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March 1982

Prepared for the U.S. Department of Energy
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Pacific Northwest Laboratory
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PREFACE

This report provides a review and synthesis of several significant studies that were conducted to assess R&D needs and opportunities for advanced energy conservation systems. The authors feel that it is important to emphasize that this effort was not intended to be a comprehensive review of the energy conservation research literature. The purpose of this study was primarily to provide information that could be used in identifying candidate R&D opportunities for a companion report, An Overview of Energy Conservation Research Opportunities. It is also important to note that the studies that were reviewed in each of the energy end-use areas are not necessarily the most widely known or most complete studies that have been performed in those areas. Rather, this report provides a preliminary overview of a representative sample of 38 energy conservation research opportunities studies using a consistent critical review format. This format allows a comparison of the types of information typically provided in the reports and initial development of a master catalog of the energy conservation and research opportunities that have been identified by a variety of sources.

This report is one of a series of studies in support of the research planning effort for the Division of Energy Conversion and Utilization Technologies in the U.S. Department of Energy. Other documents in the series contain assessments of energy conservation technology areas, methods to appraise research projects for support, and data reference sources. Publications from this project include:

Hopp, W. et al. 1981. An Overview of Energy Conservation Research Opportunities. PNL-3944, Pacific Northwest Laboratory, Richland, Washington.

Hopp, W. et al. 1981. An Overview of Energy Conservation Research Opportunities. Executive Summary. PNL-3944 Ex. Sum., Pacific Northwest Laboratory, Richland, Washington.

Imhoff, C. H. et al. 1982. U.S. Energy Conversion and Use Characteristics. PNL-4075, Pacific Northwest Laboratory, Richland, Washington.

U.S. Department of Energy. 1981. The 1981 Work Element Appraisal. DOE/CE-0024, U.S. Department of Energy, Washington, D.C.

T. L. Willke
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1.0 INTRODUCTION

Identifying research opportunities that will promote more efficient energy use is an immense task that many authors have addressed from various perspectives and with a variety of results. Consequently, a vast diversity of literature concerning opportunities for energy conservation research exists. A representative sample of this literature is reviewed with two purposes in mind: first, to synthesize the studies' results to provide a broad list of the suggested research ideas and second, to produce an overview of the studies to guide the use of this literature. This list forms a pool of candidates that can be investigated further and that is drawn upon in the companion report, An Overview of Energy Conservation Research Opportunities (Hopp et al. 1981). These reports are sponsored by and written in support of the Energy Conversion and Utilization Technologies Program of the U.S. Department of Energy (DOE).

In this report 38 studies of energy conservation research opportunities are reviewed. A list of the titles and authors for these studies is presented in the Table of Contents. Note that this effort was not intended to be a comprehensive review of the literature. Many other studies identify energy conservation research opportunities, and a more extensive bibliography including 50 additional reports has been developed by the PNL assessment staff and is included in Appendix B. However, the 38 studies chosen for review include many of the major efforts in the identification of energy conservation research and development (R&D) opportunities and provide a representative sample of the types of studies that have been performed. The sample includes studies that focus on specific energy use (e.g., auto transport), as well as studies that focus on specific types of research (e.g., materials science). The sample also includes studies that can be further contrasted in terms of long-term vs. short-term projects, evolutionary vs. revolutionary ideas, generic vs. process-specific activities, and technology base research vs. hardware development. Each of these perspectives contributes toward assuring coverage of the breadth of energy conservation R&D opportunities.

In reviewing the 38 studies the PNL assessment staff commented on the documents through a predetermined review format, which is presented in

Appendix B. In each review the technical or end-use focus is described, the research ideas identified in the study are listed, and a critical summary is given. The reviews also indicate whether the studies present end-use consumption data, estimate potential energy savings, estimate times to commercialization, summarize existing research programs, or describe the identification methodology.

A consistent summary of the studies as a whole and of the suggested research ideas provides an insight into the work that has been done to date on identifying energy conservation research opportunities. The descriptions of the individual research ideas allow a comprehensive list of topics that have been identified in the literature to be synthesized and categorized. This list may not be well justified or may not necessarily consist of promising ideas, but is a broad and complete list because it is a combination of the lists prepared in the other studies. Also, identifying each study's focus enables topical areas that have and have not been adequately covered to be systematically reviewed. This review permits an assessment of technology areas that may need further analysis of energy conservation opportunities. Further, identifying specific types of information provided by each study allows its comprehensiveness to be compared to other similar efforts. It also allows the critical reviews to act as an annotated bibliography for persons reviewing the literature.

In Section 2.0 the various research studies are compared. In Section 3.0 the characteristics of an aggregated list of research ideas are discussed. The characteristics were collected from the research opportunities studies, which are included in Appendix A. Appendix A contains a compilation of energy conservation R&D opportunities arranged by energy end-use applications. Appendix B contains an outline of the format followed in writing the critical reviews of the studies, the individual study reviews and the extended bibliography of 88 studies that describe energy conservation research opportunities.

2.0 RESEARCH OPPORTUNITIES STUDIES

The critical reviews of the 38 research opportunities studies examined in this report indicate whether the following five types of information are presented in each document:

(1) reviews of energy consumption data

(2) estimates of the conservation potential of the technologies under consideration

(3) estimates of the commercialization dates or research times of the technologies

(4) summaries of existing research programs relating to the technologies

(5) a description of the method for identifying energy conservation research opportunities used in the study.

In Table 2.1 the types of information and also the focus and the approximate number of research opportunities identified in each report are indicated. The first columns in this table refer to the numbering system used for the reports in the Table of Contents. This summary can serve as a guide to the usefulness of the various studies for different applications. It also allows some interesting comparisons and generalizations to be made about the studies.

The first characteristic that is apparent from the information in Table 2.1 is a correlation between the focus of the report and the level of specificity of the research opportunities identified in the report. The research opportunities in each report have been classified as "specific," "intermediate," and "general." "Specific" research opportunities refer to ideas for which both particular technical problems relating to energy conservation have been identified and research solutions have been proposed. An example of this might be "development of longer-lasting titanium diboride cathodes to improve the efficiency of the aluminum smelting process." "Intermediate" refers to ideas for which particular problems or needed improvements have been identified, but for which research solutions have not been specified. An example might be

TABLE 2.1. Summary of Research Opportunities Studies

Report Number from Biblio.	Focus of Report	Reviews End-Use Consumption Data	Estimates Conservation Potential of Technologies	Estimates Time to Commercialization of Technologies	Summarizes Existing Research Programs	Gives and uses a Methodology for Identifying Research Opportunities	Approximate Number of Research Opportunties Identified	Level of Specificity of Research Opportunities
1	Cement Industry	yes	no	no	no	partially	4	general/inter.
2	Iron & Steel Industry	yes	yes	yes	yes	yes	30	intermediate
3	Combustion Engines	no	no	no	no	no	20	intermediate
4	Physics-Oriented Conservation Research	yes	no	no	no	yes	75	intermediate
5	Mech. Engineering R&D Needs	no	no	no	no	no	10	general
6	Broad Conservation R&D	no	no	no	no	no	6	general
7	Transportation Sector	yes	no	partially	no	no	2	general
8	Chemicals Industry	yes	no	no	no	no	3	general/inter.
9	Steel Industry	yes	yes	yes	yes	yes	93	specific
10	Iron & Steel Industry	yes	partially	partially	yes	no	15	medium
11	Industrial Energy Conservation	no	no	no	no	no	150	specific/inter.
12	National Energy Scenarios	yes	no	no	no	no	50	intermediate
13	Mech. Engineering R&D Needs	no	no	no	no	no	10	general
14	Fluid Waste Heat Recovery	no	yes	yes	yes	no	100	specific
15	Textiles Industry	no	yes	partially	yes	no	40	specific/inter.
16	Heat Transfer	no	no	no	yes	no	13	intermediate
17	Agriculture Industry	no	yes	yes	no	no	90	specific
18	Agricultural Production	no	yes	yes	no	no	110	intermediate
19	Fluid Waste Heat Recovery	no	yes	partially	no	no	93	specific/inter.
20	High Temp. Waste Heat Recovery	no	yes	partially	no	no	15	intermediate
21	Materials	no	no	no	yes	no	19	general/inter.
22	Advanced Industrial Tech.	partially	no	no	no	yes	110	intermediate
23	Fluid Dynamics & Thermal Process	no	no	no	no	yes	100	specific
24	Paper and Allied Products	no	partially	no	no	no	2	specific
25	Steel Industry	no	no	partially	no	no	20	general
26	Automobile R&D	yes	yes	no	no	yes	12	intermediate
27	General Basic R&D Needs	no	no	no	no	no	30	inter/general
28	Tribology	no	no	no	yes	no	9	intermediate
29	Lubricant Technology	yes	yes	no	partially	partially	5	intermediate
30	Industrial Conservation	yes	no	no	no	no	2	general
31	Conservation Budget/ Recommendation	yes	partially	no	no	no	10	intermediate
32	Residential Energy Conservation	yes	no	yes	yes	partially	50	intermediate
33	Combustion Processes	no	no	no	yes	no	5	general
34	Tribology	yes	yes	partially	partially	yes	40	intermediate
35	Paper and Pulp Industry	yes	yes	yes	no	yes	46	general/specific
36	Space Heat, Cogener., Auto	yes	no	no	no	yes	10	specific/general
37	National Energy Policy	yes	partially	no	no	no	20	inter/general
38	Stirling Engines	no	no	no	no	yes	2	specific

"decreased rolling resistance in automotive tires." "General" research opportunities merely refer to ideas in which end-use areas or topics where research would presumably promote energy conservation have been identified. Examples might be research into "space heating of buildings" or "tribology." The major end-use or research focus of each report is also identified in Table 2.1. In some reports a particular area of energy use, such as the agricultural industry, is examined, whereas a particular generic research area, such as fluid dynamics, is the focus for others. In still other reports an attempt is made to cover the entire energy end-use spectrum and to consider all types of generic research. A review of Table 2.1 clearly indicates that the studies with very limited focuses, for example, to a particular industry or technology, tended to be much more specific in their descriptions and listed more research opportunities. The studies that attempted to cover a broad scope of end uses or technologies tended to be much more general in their discussions and listed fewer broad areas of research opportunities. This pattern is not surprising because identifying research opportunities in energy conservation is so broad that comprehensive and in-depth coverage is a difficult task.

Cataloging the research opportunities studies by their area of focus is another way to systematize the literature search process and to identify gaps in the literature. In Table 2.2 the studies are categorized according to their end-use focus. This summary shows that the buildings and transportation end-use sectors are well represented in the sample of 38 studies reviewed. Reports from the major manufacturing industries plus agriculture were also included in the reviews; however, because industry is composed of diverse technology areas, only a few studies describe a specific industry.

Table 2.3 categorizes the research opportunities studies according to their generic research focus. Whereas the list in Table 2.3 is far from exhaustive, it does include most of the major research areas generally considered to be applicable to energy conservation.

Table 2.1 permits further overview of the literature by providing an indication of which of the five types of information previously mentioned are included in the studies. The number of studies either completely or only partially including the corresponding information is summarized in the following list:

TABLE 2.2. Categorization of Research Opportunities Studies by End-Use Sector

End-Use Focus	Report Numbers
Buildings and Community Systems	12, 32, 36
Transportation	3,4,7,12,21,26,29, 33,34,36
Industry	
Chemicals	8
Primary Metals	2, 9, 25
Pulp and Paper	24, 35
Stone, Clay, and Glass	1
Food Processing	17, 18, 19
Textiles	15
Agriculture	17, 18, 19
General Industry	10, 11, 12, 21, 22, 36

TABLE 2.3. Categorization of Research Opportunities Studies by General Research Area

General Research Area	Report Numbers
Tribology (Material, Lubrication)	22, 28, 34
Materials (Corrosion, Composites, Net Shape, Processes,...)	21, 28
Heat Transfer/Waste Heat Recovery	14, 16, 19, 20, 21
Fluid Mechanics (Distillation, Membrane Separation,...)	23
Combustion/Engine Development	3, 21, 33, 38
Chemical Processes	8

Information Type	Completely Included	Partially Included
Reviews end-use consumption data	17	1
Estimates conservation potential of technologies	12	4
Estimates technologies' time to commercialization	7	7
Summarizes existing research programs	10	2
Gives a methodology for identifying research opportunities	10	3

Briefly, of the 38 reports, 18 presented some type of energy end-use data. In general, the reports that focused on particular energy-use functions gave end-use consumption data, whereas those that concentrated on generic research areas did not. Sixteen of the 38 studies made some effort to estimate the conservation potential of the technologies under consideration. Seven studies estimated the time to commercialization of the technologies, while another seven estimated the length of research required for particular tasks. Estimating research times is a less sophisticated form of analysis than estimating times to commercialization and was therefore marked as "partially" providing the required information in the fifth column of Table 2.1. Twelve of the 38 studies gave some form of summary of existing research programs relating to the research ideas identified.

Finally, only 13 studies used some form of systematic methodology for identifying research opportunities. The other 25 studies merely presented unjustified "laundry lists" of energy conservation research opportunities. The studies that did make use of a methodology generally used one of two basic approaches. First, some studies surveyed various experts in the field to solicit research ideas. While this method may produce reasonable results, the justification of the ideas is left up to the reader, unless detailed descriptions are provided with the ideas.

In the second method used to identify research opportunities, end-use energy data were reviewed for areas of large consumption and loss. Research ideas were then proposed to address these areas. This method is used by the

American Institute of Physics (report No. 4), Grey (report No. 26), and Ross and Williams (report No. 36). Because this method directs the search for research opportunities toward areas where significant energy savings are possible, it produces ideas that have clear application to energy conservation. For this reason, the PNL assessment staff feels that this method is the more promising approach to identifying energy conservation research opportunities and deserves further analytical attention.

The PNL assessment staff's view of this sample of research opportunities studies has led to three general conclusions. First, the staffs feel that at this time research opportunities identification is more of an art than a science. However, the beginnings of systematic approaches are apparent in some of the above-mentioned studies. Given continued development of this approach, research opportunities identification could be made into a more systematic and rigorous activity than in previous work.

Second, the studies that focused on fairly narrow segments of the end-use sectors generally were able to produce more detailed, well-justified research ideas than were the broad, sweeping studies of the entire energy picture. For this reason, the staff feels that a single, all-encompassing analysis is not the proper approach to produce a detailed, comprehensive study of energy conservation research opportunities. Rather, a synthesis of the many small, detailed studies should be performed, using additional analyses only to fill in the gaps. Tables 2.2 and 2.3 are a first step in categorizing the various studies into consistent end-use and technical formats. Additional work is needed to further develop these formats, to locate the available studies and fit them into the structure, and to identify the areas where additional analyses are required.

A third conclusion drawn from these 38 sample studies is that a considerable difference exists between the studies that focused on end-use energy consumption and those that focused on generic research. The studies of generic research areas frequently failed to give the specific applications and conservation potential of their research ideas. An integrating effort is needed to collect these generic research ideas and to apply them to the energy conservation problems listed in the end-use oriented reports. Both the generic research and the end-use reports contain a wealth of ideas. A systematic compilation and integration of these ideas has been initiated here, and further work would significantly help to provide a prioritized agenda of research opportunities that would promote more efficient energy use.

3.0 ENERGY CONSERVATION RESEARCH OPPORTUNITIES

The R&D activities relating to energy conservation in the sample 38 studies are presented and discussed in this section. These activities, which were collected from the critical reviews, are categorized into the major energy end-use sectors: buildings and community systems, transportation, and industry. A generic category also is included for activities that cut across all end-use sectors but were not suggested as specific to any single sector. The classification includes a second level that indicates the general application or industry under which the R&D need falls. In buildings and community systems, broad applications such as space conditioning and water heating are used. In transportation the general application is the mode of transport, such as auto and truck or aircraft. The categories in industry are divided among the various Standard Industrial Code (SIC) classes, although precise SIC classifications are not provided. The transportation and industrial areas are further divided into more specific processes and devices. Note that the classification levels below each end-use sector heading were chosen as the most convenient for the available data. As the data base expands and the classification technique matures, these categories most likely will adjust.

The R&D activities in each end-use sector are briefly discussed through a comparison of the following characteristics:

- short-term vs. long-term projects
- evolutionary vs. revolutionary ideas
- generic vs. process-specific activities
- technology base research vs. hardware development.

The first comparison, short-term vs. long-term projects, indicates the time horizon of both the suggested activity and in many cases the original reference. For example, several reports sponsored by the DOE were directed toward near-term needs in various industries. This comparison is also an indication of the potential role for technological developments in promoting energy efficiency. That is, long-term opportunities are unlikely to be abundant in sectors or processes that are not technologically sophisticated.

Evolutionary R&D projects represent increases in the thermal or mechanical efficiency of current processes or devices, whereas revolutionary activities represent dramatic changes in current practices. The comparison indicates the potential for radically different technological options to achieve a given task. Radically different options are typically high-risk ventures that often offer a significant potential for energy savings. The comparison also indicates that some forms of nontechnical entrenchment occur for certain modes of a technology in an end-use sector. Several suggested R&D opportunities may fall largely within an established mode of delivering a service, which is deeply rooted for institutional or other nontechnical reasons, while much less effort is placed on exploring alternate modes of providing the service. An example would be the substitution of communications for travel.

Generic activities, as previously defined, apply to more than one end-use sector, whereas process-specific technologies are generally applicable to a particular process. Levels of process-specific technologies indicate the degree of technological specificity of energy uses in a given sector. Conversely, levels of generic activities in the sectors point to degrees of cross-cutting that might be achieved with various technology areas that share the need for common advancements and identify relevant process-specific applications.

Finally, a comparison of work oriented toward technology base research vs. hardware development indicates whether the sector can benefit more from specific component development or from a broader fundamental base of development. This comparison also reflects a sector's technology intensiveness since a low technology area such as buildings and community systems does not seem to benefit from fundamental research as do the higher technology transportation and industrial sectors.

