
	b. Practices good, improvement possible but benefit is small	Pulp & Paper	42.5	11.0	40.0	25.0	60.0	35.7	24.9	48.8
		Chemical Manufacturing	42.6	12.3	30.0	20.0	70.0	34.9	23.8	48.2
		Petroleum Refining	43.8	17.9	40.0	10.0	75.0	33.4	19.1	55.4
		Combined	43.6	10.6	40.0	30.0	62.5	36.5	26.5	48.8
	c. Practices are inadequate (% facilities)	Pulp & Paper	46.0	13.1	45.0	25.0	70.0	35.9	23.6	50.3
		Chemical Manufacturing	46.9	14.2	50.0	15.0	70.0	35.8	21.6	53.1
		Petroleum Refining	40.7	19.4	30.0	15.0	80.0	30.1	15.1	51.2
		Combined	44.9	12.2	45.0	20.0	68.5	34.4	22.6	49.0
	c. Typical savings b to a (%)	Pulp & Paper	2.4	0.8	2.3	1.3	3.0	2.0	1.2	2.8
		Chemical Manufacturing	2.9	1.3	2.0	1.5	3.0	2.1	1.4	3.2
		Petroleum Refining	1.5	0.6	1.5	0.5	2.0	1.2	0.8	2.0
		Combined	2.9	1.2	2.3	1.5	3.0	2.2	1.4	3.2
	c. Typical savings c to a (%)	Pulp & Paper	6.1	1.7	5.0	4.3	9.0	5.2	3.5	7.4
		Chemical Manufacturing	6.5	2.3	5.0	3.5	10.0	5.2	3.4	7.5
		Petroleum Refining	4.6	2.0	5.0	2.5	5.0	3.9	2.2	6.0
		Combined	6.5	2.1	5.0	3.5	9.0	5.3	3.4	7.3
	c. Total savings b to a (%)	Pulp & Paper	1.0	0.4	1.0	0.3	1.5	0.7	0.4	1.2
		Chemical Manufacturing	1.1	0.5	1.4	0.4	1.5	0.8	0.5	1.3
		Petroleum Refining	0.7	0.5	0.4	0.2	1.4	0.4	0.2	0.9
		Combined	1.2	0.4	1.5	0.4	1.6	0.8	0.5	1.3
	c. Total savings c to a (%)	Pulp & Paper	2.8	1.3	2.0	0.9	4.6	1.7	0.9	3.2
		Chemical Manufacturing	3.5	1.8	2.5	1.0	6.0	1.8	0.9	3.6
		Petroleum Refining	1.5	0.8	1.3	0.5	2.8	1.1	0.4	2.0
		Combined	3.3	1.8	2.0	0.8	4.6	1.7	0.9	3.2
	d. Typical payback period (months)	Pulp & Paper	7.5	1.3	5.1	3.3	5.9	5.5	4.2	6.9
		Chemical Manufacturing	8.0	1.3	6.3	5.1	7.8	6.0	4.7	7.4
		Petroleum Refining	7.5	1.8	5.0	2.4	6.0	5.5	3.7	7.5
		Combined	8.5	1.3	6.3	5.2	7.9	6.3	5.0	7.6

Appendix F

Analysis of Expert Responses to the Steam System Improvement Opportunities Questionnaire

Figures and Tables referenced in this section begin on page 58 in the order they are mentioned in the text.

General Opportunities

Description of Analysis

The analysis was conducted for General Opportunities A1-A5, A7-A12, B1, B4-B5, B6-B7, C1-C7, D1-D2, and E1.

The analysis was performed to obtain overall estimates for the following four categories:

- Percent of Fuel Savings (Y_1)
- Percentage of Facilities where Opportunity is Feasible (Y_2)
- Typical Payback Period (Y_3)
- Total Savings ($Y_4 = Y_1 * Y_2$).

Overall estimates for the four categories described above were derived using a Monte Carlo simulation technique. The method is outlined in the following steps.

Table F-1 notes the industries for which the different experts provided responses.

1. Assign Probability Distributions and Generate Random Variate. Any response to a question covering a range of values was characterized by a probability distribution function having a lower and upper limit. Most of the responses were characterized by the uniform probability distribution. For example, if the response to fuel savings was "5 to 10%", a random variate Y_1 was generated from a uniform distribution having a lower and upper limit of 5 and 10 respectively. Because the uniform distribution is used, the random variate Y_1 is equally likely to have any value between 5 and 10. The triangular probability distribution was used in a few cases. For example, if the response to the amount of fuel savings was ">10%", a random variate Y_1 was generated from a triangular distribution with a lower and upper limit of 10 and 25 respectively (upper limit arbitrarily set at 25). For this example, the random variate Y_1 can take on any value between 10 and 25, but values near 10 have a higher chance of being selected than values near 25. The probability of being selected decreases in a linear manner as Y_1 increases from 10 to 25. The random variables Y_2 and Y_3 were generated in a similar manner. The random variate Y_4 (total savings) was obtained by multiplying percent of fuel savings by percent of facilities (e.g. $Y_4 = Y_1 * Y_2$). The probability distributions used for the questionnaire responses are presented in Tables F-2 through F-4.

