STEAM PARTNERSHIP: IMPROVING STEAM SYSTEM EFFICIENCY THROUGH MARKETPLACE PARTNERSHIPS

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ABSTRACT

Steam systems offer many opportunities for cost-effective efficiency improvements. The Alliance to Save Energy, a national nonprofit organization based in Washington DC, and the U.S. Department of Energy are working with energy efficiency suppliers to promote the comprehensive upgrade of industrial steam systems. Like EPA's Green Lights and DOE's Motor Challenge, the Steam Partnership program will encourage industrial energy consumers to retrofit their steam plants wherever profitable. The Alliance has organized a "Steam Team" of trade associations, consulting engineering firms, and energy efficiency companies to help develop this public-private initiative.

OVERVIEW

In order to put the Steam Partnership program into proper context, this paper is intended to give an overview of steam use in U.S. industry and its importance to our nation's economy. It describes a variety of steam efficiency technologies and practices that can unlock significant efficiency opportunities and help boost industrial productivity and profitability. Finally, it outlines the goals and structure of a new DOE initiative, the Steam Partnership program

Improving the energy efficiency of industrial steam plants is a significant opportunity for U.S. industry to improve plant productivity and reduce many of the costs associated with production. The Alliance to Save Energy estimates that roughly 2.8 quads (2,800 trillion Btu) of energy could be saved through cost effective energy efficiency improvements in industrial steam systems. The energy savings, worth approximately $6.3 billion (1995 dollars), could be invested in new processes and equipment to improve productivity.

Unfortunately, several factors interfere with the efficient production of steam. First, many boiler operators are not aware of steam system efficiency opportunities and have not been properly trained to look for them. Secondly, industrial plant managers often fail to recognize the importance of the boiler house or appreciate steam's role in the production process. When this happens, boiler operators and maintenance staff soon get the message, "....efficient operation of the steam system is not a priority."

Finally, operators and managers are rarely aware of steam costs. Too often steam and other utilities (e.g., compressed air and chilled water) are separated from the other factors of production - - both physically and in the financial accounting system. As a result steam costs are not assigned to individual processes or production lines. Instead, they are treated as a fixed cost and assumed to be uncontrollable.

Energy-efficient steam systems, like efficient motor and lighting systems, can generate significant savings through reduced fuel consumption. Improving energy efficiency is one of the best and least capital-intensive ways of conserving energy and reducing the amount of pollution that goes up the stack. The Alliance to Save Energy has found no lack of information on specific steam technologies, however, there is little information on steam *system* efficiency. That is why the Alliance, the Department of Energy, and the energy efficiency industry are working to correct this situation through a public-private initiative focusing on steam system efficiency. The goal of this program is assemble steam efficiency information and provide a delivery system to facilitate industry access and use.

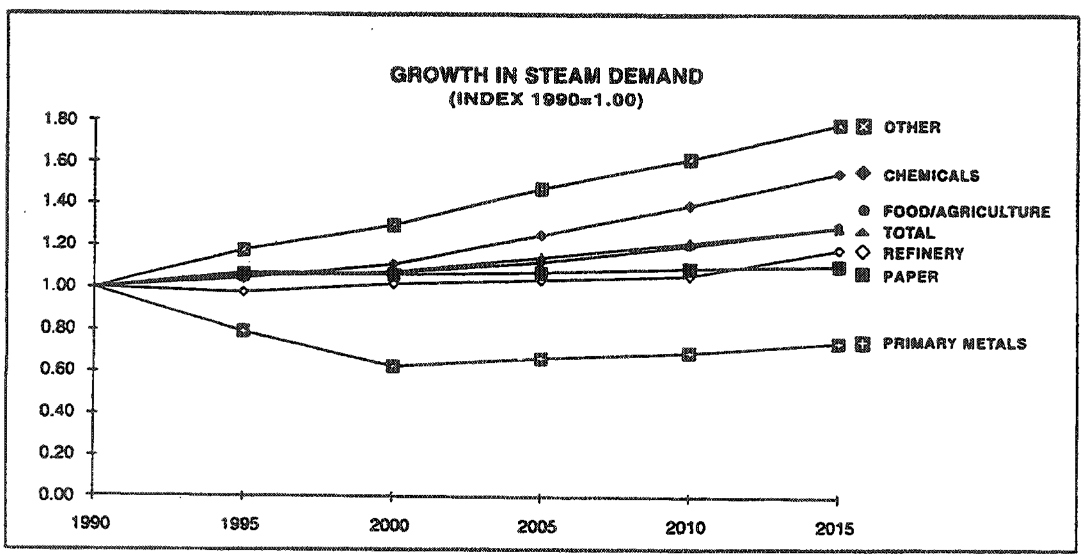
WHY STEAM IS IMPORTANT
U.S. industry uses a lot of steam. In 1995, U.S. manufacturers consumed roughly 16.55 quadrillion Btu (quads) of energy for heat, power, and electricity generation.[1] According to the Council of Industrial Boiler Owners, approximately two-thirds of all the fuel burned by these companies is consumed to raise steam, representing approximately 9.34 quadrillion Btu of the 1995 energy total.[2]