GENERIC ENERGY CONSERVATION R&D OPPORTUNITIES

As mentioned several times, the generic category comprises activities that apply to more than one end-use sector and that were not specific to any particular end use in the reports. Generic opportunities are listed in Table A.1 in Appendix A. These activities are significant because of their broad potential application. Generic activities that may be applied to all three end-use sectors include research into heat exchangers, controls and sensors, alternate fuels combustion, tribology, high-temperature and corrosion resistant materials, and electric energy storage. Because of the diversity of R&D opportunities, these activities encompass the range of short-term to long-term research. As expected from generic projects, these advancements are also predominately characterized by evolutionary changes. Both generic hardware development and generic technology base research are represented in the list of activities. These categories interact with technology base projects, which include high-temperature, corrosion-resistant materials and which provide support for hardware development such as improved heat exchangers.

To illustrate the breadth of specific applications that may benefit from the development of certain technologies, four areas have been selected: heat exchangers, heat pumps, sensors and controls, and alternate fuels and feedstocks. The R&D examples have been selected from Tables A.3 through A.5 of Appendix A and are intended to underscore the potential for specific and applied uses of generic developments. Table A.2 in Appendix A contains a list of the R&D opportunities suggested in these four areas and the end uses to which they apply. Because Table A.2 is not intended to be comprehensive, the breadth of the information shown is more significant than specific items that might be missing. None of the R&D opportunities listed in Table A.1 have been included in Table A.2 because the applications appropriate for the technologies in Table A.1 were not specified in the original reports. All four areas were mentioned in at least seven of the ten end-use focuses listed in Table 2.2. The controls and sensors area was most frequently included, having been mentioned in nine of the ten end-use areas.

Table A.2 also illustrates the wide variation in the detail of the R&D opportunities suggested in the 38 reports reviewed. Some of the applied needs have very general descriptions of the technology and its application (e.g., heat pumps in the chemicals industry), whereas other descriptions are specific in delineating the application (e.g., air-to-air heat exchangers for ventilation in buildings). These two categories apply to most of the R&D opportunities listed. A few R&D suggestions offered are specific in describing the technological opportunity (e.g., ultrasonic methods of hot iron surface inspection); however, such detail was uncommon.

Again, note that Table A.2 is not intended as a list solely composed of promising energy conservation R&D opportunities. Some needs, such as the need for a heat pump to increase waste-water temperature from $100^{O}F$ to $180^{O}F$ for sanitizing and thawing in food processing, may already be largely realized, whereas others, such as the need for a heat pump to elevate $250^{O}F$ waste heat to $400^{O}F$ in cereal manufacturing, remain. Rather, Table A.2 illustrates the potential applications of crosscutting technologies through the example of heat exchangers, heat pumps, controls and sensors, and alternate fuels and feedstocks.

BUILDINGS AND COMMUNITY SYSTEMS

The buildings and community systems sector has the simplest taxonomic structure due to the limited variety of major energy uses. The primary end uses include space conditioning, water heating, lighting, appliances, and generic activities. The category of generic activities applies to R&D suggestions that are generally appropriate to several end uses or that do not strictly apply to any of the previous categories. Table A.3 in Appendix A summarizes from the literature review the research opportunities that address the buildings and community systems sector.

In building and community systems, space conditioning consumes the largest fraction of energy, 59% in 1977, and appropriately comprises the largest number of identified R&D activities relating to this sector. These activities include the areas of passive solar design and modeling, insulation, window technologies, infiltration, home instruments for monitoring and control, and active conditioning, which includes heat pumps, furnace efficiency improvements, and air-conditioner improvements.

The R&D activities identified in these systems are predominately short-term efforts, mainly because building and community systems is not a technologically sophisticated sector. In many cases, such as passive design and modeling, the technologies exist but must be reapplied to meet new needs. The few long-term activities include developing advanced heat pumps, such as the Stirling and absorption cycle devices, and characterizing heat exchanger parameters. The demanding conditions that challenge energy-use technology in both the transportation and industrial sectors are largely absent in buildings and community systems. Harsh environments with high-temperature, corrosive energy streams are uncharacteristic of this sector. Similarly, large energy loads, large fluctuations and the need for precise sensors and systems controls are uncommon.

Essentially all of the R&D suggestions in these systems are evolutionary. No dramatic changes in building processes and design have been suggested. This situation again appears to have its roots in the low technology intensiveness of this sector and in the nontechnical barriers of radically altering the form of accepted building conventions.

Although most of the R&D suggestions are device specific, a few can be applied to the industrial and transportation sectors. The relevant suggestions include the development of advanced heat pump cycles, heat exchangers, including better characterization of flow distribution and fouling, heat loss diagnostic equipment, and improved electric motors.

The R&D activities in buildings and community systems also focus predominantly on hardware development as opposed to efforts that would establish a technology base. The exceptions are certain efforts in heat exchanger development and passive solar design research, such as the characterization of heat transfer at solid surfaces bounded by air.

TRANSPORTATION

R&D opportunities identified in the transportation sector have been divided among the various transportation modes. From the studies reviewed, these categories are autos and trucks, aircraft, and generic activities. Generic areas include those that are common to several modes, such as alternate fuels and basic studies, and those activities that do not clearly fit into one of the defined modes, such as the substitution of communication for travel. Table A.4 of Appendix A presents the list of research opportunities that are collected from the individual reports and that address the transportation sector. Each mode is further divided into specific elements. In autos and trucks, which received the majority of attention in the reports surveyed, these elements include the engine/driver, aerodynamic design, transmission, tribology, materials, other losses, accessories, and advanced concepts. Because the auto and truck subsector dominates the R&D activities presented here, it will be the focus of further discussion.

The auto industry is unique in being a large, centralized and technology-intensive sector. In the U.S. the industry is composed of a few corporations that have the resources to support a significant level of R&D. The R&D suggestions obtained through the critical reviews span the breadth of short- to long-term projects. Short-term projects would include automatic control technology to better monitor and adjust the fuel mixture, timing and accessories and to reduce aerodynamic drag, which was cited in four of the ten reports dealing with the transportation sector. However, most of the suggested activities are weighted toward long-term projects, probably resulting from recognition of the industry's capacity to resolve short-term problems when necessary. Examples of long-term projects cited in the reports include the development of Stirling engines, ceramic materials, alternate fuels capability, reduced rolling resistance, and understanding the kinetics and mechanisms of combustion.

Although a clear bias exists toward long-term R&D efforts, this bias is weighted toward evolutionary rather than revolutionary changes. The activities recommended are largely directed at improving the thermal, mechanical and aerodynamic efficiency of components through hardware development and basic studies. Similarly, the changes advocated in fuel type occur within the existing distribution system with an emphasis on those that are compatible with existing engine types. This evolutionary character seems to be due to a deeply established acceptance of the current modes of transportation support industries. The only revolutionary suggestion resulting from the reviews is the previously mentioned substitution of communications for travel.

The generic vs. process-specific nature of the R&D activities is more balanced. Many of the advancements in engine development can be applied to both the industrial and buildings and community systems sectors. For example, Stirling engine development would increase the efficiency and operating range of heat pumps. Tribological advancements, piston ring optimization and valve mechanization are other areas of generic engine application. Alternate fuels combustion and basic studies are also of generic value. These broad areas were identified with the understanding that the size and load differences between the transportation and other sectors would inhibit the direct application of new developments, but the similarities in needs will certainly enhance parallel development.

The transportation sector is also well represented by process-specific R&D activities such as improved transmissions, reduced aerodynamic drag, and reduced rolling resistance. These types of activities, unique to uses in transportation, are directed at reduced losses by focusing on the primary contributors of loss: drag, weight, and engine inefficiencies.

Comparing efforts that aid in developing a technology base with efforts that aid hardware development also appears to result in an even balance. Basic studies in the areas of combustion processes, fluid mechanics, the modeling of unregulated and hydrocarbon emissions, and tribological studies can assist the design process through modeling, thus preventing traditional practices of individual design iteration. Hardware development received equal emphasis on the list of R&D activities and cut across both generic and process-specific activities. Identified needs include the development of flywheels for regenerative braking, the continuously variable transmission, ceramic components, and the improvement of Otto, diesel and stratified charge engines, as well as the development of Stirling and Brayton cycle engines. These two aspects, hardware development and technology base research, complement each other. Hardware development benefits from information provided by technology base research, especially in transportation where the relatively narrow focus of technologies facilitates interaction between these two classes of work.

INDUSTRY

Because industry is both the most diverse and most technology intensive end-use sector, a wide spectrum of R&D opportunities exists. Industrial R&D opportunities from the literature review are summarized in Table A.5 in Appendix A. The list of activities is rich in both short-term and long-term suggestions. However, the literature reviewed tended to lean toward short-term projects, largely because of a sponsor bias toward the shorter time frame. For example, in several DOE studies investigators were directed to focus on options that could be implemented by 1985. Even though the thorough evaluations in these reports focused on short-term activities, the studies were still useful in identifying possible long-term projects.

The R&D activities in this sector are also well represented by both generic and process-specific activities. Generic activities are considered to be both those cutting across several industries and those applicable to the other end-use sectors. Generic retrofits tend to focus upon improvements that do not change the flow of current processes. Examples of generic retrofits include high-temperature recuperators for recovering the exhaust from iron blast furnaces and glass furnaces, heat pumps and vapor recompression for drying processes, and high-temperature, corrosion-resistant sensing technologies for improved monitoring and control over processes in steel, glass, and ceramic furnaces. Generic activities are therefore evolutionary. The truly revolutionary processes are suspected to arise from process-specific developments. Through this mode, intermediate process steps can be eliminated, thereby improving both energy consumption and productivity. Examples include direct one-step steelmaking, direct casting of steel and strip, ore-to-powder systems, advanced food sterilization systems, and catalysts to modify chemical processes. However, the bulk of process-specific technologies presented in the reports tended to be evolutionary or incremental improvements over current methods. This bias again relates back to the time focus of the reports and is not a result of the relative merits of either improvements.

Similarly, a bias toward hardware development vs. technology base activities is evident in the list of R&D activities and again appears to be a result of the time focus. Examples include the mach nozzle dryer in textiles and paper and pulp; microwave drying in food processing, grain, and paper; and pulp, heat pumps and high- and low-temperature heat exchangers in virtually all industries. Technology base ideas generally arise from documents that approach the topic from a fundamental perspective such as the ESCOE reports (Report Nos. 22 and 23) on fluid and thermal processes and advanced industrial processes and the Wolfe report (Report No. 4) on the efficient use of energy.

SUMMARY AND CONCLUSIONS

Because the purpose of this effort primarily was to provide information that would meet the needs of a companion report, An Overview of Energy Conservation Research Opportunities, the lists of R&D opportunities in this study are not intended to be comprehensive. Rather, this report provides a broad catalog of previously published research ideas that could promote energy conservation. Additional work is needed to more systematically appraise available R&D opportunities reports and to evaluate specific research ideas.

Reviews of the R&D opportunities listed in the tables clearly indicated that certain activities that were applied to a specific process may also be applied to others equally as well. For example, in the chemicals industry one suggested opportunity is the use of alternate sources of feedstocks to replace natural gas and coal in ammonia plants. This opportunity most likely can extend to other chemical industries; however, further investigation would be necessary to identify the full breath of such potential.

Among the reports reviewed, the transportation and buildings and community systems were well represented. The industrial sector was more difficult to thoroughly review because of the variety of diverse energy-using applications. The chemicals, textiles, and stone, clay and glass industries were least well covered, with only one report reviewed from each industry. The paper and pulp industry could also benefit from further coverage since only two reports were reviewed in that area. The primary metals, food processing and agriculture industries were better represented, with three reports reviewed in each.

In summary, the greatest diversity of R&D opportunities clearly appears in the industrial end-use sector. The transportation sector is technology intensive but far less diverse than the industries sector, and buildings and community systems offers the smallest variety of energy conservation R&D opportunities. Generally, in these studies buildings and community systems tended to lean towards short-term projects, transportation to lean towards long-term projects and industry to mix both, but with slight emphasis towards short-term projects. The buildings and community systems and transportation sectors are generally characterized by evolutionary elements, whereas the industry is a mix of both evolutionary and revolutionary ideas. Additionally, although the buildings and community systems sector focuses slightly on specific devices, all three sectors are well represented in process-specific and generic technologies. Further, technology base research is sparse in buildings and community systems, reflecting the sector's low technology intensiveness. All three sectors are well represented in hardware development opportunities.

Finally, it is interesting to note that none of the studies reviewed thoroughly appraised advanced basic materials processes, such as the direct casting of steel in industry. These processes may offer very significant energy savings and may therefore warrant further investigation.

APPENDIX A

TABLES OF ENERGY CONSERVATION R&D OPPORTUNITIES

APPENDIX A

TABLES OF ENERGY CONSERVATION R&D OPPORTUNITIES

The tables in this appendix present a categorized listing of the energy conservation R&D opportunities collected from the critical reviews included in Appendix B. Table A.1 lists generic R&D opportunities that weren't applied to specific end uses. To illustrate the specific end-use potential more clearly, applied R&D opportunities for four example technologies are listed in Table A.2. These opportunities were extracted from the end-use-oriented opportunities listed in Tables A.3, A.4, and A.5. These last three tables show the R&D opportunities according to the three major end-use sectors, buildings and community systems, transportation, and industry. The opportunities in the tables are further arranged according to narrower energy-use categories.

TABLE A.1: GENERIC ENERGY CONSERVATION R&D OPPORTUNITIES

R&D Activity	Original Reference (Report No.)
Materials	
Tribology	
Investigation of two phase bearings	27
Continued investigation of lubrication	27
Continued investigation of wear	27
Water lubricated bearings for utilities	34
High temperature Babbitt-like materials	34
Characterization of long term stability of materials in high temperature, harsh environments	28
Properties of wear resistant materials, especially at high temperatures	28
Analysis and development of cylindrical roller bearings for 3.0 million DN operation tapered roller bearings for 3.5 million DN	34
Mechanism of foreign particle wear	34
Refrigerant lubricated bearings	34
Foil bearing materials	34
Bearings for oxygen compressor service	34
Cage design and lubrication for small high speed ball bearings	34
Series hybrid bearing	34
Development of rolling element bearing materials having high fracture toughness	34
Gaspath seals active control of labyrinth seal concentricity	34
Correlate microstructures and materials properties with friction and wear behavior	28
Characterize the time-temperature effects on hard surfacing materials	28
Standardization of wear testing methods and materials	28
Existing and future data need organization to be of maximum design use	28
Wear control handbook	34
Documentation of energy-tribology statistics	34
Establish a list of reference properties for wear technology related materials	28
Support of a national tribology testing	28
Establishment of a tribology information center	28
Advisory board	34
Applications workshop	34
Processing	
Assessment of alternate processes	21
New and improved processes	21
Modification of material properties to reduced energy intensiveness of materials	12

Generic

R&D Activity	Original Reference (Report No.)
Materials (cont'd)	
Turbomachinery	
Active control of blade tip clearance	34
Abradable blade tips and shrouds	34
Recycling	
Materials from urban wastes	21
Energy from urban wastes	21
Energy and resources from agricultural wastes	21
Materials from combustion and conversion wastes	21
Energy and materials from waste-water sludges	21
Energy and materials from industrial waste	21
High Temperature	
Investigation of materials properties at high temperatures	5, 12
Mechanics	
Research on product failure, mechanism and fracture mechanics	20
Solar	
Continued studies of the semiconductor physics of photovoltaic cells	4
General	
Improve the data base on energy use in the materials cycle	21
Materials property assessment for emerging energy technologies	21
Ceramic materials assessment	3
Development of substitute materials	21
Systems study of the materials cycle	21
Integrated studies to support policy implementation	21
Heat Transfer	
Enhancement	
Understand the effect of finned tubes with shroud shapes	16
Investigate variable fin density	16

R&D Activity	Original Reference (Report No.)
Heat Transfer (cont'd)	
Enhancement (cont'd)	
Understand the influence of tube row spacing, fin height, and up stream turbulence	16
Vibration to increase gas side heat transfer coefficients	7
Boundary layer thinning techniques to achieve higher gas convective heat transfer coefficients	7
Study of heat transfer at interfaces	
• role of convection and surfaces irregularities and surfaces irregularities	13
Surface roughness to achieve higher gas convective coefficients	
• research is needed to improve our understanding of the basic phenomena involved in high flux heat transfer and prevention of burn-out	7
• knowledge of how materials perform in high heat flux systems must be developed; improved materials may be needed	7
Degradation	
Corrosion	6, 13, 27, 30
Understand the fouling of augmented surfaces	16
Fundamentals	
Flows around tubes and baffles	7
Multidimensional modeling of turbulent flows, including a general stability condition	7
Transient phase geometry determination	7
Nonconventional	
Focusing of heat transfer to achieve selective transfer, through the use of electrostatic or magnetic fields	7
Electrostatic fields to increase gas side heat transfer for coefficients	7
Investigate thermoelectric elements	16
Plastic heat exchangers	16
Improved heat pipes	31
General	
Single phase heat exchanger improvements	13
High effectiveness	13
Oil coolers	13

Generic

R&D Activity	Original Reference (Report No.)
Energy Conversion	
Combustion	
A better fundamental understanding of the effects of turbulence on combustion, especially solid fuels, flame shaping, effects of combustion variables on flame heat transfer, and on pollution	7
Development of furnace design methodology, especially with regard to heat transfer, to make furnace design more of a science than an art and to reduce dependence on empirical design of limited applicability	7
Improved fluid bed combustors	31
Reactions of nitrogen and sulfur species in fluidized bed combustion	7
Develop scaling methods for fluid bed coal combustors and kinetics of coal combustion at high pressures	7
Localized temperature fluctuations in fluidized bed combustion and gasifiers as related to ash and agglomeration	7
Particular or droplet behavior in liquid slurries and gas/vapor carriers	7
Hydrogen/hydrocarbon reactions in slurry reactors	7
Solid/hydrocarbon interactions in fluidized bed pyrolysis	7
Reactions and transport processes and solid state transformations in limestone particles under combustion, gasification and coal pyrolysis conditions	7
Relative rates of thermal catalytic reactions in hydrogenation catalysts particles	7
Mechanics and chemistry of char consumption and the interaction with ash under both combustion and gasification conditions	7
Lean combustion problems	7
Investigative problem of hydrocarbon destruction in the freeboard space of fluidized bed combustion	7
Combustion characteristics	
• mixtures over an extended fuel-air range	5, 12
• stability	5, 12
• heat transfer from combustion products	5, 12
Improved methods for scrubbing combustion gas	12, 27
Alternate Fuels	
Improved combustion of marginal fuels	12
Determine combustion characteristics	5, 12
Coal utilization for energy and raw materials	27