2. Assign Specific Value. Experts were given the opportunity to respond to a question with a specific value. When a specific value was given, that value was used in the analysis. For example, if the response to the payback period query was 6 months then $Y_3 = 6$.

3. Calculate Summary Statistics. The arithmetic mean, median, and geometric mean were calculated for Y_1 through Y_4 for each opportunity. For example, 19 experts estimated the amount of fuel savings for opportunity A1. Steps 1 and 2 generated 19 values of the random variate Y_1. Mean, median, and geometric mean values were calculated using the 19 values of Y_1. Mean, median, and geometric mean values were calculated in a similar manner for Y_2 through Y_4.

4. Generate Multiple Random Samples. Steps 1 and 3 were repeated 1,000 times so that 1,000 arithmetic means, 1,000 medians, and 1,000 geometric means were generated for Y_1 through Y_4 by opportunity.

5. Aggregate the Data. The data generated in steps 1 and 4 form three distributions (arithmetic mean, median, and geometric mean). These distributions were analyzed to formulate the final results. Arithmetic mean, median, and geometric mean values are given as estimates of central tendency. Uncertainty on the arithmetic mean value is given as ±2 standard deviations of the arithmetic mean. Uncertainty on the median and geometric means are given as the 2.5 and 97.5 percentile values of the median and geometric mean distributions.

General Versus Statistical Inference

The results assume a general inference and not a statistical inference. The summary statistics do not have a statistical interpretation that relates the estimates to the true values. Thus, the results do not represent a statistical inference in that the results and conclusions do not directly extend to an underlying population. However, the experts' knowledge does represent the state of the existing or available knowledge. In that sense, general inferences can be made; the results from the experts' information can be used to draw conclusions about the existing or available knowledge base, which may or may not represent the true state of nature. The dispersion (uncertainty) estimates have an interpretation relating to the uncertainty in the state of existing knowledge and conclusions made using the uncertainty characterization reflect this state of knowledge.

Arithmetic Mean Versus Median Versus Geometric Mean

Three measures were considered for combining the experts' answers into a single value. These measures of "central tendency" are (1) the arithmetic mean, (2) the median, and (3) the geometric mean.

The arithmetic mean is simply the weighted average of all expert responses with equal weight given to each response. This can be a disadvantage if one expert gives an answer that is far away in value from the rest and the answer is considered questionable or unreasonable. These extreme values ("outliers") have a greater influence on the arithmetic mean value than does a more "typical" answer. This is particularly true when there are just a few data points. One way of handling a questionable response is to omit it from the analysis. The danger of omitting a response is that it may possibly be the most accurate response. The expert giving the minority response may be more knowledgeable or have better insight. It is probably unwise to omit one experts' response simply because it deviates from the majority opinion, particularly if the response is backed up by data or sound reasoning. It is recommended that the expert be contacted and requested to explain any questionable responses.

A second alternative for handling a questionable response is to use a summary statistic that is less sensitive to extreme values. Two summary statistics that are less sensitive to extreme values are the median and geometric mean. The median (50th percentile value) is the value such that half the data are greater than the median and half the data are less than the median. The median is only minimally affected by the magnitude of a single observation. The median gives no consideration to the magnitude of the responses; it is simply the center value when the responses are ranked from low to high. The geometric mean, unlike the median, considers the magnitude of the responses. The geometric mean is the average of the logarithms of the data transformed back to their original units. For positively skewed data, the geometric mean is usually quite close to the median. The geometric mean is always less than or equal to the arithmetic mean. One disadvantage of the geometric mean is that there can be no zero or negative values in the data.

In the case of expert opinion, the choice of the summary statistic to use is as much a philosophical question as it is a technical question. One approach is described below.

- If you believe that all experts' opinions should be weighted equally and that all the responses are reasonable, even though some differ from the norm, then use the arithmetic mean of all the responses to summarize the data.
- If you believe that a response is completely unreasonable, then use the arithmetic mean, omitting the unreasonable response.
- If you believe that a response is questionable but not unreasonable, use the median or geometric mean to minimize the effect of the questionable response.

Uncertainty Estimates

Uncertainty estimates are given for all three measures of central tendency. The distribution of the arithmetic mean is a normal (Gaussian) distribution and the uncertainty is easily calculated as a multiple of the standard deviation of the mean. The uncertainty estimates for the arithmetic mean values are given as ± 2 standard deviations. The distributions of the median and geometric mean are skewed. In this study, the lower and upper limits on the uncertainty of the median and geometric mean are calculated as the 2.5 and 97.5 percentile values.