The U.S. manufacturing economy depends on over 54,000 large boilers to produce steam for process use, to drive mechanical equipment (e.g., pumps and fans), and to generate electricity. It costs U.S. industry approximately $21 billion (1995 dollars) a year to feed these boilers.[3]

After the fuels are burned, emissions are released into the atmosphere that cause air pollution and global warming. Each year U.S. industry releases approximately 196 million metric tons of carbon dioxide while producing steam.[4] These emissions represent over 40 percent of all U.S. industrial emissions of carbon dioxide and over 13 percent of total U.S. emissions.

Total demand for steam is projected to increase 20 percent in five major industries by 2015 (compared to 1990 levels), with demand in food processing and chemicals being even greater. Industrial requirements for steam are increasing most rapidly in the "other" category, which includes rubber, plastics, industrial machinery, and transportation equipment (See Figure 1).

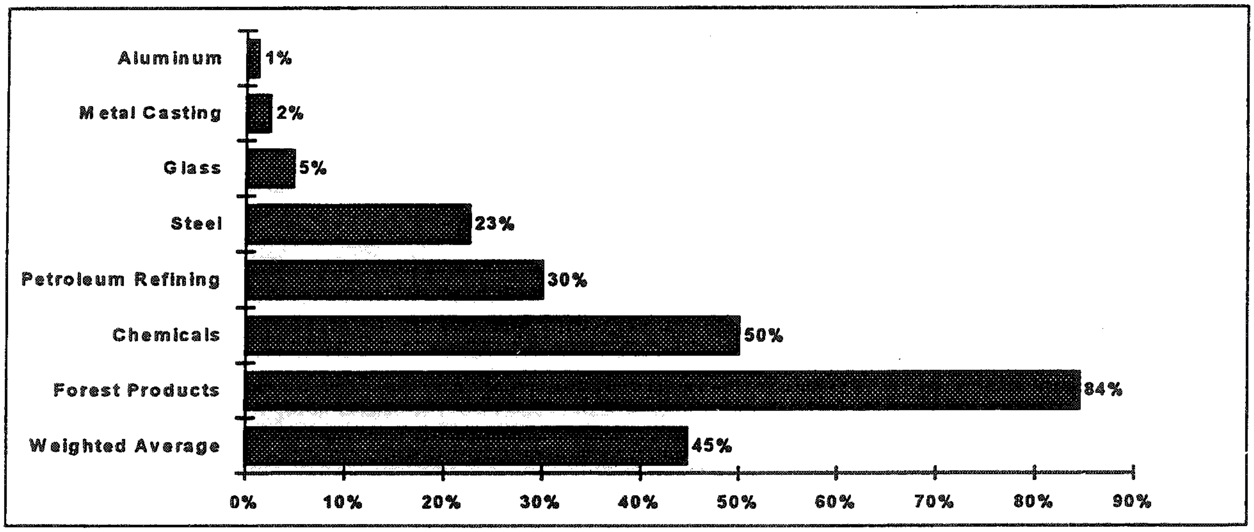
Figure 1. Growth in Steam Demand by Industrial Sector from 1990 to 2015.[5]



The seven industries represented in DOE-OIT's Industries of the Future Program are among the most energy and waste intensive in U.S. industry. When OIT examined the importance of steam in these industries, they found that on a weighted average basis, approximately 45 percent of their total energy consumption was used to raise steam.

The proportion of total energy used for steam was especially high in forest products, chemicals, petroleum refining, and steel (See Figure 2). There is a high degree of overlap between DOE's seven industries and the most steam-intensive industries, which include chemicals, pulp and paper, food and kindred products, and petroleum refining.