Generic

R&D Activity	Original Reference (Report No.)
Energy Conversion (con'd)	
Alternate Fuels (cont'd)	
Coal fired gas turbine	37
Coal fired Stirling or Ericsson engines	37
Coal fired diesel engines	37
Motors	
High efficiency electric motors • alternating current synthesizer	36
Heat Pumps	
Modeling	13
Seasonal operation	13
Furnaces	
Heat exchange design and controls	13
Draft control	13
Cogeneration	
Cogeneration of heat and electricity • alternate engines (Stirling, closed cycle Brayton)	12
Gas Turbines	
High temperature materials	13
Advanced turbine and compressor configurations	13
5-25 MW size for pumping and integrated energy systems	5
Coal fired gas turbines	37
25-100 MWe highly efficient, heavy fuel tolerant gas turbines for cogeneration	5
Fuel Cells	
Advanced fuel cells including molten carbonate fuel cell	5
Processes that produce chemical fuel from waste energy which is, in time, used in a fuel cell to produce electricity during peak periods	7
Higher reliability	5
Fuel flexibility	5
Lower costs	5

Generic

R&D Activity	Original Reference (Report No.)
Energy Conversion (cont'd)	
Electrodes	
Electrode reaction mechanisms including gas nucleation and evolution dissolution and precipitation reactions and solid transformation	7
Transport phenomena such as ionic transport in membranes and solid electrolytes and heat and mass transfer in porous electrodes	7
Understanding and improvement of electrode catalyses with emphasis on aging processes in oxygen, hydrogen and chlorine electrodes, and electrocatalysis	7
Advanced	
Themionic converters	5
Lysholm helical screw expander	5
High temperature power cycles--up to 2500^{o}C	
Fluid Mechanics	
Separations	
Investigation of osmosis	27
Basic research on transport in membranes	4, 27
Investigation of absorption	27
Improved understanding of thin film mechanisms	
• establishment, maintenance, boiling	7
Hydraulics	
Hydraulic transmissions	36
Mechanisms of turbulence and inertia in hydrodynamic bearings	34
Reduction of power loss in turbulent bearings	34
Fundamentals	
Fundamental investigation of two-phase flow	4
Basic studies of boiling-aging effect	16, 27
Turbomachinery	
High speed pumps/turbines	
• centrifugal separation effect	7
• theory and data for rotating flows	7
• steady and unsteady flow behaviors	7
• improved understanding of cavitation on phenomena	7
Corrosion-cavitation interaction	18

Generic

R&D Activity	Original Reference (Report No.)
Controls	
Sensors	
Research on non-destructive testing	20
Quantitative NDE for energy conservation transmission and production systems	22
Self powered sensors for remote monitoring	22
Real time process control for manufacturing operations	22
Automated inspection systems for remote or hazardous environments	22
Sensors for well logging and minerals exploration	22
Automatic	
Automatic monitoring of energy performance	12
Improved automatic control technology	12, 27
General	
Improved methods for energy monitoring and house-keeping	12, 27
Storage	
Thermal	
Thermal energy storage by freezing and melting of high freezing point materials	7
Endothermic chemical storage, exothermic	7
Electric	
Novel batteries	7
Rechargeable batteries of greater power density	4
General	
Process	
Process retrofit technologies	12
Advance physical understanding and mathematical modeling techniques	22
Analysis of energy required for various materials and processes to produce a specific part	21, 22

Generic

R&D Activity	Original Reference (Report No.)
General (cont'd)	
Process (cont'd)	
Basic new processes that reduce overall requirements for energy and other resources per unit output (e.g., recycling, durability)	12
Methods to assess and reduce net energy content of manufactured parts (i.e., starting with new net shape forms in machining processes)	22
Design	
Greater incorporation of computer aided design, computational methods, and optimization techniques	22
Incorporating life cycle energy accounting	22
Data bank and advanced design methodology handbook	22
Oxygen	
Develop low energy, inexpensive method of producing crude oxygen or enriched air (e.g., absorption, diffusion, or para-magnetic separation)	7

Table A.2: EXAMPLES OF R&D OPPORTUNITIES IN TECHNOLOGIES ACROSS END-USE SECTORS

R&D Activity	Original Reference (Report No.)
Heat Exchangers	
Buildings and Community Systems	
Air-to-air heat exchangers for ventilation	27, 37
Heat exchangers to recover both latent and sensible heat	27
Improved heat exchangers for fuel-fired equipment	32
Basic heat transfer studies at solid-fluid interfaces, with a view to decreasing the temperature across heat exchangers operating close to ambient temperature	4
Applied toward improving air conditioners/refrigerators	
• augmented surfaces to yield enhanced performance under dehumidifying, frosting or icing conditions	16
• contact resistance in the use of augmented fin surfaces must be reduced	16
• fouling factors	16
Chemicals Industry	
Low cost heat exchangers	20
Exchanger coolant flow control	19
Primary Metals Industry	
Heat exchanger development	19
High temperature heat exchangers and recuperators	25
Ceramic recuperators	9
Ceramic heat wheel	25
Metallic counterflow recuperators	9
Flexible membrane development	19
Fluid bed cooling	25
Textiles Industry	
Heat recovery of contaminated exhausts	15
Heat recovery from boiler stack gas	15
Food Processing Industry	
Improved heat recovery systems	17
Heat exchanger cleaning and filtering for fouling prevention	17
Dryer exhaust recovery with fouling control	17

R&D Activity	Original Reference (Report No.)
Heat Exchangers (cont'd)	
Stone, Clay, & Glass Industry	
More efficient heat exchangers to preheat raw materials using waste heat	11
Paper & Pulp Industry	
Improved low temperature heat exchangers	19
Application of fluid bed heat exchangers to waste heat recovery	19
Utilization of heat sinks or balancing condensors	19
ASME coding of compact heat exchangers	19
Improved paper machine hood economizers	19
Corrosion resistant economizers	19
Heat recovery from paper dryers using heat wheels	19
Reradiant recuperator	19
Agriculture	
Utilization of lined tunnels below grade as heat exchangers	18
Design equations for heat pipes & heat exchangers	19
Heat Pumps	
Buildings and Community Systems	
Heat pump cycles and technoloty to extend the useful temperature range	4
Systems studies of solar-assisted heat pumps	4
Systems studies (and hydrology) of using ground water as the low temperature reservoir of a heat pump	4
Fuel fired heat pumps	32
Absorption heat pumps	32
Chemicals Industry	
Industrial heat pumps	19
Textiles Industry	
Heat pump utilization of waste heat streams	15
Food Processing Industry	
Utilization of heat pumps in current manufacturing processes	17

R&D Activity	Original Reference (Report No.)
Heat Pumps (cont'd)	
Food Processing Industry (cont'd)	
Heat pump for 200 F waste heat elevated to 450 F in cereal manufacturing	17
Waste water from 100 F to 180 F for sanitizing and thawing	17
Stone, Clay, & Glass Industry	
Utilization of heat pumps	
Paper & Pulp Industry	
Conserving hood waste heat via heat pumps	19
Conserving waste heat in low temperature water to higher temperature water via heat pumps	19
Rankine and electric heat pumps	35
Agriculture	
Evaluation of technical and economic feasibility of heat pumps for grain drying	18
Controls & Sensors	
Buildings and Community Systems	
Development of an easy to use local heat flux meter	4
Development of infared equipment for diagnostic studies of houses	4
Development of cheap home instruments for monitoring and control	
• degree-days-per-gallon meter (with suitable time averaging)	4
• clock-programmed thermostat	4
• on-line monitor of furnace burner efficiency	4
Packaging of a meter to measure air exchange rate	4
The development for larger buildings of on-line monitoring of several features of air quality coupled with control of reconditioned air vs., fresh air	4
Advanced zoned temperature control (toward localized task heating	37
Controls for space heating and cooling	32
Basic studies of automatic control technology	12
Meters for time-dependent utility pricing	12

R&D Activity	Original Reference (Report No.)
Controls & Sensors (cont'd)	
Transportation	
Automatic control technology (fuel mixture, timing, and accessories)	12
Implementation of other monitoring meters of engine efficiency, fuel flow, and automatic transmission gear	4
Inexpensive miles-per-gallon meter	4
Idle-off systems	26
Primary Metals Industry	
Computer optimization of power use in electric arc furnaces	9
High temperature inspection and surface conditioning	2, 9
Surface inspection	
• ultrasonic methods	25
• eddy current methods	25
• optical and other methods	25
• hot grinding	25
Air-fuel ratio controllers	
• multiburner combustors	9
Improvements in temperature sensing	2
High temperature sensors	9
Energy management through computer control	9
Computer control of blast furnace thermal & metallurgical processes	9
Textiles Industry	
Moisture analyzer	15, 19
Development of automatic power factor correction techniques for individual electric motors	11
Control and corrction of high-frequency transient peaks by Zener diodes	11
Improved management and control of electrical energy demand	11
Improved synchronous swithching of heavy electrical loads	11
Food Processing Industry	
Automatic air-fuel ratio control for small boilers	17
Better ammonia and freon refrigeration systems and controls for defrosting	17
Stone, Clay, & Glass Industry	
Reliable temperature measurement process diagnostics	11

R & D Activity	Original Reference (Report No.)
Paper & Pulp Industry	
Automatic control bleaching	35
Automatic control digester	35
Advanced air-fuel ratio control systems	35
Agriculture	
Development of simplified flow meter	18
Alternate Fuels & Feedstocks	
Buildings and Community Systems	
Water-oil emulsion for heating equipment	32
Transportation	
Preparation and characterization of test fuels	3
Novel fuels	4, 7
Fuel emulsions	4, 7
Hardware development testing	33
Development of auxilliary apparatus and instruments	33
Engine tests	3
Laboratory simulation tests	3
Data analysis and recommendations	3
Development of exhaust analysis techniques	3
Chemicals Industry	
Biomass conversion to chemicals and polymers	11
Alternate sources of feedstocks for ammonia plants to replace natural gas with coal	17
Coal liquefaction and gasification to provide chemical feedstocks	11
Primary Metals Industry	
Direct use of coal in manufacturing of oxide pellets (replace oil or natural gas)	9
Biomass as fuel/reductant for iron ore	9
Hydrogen as fuel/reductant for iron ore	9
Steelforming furnace using direct coal firing rather than oil or natural gas	2
Heavy oil combustion	25
Pyrolysis of low grade coals	25
Gasification of coal	2, 9, 25
Cothane process for making methane from waste CO	9

R & D Activity	Original Reference (Report No.)
Alternate Fuels and Feedstocks (cont'd)	
Textiles Industry	
Alternate fuels for finishing	15
Ginning waste as a substitute fuel for drying	17
Generation of power for cotton gins by using gin waste	17
Food Processing Industry	
Alternate fuels to replace natural gas	17
Utilization of solid wastes as an energy source	17
Methane production and anaerobic digestion of wastes	17
Paper & Pulp Industry	
Fundamentals of wood combustion (gasification, cogeneration applications)	11
Alternative fuels for lime kilns	35
Coal derived fuels for combined gas steam turbines	35
Bark and hog fuel preparation	35
Agriculture	
Substitution of scarce fuels	18
Alternative source of energy - coal fired steam turbine	18
Alternative sources of energy for pumping energy	18
Feasibility of converting feedlot wastes to industrially useful oxychemicals	18
Integration of animal feeding, fuel production and fertilizer use in the use of crop residues and animal wastes	18
Define and demonstrate optimum systems for production of industrial chemicals from collected agricultural residues	18
Define and demonstrate optimum liquid fuel production production systems	18
Utilization of waste heat to enhance biogas production	19
Improvement of biogas production system reliability	19
Define and demonstrate gas-generating systems for farm and off-the-farm use	18
Define and demonstrate direct combustion of field crop residues for on-the-farm and off-the-farm use	18

Table A.3: BUILDINGS AND COMMUNITY SYSTEMS CONSERVATION R&D OPPORTUNITIES

R&D Activity	Original Reference (Report No.)
Space Conditioning	
Passive solar design • indirect and direct gain and thermal storage	12, 32, 37
Theoretical and experimental studies of external features, including sun control and surfaces of variable reflectivity	4
Microscopic studies, experimental and theoretical, of heat transfer at solid surfaces bounded by moving air	4
Investigation of a "thermal diode"	4
Re-insulation methodologies	12
Movable window insulation	37
Improved insulating materials (flow phenomena in porous media-pressure and temperature drop through insulation)	5
Development of layered material with variable, controllable conductivity	4
Optimization of insulation for the distribution of space heat	4
Environmental and health effects of insulation	27
Investigation of building materials with large specific heats	4
Radon gas and other health impacts from building materials	27
Development of window coatings to control heat loss (low IR absorpitivity, photosensitive coatings...)	4
Inside: development of methods to control air flow, especially near walls, windows, and ducts	4
Outside: studies of micrometeorology, wind effects on heat transfer and infiltration, control of local air flow patterns	4
More flexible computer modeling to include the effect of wind	4
Measurement and modeling of thermal response functions of buildings (to changing weather conditions)	4
Theoretical modeling together with experimental studies to select new materials and filler gases, to control cell size, and to enhance fire resistance	4
Utilizing effluent waste energy in heating/cooling buildings	19
Systems analysis of district systems to supply both heat and electricity to a building house or group	4
Studies of heat transport over long distances (including heat transported as chemical potential energy)	4
Air-to-air heat exchangers (ventilation)	27,37

Buildings and Community Systems

R&D Activity	Original Reference (Report No.)
Space Conditioning (cont'd)	
The development of devices to recondition air	4
Heat exchangers to recover both latent and sensible heat	27
Basic study of air infiltration	37
Search for new desiccants, especially with a view to lowering the regeneration temperature	4
Heat pumps cycles and technology to extend the useful temperature range	4
Systems studies of solar-assisted heat pumps	4
Systems studies (and hydrology) of using ground water as the low temperature reservoir of a heat pump system	4
Advanced fuel-fired equipment	32
• fuel-fired heat pumps	32
• more efficient compressors	32
• multiple compressors (enhance part-load efficiency)	32
• improved heat exchangers	32
• more efficient motors	32
• automatic fan controls	32
• improved airflow	32
• absorption air conditioners	32
• absorption heat pumps	32
• gas turbine	32
• Stirling engine	32
• diesel engine	32
• Rankine engines	32
Basic heat-transfer studies at solid-fluid interfaces, with a view to decreasing T across heat exchangers operating close to ambient temperature	4
Pilot/Burner retrofit	12
Electric pilot for gas furnace	37
Direct fossil-fired heating equipment	
• reduce burner firing rate (by 25%)	32
• boiler water temperature reduction (35 F)	32
• burner efficiency adjustment	32
• retention head burner	32
• stack heat reclaimer	32
• low input/variable firing rate burners	32
• ducting combustion air from outdoors	32
• vent damper	32, 37
• modern high efficiency burner-boiler	32
• blue flame burner-boiler	32
• outdoor boiler installation	32
• combustion air humidification	32
• water-oil emulsion	32

R&D Activity	Original Reference (Report No.)
Space Conditioning (cont'd)	
Advanced fuel-fired equipment	
• pulse combustion furnaces and boilers	32
Development of easy-to-use local heat flux meter	4
Development of infared equipment for diagnostic studies of houses	4
Development of cheap home instruments for monitoring and control, such as a degree-days-per-gallon meter (with suitable time averaging)	4
Development of cheap home instruments for monitoring and control, such as a clock-programmed thermostat	4
Development of cheap home instruments for monitoring and control, such as an on-line monitor of furnace burner efficiency	4
Packaging of a meter to measure air exchange rate in a room or building	4
The development for larger buildings of on-line monitoring of several features of air quality coupled with control of reconditioned air vs. fresh air	4
Advanced zoned temperature control (toward localized task heating)	37
Controls and distribution system	
• controls for space heating and cooling	32
Solar space cooling	12, 37
Systems studies of groundwater cooling	4
Interdisciplinary studies of ground-water hydrology for heat transfer applications	4
Broad search for new techniques using heat to power air conditioners; experimental studies of absorption nd absorption cycles	4
Improved air conditioners/refrigerators	
• augmented surfaces to yield enhanced performance under dehumidifying, frosting, or icing conditions	16
• contact resistance in the use of augmented fin surfaces must be reduced	16
• study maldistribution of fluid	16
• fouling factors	16
• steady and unsteady flows in orifices, entrances, exits, branches	16
Water Heating	
Continued development of solar hot water heating systems	4
Systems studies of heating or "boosting" water at the point of use	4
Detailed measurements and modeling of patterns of hot water heating and use in houses	4

Buildings and Community Systems

R&D Activity	Original Reference (Report No.)
Lighting	
Development of small and/or screw-in fluorescent lamps (mostly engineering)	4
Basic research on gas discharges and on fluorescence with a view to increasing the efficacy of light sources and controlling the color	4
Development of efficient kHz power supplies and further studies of frequency-dependence of fluorescent-lamp efficacy	4
Exploration of more effective ways to use sunlight indoors	4
Interdisciplinary studies of lighting needs for various tasks - intensity, uniformity, spectral distribution	4
Appliances	
Improved air conditioners/refrigerators	
• augmented surfaces to yield enhanced performance under dehumidifying, frosting, or icing conditions	16
• contact resistance in the use of augmented fin surfaces must be reduced	16
• study of maldistribution of fluid	16
• fouling factors	16
• steady and steady flows in orifices, entrances exits, branches	16
Integrated appliances	
• air conditioner/water heater	32
• furnace/water heater	32
• refrigerator/water heater	32
• drain water heat recovery	32
High performance electric motors (appliances)	12
Generic	
Systems studies of house-scale heat and electricity systems based on fuel cells (possibly ones deliberately chosen to have low electrical efficiency)	4
Solar: seasonal storage, cogeneration, heat pumps	37
Systems analysis of district systems to supply both heat and electricity to a building house or group	4
Impact of waste heat utilization on power plant engineering	19
Waste heat utilization for multicultural biological systems	19
Waste heat for desalination	19
Recreational use of waste heat	19
Energy transport and storage	19
Research on heat storage for better load averaging of both solar and electric power	4