Differences Among Industry Groups

There appears to be little difference among the industry groups. This is not surprising because experts were assigned to multiple groups. Because experts cross groups, the groups are not independent. Because of the lack of independence between groups, it would be incorrect to perform statistical tests for differences among groups.

References:

1. Meyer, Mary A. and Booker, Jane M. (2001) *Eliciting and Analyzing Expert Judgment, A Practical Guide*, ASA-SIAM Series on Statistics and Applied Probability.

2. *The Statistical Analysis System (SAS)* Version 8.01, 1999–2000; SAS Institute, Cary, NC.

Table F-1. List of Experts by Industry Group

	Industry Group		
Expert	**Pulp and Paper**	**Chemical Manufacturing**	**Petroleum Refining**
01. Harrell	X	X	X
02. Dawson	X	X	
03. Griffin	X	X	
04. Wilson	X		
05. Crain	X		
06. Paffel	X	X	X
07. Turner		X	
08. CEC	X	X	X
09. Kumana	X	X	
10. Johnson	X	X	X
11. KEH		X	
12. Jendrucko	X	X	X
13. Wulfinghoff	X	X	X
14. Larkin	X	X	X
15. Hahn	X	X	X
16. Eckerlin	X	X	
17. Gangi	X	X	X
18. Kosanovic	X		
19. Iordanava	X	X	X
Total	**17**	**16**	**10**

Table F-2. Probability Distributions for Monte Carlo Simulation: Typical Amount of Fuel Savings

Responses	Probability Distribution	Lower Limit (%)	Upper Limit (%)
Questionnaire Selections			
<1%	Uniform	0	**1**
1-2%	Uniform	1	**2**
2-5%	Uniform	2	**5**
5-10%	Uniform	5	**10**
>10%	Triangular	10	**25**
Other Responses			
0%	Single Value Used		
0.5-2%	Uniform	0.5	**2**
<1-2%	Uniform	0.5	**2**
<2%	Uniform	0.5	**2**
<1-5%	Uniform	0.5	**5**
1-5%	Uniform	1	**5**
2-10%	Uniform	2	**10**
<10%	Uniform	1	**10**
5-20%	Uniform	5	**20**
5-30%	Uniform	5	**30**
15-25%	Uniform	15	**25**

Table F-3. Probability Distributions for Monte Carlo Simulation: Percentage of Facilities for Which the Opportunity is Feasible

Responses	Probability Distribution	Lower Limit (%)	Upper Limit (%)
Questionnaire Selections			
<5%	Uniform	0.5	5
5-10%	Uniform	5	10
10-20%	Uniform	10	20
20-50%	Uniform	20	50
>50%	Triangular	50	75
Other Responses			
0%	Single Value Used		
0-10%	Uniform	0	10
0-20%	Uniform	0	20
1-5%	Uniform	1	5
<5%	Uniform	0.5	5
1-10%	Uniform	1	10
1-20%	Uniform	1	20
4%	Single Value Used		
5-30%	Uniform	5	30
10-30%	Uniform	10	30
15%	Single Value Used		
17%	Single Value Used		
23%	Single Value Used		
27%	Single Value Used		
20-40%	Uniform	20	40
40-50%	Uniform	40	50
80-100%	Uniform	80	100
90%	Single Value Used		

Table F-4. Probability Distributions for Monte Carlo Simulation: Typical Payback Period

Questionnaire	Probability Distribution	Lower Limit (Months)	Upper Limit (Months)
Questionnaire Selections			
<1 month	Uniform	0.1	0.9
1-6 months	Uniform	1	6
6 months-1 year	Uniform	6	12
1-2 years	Uniform	12	24
2-3 years	Uniform	24	36
>3 years	Uniform	36	60
Other Responses			
<1 month	Uniform	0.1	0.9
1.2 months	Single Value Used		
0-4 years	Uniform	6	48
1-3 years	Uniform	12	36
1-4 years	Uniform	12	48
12 months	Single Value Used		
23 months	Single Value Used		
29 months	Single Value Used		
2-4 years	Uniform	24	48
>2 years	Uniform	24	60

Appendix G

Reasons for Implementing Performance Improvement Opportunities

This appendix discusses the expert responses describing the reasons that the improvement opportunities are implemented. Experts were requested to list in order the reason or reasons each improvement opportunity is typically implemented. The reasons were ranked by weighting method. This method accounted for the number of times a reason was identified for each improvement opportunity and the order it was ranked when more than one reason was identified.