Figure 2. Percent of Total Energy Used by DOE-OIT Focus Industries to Produce Steam[6]



STEAM ENERGY EFFICIENCY POTENTIAL

Because steam distribution losses can have a significant impact on boiler operations, the efficiencies of boilers and their distribution systems are closely interrelated. For this reason, we have defined the energy efficiency potential for industrial steam systems *as the total of all the cost effective efficiency opportunities in steam generation, distribution, and application, as well as in steam system operation and maintenance*. The Alliance estimates that a total steam system efficiency potential of 30 to 40 percent is available to U.S. industry in three major areas: boilers, steam system operation and maintenance practices, and steam distribution (condensate return) opportunities. (See Table 1).

Table 1. Steam System Efficiency Potential

Boilers	**2-5%**
- boiler tune-ups	1-2%
- heat recovery equipment	2-4%
- emissions monitoring and control	1-2%
System Operation and Maintenance	**10-15%**
- water treatment	10-12%
- load control	3-5%
Distribution System	**15-20%**
- steam leaks and traps	3-5%
- condensate return	10-15%
- insulation	5-10%
Total	**30-40%**

There is a significant range of operating efficiencies for boilers, depending on the type of fuel, the use of heat recovery equipment, and the operating load. A total steam efficiency potential of 30 to 40 percent appears reasonable when using a systems approach. If all U.S. manufacturers improved the efficiency of their steam systems by even 30 percent they would save approximately 2.8 quadrillion Btu of steam energy - - enough to supply the total energy needs of Michigan for a year, generate dollar savings of $6.3 billion (1995 dollars), and reduce emissions by 60 million metric tons of carbon dioxide and 30 thousand metric tons of nitrous oxide.

Steam system efficiency is a global opportunity as well, representing an energy savings potential that is five times greater than in the United States alone. Developing countries dedicate a large portion of their scarce energy resources to generate steam. Many of these countries are facing high growth rates and it is uncertain where the energy will come from to meet future demand. If the steam efficiency technologies described here were more widely adopted internationally, energy demand could be reduced by at least 14 quads and carbon dioxide emissions could be reduced by over 250 million metric tons.[7]

ACHIEVING EFFICIENCY GAINS THROUGH STEAM TECHNOLOGIES AND PRACTICES

Industrial steam systems contain many cost-effective efficiency opportunities. Each opportunity, by itself, may appear small, improving energy efficiency only a few percentage points. However, the energy savings can add up quickly. Common examples of steam system efficiency opportunities in steam generation, distribution, and operation/maintenance are discussed below.

Opportunities in Steam Generation

Boiler efficiency is the percentage of the fuel's energy which is converted to steam energy. Substantial energy losses are caused by waste heat literally going "up the chimney, " or stack. Therefore, reducing stack losses is probably one of the greatest opportunities to improve steam generation efficiency. Incomplete combustion and heat loss from exterior boiler surfaces can also cause significant losses. Together, these losses can reach 30 percent of the fuel input. The three basic strategies for minimizing stack gas heat loss are:

(1) minimizing excess air in combustion
(2) keeping heat transfer surfaces clean
(3) adding flue gas heat recovery equipment where justified

Assuming boilers are in good repair and properly maintained, the average efficiency of boilers ranges from 76 to 81 percent on natural gas, 78 to 84 percent on oil, and 81 to 85 percent on coal. These efficiency levels can be improved by 2 to 5 percent, on average, with boiler tune-ups and auxiliary equipment where economically justified.[8] Unfortunately, many boilers are not properly operated and maintained. Without proper operation and maintenance practices fuel handling equipment can get worn, burners and controls can get out of adjustment, boiler water and flue gases are not properly treated, and hot condensate is not recovered. As a result of these conditions steam system efficiency can be significantly reduced. As a rule of thumb, if a boiler has not been maintained for two years, a 20-30 percent gain of efficiency is immediately possible through maintenance.[9]

Boiler losses can be reduced with combustion controls and waste heat recovery equipment such as combustion air preheaters and economizers. The economics can be very attractive with boiler efficiency increasing 1.0 percent for each 15 percent reduction in excess air, 1.3 percent reduction in oxygen, or 40°F reduction of stack gas temperature. For new or expanding plants, proper boiler design can have a significant impact on the efficiency of steam utilization as well.