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
Basic studies of automatic control technology	12
Meters for time-dependent utility pricing	12
Controls and distribution systems	
• controls for individual equipment (lights, etc.)	32
Extensive data gathering and modeling of energy-use patterns of existing houses and buildings of various types	4
Inventory of energy sources and energy needs	19

Table A.4: TRANSPORTATION ENERGY CONSERVATION R&D OPPORTUNITIES

R&D Activity	Original Reference (Report No.)
Autos and Trucks	
Engine/Driver	
Improved Otto cycle	26
Combustion efficiency and emissions research	12
Adiabatic diesel	4, 26, 31
Reduction in size and weight of the diesel engine	4, 26, 31
Reduced noise and emissions from the diesel engine	4, 26, 31
Gas floated pistons for adiabatic diesel	34
Lubrication system for adiabatic diesel	34
Coatings for extreme temperatures in an adiabatic diesel engine	34
Concepts and techniques for extreme high-temperature lubrication in an adiabatic diesel engine	34
Heater head design for the Stirling engine	4, 31
Ceramic parts for the Stirling engine	4, 31
General development of the stratified charge engine	31
General development of the Brayton engine	31
General development of the Rankine engine	31
Hybrid power plants (small internal combustion engines plus a source of boost power)	4
Electric vehicles	
• high performance batteries	31
Aerodynamics	
Reduced aerodynamic drag (experimental studies of autos and trucks, including effect of relative vehicle belly and road motion)	4, 12, 26, 27
Transmission	
Improved transmissions (continuously variable...)	26
Rheology of traction fluids	34
Traction fluid development	29, 34
Concepts and designs of traction drives	34
Tractor CVT prototype development and testing	34
Thrust bearing for CVT	34
Materials for traction drives	34
Traction contact study	34
Tribology	
Mechanics of boundary friction (sliding wear)	29
Piston ring - cylinder friction reduction	26

R&D Activity	Original Reference (Report No.)
Autos and Trucks	
Tribology (cont'd)	
Analytical model of ring lubrication	34
Piston ring optimization studies	34
Piston ring materials and coatings	34
Measurement of piston ring losses	34
Friction reduction	
• xylan coatings	26
Coatings for extreme temperatures in an adiabatic diesel engine	34
Concepts and techniques for extreme high-temperature lubrication in an adiabatic diesel engine	34
Automotive engine lubricants	34
Improved understanding of non-Newtonian viscosity improvers	29
Improved understanding of relationships between viscosity, volatility, temperature and wear	29
Improved understanding and chemistry of interactions between lubricant additives (compatibility and formulation techniques)	29
Materials	
Reduced vehicle weight	
• materials, crashworthiness of lighter vehicles	31
Ceramic materials assessment	3
Other losses	
Reduced rolling resistance	
• viscoelastic materials	31
• radial tire designs	31
• trade-offs between functions of wheels, tires and suspension	31
Accessories	
Automatic control technology (fuel mixture, timing, accessories)	12
Implementation of other monitoring meters of engine efficiency, fuel flow, automatic transmission gear	4
Inexpensive miles-per-gallon meter (real time data)	4
Idle-off systems	26
Valve resizing	26
Valve mechanization	3
Valve control assessment	3
Turbine design studies for compressive charging	3

Transportation

R&D Activity	Original Reference (Report No.)
Autos and Trucks	
Accessories (cont'd)	
Supercharging assessment studies	3
Reduced accessory power	
• heat powered air conditioners	31
Advanced working fluids	27
Advanced Concepts	
Experimental and theoretical studies of flywheels	4
Harnessing braking energy with a dynameter	4
Chemical energy storage	12
Transportable heat engine van capable of delivering steam and refrigerant to part-time food processing plants during harvest	31
Aircraft	
Materials	
Lighter weight aircraft	
• materials	12
• structural design	12
Aircraft engines with higher efficiencies and lower emissions	12
Generic	
Alternate Fuels	
Preparation and characterization of test fuels	3
Novel fuels	4, 7
Fuel emulsions	4, 7
Hardware development testing	33
Development of auxilliary apparatus and instruments	33
Engine tests	3
Laboratory simulation tests	3
Data analysis and recommendations	3
Development of exhaust analysis techniques	3
Basic Studies	
Theoretical and analytical studies	33
Spray combustion studies	3

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
Basic Studies (cont'd)	
Spray formation studies	3
Fuel injection dynamics studies	3
Engine modification design and evaluation	3
Modeling of unregulated HC emissions	3
Chemical kinetics and mechanisms	
• experimental studies of unregulated HC emissions chemistry	3
• oil decomposition modeling	3
• emissions vs. oil consumption, engine measurement	3
Fluid mechanics	
• rationalization of engine fluid mechanics	3
Miscellaneous	
Improved intermodel transfer technology	12
Improved traffic control methods	12
Novel ideas	
Communications substituted for travel	27, 37

TABLE A.5: INDUSTRIAL ENERGY CONSERVATION R&D OPPORTUNITIES

Chemicals

R&D Activity	Original Reference (Report No.)
Processing	
Fundamental research in catalysis	11
Specialized catalysts for solution processes	8
Polymer characterization in a fundamental sense	11
Process development for polymer production in SIC 2821 (plastics, materials, and resins)	8
Developing less energy intensive processes for synthetic rubber prroduction. Rubber prroduction via slurry or bulk reaction could be significantly less energy intensive than solution processes currently used	8
Fundamental research in surface chemistry	11
Determination of fluid pphysical and thermodynamic properties	19
Investigation of advanced water desalination methods	4
Exploration of catalyzed solar photolysis of water	4
Solar evaporation of potash brines to concentrate and crystallize potash	17
Conservation of energy during production of phosphoric acid	17
Wet grinding of phosphate rock	17
Conserve energy in phosphate rock mining by extracting P_2O_5 directly from rock-clay matrix	17
Improve heat reecovery in existing ammonia plants	17
Combine the operations of an anhydrous ammonia plant and a steel blast furnace	17
Conservation of electrical power in granulation plants	17
Conservation of energy in granulation plants	17
Efficient marketing and distribution of fertilizers and agricultural chemicals	17
Study total energy consumption of marketing sytems for anhydrous ammonia versus nitrogen solution	17
Sources	
Biomass conversion to chemicals & polymers	11
Alternate souurces of feedstocks for ammonia plants to replace natural gas with coal	17
Use of coal as a fuel for ammonia plants instead of natural gas	17
Coal liquefaction & gasification to provide chemical feedstocks	11
Environmental	
Improve efficiencies of pollution control equipment in fertilizer plants	17

Chemicals

R&D Activity	Original Reference (Report No.)
Heat Recovery	
Heat exchangers	20
Lower cost heat exchangers	19
Exhanger coolant flow control	19
Generic	
Electrical power generation	20
Bottoming cycles	20
Industrial heat pumps	19
Expander technology	19
Absorption refirgeration	20
Low cost chilled water	19
Pipe tracing, monitoring and control	19
Study of insulation characteristics	19
Fundamental research on corrosion	11
High temperature preheated combustion air and burners	20
Studies of adsorption techniques for molecular seperation	4
Utilization of government owned & operated high energy radiation sources for chemical process research	11
General	
Provide (through NBS) continuing charcterization of basic physical 7 thermochemical data on materials of interest to chemical & polymer industry	11
Handbook on waste heat recovery systems and applications	19
Study of possible modes for federal incentives regarding energy conservation	19

Primary Metals

R&D Activity	Original Reference (Report No.)
Iron & Steel	
Ore Preparation	
Improved particle reduction (low energy) • pelletizing	11
Direct use of coal in the manufacture of oxide pellets (replace oil or gas)	9
Conversion from natural gas or fuel oil to coal in pelletizing plants	2
Tar-bonded green briquetts charged to BF	9
Improved sintering process (McDowell-Wellman)	9, 11
Self-reducing agglomerates (carbon-bearing) for BF	9
Prereduction during final stages of agglomeration	9
Optimized fuel mix for agglomeration	9
Substitution of semicoke or char for coke breeze for agglomeration	9
Grinding of iron ore	
• improvement in particle classification	2
Recovery of heat from flue gas in agglomerating plant	9
Cokemaking Form coke	2, 9
Dry quenching of coke	2, 9, 25
Improved particle reduction	
• cokemaking	11
Coal injection	2
Charging of preheated coal to ovens	9
Automatic thermal control of coke batteries	9
Thermal stabilization of coke	9
Thin-wall coke ovens	9
Reduced-temperature coking (semi-coke)	9
Partial (surface) coking (semi-coke)	9
Ironmaking	
Electrolytic refining of iron	10
Decreased slag volume (richer ore)	9
Direct elecrolytic reduction of iron oxides to pure iron	9, 10
Nuclear-derived heat for reduction of iron ore	9
Alkaline carbonates as catalysts for reduction of iron ore	9
Biomass as fuel/reductant for iron ore	9
Hydrogen as reductant for iron ore	9

R&D Activity	Original Reference (Report No.)
Iron & Steel	
Ironmaking (cont'd)	
Gasification of coal in BF	9
Gasification of coal to produce reducing gas	9
Use of direct reduced iron in BF burden	9
Preheating of raw materials to BF	9
Improved effectiveness of BF blast stoves	9
Evaporative cooling of BF	9
Cooling of combustion-zone parts with steam instead of water (steam superheater)	9
Enrichment of BF air with oxygen	9
Blowing of BF with straight oxygen (instead of air)	9
Injection of hydrocarbons to BF	9
Improving charging techniques for BF	9
Increased use of basic sinter in BF	9
Injection of coal into BF	9
Reducing gas injection to stack	2
Injection of hot reducing gases to BF zone-controlled modified BF	9
Bell-less top for high-pressure BF	9
Use of BF top pressure to generate electricity	9
Segregation of BF top gas	9
Increased recovery of BF top gas	9
Stripping of N_2 and CO_2 from top gas	9
Optimizing silicon content of hot metal from BF	9
External desulfurization of BF hot metal	2, 9
Improved transportation of hot metal	9
More efficient ladle preheater	2, 9
Hydrometallurgical production of iron by electrolysis	9
Improved blast furnace process	
• distribution of gas & solids	11
• modeling of fluid flow in furnace, strength of materials that go into furnace, relative size of materials, etc.	11
Computer control of BF thermal and metallurgical processes	9
Recovery of heat from BF slags	9, 25
Steel Casting	
Direct casting of thin-gage steel sheet	9
Continuous rheocasting of steel strip	9
Continous casting of preforms like beam blanks	2
Solidification (form nearer to final product)	
• studies of effects on properties and processing	11
• formation properties of surfaces	11

R&D Activity	Original Reference (Report No.)
Iron & Steel	
Steel Casting (cont'd)	
• basic properties of melts & slurries11	
• effects of non-uniformities such as fluid-flow, heat transfer, fusion temperature, & compositonal variations on processing and properties	11
• modification of limiting factors (thermal diffusity..)	11
Steelmaking	
Preheating of scrap charges to steelmaking furnaces	9, 25
Electric arc furnace scrap	2
Woolworth scrap preheater	9
CO collection from BOF for scrap preheating	2
Use of EAF top gas to preheat scrap	9
Increased use of direct reduced iron	9
Electric arc furnace	
• Modeling	2
Electric arc furnace modification	9
Computer optimization of power use in EAF	9
Conversion of regular-power EAF's to high power	9
Direct steelmaking with nuclear energy	10
Plasma-arc steelmaking	9, 10
Increased use of BOF off gas (suppressed combustion)	9
Utilization of BOF off-gases other than for scrap preheating	2
Steelforming	
High-temperature inspection and surface conditioning	2, 9
Surface inspection	
• ultrasonic methods	25
• eddy current methods	25
• optical & other methods	25
• hot grinding	25
Direct rolling of ingots and slabs	9
Heating furnace designs for increased efficiency	9
Induction heating of slabs, billets, and bars	9, 11
High frequency induction	10
Electric resistance heating of billets	9, 10, 11
DC electric resistance heating of continuous sheets	9
Pulse heating	11
Monobeam slab-reheating furnace	2, 9
Vacuum furnace	10

Primary Metals

R&D Activity	Original Reference (Report No.)
Iron & Steel	
Steelforming (cont'd)	
Basic research into heating steel (electrical properties of steel, effect of heating rates & method of energy application on properties, methods of applying energy)	11
Evaporative cooling of skids in reheat furnaces	9
Hot working and heat treatment	25
Improved forge furnaces efficiencies	2, 9
Improved slot forge furnaces	9
Projectile forming	11
Electroforming	10
Plasma arc spray forming	10
Fluidized-bed heat treatment	9
Computerized annealing system for batch coil annealing	9
Nitrogen-based carburizing atmospheres	9
Direct firing for batch annealing (replace radiant)	9
Furnace using direct coal firing rather than gas or oil	2
Continuous casting slurries	25
Powder metallurgy	10
Powder rolling	10
Steel sheet via powder metallurgy	9
Mechanism of metal rolling	34
Metal processing	34
Waste heat recovery in annealing	2
Novel Processes	
Direct (continuous) ironmaking/steelmaking (ore to steel in one step)	9
Advanced alternatives to the blast furnace--direct steelmaking	
• basic mechanisms of oxidation and reduction	11
• problem of containment (refractory)	11
"S" process; DR shaft over vertical shaft melter	9
Plasma arc steelmaking and spray forming together	10
Advanced alternatives to the blast furnace--plasma arc	
• generating and maintaining plasma flows	11
Advanced alternates to the blast furnace	
• methods of applying energy, particularly electrical	11
Produce electric power during Ox-Red reaction, also to generate hydrogen as a reducing agent	10
Advanced alternatives to the blast furnace--nuclear steelmaking	
• material requirements (severe in nuclear steelmaking)	11
Nuclear-derived heat for reduction of iron ore	9
Steam coal or lignite based process	2

Primary Metals

R&D Activity	Original Reference (Report No.)
Iron & Steel	
Recycling	
Increased recycling of scrap	9
Recovery of metallic and carbon values	2
Impurities removal from scrap	11
Heat Recovery	
Waste heat recovery	2, 9
Heat exchanger development	19
High temperature heat exchangers and recuperators	25
Ceramic recuperators	9
Ceramic heat wheel	25
Metallic counterflow recuperators	9
Low temperature heat recovery	25
Flexible membrane heat exchanger development	19
Fluid bed cooling	25
Generic	
Improvements in burner design	2
New coal burner	2
Blue flame burner	25
Coal injection with plasma burner	25
High-temperature recuperator/burner/ducting	9
Air-fuel ratio controllers	
• multiburner combustors	9
Enrichment of combustion air in oxygen content (by means other than addition of elemental oxygen)	9
Improvements in control of combustion	2
Heavy fuel oil combustion	25
Pyrolysis of low grade coals	25
Cogeneration	2, 9
Gasification of coal to produce fuel	9
Continuous gasification of coal	25
Blast gasifier	2
Cothane process for making methane from waste CO	9
Improvements in high-temperature materials	2
Ceramic-fiber insulation	9
Coatings with high IR reflectance and high durability	10
Improvements in temperature sensing	2
High-temperature sensors	9
Energy management through computer modeling and control	9
Computer control of BF thermal and metallurgical processes	9
Vapor recompression of 125°F steam	19

Primary Metals

R&D Activity	Original Reference (Report No.)
Iron & Steel (cont'd)	
General	
Regional energy management	2
Improvements in plant energy management	2
Source-sink location coordination	19
Increase yield of various iron and steel processes	9
Oxygen use in lime kilns; fluid bed process	2
Bleedwater chemical treatment	19
Environmental	
Basic mechanisms of fume formation, fine particle technology, dust formation, gas cleaning mechanisms, slag processing, materials recovery	11
Foundary	
Cupola modification to eliminate after-burners	9
Coal-fired rotary furnace for melting iron (replace oil)	9
Alloys	
Codeposition of alloys	11
Aluminum	
Processing	
Direct reduction of aluminum	11
Inert anodes	11
Purification technology for recycling aluminum alloys	11
Replacement of petroleum coke w/coke from coal in anodes	11
Recover energy from spent bauxite discharge	19
Generic	
Recycling	
Recover valuable minerals from waste products (mill tailings, smelter dust & slag, scrubber sludge, steel plant slag, thermal power plant ash, garbage)	11

Primary Metals

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
Fluid Mechanics	
Improved understanding of fluid flow through static & dynamic particle systems	11
Separation & Mining	
Improve separation of minerals by use of high-gradient, high-field magnets	11
Methods to extract minerals or metals from seawater	11
Develop alternative processes for extracting copper, lead, zinc, and nickel from sulfide ores	11
Study of energy inefficiencies in ore beneficiation to approach more closely the minimum separative work	4
Find better ways of fracturing rock	11
Basic research in grinding (only about 5% efficient)	11
Chemistry & Materials	
Improve flotation & flocculation processes by research on surface active agents	11
Augment understanding of the physics & chemistry involved in mineral processing	11
Study of impurity element distribution between slag, metal, matte and gas phases	11
Develop a data bank on the physical and chemical properties of metals and their compounds	11
Electrolyte	
Basic reseach on the physics of charge transfer at electrolyte-electrode interfaces	4
Research into principles of solid electrolytes	4