A1. Minimize Boiler Combustion Loss by Optimizing Excess Air
1. Energy savings
2. Safety/environmental
3. Performance improvement

A2. Improve Boiler Operating Practices
1. Energy savings
2. Reduced maintenance
3. Performance improvement

A3. Repair or Replace Burner Parts
1. Energy savings
2. Safety/environmental
3. Performance improvement

A4. Install Feedwater Economizers
1. Energy savings
2. Performance improvement
3. Safety/environmental

A5. Install Combustion Air Preheaters
1. Energy savings
2. Increased capacity
3. Safety/environmental

A7. Clean Boiler Heat Transfer Surfaces
1. Energy savings
2. Performance improvement
3. Improved reliability

A8. Improve Blowdown Practices
1. Energy savings
2. Reduced maintenance
3. Safety/environmental

A9. Install Continuous Blowdown Heat Recovery

1. Energy savings
2. Increased capacity
3. Performance improvement
3. Safety/environmental

A10. Add/Restore Boiler Refractory

1. Energy savings
2. Safety/environmental
3. Performance improvement

A11. Establish the Correct Vent Rate for the Deaerator

1. Energy savings
2. Increased capacity
3. Reduced maintenance
3. Safety/environmental

A12. Reduce Steam System Generating Pressure

1. Energy savings
2. Reduced maintenance
3. Safety/environmental

B1. Improve Quality of Delivered Steam

1. Energy savings
2. Performance improvement
3. Improved reliability

B4. Minimize Vented Steam

1. Energy savings
2. Performance improvement
2. Increased capacity

B5. Repair Steam Leaks

1. Energy savings
2. Safety/environmental
3. Increased capacity

B6. Isolate Steam from Unused Lines

1. Energy savings
2. Safety/environmental
3. Reduced maintenance

B7. Improve System Balance

1. Energy savings
2. Performance improvement
3. Safety/environmental

C1. Optimize Steam Use in Pulp and Paper Drying Applications

1. Energy savings
2. Increased capacity
3. Performance improvement

C2. Optimize Steam Use in Pulp and Paper Air Heating Applications
1. Energy savings
2. Increased capacity
3. Performance improvement

C3. Optimize Steam Use in Pulp and Paper Water Heating Applications
1. Energy savings
2. Increased capacity
3. Improved reliability
3. Reduced maintenance

C4. Optimize Steam Use in Chemical Product Heating Applications
1. Energy savings
2. Increased capacity
3. Improved reliability

C5. Optimize Steam Use in Chemical Vacuum Production Applications
1. Energy savings
2. Increased capacity
3. Improved reliability

C6. Optimize Steam Use in Petroleum Refining Distillation Applications
1. Energy savings
2. Increased capacity
3. Improved reliability

C7. Optimize Steam Use in Petroleum Refining Vacuum Production Applications
1. Energy savings
2. Increased capacity
3. Improved reliability

D1. Improved Condensate Recovery
1. Energy savings
2. Performance improvement
3. Increased capacity

D2. Use High-Pressure Condensate to Generate Low-Pressure Steam
1. Energy savings
2. Increased capacity
3. Performance improvement

E1. Implement a Combined Heat and Power (Cogeneration) Project
1. Energy savings
2. Increased capacity
3. Improved reliability

Appendix H

Recommendations for Assessing the Effectiveness of the BestPractices Steam Program

Figures referenced in this section begin on page 74 in the order they are mentioned in the text.

An important objective of the BestPractices program is to increase awareness among industrial end users regarding the cost savings and performance benefits of energy projects. Achieving this objective requires outreach. As a result, a strategy of measuring the effectiveness of BestPractices must assess the effectiveness of its outreach vehicles, combining feedback from several sources. Many of these sources can be derived from the awareness-building efforts in which BestPractices currently participates, including training seminars, workshops, Allied Partners, and plant assessments. Responses from stakeholders who engage in these efforts can be valuable and should be elicited.

Other sources of feedback include the Energy Information Administration's *Manufacturing Energy Consumption Survey 1994* (MECS), and tools that BestPractices has developed. Formerly a triennial survey, MECS is a now quadrennial survey that is required of manufacturing facilities in the United States. Although the survey is intended to determine fundamental characteristics of industry energy use, it also gathers information to determine whether a facility actively participates in efforts to improve its energy use. An important advantage to MECS is the relatively large population of facilities that responds to the survey. A disadvantage is the fact that the survey is conducted every 4 years, meaning long stretches between new feedback data.

Other sources of feedback are necessary to supplement the data acquired from MECS every 4 years, and to provide a more timely sense of the effectiveness of the BestPractices Steam program. Additionally, although MECS offers access to a large population of end users, many industry participants, such as consultants and service providers, are not respondents. As feedback from this expert population is essential, it must be acquired using other means.