Using emissions monitoring equipment not only helps plant operators track emissions, it can also lower plant energy bills. Researchers from the North Carolina State University evaluated the performance of continuous emissions monitoring systems on industrial boiler efficiency. The monitoring systems reduced excess air by 30 percent (under low fire conditions) and 15 percent (under high fire conditions). These adjustments are projected to reduce stack loss by 1.4 percent. The resulting energy savings were enough to achieve a simple payback of 2.5 years.[10]

Opportunities in Maintenance and Operation

There are many opportunities to improve the efficiency of both boilers and the steam distribution system through improved maintenance and operation. A few examples are discussed below.

- **Water Treatment**. Water treatment is an important aspect of boiler operation which can affect efficiency or result in plant damage if neglected. For instance, without proper water treatment, scale can form on boiler tubes, reducing heat transfer and causing a loss of boiler efficiency of as much as 10 to 12 percent.[11] Water treatment represents a substantial portion of overall boiler operating costs. Therefore, improved efficiency throughout the steam system reduces a this significant operating cost.

- **Condensate Return.** Recovering hot condensate for reuse as boiler feed water is another important way to improve efficiency of the system. The energy used to heat cold makeup water is a major part of the heat delivered for use by the steam system, requiring an additional 15 to 18 percent of boiler energy for each pound of cold makeup water.

- **Load Controls.** There have been great advances in boiler control technology as older pneumatic and analog electronic control systems have given way to digital, computer-based distributed control systems. These systems are more reliable and can extend boiler life. Modern, multiple burner control, coupled with air trim control can result in fuel savings of 3 to 5 percent.[12] For example, a boiler economic load allocation system optimizes the loading of multiple boilers providing steam to a common header so as to obtain the lowest cost per unit of steam. Honeywell Inc.'s Industrial Automation and Control Division commonly recommends this technology to help customers reduce boiler fuel consumption by 1 to 3 percent and improve performance.[13]

Steam Distribution

Taking care of the steam distribution system is often considered to be part of good steam system maintenance. In terms of efficiency, the two do overlap; however, individual steam distribution energy savings can be substantial and merit separate treatment. Steam leaks, steam traps, and insulation are a few of the most rewarding energy efficiency opportunities. On average they can improve a steam systems energy efficiency from 10 to 15 percent. Below are a few examples of steam efficiency opportunities in the distribution system.

- Steam Leaks. A neglected steam distribution system can be very costly. In such systems, leaks will be found in the piping, valves, process equipment, steam traps, flanges, or other connections. Fixing steam leaks is a simple, no cost/low cost opportunity to save energy and money. Steam systems can realize a 3 to 5 percent efficiency improvement when steam leaks are actively identified and repaired.

- Steam Traps. Saving energy through a steam trap maintenance program can seem "too good to be true," yet, the savings are often dramatic. In the absence of a maintenance program, it is common to find 15 to 20 percent of a plant's steam traps to be malfunctioning. Energy efficiency gains of 10 to 15 percent are common when steam traps are actively maintained. Armstrong International estimates that, on average, each defective trap wastes over 400,000 lbs of steam a year, worth over $2,000.[14] These savings can add up quickly, especially for plants with many traps. For instance, a typical petrochemical plant will have over 5,000 steam traps, and can save hundreds of thousands of dollars in single year. Savings are also significant for medium-sized plants that often have a couple thousand traps, and even small plants commonly have several hundred.

- Insulation. A recent analysis estimated the economic conservation potential of thermal-insulation related efficiency to be 5 percent or less of total industrial energy use. However, plants audited under DOE's Industrial Assessment Center program demonstrated a savings potential ranging from 3 percent to as high as 13 percent of total natural gas usage on average.[15] When a Georgia-Pacific plywood plant in Madison, Georgia, upgraded the insulation on the steam lines to its dryers, the plant was able to cut steam usage by approximately 6,000 lbs./hour, eliminate the use of purchased fuel, reduce CO2 emissions by 6 percent, and achieve a 6-month payback on investment[16]

WHAT IS THE STEAM PARTNERSHIP PROGRAM?

Although information about specific steam technologies is readily available, there is little public information that addresses the benefits of improving the efficiency steam plants as a system, including generation, distribution, application, and return. That is why a program is needed to:

(1) *improve* industrial competitiveness through enhanced productivity and lower production costs
(2) *provide* steam plant operators with the tools and technical assistance they need to improve the efficiency of their steam plants, and
(3) *promote* greater awareness of the energy and environmental benefits of efficient steam systems though improved technology and operation.