Stone, Clay & Glass

R&D Activity	Original Reference (Report No.)
Cement	
Grinding	
Roller mill for raw material grinding	1
Kiln	
New cement process which uses no pyro processing step	1
Oxygen enrichment of kiln combustion air	1
Develop small non-rotating furnaces to produce Portland cement	11
Recycling	
Use of slag or other pozzolonic additives to Portland cement	1
Study processes to produce high quality clinker from waste cement dust	11
Generic	
High temperature filtration to use 800-900^{o}F waste heat from cement plants to produce electricity	11
Develop coal gasification units so that ash, sulfur and alkalies are not added to clinker composition	11
General	
Ability to predict fundamental properties of cement products - reduces the requirement for overdesign	11
Development of radically changed compound composition in cement (e.g., silicates and aluminates that form at lower temperatures)	11
Advanced energy storage and transport	20
Change in standards from composition to performance standards - permits substitional materials in cements	11
Glass	
Melting/Fining	
Glass and steel furnace refractories research to improve vessel life and product quality	11
Innovative glass melting process research, e.g., high energy concentration in a small area and with rapid transport of batch through the zone	11

R&D Activity	Original Reference (Report No.)
Glass (cont'd)	
Heat recovery	
Thermal audit of waste heat sources	20
Stack gas heat recovery	20
Generic	
Oxygen-enriched combustion air	20
General	
Alkali resistant glass applicable to reinforce concrete, (e.g., reactions of cement with other filler materials)	11
Ceramics	
Forming	
Coating of fine mineral particles, e.g., coating of fluxing materials in aggregate materials of proper size distribution in order to develop better ceramic bodies at lower temperatures	11
General	
Fundamental research on surfaces of ceramics	11
Foamed ceramic materials; high strength at low density. (Low with construction group)	11
Fundamental studies on the brittle nature of ceramic materials; success will permit use of high temperature stable materials for turbine applications yielding magnificantly higher efficiencies	11
Fundamental studies for increasing the fuel effectiveness in firing ceramic products; some processes are only 5-10% efficient	11
Generic	
Furnaces	
High temperature preheated combustion air and burners	20

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
Heat Recovery	
Heat exchangers	20
More efficient heat exchangers to preheat raw materials using waste heat	11
Heat pumps	20
Grinding	
Fundamental research on grinding processes	11
Recycling	
Fundamental research on fly ash	11
Utilization of waste materials, tailings, recycle, etc., a) fly ash b) calcium sulfate c) slags and scorias d) substitution for asbestos or other materials where there are environmental problems	11
Cogeneration	
Electrical power generation	20
Bottoming cycles	20
Cogeneration	20
Sensors & Controls	
Reliable temperature measurement process diagnostics	11
Modeling	
Fundamental system analysis for net process energy consumption, e.g., conversion to electricity from gas or oil for glass melting	11
Development of algorithms models for use in real industrial processes	11
Storage	
Heat storage, (high temperature regenerative process) encapsulation in stable refractory material of materials which will change phases	11

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
General	
Lower temperature processes	11
Understand fine particle processes and characterization techniques	11
Prereaction of materials, thermal or chemical, prior to processing	11
Selected phase equilibrium diagrams	11
High temperature phase composition studies, would lead to high temperature processing units	11
New plants follow markets, need for local material and process variations to fit optimal model; basics of reformulation are not well established and research is necessary	11

Paper & Pulp

R&D Activity	Original Reference (Report No.)
Wood Preparation	
Bark separation from chips	35
Pulping	
Pulp washing	35
Pulp pressing	35
Mechanical pulping	35
Automatic control digester	35
Reuse of low-value heat to heat chips	35
Hydropyrolysis	35
Chemical Recovery	
Plasma technology	11
Electrochemical regeneration using reducing power of black liquor	11
New lime producing technology	11
Bleaching	
Automatic control bleaching	35
Chemistry of causticization	11
Papermaking	
Dry forming	11, 35
High consistency forming/cleaning	11, 35
Electromagnetic displacement	11
Fluid displacement	11
Physical displacement	11
Paper pressing	11, 35
Extended nip press	35
High temperature forming	11
Mach nozzle drying	24, 35
Mechanical dewatering	35
Fluidized bed drying	35
Microwave drying	35
Fundamentals of fiber-solvent interaction	11
Fundamentals of fiber-fiber bonding	11
Waste & Heat Recovery	
Improved low temperature heat exchangers	19
Low level heat utilizationll	
Application of fluidized bed heat exchangers to waste heat recovery	19

R&D Activity	Original Reference (Report No.)
Waste & Heat Recovery (cont'd)	
Utilization of heat sinks or balancing condensers	19
Reduce water to recovery boiler	35
ASME coding of compact heat exchangers	19
Improved paper machine hood economizers	19
Corrosion resistant economizers	35
Heat recovery from paper dryers using heat wheels	35
Reradiant recuperator	35
Conserving hood waste heat via heat pumps	19
Converting waste heat in low temperature water to higher temperature water via heat pump	19
Investigation of feasibility of bark drying for heat recovery	19
Economics of solar augmentation and conceptual design of system for waste stream heat recovery	19
New recovery technology	35
Resource recovery logistics	35
Wastepaper recycling	35
Wastepaper characterization	35
Solid waste (sludge) utilization	11
Batch-digester heat reuse	35
Freeze crystallization of black liquor	35
Bark and hog fuel preparation	35
Generic	
Use of hot water from flue gas scrubbing	35
Cogeneration	35
Vapor compression	35
Rankine and electric heat pump	35
Automatic control recovery boiler	35
Advanced air/fuel ratio control systems	35
Clean-burning bark burners	35
Fundamentals of wood combustion (gasification, cogeneration applications)	11
Alternative fuels for lime kilns	35
Coal-derived fuels for combined gas steam turbines	35
Membrane technology for air enrichment	35
Pressurized fluidized bed	35
Gasifier	35
Low cost gasifier	11
Steam distillation of methanol	35
General	
Higher feedstock temperatures - allows for reduced viscosity, surface tension, and increased drainage (reduces pumping losses); also means less heat would be needed in the drying section	24

R&D Activity	Original Reference (Report No.)
General (cont'd)	
Solid waste disposal	35
Non-biological effluent treatment	11
Improved pest control	11
Biological, genetic improvements in trees	11
Increased end product moisture	35
Computer applications to energy management	35
Technical information	35
Energy management handbook	35

Food Processing

R&D Activity	Original Reference (Report No.)
Dairy	
Development and dissemination of technical educational materials and technology transfer	17
Development of alternatives to current package sealing techniques	17
Integrated energy systems for dried food products	17
Identification and evaluations of constraints on energy utilized by the dairy products industry	17
Development of a 2:1 sterile concentrate milk beverage	17
Improvement of energy efficiency of in-plant clean-up practices	17
Phase I: Feasibility study of sterile fluid milk as a major conservation measure; Phase II: Development and demonstration of a pilot system	17
Fruits & Vegetables	
Improved refrigeration equipment and processes	17
Earth covered and/or underground storage of cold and/or frozen products	17
Water removal	17
Sterilization	17
Bulk reduction to decrease handling, warehousing and transportation costs	17
Grain	
Improved equipment design	17
Alternate processing and formulation methods to reduce energy consumption	17
Liquid concentration	17
Improved technology for process and moisture control	17
Meats	
Re-use of hot and/or tempered water through filtration	17
Reduce energy used in high pressure and high temperature water beef carcass washer	17
Systems analysis of energy use in the meat industry	17
Recycle waste water effluents through reclamation system to produce crystal clear potable water certifiable by U.S. Health Dept. Laboratories	17
Reduce energy used in beef and hog viscera inspection tables	17
Investigate use of outside winter air for refrigeration in northern plants	17

R&D Activity	Original Reference (Report No.)
Meats (cont'd)	
Substitution of sanitation for refrigeration energy to reduce energy used in chilling red meats	17
Elimination of after-burners	17
Reduce natural gas consumption in hog singeing operation	17
Develop means of eliminating condensation on plant ceiling that is less energy intensive than current procedure	17
Hot deboning	17
Industrial boiler system	17
Development of alternate methods for chilling carcasses	17
Develop alternate method of removing water from material to be rendered inedible	17
Improving scalding and de-hairing methods for hogs, on-line with mechanical equipment and chemicals	17
Vacuum chilling and storage of red meat	17
Reduction of the amount of water used in all meat and poultry processing plants	17
Immersion chilling of red meats	17
Microwave for processing - new construction	17
Pressurize meat processing smoke houses	17
Reduce energy use in refrigerated transport	17
Demonstration of energy conservation measures	17
Minimize packaging material for meats	17
Generic	
Improved combustion efficiency	17
Automatic air/fuel ratio control for small boilers	17
Recovery of lost heat escaping plant in waste effluent	17
Better ammonia and freon refrigeration systems and controls for defrosting	17
Elimination of steam traps with introduction of a sump at lower physical level and pumping of condensate under pressure to steam generator	17
Improved steam traps	17
Improved heat transfer and heat recovery capability of drying systems	17
Improved heat recovery systems	17
Heat recovery - gases and water	17
Refrigeration waste heat recovery	17
Raise low pressure steam to 100 psig level by compression cycle	17
Vapor compression with wetter steam	17
Utilization of heat pumps in current manufacturing processes	17
Improve the efficiency of absorbers for 140°F input water	17
Heat pump or heat pipe for 250°F waste heat elevated to 400°F in cereal manufacturing	17

Food Processing

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
Waste water $100^{o}F$ to $180^{o}F$ for sanitizing and thawing	17
Increase of water temperature for clean-up using solar augmentation	17
Heat exchanger cleaning and filtering for fouling prevention	17
Dryer exhaust recovery with fouling control	17
Recovery of contaminated condensate for reuse	17
Electrical production during generation of low pressure steam	17
Fuel cell application	17
Reuse of hot or tempered water through filtration	17
Fuel substitution	17
Alternate fuels to replace natural gas	17
Utilization of solid wastes as an energy source	17
Heat storage in small volumes	17
Methane production and anaerobic digestion of wastes	17
General	
Packaging	
Equipment ratings	
Systems studies of industrial parks	17
Evaluation of current practices in food processing firms	17
Education of the public	17
4-day, 40-hour work week effect on energy consumption, and effect on economies of various plant capacities	17

Textiles

R&D Activity	Original Reference (Report No.)
Preparation & Dyeing	
Moisture analyzer	15, 19
Pad/batch preparation and dyeing	15
Energy optimization in textile scouring	15
Energy efficient moisture removal systems	15
Direct application of process chemicals	15
Low-energy continous dye systems	15
Sludge incineration	15
Anaerobic digestion of sludge	15
Wet process modification	19
Foam dyeing	19
Spray dyeing	19
Wet-on-wet dyeing	19
Vapor dyeing	19
Electrostatic deposition of dyes	
Conversion from pneumatic to mechanical materials handling at gins	17
Reduction of energy consumption in wool scouring	17
Reduction of hot water usage in wet-processing of cotton-containing textiles	17
Elimination of drying processes in wet-processing of cotton-containing textiles	17
Field cleaning of seed cotton	17
Improved lint cleaning at gins	17
Improvement of efficiency of gin seed cotton dryers	17
Fiber and raw material	
• maximize use of raw materials	11
• separation, recovery, and resuse of fiber, chemicals	11
Yarn and Fabric	
Tuft to yarn system	15
Low energy sizing	15
Electrostatic waste removal	15
Optimizing power needs of greige mill	15
Curriculum for fixers & changers	15
Energy conservation in yarn forming and preparation	15
Electrostatic spinning	15
Computer model of energy needs of a mill	15
Energy conservation in texturing	15
Energy conservation in weaving	15
New fiber-to-yarn techniques for agricultural fibers	17
Finishing	
Moisture analyzer	15, 19
Low temperature curing	15
Improvement of drying technology	15

R&D Activity	Original Reference (Report No.)
Finishing (cont'd)	
Optimization of drying techniques	15
Metering techniques for finishing agents	15
New size development	15
Development of effective mechanical dewatering techniques to minimize energy required for drying (paper industry analogy)	11
Study of the machnozzle	15
Radiation curing	15
Systems analysis of a finishing plant	15
New bleaching technology	15
Microwave or dielectric heating	15
Modification of steam can technology	15
Flame curing finishes	15
Mass and energy flows in a textile finishing plant	19
Tenter frame drying	19
Radiation curing	19
Spray finishing	19
Wet-on-wet finishing	19
Vapor finishing	19
Electrostatic deposition of finishes	19
Heat recovery	
Heat recovery of contaminated exhausts	15
Heat pump utilization of waste heat streams	19
Cleaning exhaust emissions for heat recovery	15
Heat recovery from boiler stack gas	19
Generic	
Development of cogeneration systems	15
Development of coal boiler	15
Exhaust gas incineration	15
Power measurement equipment	15
Energy conservation via lubricants	15
Alternate fuels for finishing	15
Ginning waste as a substitute fuel for drying	17
Generation of power for cotton gins by using gin waste	17
Application of heat pumps to specific textile processes	19
Compression process using hydraulic power instead of steam power	17
Development of pressurized hot water vs. steam for process heating systems (includes reuse of hot process liquors)	11

Textiles

R&D Activity	Original Reference (Report No.)
Generic (cont'd)	
Development of improved insulation and heat storage technologies to minimize heat energy requirements	11
Development of automatic power factor correction techniques for individual electric motors	11
Control and correction of high-frequency transient peaks by Zener diodes	11
Development of more efficient electrical motors	11
Improved management and control of electrical energy demand	11
Improved synchronous switching of heavy electrical loads	11
Minimize air cooling and humidification requirements	11
Effluent neutralization via flue gases	15
Anaerobic digestion of concentrated waste	19
Projection of future solar collector costs	19
General	
Improved screening and evaluation of developments and innovations	11
Energy analysis of textile processes	15
State-of-the-art review of energy use in textiles	15
Dewatering processes	19
Improved process efficiency	11
Improved in-plant environment for process control and workplace	11
More efficient machines	11
Continuous product flow	11
Retrofits for improved efficiency	11
Process improvement	11
• new, more efficient routes from fiber to product fiber to product	
Low-energy processing	11
Reduce use of liquids	11
Compressed process lines	11
Continuous flow, improved materials handling	11
Product modification	11
Product improvement	
• improved durabilty, useful life	11
• improved performance	11
• individualization of basic product through finishing versus construction	11
Development of new end uses for textile and apparel industry by-products	11
Development of new generic fibers from renewable resources	11
Development of new natural fibrous and auxiliary raw materials	11

Textiles

R&D Activity	Original Reference (Report No.)
General (cont'd)	
Optimization of fiber blends and fabric finishes for both function and ease of separation and recycling	11
Development of economic recycling techniques for extraction of fibrous materials from finished fabrics	11
Development of effective energy cost accounting by style, shade, etc.	11
More effective manpower training in energy-conservative skills (possible new incentives for conservation)	11

Agriculture

R&D Activity	Original Reference (Report No.)
Crop Production	
Increased fertilizer efficiency	18
Biological nitrogen fixation	18
Energy reduction through increased pesticide efficiency	18
Energy conservation through reduced tillage	17, 18
Reduced weather vulnerability	18
Cropping for more energy-efficient food chains	18
Multiple cropping for energy efficiency	18
Loss reduction in harvesting	18
Increase efficiency of nutrient utilization	18
Energy conservation through genetic improvement (photosynthetic efficiency)	18
Effect of continuous crop residue removal on soil productivity	18
Agricultural utilization of non-agricultural by-products	18
A systems approach to energy conservation in agricultural production	18
Alternate portable fuel systems for agricultural production	18
Reduction of transport energy in crop production	18
Systems approach to utilizing waste heat in intensive crop production and marketing	19
Animal Production	
Improved milk-handling procedures	18
The facts of meat animals and energy use	18
Potential for energy-flexible systems	18
Promotion, acceptance, and adoption of energy-saving methods of livestock production	18
Develop and demonstrate forage and grain handling systems	18
Feasibility of the utilization of industrial low temperature waste heat	18
Integrated milk production and sanitation systems	18
Future requirements for energy in animal and poultry production	18
Energy self-sufficient animal production systems	18
Minimizing energy costs of environmental modifications of animal production systems	18
Improve motor efficiency and make more efficient use of motors in farmstead equipment	18
Matching animal production with processing or manufacturing process	18
Conservation of energy used to control the environment in livestock housing	18
Conservation of energy in the construction and use of buildings for livestock production	18

R&D Activity	Original Reference (Report No.)
Animal Production (cont'd)	
Development of effective animal manure management systems	18
Conservation of energy used for handling livestock waste	18
Recovery and development of energy from animal excreta	18
Energy conservation in feed-handling equipment	18
Improvement of the energetic efficiency of animals by physiological and nutritional means	18
Conserving energy in transport	18
Environmental control of swine houses utilizing waste heat contained in liquid streams	19
Environmental control of poultry houses utilizing waste heat contained in liquid streams	19
Development of intensive catfish fingerling production systems utilizing power plant discharge water	19
Intensive integrated fish production utilizing waste heat	19
Other Production	
Combination systems for aquacultural production	18
Domestic aquacultural production	18
Improving efficiencies of vehicle use in aquacultural production	18
Utilizing low grade waste heat in aquacultural production	18
Increasing efficiency of materials - handling systems in aquacultural production	18
Utilizing waste heat from steam electric-generating plants in the culture of aquatic food	19
Combination systems	18
Establishing data base for energy conservation in controlled-environment agriculture	18
Substitution of scarce fuels	18
Reduction of energy use in the transportation and marketing of vegetables, fruits, and flowers	18
Systems analysis of intensive vegetable, grain and flower production for energy conservation	18
Biological and physiological alterations of crops	18
Development of new construction materials for greenhouses	18
Increased space utilization in greenhouses	18
Greenhouse orientation and shape	18
Improved greenhouse heating systems	18
Reducing energy consumption for cooling greenhouses	18
Reducing heat losses in greenhouses	18
Energy-effective use of lighting systems for heating and constant year-round production	18
Utilizing power plant waste heat for greenhouse environmental control	19