A common method of eliciting feedback is to issue questionnaires to people who access the tools and services of a program. Although such feedback is generally intended to assess the usefulness of the tool or service, in this case the feedback will also be used to measure the effectiveness of the sponsoring program. Because these questionnaires are typically optional, stakeholder feedback can be encouraged by promoting a sense of a common goal, to improve steam system efficiency and performance.

There are several BestPractices tools that are intended to increase awareness of the benefits of steam system management. The interest in these tools can itself be an indicator of how BestPractices is affecting general industry awareness.

Altogether, there are several principal sources of feedback data:

- Attendees of workshops/training seminars
- Feedback from event instructors;
- Recipients of the steam system sourcebook
- Allied Partners
- Recipients of the Steam System Scoping Tool
- Participants in plant wide assessments/a showcase demonstrations/case studies
- Web site activity
- MECS.

Workshops and Training Seminars

There are several workshops and training seminars that are conducted each year with participation from the BestPractices program. Examples of these workshops include "Utility System Energy Saving Techniques to Reduce Plant Operating Costs" and "Capturing the Value of Steam Efficiency—A Workshop for Plant Managers." Attendees of these events can be requested to provide feedback regarding the effectiveness both of the seminar and of BestPractices in general.

Instructor Feedback

Another important feedback resource is the set of instructors for these courses. These instructors can effectively indicate whether the content they are presenting is reaching the course attendees. These instructors can also determine whether BestPractices resources are sufficient and which program improvement opportunities are likely to be most effective.

Steam System Sourcebook

Steam BestPractices has developed a resource titled *Improving Steam System Efficiency, A Sourcebook for Industry*. The sourcebook describes improvement opportunities within the context of basic steam system operating principles. The sourcebook is a desktop reference that will increase the awareness of steam system stakeholders to the costs of inefficient operating practices. It also describes the performance and reliability benefits of improving system efficiency and provides a comprehensive list of resources that can help the user implement efficiency improvements.

Similar to the compressed air sourcebook and the pumping system sourcebook, the steam system sourcebook will be distributed to industry stakeholders. In return, OIT establishes a link to each end user that receives the reference manual. This link can be used as a means to follow up on the effectiveness of the sourcebook itself and on BestPractices in general.

The number of sourcebook recipients provides one indication of the effectiveness of the BestPractices program. Another indication of this effectiveness is direct feedback from the recipients of this sourcebook.

Steam System Scoping Tool

The Steam System Scoping Tool is intended to develop a greater awareness in industry of the opportunities to improve steam system efficiency and performance. The Scoping Tool also allows a user to compare his or her system operations against identified best practices and against other industrial facilities. The Scoping Tool encourages users to submit their facility data as part of an effort to build a database of industry practices that will allow measurement and comparison against other industrial facilities.

Although the Steam System Scoping Tool is designed to help facilities increase awareness of their own systems, the feedback from this tool can also be used to assess the effectiveness of the program that sponsored it. The Steam Scoping Tool can be used in two ways to indicate BestPractices effectiveness. The first is to track the number of requests for mail orders or downloads from the Web site. The second, and perhaps most important, is to track the number of completed results returned to BestPractices.

Allied Partner Surveys

Currently, BestPractices' Allied Partners are encouraged to provide feedback to the program in order to improve the program's overall effectiveness. A questionnaire is issued to Allied Partners annually. Allied Partners already have a relatively high awareness level of the program, its objectives, and its tools. However, Allied Partners are also industry stakeholders and can provide feedback regarding their view of the BestPractices program's effectiveness within their industries.

Case Studies, Plant-Wide Assessments, and Showcase Projects

Plant-wide assessments, showcase demonstrations, and case studies offer valuable examples with which BestPractices can demonstrate the benefits of the systems approach in managing steam systems. End users at facilities that participate in these efforts are well positioned to provide feedback that indicates how effective BestPractices tools and resources are in identifying and implementing improvement opportunities.

Plant-wide assessments have a relatively broad scope and include utility systems other than steam. These assessments often promote close contact between the industry stakeholder and the BestPractices program. This contact can facilitate extensive feedback, which can be acquired using a written tool, such as a questionnaire, as well as a verbal tool, such as an interview. Consequently, a BestPractices representative should present the questions that are provided in Figure H-6. However, instead of allowing the plant personnel to write in responses, the BestPractices representative should write up a discussion of the answers, incorporating insights obtained from verbal communication.

Plants that participate as showcase facilities are eligible for targeted assessments of their steam systems. These facilities, like those that participate in plant-wide assessments, can provide helpful feedback with respect to the effectiveness of BestPractices resources. Depending on the level of contact between the facility and the BestPractices representative, either a questionnaire or an interview should be used to obtain this feedback. In cases where the questionnaire is more appropriate, the questions like those found in Figure H-6 should be presented.