The Alliance to Save Energy and the Department of Energy's Office of Industrial Technologies are developing a public-private partnership to address the efficiency needs of industrial steam systems. Leading providers of energy efficient steam products and services are working with DOE and the Alliance to develop the program. As envisioned, the program will have three basic components:

HOW IS THE STEAM PARTNERSHIP STRUCTURED?

As envisioned, the Steam Partnership program will have three major components - Steam Challenge, Steam Team, and Steam Partners.

Steam Challenge

This program component consists of a voluntary energy efficiency program targeted to the needs of industrial steam "systems". Rather than promoting the energy savings of any single steam efficiency technology, this program will take a comprehensive approach to promote greater awareness of energy efficiency and pollution prevention opportunities throughout the steam system - from the burner to the boiler, to distribution, to the process, and back to the boiler.

Modeled after DOE's successful Motor Challenge Program, the Steam Partnership program will invite industrial companies to take advantage of the program's technical resources on steam efficiency (see below). In addition, industrial companies will be encouraged to make voluntary commitments to improve their steam plant's efficiency wherever profitable.

Steam Team

The Alliance is organizing a "Steam Team" of trade associations and companies from each of the relevant steam efficiency industries to support the steam efficiency program. Today, the Steam Team includes, Association of Energy Engineers, the North American Insulation Manufacturers Association (NAIMA), the American Gas Association (AGA), the Council of Industrial Boiler Owners (CIBO), Armstrong International, Honeywell Inc., and Spirax -Sarco Engineering. It is anticipated that additional manufacturers (and associations) of other steam-related technologies, such as boilers, water treatment, burners, heat exchangers, diagnostic analysis equipment, pumps, and service providers, such as energy service companies and consulting engineering firms, will also be invited to participate. The Steam Team participants are assisting in developing a plan and undertaking activities to help promote the steam system efficiency concept.

In addition, the Steam Team are contributing materials to be used as educational tools and materials. The goal of this activity is to centralize steam efficiency information that is objective, technically competent, and easy to use. Below are a variety of information tools and activities that the Steam Team is considering:

- Developing a clearinghouse of existing information on individual steam technologies
- Integrating existing information to promote efficient steam systems
- Coordinating the use of training and education materials for steam workshops
- Developing Steam Efficiency Software Tools

- Developing Steam System Auditing Procedures
- Developing a Steam Efficiency Technical Assistance Hotline/Webpage
- Directory of Steam Technology Suppliers and Service Providers
- Producing publications highlighting the potential savings in steam systems
- Demonstration of energy efficient steam technologies and practices through showcase demonstrations

Steam Partners
The Alliance plans to involve many organizations servicing the energy needs of industry to help deliver the "steam efficiency" message. These organizations include the Association of Energy Engineers, DOE's Industrial Assessment Centers, state and local manufacturing assistance centers, state energy offices, electric and gas utilities and industry trade associations. Another major deliverer of the Steam Partnership Program would be the marketing and sales staff of the energy efficient product manufactures participating in the effort.

Centralizing public and private information on steam efficiency and developing tools to match the needs of industrial end-users are important objectives of the Steam Partnership program. Using both public and private resources, the partnership will be able to generate greater awareness of steam efficiency and its economic, energy, and environmental benefits.

STEAM EFFICIENCY RESOURCES
As mentioned previously, good information exists on individual steam technologies, but there is little to be found on steam *systems* efficiency. The Alliance to Save Energy has collected some preliminary information on steam efficiency. Below is a brief overview of information resources that are currently available.

- **North American Insulation Manufacturers Association** - 3E Plus Software, Georgia Pacific Case Study, study of the energy and efficiency benefits of industrial insulation, industrial insulation fact sheets and brochures, and NAIMA's Commercial and Industrial Operating Committee.
- **American Gas Association** - a variety of publications relating to natural gas technologies, industrial energy use trends, equipment profiles, and AGA's Commercial and Industrial Marketing Committee.
- **Industrial Gas Technology Commercialization Center** - a variety of publications relating to new natural gas technologies in the industrial sector.
- **Council of Industrial Boiler Owners** - a wide variety of publications on environmental emissions, cogeneration, boiler technologies, and alternative fuels. Currently drafting an energy efficiency handbook for power plant operators. CIBO has over 65 members representing 19 major industries.
- **Honeywell Inc.** - A *Journal on Industrial Automation* and Control, Honeywell's *Industrial Energy Notes*, case studies, boiler diagnostic software.
- **DOE-OIT:** Information on low emission burners for boilers, industrial heat pumps, process integration using pinch technology, and high performance steam.
- **Armstrong International** - Three worldwide factory seminar facilities, 13 North American sales representative facilities, 4 international sales representative facilities, 8 co-sponsored facilities, 2 mobile seminar vans, extensive library of video tapes, Armstrong Preventive Maintenance software, CD-Rom, *Trap Magazine*, database of steam trap performance.
- **DOE-EPA Climate Wise Program** - provides technical assistance, workshops, seminars, and case studies on energy efficiency to participating companies.[17]