Agriculture

R&D Activity	Original Reference (Report No.)
Other Production (cont'd)	
Heating greenhouse crop-rooting media and enhancement of greenhouse above root media atmosphere with CO_2 from relatively clean stack heating	19
Utilization of area waste heat by area agriculture	19
Crop variety testing in waste heat-warmed soil conditions	19
Economic feasibility of soil warming systems	19
Distribution for piping systems for soil warming and subsurface irrigation	19
Heat and mass transfer in soils as applied to soil warming	19
Enhanced water plant producton for food, feed, and biomass via waste heat	19
Large scale environmental control complexes	19
On Farm Processing	
Use of industrial waste heat for crop drying	18
Identification of potential areas of using waste heat for crop drying	19
Mechanisms for utilizing waste heat to dry agricultural crops	19
Preservatives to delay drying as applied to cereal grains	18
Development and demonstration of dryeration	18
Utilization of lined tunnels below grade as a heat exchanger	18
Direct oil-fired burner for crop drying	18
Evaluation of technical and economic feasibility of heat pumps for grain drying	18
Investigation of the technical and economic feasibility of a coal-fired grain dryer	18
Innovative design of grain dryers	18
Low temperature grain drying	18
Heat recovery systems for crop dryers	18
Grain dryer fuel from non-grain plant parts	18
Containerization for low-energy grain handling	18
Establishing energy use patterns for livestock feed processing/handling systems	18
Energy conserved and effect on electrical demands resulting from peak load shifting	18
Demonstrating energy conservation through recycled heat from dairy farm milk refrigeration units	18
On-farm milk volume reduction systems	18
Annual cycle energy systems applied to farm processing	18
Use of low grade energy contained in liquid effluents for dairy operations	19
Heat storage for agricultural uses	19
Methods for waste heat transport with distance limitations	19
Utilization of waste heat in closed-loop, dehydration-pelletizing systems	19

R&D Activity	Original Reference (Report No.)
Water Resources (cont'd)	
Recharge of aquifiers to reduce lift for pumped irrigation	18
Measures for retaining water on land to reduce irrigation pumping	18
Development of a simplified flow meter	18
Drainage materials and design practices for energy conservation	18
Energy conservation by improved drainage pumping plant efficiencies	18
Energy conservation in agricultural drainage installation	18
Irrigation system efficiency	18
Improvements of motor and engine efficiencies	18
Energy conservation due to improved pumping plant efficiencies	18
Irrigation management	18
Energy limitations for reclamation of submerged lands	18
National impacts of energy conservation in water resources	18
Development of educational material for evaluating alternatives to improve pumping plant efficiency	18
Water harvesting as an alternative to pumped irrigation	18
Water application efficiency	18
Development of new well screens and gravel pack procedures to reduce drawdown in wells	18
Use of waste water to replace pumped water	18
Crop response to limited water and nitrogen input	18
Solar energy as an alternate source of energy for pumping water	18
Wind as a source of energy for pumping water	18
Improvement of pump efficiency	18
Alternate source of energy - coal fired steam turbine	18
Alternate sources of energy for pumping water	18
Generic	
Waste heat utilization to improve quality of inland water streams	19
Frost control via waste heat sources	19
Advancement of refrigeration and air conditioning technologies utilizing waste heat	19
Technology and information transfer	19
Survey of waste heat recovery and utilization for agricultural applications	19
Production of fresh water in arid regions using waste heat	19
Design equations for heat pipes/heat exchangers	19
Substitution of scarce fuels	18
Methods for waste heat transport with distance limitations	19
Byproducts	
Use of byproducts in agriculture	17
Feasibility of converting feedlot wastes to industrially useful oxychemicals	18

Agriculture

R&D Activity	Original Reference (Report No.)
Byproducts (cont'd)	
Demonstration of cascade feeding systems for poultry, steers, and brood cattle	18
Health and consumer aspects in the feeding of animal wastes to livestock	18
Development of energy-efficient equipment to collect, process, store and re-feed livestock wastes	18
Relative efficiency and economic aspects of utilizing manure	18
Use of mineral content derived from crop residues	18
Integration of animal feeding, fuel production and fertilizer use in the use of crop residues and animal wastes	18
Demonstration of practical methods of CO_2 enrichment for crop growth	18
Increase developmental efforts on the enzymatic hydrolysis of cellulosic residues to sugars	18
Define and demonstrate optimum systems for production of industrial chemicals from collected agricultural residues	18
Define and demonstrate optimum liquid fuel production systems	18
Utilization of waste heat to enhance biogas production	19
Improvement of biogas production system reliability	19
Define and demonstrate gas-generating systems for farm and and off-the-farm use	18
Demonstration of direct combustion of field crop residues for off-the-farm use	18
Demonstration of direct combustion of field crop residues for on-the-farm use	18
Definition of economical methods of whole crop harvesting for optimum grain quality, energy use, and residues collection	18
Practicality of the redesign of grain crops to maintain grain yield but increase total biomass	18
Availability of field crop residues for specific crops and regions	18
Development of methods for harvesting, storing and transporting crop residues considering off-the-farm use	18
Use of waste heat to enhance composting	19

APPENDIX B

CRITICAL REVIEWS

APPENDIX B

CRITICAL REVIEWS

The first section of this Appendix presents the outline that describes the format utilized by the assessment staff of this study to write the reviews of individual research opportunities studies. This outline is followed in each of the individual reviews included in this Appendix.

The second section of the Appendix presents the written reviews of the 38 reports that were surveyed for this study. The summaries in Tables 2.1, A.1, A.2, A.3, and A.4 are taken from these reviews. Each written review presents a summary of the types of information provided in the report, a list of R&D opportunities and a critical summary by the reviewer that follows the outline shown in section one. Many of the individual reviews also attach material from the reports, such as tables, figures, or bibliographies. These reviews and attachments provide a summary of the salient information on energy conservation research opportunities presented in the 38 reports reviewed for this study.

The third section of this Appendix presents a bibliography of 88 reports that discuss energy conservation research opportunities. The 38 reports that were reviewed for this study are included in this section and are indicated by a bullet (•). The additional 50 reports shown in this bibliography are those that we feel should be reviewed in any further efforts of this type.

B.1 CRITICAL REVIEWS--FORMAT

I. Standard Bibliographic Reference
-including source of funding (sponsor)

II. Areas of Technical and/or End-Use Focus
-describe at level of detail appropriate for report

III. Types of Information Provided (describe where necessary)

1. Did report review energy end-use data relating to focus of study?
2. Did report estimate energy savings that could result from research?
3. Did report estimate time to commercialization of technologies being considered?
4. Did report review existing research programs relating to technologies being considered?
5. Did report present a methodology for identifying research opportunities? (if so, describe briefly)

IV. List of Individual R&D Opportunities

1. Description of Research Opportunity (as presented in report)
   -page in report that refers to R&D opportunity
   -sector/device/process to which R&D applies
   -technical barrier addressed
   -why is this R&D needed? (in end-use or technical terms)
2. Estimated Energy Savings from Use
3. Time to Commercialization
4. Existing R&D Programs
5. References that Offer Additional Information

V. Critical Summary
-comprehensiveness
-level of detail
-technical accuracy
-justification of R&D opportunities

VI. Individual Reviewer's Comments
-compatibility with other studies
-any remarks not addressed elsewhere in review

VII. Attachments

-summary tables or figures that describe research opportunities

-bibliographies of other research opportunities studies

B.2: REVIEWS OF 38 INDIVIDUAL ENERGY CONSERVATION R&D OPPORTUNITIES STUDIES

- Report No. 1

I. A.D. Little, Inc. Environmental Considerations of Selected Energy - Conserving Manufacturing Process Options. Volume X. Cement Industry Report. EPA-600/7-76-034j. U.S. Environmental Protection Agency, Cincinnati, Ohio. 1976.

II. Technical and/or End Use Focus

The report focuses on the calcining step which uses 70 to 80% of the energy used in cement production. Only process changes having a high probability of implementation by 1991 were studied in detail; this limited the study to four processes which exist today and are the product of a considerable number of years of active development. Four other processes are mentioned on page 4. The report assesses the four selected processes with respect to pollution and environmental consequences, probability of potential for change, and energy conservation consequences.

III. Types of Information Provided

1. Energy use data were reviewed for the cement industry (yearly) and the predominating cement production process (Btu/ton of cement) and for each of the four selected clinker processes (Btu/ton).

2. Energy savings from R&D not estimated.

3. Time to commercialization not estimated.

4. Existing research in cement production not reviewed.

5. Selection of processes to be studied based on highest energy-using step and existing commercial processes.

IV. R&D Opportunties

No R&D opportunities were listed for the four focus calcining processes, presumably since they are already fully developed. There may be R&D opportunities, not expressed in this report, for the four other energy conserving processes mentioned:

- roller mill for raw material grinding
- oxygen enrichment of kiln combustion air
- new cement process which uses no pyroprocessing step
- use of slag or other pozzolonic additives to Portland cement.

V. Critical Summary

Comprehensiveness, level of detail and technical accuracy for the process changes studied are very good. Apparently, there are no significant remaining R&D opportunities in those four processes. R&D opportunities identified have only to do with characterization of gaseous and particulate emissions and possible use of waste kiln dust (apparently not a big problem).

VI. Comments

The four processes mentioned in III above should be reviewed for energy conservation potential and possible R&D opportunities.

Reviewed by WEG.

• Report No. 2

I. A.D. Little, Inc. RD&D for Energy Conservation Preliminary Identification in Iron and Steelmaking. SAN/1692-1. Division of Industrial Energy Conservation, U.S. Department of Energy, January 1978.

II. Technical and/or End-Use Focus

This report focused on near-term (5-10 yr) research needs in the Iron and Steel industry. This study only discussed the direct use of energy and did not consider secondary effects (e.g., manufacture of materials used in steelmaking).

III. Types of Information Provided

1. Energy use data were given for each process discussed.

2. Estimates of possible energy savings were given.

3. Development times for the projects were normally included.

4. Existing R&D programs in each project area were mentioned.

5. An approach for identifying the research opportunities was given. In the study, three types of conservation opportunities were examined: 1) conceptual opportunities within each process, 2) new technologies that could replace current technologies, and 3) general technologies. To gather information, major steel companies were visted, a meeting was held with the American Iron and Steel Institute, and previous studies were reviewed. Because the time frame was less than ten years, the authors judged that major portions of any idea worth considering must have already been piloted or tested on a large scale. Cost benefit assessments were also performed for each of the processes.

IV. R&D Opportunities

See attached sheets.

V. Critical Summary

Following a process-to-process outline, this report presented a coherent and comprehensive picture of conservation research needs in the steel industry. The projects discussed were examined technically and economically and the explanations were clear and not overburdened with technical detail.

A major drawback limiting the usefulness of this report to the ECUT project is the short time frame of the report: less than 10 years. This caused the authors to rely on technologies which have already been demonstrated on a large scale. Therefore, untested or sparsely tested ideas, regardless of their merit and possible impact on energy conservation in the longer term, were not investigated.

VI. Comments

The literature reviewed to aid in compiling this report is listed below:

- "Energy Conservatin in the Steel Industry," by American Iron and Steel Institute, 26 May 1976;
- "Evaluation of the Theoretical Potential for Energy Conservation in Seven Basic Industries," prepared for FEA by Battelle Columbus Laboratories, 11 July 1975;
- "Recommendations for Future Government-Sponsored Research and Development in the Paper and Steel Industries," prepared for ERDA by Thermo Electron Corp., August 1976;
- "Energy Use Patterns in Metallurgical and Non-Metallic Processing, Phase 8: Opportunities to Improve Energy Efficiency" (NTIS PB-261 152) prepared for the Bureau of Mines by Battelle Columbus Laboratories, Ohio, 17 September 1975;
- "Potential for Energy Conservation in Nine Selected Industries," prepared for FEA by Gordian Associates;
- "Environmental Considerations of Selected Energy-Conserving Manufacturing Process Options" (EPA-600-7 - 76-034), prepared for EPA by Arthur D. Little, Inc., December 1976;
- "Steel and the Environment - A Cost Impact Analysis," prepared for the AISI by Arthur D. Little, Inc., May 1975;
- "Risk/Rate of Return Tradoff Analysis: A Case for Federal Support" (draft) prepared for ERDA by Energy and Environmental Analysis, Inc., 30 August 1976.

Reviewed by GJH.

TABLE I-1

MAJOR ENERGY CONSERVATION OPPORTUNITIES FOR ENGINEERING DEVELOPMENT IN IRON AND STEELMAKING

Sector	Examples of Energy-Conserving Technology	Minimum Total Funding to Demonstrate a New Technology ($ Millions)	Comments	Funding For Broader Demonstration ($ Millions)
Reheating, Including Annealing	Monobeam furnace (B)	15 - 25	(a)	
	Better heat recuperation (B)		(a)	
	Furnace using direct coal firing rather than gas or oil (A)	15 - 50	Engineering problems need to be resolved	60 - 120
	Improved forge furnace efficiencies (C)	1 - 20	(a)	
	Waste heat recovery in annealing (C)		(a)	
Blast Furnace	Coal injection (A)	5 - 15	(a)	
	External desulfurization (A)	5 - 10	Demonstration needed on a continuous basis	60 - 200
	Reducing gas injection to stack (A)	5 - 25 (?)	Potentially interesting if economic coal gasifier developed	
Coke Making	Dry quenching (A)	15 - 25	U.S. demonstration of foreign technology needed	30 - 300
	Form coke (A)	30 - 100	Medium Btu by-product gas process desirable	
More Scrap Use in Steelmaking, Including Preheating Technologies	CO collection from BOF for scrap preheating (A)	1 - 10	Good engineering concept needed	15 - 25
	Electric arc furnace scrap preheat (B)	1 - 5	Good engineering concept needed	
Coal-based Gasifier/Burner	Blast gasifier (A)	20 - 60	(a)	
	New coal burner (A)	1 - 40 (?)	Sulfur and ash removal needed from hot gas stream	50 - 200
Yield Improvement:				
Conserving Slab Heat	Hot inspection and spot scarfing (A)	1 - 10 (?)	Research and development required	1 - 50
Casting and Rolling	Continuous casting of preforms like beam blanks (B)	50 - 100	New semi-finished steel forming technology requires conceptual development and demonstration. (Slab, bloom, and billet casting need economic incentives for implementation.)	50 - 200

(A) Potential for national energy conservation of 50-500 x 10^{12} Btu/yr.
(B) Potential for national energy conservation of 5- 50 x 10^{12} Btu/yr.
(C) Potential for national energy conservation of 0.5-5 x 10^{12} Btu/yr.
(a) Reasonable to moderate extrapolation of currently available technology

TABLE I-2

EXAMPLES OF OTHER ENERGY CONSERVATION OPPORTUNITIES IN THE IRON AND STEEL INDUSTRY

Sector	Example of Concepts	Energy Conservation Potential*	Comments
Agglomeration	Conversion from natural gas or fuel oil to coal in pelletizing plants	B	Technology established
Grinding of Iron Ore	Improvement in particle classification	B	Small improvements over time
Electric Arc Furnace	Modeling	B	Small improvements over time
Basic Oxygen Furnace	Utilization of BOF off-gases other than for scrap preheating	B	CO gas collection technology established, but an economic system for use of CO is still to be devised
Flue Dusts and Sludges	Recovery of metallic and carbon values	B	An important problem relating to waste disposal
Ladle Preheating	More efficient ladle preheater	B	Logistical and engineering problem
Direct Reduction	Steam coal or lignite based process	A	Conserves metallurgical coal; process development expected to be capital-intensive
Lime Manufacture	Oxygen use in lime kilns; fluid bed process	B	Most applications would be outside of steel industry

* A: Potential for national energy conservation of 50-500 x 10^{12} Btu/yr
B: Potential for national energy conservation of 5- 50 x 10^{12} Btu/yr
C: Potential for national energy conservation of 0.5-5 x 10^{12} Btu/yr

TABLE I-3

OTHER MAJOR ENERGY CONSERVATION OPPORTUNITIES USEFUL TO THE IRON AND STEEL INDUSTRY

Sector	Major Application
Improvements in High-Temperature Materials	Recuperators, regenerators, skids for reheating furnaces
Improvements in Plant Energy Management	Computer control of energy management and production scheduling
Improvements in Temperature Sensing, Burner Design, and Control of Combustion	Reheating furnaces
Cogeneration	Use of low-temperature heat
Regional Energy Management	Highly industrialized areas

• Report No. 3

I. Aerodyne Research, Inc. An Assessment of the Potential Impact of Combustion Research on Internal Combustion Engine Emissions and Fuel Consumption. PB-0290953. Aerodyne Research, Inc. Bedford, MA, January 1979.

II. Technical and/or End-Use Focus

The technical focus is on automotive combustion engines.

III. Types of Information Provided

1. No review of end-use data was made.

2. No estimates of energy savings from research were made.

3. The report recommended a level of effort for the various research projects suggested. As part of the level of effort a contract time was presented; however, because the research is much more basic than applied toward the commercialization of a device, times to commercialization were not included.

4. Current programs were not reviewed as the work of others directly relate to the suggested research activities.

5. No methodology presented.

IV. R&D Opportunities

See attached pages.

V. Critical Summary

This report is a very technically oriented view at needed research in engine combustion. Quantitative estimates of potential energy savings from the suggested research was not included. Rather, justification for the research stemmed from the expressed need to optimize fuel consumption while controlling pollutants by understanding the basic combustion processes. That is, the need is assumed if optimum engine designs are desired. Meaningful energy conservation estimates may well be much more appropriate after the basic processes are understood and various design changes are postulated.

Technical explanations of the need for research are included with thorough descriptions of major factors controlling fuel consumption and pollution.

VI. Comments

Reviewed by GJH.