Case studies are developed based on specific projects that have been implemented. These case studies are identified from plant assessments, showcase demonstrations, and communications with industry observers and consultants. Because these case studies tend to require less interaction between the facility and the BestPractices program, a questionnaire should be used to elicit feedback from the facility.

Case study feedback can provide insight into overall industry awareness of the BestPractices program and its resources. Unlike with plant-wide assessments and showcase demonstration participants, facilities that are the subject of case studies may not have extensive contact with the BestPractices program and therefore may offer a more representative industry perspective. Additionally, many more case studies are developed each year than plant-wide assessments and showcase demonstrations. As a result, case study feedback may provide helpful indications of the success of BestPractices awareness building efforts.

Web Site Activity

Another method of measuring BestPractices effectiveness is monitoring interest in Web site resources. Counting the number of Web site "hits" and the number of file downloads of BestPractices resources can indicate the level of interest in the program's offerings. Several aspects of Web site activity can be measured including number of "visits" to each Web site page and the number of times that a file, such as a tip sheet, is accessed.

Translating Web site activity data into meaningful information first requires establishing a baseline. A baseline period of a week or a month should be selected and the number of times that the Web site is visited should be recorded. Future activity can then be compared to that baseline.

Because many BestPractices resources are available from the Office of Industrial Technologies Web site (and also from the Alliance to Save Energy's "Steaming Ahead" Web site), monitoring Web site activity can help indicate which resources are receiving the greatest amount of attention. This information can be further used to apply awareness enhancing resources where industry stakeholders find the greatest need.

Additionally, monitoring Web site activity would incorporate the measurement of interest in resources, such as tip sheets. Tip sheets are among the more instructive tools offered by BestPractices. Increased interest in these tip sheets can indicate expanding awareness of the BestPractices program and increased industry concern for improved steam system efficiency and performance.

Manufacturing Energy Consumption Survey

The Energy Information Administration, under the U.S. Department of Energy, is currently considering revising its MECS questionnaire. Several reasons were cited for this revision effort, including improving the usefulness of the survey results to industry and reducing the costs of analyzing the data. This may be an appropriate time to adjust the survey to acquire the best information available to effectively structure policy and to optimize resources that improve industrial competitiveness.

The most recent MECS used three forms to survey three groups of industries. The forms and sections that gathered data regarding energy management programs were EIA-846A (1999) Section 16, EIA-846B (1999) Section 13, and EIA-846C (1999) Section 19. Each form shares the same questions with respect to facility management and participation in energy management programs. The proposed correction to the forms is shown in Figure H-7. The added query is consistent with the other queries that are currently used.

Assessing the Data

The baseline for BestPractices effectiveness consists of the first set of questionnaires that are returned. This essentially represents the current state of how effectively BestPractices is operating now.

A proposed method for quantifying the questionnaire results is presented below. Weights are assigned to the BestPractices portion of the questionnaire (excellent = 2, adequate = 1, and inadequate = 0). Currently, these weights are arbitrary, but they can be changed in response to feedback. The percentage of respondents reflects the total population of the responses for that period.

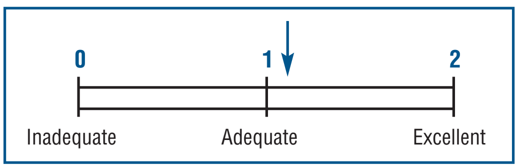
To illustrate this approach, consider the following example. Assume three workshops are presented and each has 20 attendees who provide feedback. Of this population of 60 attendees:

- 18 reported that they felt BestPractices offered excellent resources in helping them improve their steam system management
- 30 reported the resources were adequate

Example Feedback from Workshops

BestPractices Questions	Percent of Respondents	Assigned Weight	Combination
Have you used the resources?	30%	2	0.6
If yes, have they been useful or not?	Y= 50%, N=20%	1, 0	0.5, 0
Total			1.1

- 12 reported the resources were inadequate.



Effectiveness indication for this tool is plotted below:

Each outreach vehicle is assigned a weight that indicates its strength as an awareness measure. These weights are based on a ranking system from 1 to 5, with 5 being the strongest indicator. Currently, these weights are arbitrary; however, they can be modified based on feedback both from within the BestPractices program and from other sources.