CURRENT PROGRAM ACTIVITIES

On January 16, 1997, the Alliance to Save Energy and the Department of Energy's Office of Industrial Technologies met with representatives from ten key organizations to discuss how the steam partnership program should be structured.[18] The meeting participants strongly supported the steam initiative Currently, the program is pursuing the following initiatives:

Identify Industry's Greatest Steam Information Needs

The Steam Partnership is conducting focus groups to determine what types of steam efficiency information and services would be most useful to plant operators and most likely to garner the support of industrial decisionmakers. Over the next six months, the Alliance and DOE should work closely with industrial steam users through focus groups and roundtable meetings to obtain this information and draft a product development plan based on the results.

Centralize Steam Information

Many of the meeting participants have access to excellent steam information, such as case studies, product descriptions, bibliographies, fact sheets, diagnostic software, product and service provider lists, and education and training materials.[19] The Steam Partnership is in the process of making these resources available to a wider audience by developing a steam efficiency information kit and a dedicated steam efficiency webpage.

Develop a Steam Efficiency Diagnostic Tool

Several software tools are now available for individual steam technologies, such as steam traps, insulation, and boiler controls. The Partnership is investigating the possibilities of linking these software tools together and incorporating other steam "modules" (i.e., water treatment, boiler tune-up, common steam applications) in order to estimate comprehensive steam efficiency potential. By incorporating historical data, this steam software tool could also be used to benchmark a particular steam system's relative performance *vis-à-vis* an industry average or best practice.

Raise the Visibility of Utility Cost

In terms of cost, it is important for the Steam Partnership to raise the visibility of supplying utilities to the plant. Plant managers sometimes treat energy (which ranges from 3 to 13 percent of production costs) as a fixed cost, when in fact it is a variable cost that is very much within their control.

Consider Non-Energy Benefits of Efficiency

In addition to energy cost savings, the Steam Partnership should highlight non-energy benefits, or "co-benefits." These benefits include the environmental benefits, worker safety and health, and productivity improvements associated with steam efficiency. Public recognition that comes from participating in a public-private program may also prove compelling to industrial decisionmakers.

CONCLUSION

The Steam Partnership is a unique opportunity to increase industry's awareness of energy efficiency, achieve major energy and cost savings, and improve productivity. Creating a working partnership between the U.S. Department of Energy and the wide range of companies servicing industrial steam systems is critical to the program's success. The three program components (Steam Challenge, Steam Team, and Steam Partners) represent the core activities of the Steam Partnership program. While the program's initial focus is the U.S. industrial sector, there is interest in expanding the program to include other steam-intensive sectors, such as schools, hospitals, municipal district heating systems, the Federal government, and internationally.

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[17] Climate Wise is a voluntary program sponsored by DOE and EPA. Participating companies volunteer to reduce their greenhouse gas emissions by implementing energy efficiency and pollution prevention measures. Climate Wise partners receive public recognition and awards for their achievements.

[18] The following organizations participated in the January 16, 1997 Steam Power Partnership Planning meeting: Alliance to Save Energy, American Gas Association, Armstrong International, Council of Industrial Boiler Owners, DOE-EPA's Climate Wise Program, DOE's Office of Industrial Technologies, DOE's Motor Challenge Program, EPA's Office of Policy, Planning and Evaluation, Honeywell, Inc., Lawrence Berkeley National Laboratory, North American Insulation Manufacturers Association, and Plum Street Enterprises. A meeting summary is available from the Alliance to Save Energy, 202-857-0666.

[19] In fact, the author is currently collecting information on steam technologies and steam system efficiency opportunities and would appreciate additional contributions.