TABLE 7-1 SUMMARY OF RECOMMENDED RESEARCH PROGRAMS

Research Topic/Task	Number of Contracts	Duration of Contracts (yrs.)	Total Level of Effort ($K/yr.)	Total Expenditure Over Program ($K)
1. Fluid Mechanics				
a. Rationalization of Engine Fluid Mechanics	2 (Spark Ignition Engines) 2 (Diesel Engines)	5 (each)	600 to 1000	3000 to 4200
2. Chemical Kinetics and Mechanisms				
a. Emissions vs. Oil Consumption Engine Meas.	1	1	200	200
b. Emissions vs. Oil Characteristics Engine Meas.	1	2	200	400
c. Oil Decomposition Modeling	1	2	200	400
d. Experimental Studies of Unregulated HC Emissions Chemistry	2	5	200 to 600	2400
e. Modeling of Unregulated HC Emissions	2	5	200 to 300	1200
f. Engine Modification Design and Evaluation	2	3	100 to 500	1800

TABLE 7-1 SUMMARY OF RECOMMENDED RESEARCH PROGRAMS (Cont.)

Research Topic/Task	Number of Contracts	Duration of Contracts (yrs.)	Total Level of Effort ($K/yr.)	Total Expenditure Over Program ($K)
3. Fuel Injection and Spray Combustion				
a. Fuel Injection Dynamics Studies	2	3	100	300
b. Spray Formation Studies	2	5	200	1000
c. Spray Combustion Studies	2	5	300	1500
4. Fuel Characteristics and Modifications				
a. Preparation and Characterization of Test Fuels	1	1	75	75
b. Development of Exhaust Analysis Techniques	2 to 3	2	150 to 225	300 to 450
c. Laboratory Simulation Tests	1	2	75	150
d. Engine Tests	1	2	75	150
e. Data Analysis and Recommendations	1	2	50	100

TABLE 7-1 SUMMARY OF RECOMMENDED RESEARCH PROGRAMS (Cont.)

Research Topic/Task	Number of Contracts	Duration of Contracts (yrs.)	Total Level of Effort ($K/yr.)	Total Expenditure Over Program ($K)
5. Cycle Modification				
a. Supercharging Assessment Studies	1	1	50	50
b. Ceramic Materials Development	2	3	600	1800
c. Turbine Design Studies	2	2	400	800
d. Valve Control Assessment	1	1	50	50
e. Valve Mechanization	---------- Contingent on 5a ----------			
Program Totals	~30	1 to 5	~3000	~16000

APPENDIX A

REFERENCES

1. Lichtz, L.C., Internal Combustion Engines, McGraw-Hill (1951).

2. Taylor, C.F., The Internal Combustion Engine in Theory and Practice, Vol. I and II, MIT Press (1960).

3. Austin, T.C. and McFadden, J.J., "A Study of Stratified Charge for Light-Duty Power Plants," Vol. I, Ricardo & Co., EPA-460/374-011A (October 1975).

4. Inoue, K., Ukawa, H., Fujii, I., "Fuel Economy and Exhaust Emissions of the Honda CVCC Engine," Combustion Science and Technology, Vol. 12, pp. 11 - 27 (1976).

5. Mitchell, E. and Alperstein, M., "Texaco Controlled-Combustion System - Multifuel, Efficient, Clean, and Practical," Combustion Science and Technology, Vol. 8, pp. 39 - 49 (1973).

6. Miyake, M., Okada, S., Kawahara, Y., and Asai, K., "A New Stratified Charge Combustion System (MCP) for Reducing Exhaust Emissions," Combustion Science and Technology, pp. 29 - 46 (1976).

7. Leighton, P.A. Photochemistry of Air Pollution, Academic Press, New York, N.Y. (1961)

8. Niki, H., Daby, E.E., and Weinstock, B., "Photochemical Smog and Ozone Reactions," Adv. Chem., 113, 16 (1972).

9. Hecht, T.A., Seinfeld, J.H., and Dodge, M.C., "Further Development of Generalized Kinetic Mechanics for Photochemical Smog," Envir. Sci. & Tech., 8, 327 (1974).

10. Calvert, J.G., "Hydrocarbon Involvement in Photochemical Smog Formation in Los Angeles Atmosphere," Envir. Sci. & Tech., 10, 256 (1976).

11. Chameodes, W.L. and Walker, J.C.G., "A Time-Dependent Photochemical Model for Ozone Near the Ground," J. Geophys. Res., 81, 413 (1976).

12. Fishman, J. and Crutzen, P.J., "A Numerical Study of Tropospheric Photochemistry Using a One-Dimensional Model," J. Geophys. Res., 82, 5897 (1977).

References (Cont.)

13. Johnston, H.S., "Reduction of Stratospheric Ozone by Nitrogen Oxide Catalysts from Supersonic Transport Exhausts," Science, 173, 517 (1971).

14. "The Effects of Stratospheric Pollution by Aircraft," Final Report of the CIAP Program, Department of Transportation, Washington, D.C. (December 1974).

15. Calvert, J.G., "Test of the Theory of Ozone Generation in Los Angeles Atmosphere," Envir. Sci. & Tech., 10, 248 (1976).

16. Vuk, C.T., Jones, M.A., and Johnson, J.H., "The Measurement and Analysis of the Physical Character of Diesel Particulate Emissions," SAE Transactions, Paper No. 760131, 556 (1976).

17. Laresgoiti, A., Loos, A.C., and Springer, G.S., "Particulate and Smoke Emission from a Light-Duty Diesel Engine," Envir. Sci. & Tech., 11, 973 (1977).

18. Spindt, R.S., "Second Year Report on Polynuclear Aromatic Content of Heavy Duty Diesel Engine Exhaust Gases," Gulf Research and Development Co., Pittsburgh, Pennsylvania (January 1977).

19. Gross, G.P., "The Effect of Fuel and Vehicle Variables on Polynuclear Aromatic Hydrocarbon and Phenol Emissions," SAE, Paper No. 720210, (1972).

20. Newhall, H.K., Jetoft, R.E., and Ballinger, P.R., "The Effect of Unleaded Gasoline Composition on Polynuclear Aromatic Hydrocarbon Emissions," SAE, Paper No. 730834, (1973).

21. Zughini, N., Menglini, S., Arteconi, M., and Sezzi, F., "Polynuclear Aromatic Hydrocaroons in Vehicle Exhaust," SAE, Paper No. 7308361.

22. Blumer, M., Blumer, W., and Reich, T., "Polycyclic Aromatic Hydrocarbons in Soils of a Mountain Valley: Correlation with Highway Traffic and Cancer Incidence," Envir. Sci. & Tech., 12, 1082 (1977).

23. Gage, S., "Precautionary Notice on Laboratory Handling of Exhaust Products from Diesel Engines," EPA Memo (November 1977).

24. Spindt, R.S., Barnes, G.J., and Somers, J.H., "The Characterization of Odor Components in Diesel Exhaust Gas," SAE, Paper No. 710605 (1971).

25. "Chemical Identification of the Odor Components in Diesel Engine Exhaust," Arthur D. Little, Inc., Final Report to CRC and NAPCA, CRC Project CAPE-7-68, HEW Contract No. CPA-22-69-63 (June 1970).

References (Cont.)

26. Somers, J.H., and Kittridge, G.D., "Review of Federally-Sponsored Research on Diesel Exhaust Odors," Report No. 71-75, EPA, Ann Arbor, Michigan (July 1971).

27. Levins, P.L., Kendall, D.A., Caragay, A.G., Leonardos, G., and Oberholtzer, J.E., "Chemical Analysis of Diesel Exhaust Odor Species," SAE, Paper No. 740216, SAE Transations, 949 (1974).

28. Springer, K.J., "Investigations of Diesel-Powered Vehicle Emissions VII," EPA Publication, No. EPA-460/3-76-034 (February 1977).

29. Henein, N.A., "Analysis of Pollutant Formation and Control and Fuel Economy in Diesel Engines," Prog. Energy Comb. Sci., 1, 165 (1976).

30. Patterson, D.J. and Henein, N.A., Emissions from Combustion Engines and Their Control, Ann Arbor Science, Ann Arbor, Michigan (1972).

31. Darnall, K.R., Lloyd, A.C., Winer, A.M., and Pitts, J.H., Jr., "Reactivity Scale for Atmospheric Hydrocarbons Based on Reaction with Hydroxyl Radical," Envir. Sci. & Tech., 10, 692 (1976).

32. Keeling, C.D. and Rotty, R.M., "The Global Carbon Dioxide Problem," Baes, C.F., et al., Eds., Report No. ORNL-5194, Dept. of Commerce, Washington, D.C. p. 18 (1976).

33. Stuiver, M., "Atmospheric Carbon Dioxide and Carbon Reservoir Changes," Science, 197, 253 (1978).

34. Woodall, G., et al., "The Biota and the World Carbon Budget," Science, 199, 14 (1978).

35. Mercer, J.H., "West Anartic Ice Sheet and CO_2 Greenhouse Effect: A Threat of Disaster," Nature, 271, 321 (1978).

36. McElroy, M.B. and McConnel, J.C., "Nitrous Oxide: A Natural Source of Stratospheric NO," J. Atmos. Sci., 28, 1095 (1971).

37. McElroy, M.B., Wofsy, S.C., and Yung, Y.L., "The Nitrogen Cycle: Perturbations Due to Man and Their Impact on Atmospheric N_2O and O_3," Phili. Trans. Roy. Soc., 277B, 159 (1977).

38. Wang, W.C., Yung, Y.L. Lucis, A.A., Mo, T., and Hansen, J.E., "Greenhouse Effects Due to Man-made Perturbations of Trace Gases," Science, 194, 685 (1976).

References (Cont.)

39. Weiss, R.F. and Craig, H., "Production of Atmospheric Nitrous Oxide by Combustion," Geophys. Res. Lett., 3, 751 (1976).

40. Pierotti, D. and Rasmussen, R.A., "Combustion As a Source of Nitrous Oxide in the Atmosphere," Geophys. Res. Lett., 2, 265 (1976).

41. Elkins, J.W., Kolb, C.E., and Wofsy, S.C., Unpublished results.

42. Kaplan, W.A., Elkins, J.W., Kolb, C.E., McElroy, M.B., Wofsy, S.C., and Duran, A.P., "Nitrous Oxide in Fresh Water Systems: An Estimate for the Yield of Atmospheric N_2O Associated with Disposal of Human Waste," Pure Appl. Geophys., in press.

43. Esser, J. and Laidler, K.J., "The Pyrolysis of Ethane in the Presence of Nitric Oxide," Int. J. Chem. Kinet., 2, 37 (1970).

44. Schuchmann, H.P. and Laidler, K.J., "The Pyrolysis of Acetaldehyde in the Presence of Nitric Oxide," Int. J. Chem. Kinet., 2, 349 (1970).

45. Fenimore, C.P., "Formation of Nitric Oxide in Premixed Hydrocarbon Flames," Thirteenth Symposium (International) on Combustion, p. 373, The Combustion Institute, (1971).

46. Iverach, D., Basden, K.S., and Kirov, N.Y., "Formation of Nitric Oxide in Fuel-Lean and Fuel-Rich Flames," Fourteenth Symposium (International) on Combustion, p. 767, The Combustion Institute (1973).

47. Schuchmann, H.P. and Laidler, K.J., "Nitrogen Compounds Other Than NO in Automobile Exhaust Gas," J. Air Pollut. Cont. Assoc., 22, 52 (1972).

48. Myerson, A.L. and Blair, D.W., "Reduction of Nitric Oxide in Automobile Engine Exhaust by Ethane-Air Injection," Envir. Sci. & Tech., 10, 461 (1976).

49. Somers, J.H., EPA Office of Mobile Source Emission Control, Research Triangle Park, NC - Private Communication.

50. Heywood, J.B., "Pollutant Formation and Control in Spark-Ignition Engines," Prog. Engr. Comb. Sci., 1, 135 (1976).

51. Cadle, S.H., Chock, D.P., Monson, P.R., and Heuss, J.M., "General Motors Sulfate Dispersion Experiment: Experimental Procedures and Results," J. Air Pollut. Control Assoc., 27, No. 1 (1977).

References (Cont.)

52. Chock, D.P., "General Motors Sulfate Dispersion Experiment: Assessment of the EPA Hiway Model," J. Air Pollut. Control Assoc., 27, No. 1 (1977).

53. Wilson, W.E., et al., "General Motors Sulfate Dispersion Experiment: Summary of EPA Measurements," J. Air Pollut. Control Assoc., 27, No. 1 (1977).

54. Bowman, C.T., "Kinetics of Pollutant Formation and Destruction in Combustion," Prog. Energy Combust., Science, No. 1, 33 (1975).

55. Raine, R.R., Duggal, V.K., and Pratt, N.H., "A Comprehensive Review of Diesel Combustion Models for NO_x and Smoke Emissions," Consultation Report No. 108176, University of Southampton, Southampton, England (November 1976).

56. Zeldovich, Y.B., Sodovnikov, P.Y., and Frank-Kamenetski, D.A., "Oxidation of Nitrogen in Combustion," Academy of Sciences of USSR, Institute of Chemical Physics, Moscow-Lenigrad (1947).

57. Lavoie, G.A., Heywood, J.B., and Keck, J.C., "Experimental and Theoretical Study of Nitric Oxide Formation in Internal Combustion Engines," Combust. Sci. Technology, 1, 313 (1970).

58. Baulch, D.L. Drysdale, D.D., Horne, D.B., and Lloyd, A.C., "Evaluated Kinetic Data for High Temperature Reactions," Vol. 2, CRC Press, Cleveland, Ohio (1973).

59. Sarofin, A.G. and Pohl, J.H., "Kinetics of Nitric Oxide Formation in Premixed Laminar Flames," Fourteenth Symposium (International) on Combustion, p. 739, The Combustion Institute (1973).

60. Homer, J.G. and Sutton, M.M., "Nitric Oxide Formation and Radical Overshoot in Premixed Hydrogen Flames," Combust. Flame, 20, 1 (1973).

61. Bowman, C.T., "Investigation of NO Formation Kinetics in Combustion Processes: The H_2, O_2, N_2 Reaction," Combust. Sci. Tech., 3, 37 (1971)

62. Fenimore, C.P., "Reactions of Fuel-Nitrogen in Rick Flame Gases," Combust. Flame, 26, 249 (1976).

63. Fenimore, C.P., "Formation of Nitric Oxide From Fuel Nitrogen in Ethylene Flames," Combust. Flame, 19, 289 (1972).

64. Lyon, R.K. and Lungwell, J.P., "Selectrive Noncatalytic Reduction of NO_x with NH_3," EPRI NO_x Control Technology Seminar, San Francisco (February 1976).

References (Cont.)

65. Begeman, C.R. and Colucci, J.M., "Polynuclear Aromatic Hydrocarbon Emissions From Automotive Engines," SAE, Paper 700469 (1970).

66. Giger, W. and Blumer, M., "Polycyclic Aromatic Hydrocarbons in the Environment: Isolation and Characterization by Chromatography, Visible, Ultraviolet, and Mass Spectroscopy," Anal. Chem., 46, 1663 (1974).

67. Greinke, R.A. and Lewis, I.C., "Development of a Gas Chromatographic - Ultraviolet Absorption Spectroscopic Method for Monitoring Petroleum Pitch Volatiles in the Environment," Anal. Chem., 47, 2151 (1975).

68. Lavoi, G.A. and Blumber, P.N., "Measurements of NO Emissions From a Stratified Charge Engine: Comparison of Theory and Experiment," Combust. Sci. Tech., 8, 25 (1973).

69. Lefebvre, A.H. (Ed), " Lean Premixed/Prevaporized Cobustion," Workshop at Lewis Research Center, Cleveland, Ohio, NASA CP-2016 (January 20-21, 1977).

70. "Aircraft Engine Emissions," Conference held at Lewis Research Center, NASA CP-2021 (May 18-19, 1977).

71. Roberts, R., Peduzzi, H., and Niedzwiecki, R.W., "Low Pollution Combustor Designs for CTOL Engines - Results of the Experimental Clean Combustor Program," AIAA Paper No. 76-762 (July 26-29, 1976).

72. Gleason, C.C. and Niedzwiecki, R.W., "Results of the NASA/General Electric Experimental Clean Combustor Program," AIAA Paper 76-763 (July 26-29, 1976).

73. Tabaczynski, R.J., "Turbulence and Turbulent Combustion in Spark Ignition Engines," Prog. Energy Comb. Sci., 2, 143 (1976).

74. Semenov, E.S., "Studies of Turbulent Gas Flow in Piston Engines," NASA Technical Transaction F-97 (1963).

75. Taylor, E.S., Personal Communication (March 1978).

76. Chigier, N.A., "The Atomization and Burning of Liquid Fuel Sprays," Prog. Energy Comb. Sci., 2, 97 (1976).

77. Samson, R., Bedeaux, D., Saxton, M.J., and Deutch, J.M., "A Sample Model of Fuel Spray Burning I: Random Sprays," Combust. Flame, 31, 215-221 (1978). "A Sample Model of Fuel Spray Burning II: Linear Droplet Streams," Combust. Flame, 31, 223 (1978).

References (Cont.)

78. Jones, A.R., "A Review of Drop Size Measurement - The Application of Techniques to Dense Fuel Sprays," Prog. Energy Comb. Sci., 3, 225 (1977).

79. Faeth, G.M., "Current Status of Droplet and Liquid Combustion," Prog. Energy Comb. Sci., 3, 191 (1977).

80. Charles, R., Private Communication, 1977.

81. "A New Approach to Variable Displacement," Automotive Ener., 85, 30 (May 1977).

82. Bryzik, W., "Adabatic Diesel Engine," Research/Development, (January 1978).

• Report No. 4

I. American Institute of Physics. Efficient Use of Energy: AIP Conference Proceedings No. 25. American Institute of Physics, New York, 1975.
- funding by National Science Foundation, Federal Energy Administration and Electric Power Research Institute.

II. Technical and/or End-Use Focus

Technically, this report concentrates on Physics-oriented research that can contribute to energy efficiency. In end-use terms, it concentrated on energy use in buildings, the automobile, and selected industrial processes.

III. Types of Information Provided

1. Energy use in broad sectors as well as specific devices was reviewed.

2. Report did not identify the conservation potential for individual research tasks. Broad efficiency improvements that are possible were identified for many areas, however.

3. No estimates of times to commercialization were made.

4. No review of existing research programs was made.

5. The report used a 2nd law approach to indicate areas of large potential improvement and then examined areas of knowledge that could be improved to increase efficiencies in these areas.