Outreach Vehicle Example

Outreach Vehicle	Weight
Workshops/Training Seminar	3
Instructor Feedback	4
Steam System Sourcebook	3
Allied Partner Surveys	2
Steam Scoping Tool	3
Plant-Wide Assessments/Showcase Demonstrations/Case Studies	2
Web Site Activity	4
MECS	4

Summary Table Example

Outreach Vehicle	Frequency of Data Compilation	Annualized Intervals	Weight	Effectiveness	Total Score
Workshops/Training Seminars	Each session	Number of sessions	3	1.1	3.3
Instructor Feedback	Each session	Number of sessions	4		
Steam System Sourcebook	Semiannual	2	3		
Allied Partners Surveys	Annual	1	2		
Scoping Tool	Semiannual	2	3		
Plant Wide Assessments/ Showcase Demonstrations/Case Studies	Each event	Number of events	2		
Web Site Activity	Monthly	12	4		
MECS	Quadrennial	0.25	4		
Total					**3.3**

Implementation Plan

To begin measuring the effectiveness of the BestPractices program, questionnaires regarding the effectiveness of the outreach programs, such as seminars, workshops, and training sessions, should be developed. Although these questionnaires will also seek feedback regarding specific aspects of the workshop or seminar, they should also contain a set of standard BestPractices program questions. A suggested approach is to develop a questionnaire form that contains this set of standard questions. The instructors or sponsors responsible for developing the lesson plan or setting the agenda would add to this form to acquire the feedback that specifically applies to their seminar, workshop, or training session.

Instructor Feedback. In addition to the questionnaires returned by the attendees of the workshops and training sessions, the instructors should respond to a separate questionnaire that seeks their feedback regarding the BestPractices program. Instructors who participate in multiple events should fill out a questionnaire for each different group of attendees, in an effort to reflect the perceptions of different groups.

Allied Partner Feedback. Allied Partner survey forms can be developed using a similar approach. The survey form should be developed and a schedule for sending these forms to the Allied Partners should be set. An annual survey period is recommended.

Steam System Sourcebook. A feedback form for the Steam System Sourcebook should also be developed. After allowing a reasonable amount of time for the recipient to review the sourcebook, the follow-up questionnaire should be sent to them. This feedback effort should be incorporated into the process of sending out the sourcebook, for example, setting up a reminder message to issue the follow-up questionnaire one month after the sourcebook is shipped or downloaded.

Scoping Tool. The Scoping Tool provides two attractive types of data: (1) the number of downloads or mailing requests; and (2) completed Scoping Tool results that are returned to BestPractices. A baseline for both feedback measures should be established. Collecting information on the number of Scoping Tool downloads can be part of the Web site activity monitoring effort. Scoping Tool results that are returned should be included into a database or spreadsheet format.

Plant-Wide Assessments/Showcase Demonstrations/Case Studies. Questionnaires for the case studies, plant-wide assessments, and showcase demonstrations should be developed. Additionally, because of the relatively close contact between the industry participants in the plant-wide assessments and the showcase demonstrations and the BestPractices program, BestPractices program representatives should be encouraged to seek feedback data. Feedback obtained through verbal discussion can supplement written questionnaire responses.

Web Site Activity. Tracking interest in the Web site resources should be performed with commercially available software. The level of automation and detail of data acquisition depends on the available resources. Several companies offer a range of Web site and Web page monitoring services that count visits to a Web page and that track file downloads. The number of times that resources such as tip sheets and case studies are downloaded should be compiled on a monthly basis.

MECS. The recommended MECS questionnaire changes should be incorporated at the earliest convenience. Because 2002 is a survey year for MECS, modification to the questionnaire forms should be considered as soon as practical.

Overall Program Assessment. Assessing the overall effectiveness of the program should be performed annually. Interim updates are also recommended. Issuing, collecting, and, if necessary, revising the questionnaires should be incorporated as a normal operating task that is an integral component of other BestPractices activities. This is similar to the continuous improvement programs that many companies have adopted. Often an administrator is charged with establishing the procedures for collecting the data then entering it into a spreadsheet or database program. Reports and updates can be generated automatically. Periodic review of the questionnaires and of the program assessment techniques is recommended.

Conclusion

Measuring the effectiveness of the BestPractices program requires input from industry stakeholders. Quantifying this feedback can be an effective way of measuring whether the BestPractices program has increased industry awareness. Some sources of this feedback are derived from the tools that the program has developed and is developing. MECS provides a broad-based indication that can supplement the more frequent feedback sources. As the BestPractices program matures, hopefully feedback from these responses will indicate the following.

- More facilities are implementing steam system projects.
- More facilities are designating energy managers (champions for the energy projects).
- More resources are being added to the BestPractices repository.
- More respondents are accessing these resources.
- More respondents are reporting that BestPractices resources are helpful.

Conversely, if the BestPractices program is not successful in advancing industry awareness, its tools and outreach vehicles can be modified and improved. Much like the continuous improvement initiatives adopted by many industrial facilities, a program that constantly monitors its performance and seeks ways to improve it greatly improves its chances for success.

Figure H-1. Framework for Workshops and Training Seminars Feedback

Feedback Interval	
Each event	
Feedback Population	**Response**
Number of attendees	
Number of attendees that provide feedback	
Feedback Assessment	
Seminar Question	
Did you find the seminar useful?	
Facility Operations Questions	
Have you implemented any steam system improvements?	
Do you have an energy manager?	
Do you track the efficiency and performance of your steam system?	
If yes, do you follow a formal steam system maintenance program?	
Have you noticed improvement in system performance or efficiency?	
If there has been an efficiency gain, can you estimate the fuel savings?	
BestPractices Questions	
Have you used the resources?	
If yes, have they been useful or not?	

Figure H-2. Framework for Instructor/Sponsor Feedback

Feedback Interval	
Each seminar	
Instructor Question: Based on your views of attendee interest, how would you assess the effectiveness of the BestPractices program?	**Response**
BestPractices is making a significant impact on industry awareness.	
There is not much evidence that BestPractices is affecting industry awareness.	
BestPractices has not yet made much of an effect, but its too early to determine.	

Figure H-3. Framework for Steam System Sourcebook Feedback

Feedback Interval	
Update semianually	
Feedback Population	**Response**
Number of recipients (downloads and hardcopy mailings)	
Number of recipients that provide feedback	
Feedback Assessment	
Sourcebook Questions	
Did you use the sourcebook?	
Did the sourcebook assist in identifying improvement projects?	
How many projects have you implemented?	
Have these projects made a measurable difference in energy costs?	
If there has been an efficiency gain, can you estimate the fuel savings?	
Do you have an energy manager?	
Do you track the efficiency and performance of your steam system?	
If yes, do you follow a formal steam system maintenance program?	
Have you noticed improvement in system performance or efficiency?	
If yes, can you estimate the fuel savings?	
BestPractices Questions	
Have you used the resources?	
If yes, have they been useful or not?	

Figure H-4. Framework for Steam System Scoping Tool Feedback

Feedback Interval	
Semiannual	
Feedback Population	**Response**
Number of recipients (both downloads and hardcopy mailings)	
Number of recipients that provide feedback	
Feedback Assessment	
Sourcebook Questions	
Have you implemented any steam system improvements?	
Do you have an energy manager?	
Do you track the efficiency and performance of your steam system?	
If yes, do you follow a formal steam system maintenance program?	
Have you noticed improvement in system performance or efficiency?	
If yes, can you estimate the fuel savings?	
BestPractices Questions	
Have you used the resources?	
If yes, have they been useful or not?	

Figure H-5. Framework for Allied Partner Surveys Feedback

Feedback Interval	
Annual	
Feedback Population	**Response**
Allied Partners	
Number of Allied Partners that provide feedback	
Feedback Assessment	
Have you implemented any steam system improvements?	
Do you have an energy manager?	
Do you track the efficiency and performance of your steam system?	
If yes, do you follow a formal steam system maintenance program?	
Have you noticed improvement in system performance or efficiency?	
If yes, can you estimate the fuel savings?	
BestPractices Questions	
Have you used the resources?	
If yes, have they been useful or not?	

Figure H-6. Framework for Plant-Wide Assessments/Showcase Demonstrations/ Case Studies Feedback

Feedback Interval	
Each case	
Facility Operations Questions	**Response**
Have you implemented any steam system improvements?	
Do you have an energy manager?	
Do you track the efficiency and performance of your steam system?	
If yes, do you follow a formal steam system maintenance program?	
Have you noticed improvement in system performance or efficiency?	
If there has been an efficiency gain, can you estimate the fuel savings?	
BestPractices Questions	
Have you used the resources?	
If yes, have they been useful or not?	

Figure H-7. Representation of MECS Queries and the Proposed Modification

	Participate		Cost Paid by This Establishment			
	Yes	No	None	Some	All	Don't Know
Energy Management Activities						
Energy audits						
Electricity load control						
Power factors correction or improvement						
Equipment installation or retrofit for the primary purpose of using a different energy source						
Standby generation program						
Equipment installation or retrofit for the primary purpose of improving energy efficiency, affecting these systems:						
Steam production /system						
Compressed air system						
Direct/indirect process heating						
Direct process cooling, refrigeration						
Energy Management Activities						
Direct machine drive						
Facility heating, ventilation, and air conditioning, excluding Energy Star Program						
Facility lighting, excluding Green Lights Program						
Indicate only whether the establishment participated in the energy-management activity.						
Special rate schedule						
Equipment rebates						
U.S. Environmental Protection Agency's Energy Star Program						
U.S. Environmental Protection Agency's Green Lights Program						
U.S. Department of Energy's Motor Challenge Program						
U.S. Department of Energy's BestPractices Steam						
Indicate any other energy management activities not specified above, including other government programs.						
Specify						
Does this establishment have a full-time energy manager?						

For more information, please contact:

OIT Clearinghouse
Phone: (800) 862-2086
Fax: (360) 385-8303
clearinghouse@ee.doe.gov

Visit our Web site at www.oit.doe.gov

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