IV. R&D Opportunities

SECOND LAW EFFICIENCY (p. 9).

(1) Systematic investigation of points of entropy increase in energy-using systems.

(2) Calculations of second-law efficiencies for industrial processes with a view to identifying the most fruitful areas for technical improvement.

(3) Systems studies of the cascading of heat energy in specific industries.

(4) Classification of processes according to the minimum required energy quality with a view to better matching of energy source and energy use.

(5) Interdisciplinary investigation of more sophisticated procedures of energy and entropy accounting.

Second Law Efficiency provides a norm or standard of performance against which present use of energy can be evaluated. This is crucial for determining allocation of funding for research (p. 5).

References:

C. A. Berg, "Conservation in Industry", Science '84, 264 (19 April 1974).

Federal Power Commission, A Technical Basis for Energy Conservation, staff report FPC/OCE/2 (U. S. Federal Power Commission, April 1974).

J. H. Keenan, E. P. Gyftopoulos, G. H. Hatsopoulos, "The Fuel Shortage and Thermodynamics", in Proceedings of the MIT Energy Conference (MIT Press, Cambridge, MA, 1973).

BUILDINGS (p. 9-11)

(A) Energy Management

(1) Studies of heat transport over long distances (including heat transported as chemical potential energy).

(2) Systems analysis of district systems to supply both heat and electricity to a building or a group of houses.

(3) Systems studies of house-scale heat and electricity systems based on fuel cells (possibly ones deliberately chosen to have low electrical efficiency).

(4) Extensive data gathering and modeling of energy-use patterns of existing houses and buildings of various types.

(5) Research on heat storage for better load averaging of both solar and electric power.

(B) Thermal Properties of Buildings

(1) More flexible computer modeling to include the effect of wind.

(2) Measurement and modeling of thermal response functions of buildings.

(3) Investigation of building materials with large specific heats.

(4) Theoretical and experimental studies of external features, including sun control and surfaces of variable reflectivity.

(C) Insulation

(1) Theoretical modeling together with experimental studies to select new materials and filler gases, to control cell size, and to enhance fire resistance.

(2) Investigation of a "thermal diode".

(3) Development of layered material with variable, controllable conductivity.

(4) Development of window coatings to control heat loss.

(5) Optimization of insulation for the distribution of space heat.

(D) Aerodynamics

(1) Outside: studies of micrometeorology, wind effects on heat transfer and infiltration, control of local air flow patterns.

(2) Inside: development of methods to control air flow, especially near walls, windows, and ducts.

(3) General: microscopic studies, experimental and theoretical, of heat transfer at solid surfaces bounded by moving air.

(E) Air Conditioning

(1) Broad search for new techniques using heat to power air conditioners; experimental studies of absorption and absorption cycles.

(2) Search for new desiccants, especially with a view to lowering the regeneration temperature.

(3) Systems studies of groundwater cooling.

(4) Interdisciplinary studies of ground-water hydrology for heat-transfer applications.

(F) Space-Heating

(1) Continued research on heat-pump cycles and technology to extend the useful temperature range.

(2) Systems studies of solar-assisted heat pumps.

(3) Systems studies (and hydrology) of using ground water as the low-temperature reservoir of a heat-pump system.

(4) Basic heat-transfer studies at solid-fluid interfaces, with a view to decreasing T across heat exchangers working not far from ambient temperatures.

(G) Hot Water

(1) Detailed measurements and modeling of patterns of hot-water heating and use in houses and buildings.

(2) Systems studies of heating or "boosting" water at the point of use.

(3) Continued development of solar hot-water heating systems.

(H) Lighting

(1) Basic research on gas discharges and on fluorescence with a view to increasing the efficacy of light sources and controlling the color.

(2) Development of small and/or screw-in fluorescent lamps (mostly engineering).

(3) Development of efficient kHz power supplies and further studies of frequency-dependence of fluorescent-lamp efficacy.

(4) Interdisciplinary studies of lighting needs for various tasks--intensity, uniformity, spectral distribution.

(5) Exploration of more effective ways to use sunlight indoors.

(I) Instrumentation

(1) Development of easy-to-use local heat flux meter.

(2) Development of cheap home instruments for monitoring and control, such as a clock-programmed thermostat, a degree-days-per-gallon meter (with suitable time averaging) and an on-line monitor of furnace burner efficiency.

(3) Packaging of a meter to measure air exchange rate in a room or a building.

(4) The development for larger buildings of on-line monitoring of several features of air quality coupled with control of reconditioned air vs. fresh air; the development of devices to recondition air.

(5) Development of infrared equipment for diagnostic studies of houses.

THE AUTOMOBILE (pp. 11, 12)

(A) The Power Plant

(1) Basic studies of the combustion process; development of advanced combustion diagnostic techniques (see APS 1974b).

(2) Continued research on external combustion engines (Rankine, Stirling).

(3) Continued research on small diesel engines, to reduce their weight, noise, smoke, and odor.

(4) Studies of a variety of hybrid power plants (small internal combustion engines plus a source of boost power).

(5) Extended studies of fuel emulsions and novel fuels (see APS 1974b).

(B) Energy Storage

(1) Further systems studies of harnessing braking energy with a dynamotor.

(2) Basic research on rechargeable batteries (see Electrochemical processes, below).

(3) Experimental and theoretical studies of flywheel storage.

(C) Weight

(1) Exploration of lighter automobile structural materials.

(2) Studies of the crashworthiness of lighter (not necessarily smaller) cars.

(D) Tires and Suspension

(1) Basic studies of viscoelastic materials and exploration of radically new tire designs.

(2) Exploration of tradeoffs in function among tires, wheels, and suspension, with a view to increasing the role of the suspension and decreasing that of the tire, to preserve ride and safety while decreasing rolling resistance.

(E) Air Drag

(1) More elaborate studies, experimental and theoretical, of automobile (also truck) air drag, including the effect of relative motion of the vehicle belly and the road.

(F) Instrumentation

(1) Development of a sophisticated yet inexpensive miles-per-gallon meter capable of integrating over various times or distances.

(2) Implementation of other monitoring meters of engine efficiency, fuel flow, automatic-transmission gear.

(G) Accessories

(1) Development and refinement of heat-powered air conditioners for automobiles and trucks.

(H) Automobile References

TEP, Research and Development Opportunities for Improved Transportation Energy Usage, summary of the Transportation Energy Panel, report No. DOT-TSC-OST-73-14 (U. S. Department of Transportation, September 1972.)

NAS, An Evaluation of Alternative Power Sources for Low-Emission Automobiles (National Academy of Sciences, Washington, D. C. 1973).

INDUSTRIAL PROCESSES (pp. 12, 13)

(A) Electrochemical Processes

(1) Basic research on the physics of charge transfer at electrolyte-electrode interfaces.

(2) Basic physical studies of the principles of solid electrolytes.

(3) Continued search for rechargeable batteries of greater energy density.

(4) Basic research on all aspects of surface phenomena, especially as applied to fuel-cell performance.

(B) Photochemical Processes

(1) Exploration of catalyzed solar photolysis of water.

(2) Continued studies of the semiconductor physics of photovoltaic cells.

(B) Physical Processes

(1) Studies of adsorption techniques for molecular separation.

(2) Basic research on transport in membranes.

(3) Careful studies of the energy inefficiencies in ore benefication and water desalination to seek ways to approach more closely the minimum separative work.

(D) Heat Transfer

(1) Basic studies of heat transfer at interfaces--the role of convection, the role of surface irregularities.

(2) Basic studies of boiling.

(3) Fundamental investigation of two-phase flow.

(4) More detailed discussions of these areas are presented on pages 122-134.

V. Critical Summary

The AIP Study is probably the best single study of overall energy conservation research needs that has been performed to date. It reviews a wealth of physical data in order to highlight opportunities for energy conservation and then addresses these opportunities through well-reasoned and detailed disussions of the technologies in question. The resulting list of R&D needs is the most comprehensive available.

The only weakness of the study stems from the broad scope of what has been attempted. Because the list of R&D needs is so long, the report makes a summary of needs, which while concise, tends to look like a laundry list without obvious justification in end-use terms. Upon reading the supporting text, one finds that this is definitely not the case. A great deal of analysis lays the foundation for evaluating the conservation potential for almost any piece of research that could be performed. This particular study stops short of performing this type of specific analysis of individual research tasks, but provides essential input to such a project.

VI. Comments

Ross and Williams have followed up on the AIP work and their work makes a good companion to this study.

Reviewed by WJH.

- Report No. 5

I. American Society of Mechanical Engineers. Research Needs Report: Environmental and Conservation Research. American Society of Mechanical Engineers Task Force on Environmental and Conservation Research, American Society of Mechanical Engineers, New York, 1979.

II. Technical and/or End-Use Focus

Research opportunities focused on environmental and conservation research addressable by mechanical engineers. Conservation broken down into energy and materials.

III. Types of Information Provided

1. Little energy use data.

2. Some estimates of possible efficiency gain.

3. No estimates of time to commercialization.

4. No review of existing research.

5. No methodology presented.

IV. R&D Opportunities

(1) Combustion - heat transfer from combustion products, combustion stability, combustion of mixtures over an extended fuel-air range, and alternate fuels are all promising R&D topics that could improve efficiencies in highway vehicles, aircraft, rail, marine, pipeline, residential and industrial use. Examples of advanced concepts are stratified charge, prevaporizing burners in boilers and furnaces and using coal or coal-derived fuels in industrial process burners.

(2) Fuel Cells - for electric power generation using alternate fuels with improved efficiency (38 to 50%). Fuel cell technology base needs to be broadened to allow fuel flexibility, lower costs, higher reliability and the development of advanced fuel cells (especially the molten carbonate fuel cell).

(3) Alternative Engine Cycles - In particular, Stirling and closed Brayton cycle engines have varied applications including high grade heat topping, in-plant power generation, integrated and total energy systems, etc. Current engines are too costly and expensive. Critical needs are for development of low cost heat-source heat exchangers for the Brayton engine and ceramic materials for the Stirling engine.

(4) Gas Turbines - Need high efficiency, low cost, multifuel industrial gas turbines (5 to 25 MW) for integrated energy systems, pipeline pumping, marine and railway propulsion and dispersed power generation. Also need to commercialize highly efficient, heavy-fuel tolerant gas turbines (25 to 100 MW) for industrial cogeneration power plants and utility intermediate load power generation.

(5) Heat Recovery Systems (Heat Exchangers) - Development of more compact and efficient heat exchangers is needed. Corrosion resistant materials are needed. Research needs to be done on once-through

boilers and heat exchangers for organic Rankin cycle waste heat recovery systems.

(6) High Temperature Power Cycles - Peak steam power plant temperatures are currently about 540°C. Some of the high temperature energy available (i.e. between 2500°C and 540°C) could be converted into electricity by devices such as the Lysholm helical screw expander or the thermionic convertor. Both device and material development is needed.

- Efficiencies:

Steam cycle	36%
Steam cycle + thermionic	47%
Steam cycle + thermionic + MHD	62%

- References:

Fitzpartrick, G. O., E. J. Britt, "G. Carnasciali. 1977." Increased Central Station Powerplant Efficiency with a Thermionic Topping System", Proc. 12th Intersociety Energy Conversion Engineering Conference, Washington, D. C., August 1977, pp. 1602-1609.

(D) Energy Conservation in Buildings

(1) Insulation Materials - Cheaper and more efficient insulating and sealing materials. Window coatings (low infrared emissivity, or high reflectivity depending upon application. Also photosensitive coatings.

(2) Building Control Strategies - Research needed into accurate, low cost computer methods for determining building loads and transient conditions in order to select and operate energy conserving equipment for all types of buildings in any location.

V. Critical Summary

A nice laundry list with some detail, technically accurate, not well justified.

VI. Comments

R&D opportunities presented should be considered in light of any justification attainable before prioritizing them.

Reviewed by WEG.

- <u>Report No. 6</u>

I. American Society of Mechanical Engineers. <u>Research Needs Report: Fundamental Research Needs</u>. American Society of Mechanical Engineers Task Force on Fundamental Research, American Society of Mechanical Engineers, New York, 1978. ASME Task Force on Fundamental Research, American Society of Mechanical Engineers, New York, 1978.

II. <u>Technical and/or End-Use Focus</u>

Broad, non-specific focus.

III. <u>Types of Information Provided</u>

1. No end-use energy data were reviewed.

2. No energy savings estimate was made.

3. No estimate of time to commercialization was made.

4. No review of existing programs was made.

5. R&D opportunities identified by singling out specific disciplines for thorough scrutiny by a task force of sufficient power. References 5, 6, 7, 12, 13, 14, 15 and 16 (list attached) deal with planning R&D activities.

IV. <u>R&D Opportunities</u>

The following R&D areas were listed and discussed in a half page. It was intended that they be then submitted to specific discipline task forces.

- Heat transfer
- Fluid mechanics
- Materials
- Thermodynamics including combustion or reaction kinetics.
- Dynamics and control
- Tribology

V. <u>Critical Summary</u>

A broad brush look not necessarily complete, with no detail or justification.

IV. <u>Comments</u>

Broadly supports other R&D studies.

Reviewed by WEG.

References

(1) McC. Mathias, Charles, Jr.: Wanted: More Support for Basic Research. C&EN, Feb. 14, 1977, p. 2.

(2) Naval Research Advisory Committee: Basic Research in the Navy. Volumes 1 and 2, June 1959. Prepared by Arthur D. Little, Inc., under Contract NONR-2515(00).

(3) Anon: Technology in Retrospect and Critical Events in Science. Volumes 1 and 2, January 1969. Prepared by IIT Research Institute under Contract NSF-C535 for the National Science Foundation.

(4) Naval Analysis Memorandum DR/NAM-6, Naval Research Utility. July 1968.

(5) Anon: An Approach to the Evaluation of Basic Research Projects. NSF-C481, June 1967.

(6) Anon: A Methodological Approach to Measuring Change in Science Produced by Basic Research, NSF-C528, November 1968.

(7) Anon: A Comparative Study of the Prospective and Retrospective Approaches to the Evaluation of Proposed Basic Research, NSF C561, July 1969.

(8) Foy, Rustrum: The Unhealthy State of Basic Research. C&EN, Jan. 10, 1977, P. 4.

(9) Editor's Page: Max Tishler on Basic Research. C&EN March 28, 1977, p. 5.

(10) Anderson, W. J.: Fundamental Research Needs: A Status Report of the Task Force on Fundamental Research. ASME Paper 76-WA/RGPC-5.

(11) Kaufman, C. B.: The Future Social Climate for R&D. Research Management, January 1975, pp. 29-32.

(12) Gear, A. E.: A Review of Some Recent Developments in Portfolio Modelling in Applied Research and Development. IEEE Transactions on Engineering Management, Vol. EM-21, No. 4, November 1974, pp. 119-125.

(13) Moore, R. L.: Methods of Determining Priorities in a Program of Research. IEEE Transactions of Engineering Management, Vol. EM-21, No. 4, November 1974. pp. 126-140.

(14) Verschuur, J. J., and Potjer, A. A.: Maximization of the Economic Value of Research Through Quantifying the Relations Between Research and the Market. IEEE Transactions on Engineering Management, Vol. EM-21, No. 4, November 1974, pp. 115-188.

(15) Havemeyer, C., and Lorentzen, R. R.: SARA-A Research Planning Tool RCA Eng. Vol. 21, No. 3, Oct.-Nov. 1975, pp. 74-77.

(16) Grossman, D. and Gupta, S. N.: Dynamic Time-Staged Model for R&D Portfolio Planning-A Real World Case. IEEE Transactions on Engineering Management, Vol. EM-21, No. 4, November 1974. pp. 141-147.

(17) Sabersky, R.H.: Heat Transfer in the Seventies. Journal of Heat and Mass Transfer, Vol. 14, pp. 1927-1949.

- Report No. 7

I. Anderson, Carl J. Research and Development Needs for Transportation. Lawrence Livermore Laboratory, April 10, 1975.

II. Technical and/or End-Use Focus

As implied by the title, this document is concerned solely with the transportation end-use sector.

III. Types of Information Provided

1. Transportation end-use data from 1971 were reviewed.
2. No estimates of energy savings from research were made.
3. The author looks toward a time to commercialization of 20-25 years for the research project.
4. Apparently few programs existed at the time and those that did were sparsely funded. Thus, existing programs were not reviewed.
5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

(1) Alternate fuels.

(2) Electric vehicles.

V. Critical Summary

This article was written in the wake of the first oil embargo and hence is a report advocating the redirection of programs estimated when oil was cheap and copious. The author does not attempt to deal with specific research needs.

To justify government involvement the author notes the heavy automotive use of fuel oil in 1971 and he notes that recent innovations (stratified charge, disc brakes, automatic transmissions, power steering, rotary engines, radial tires, etc. . . .) have come from outside the U. S. auto industry.

The title R&D Needs for Transportation is perhaps a misnomer since few needs were identified other than the need for a more efficient engine. Since the report dealt primarily with the general need for more research, a more appropriate title might be "The Need for Government Sponsored R&D in Transportation".

IV. Comments

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Reviewed by GJH.

REFERENCES

1. Secretary Kissinger, Dept. of State Bulletin, 12/2/74.

2. Anderson, et al. An Assessment of U.S. Energy Options for Project Independence. LLL, Sept. 1, 1974.

3. Energy Conservation in the U.S.: Short Term Potential 1974-1978, National Petroleum Council (March 1974).

4. Project Independence Report, Federal Energy Administration (Nov. 1974).

5. Federal Research and Development Program Plan for Transportation Energy Conservation, DOT-OST-TST-74-16, May 21, 1974.

6. Hearings and Research on Ground Propulsion Systems Subcommittee on Space Science and Applications, Feb. 4-6, 1974 (quoted in No. 8).

7. P. Chenea at a Meeting of the GM Public Policy Committee, 1970, (quoted in No. 8).

8. FEA Energy R&D Office, "The Role of the Federal Government in Automotive R&D", 11/6/74.

9. D. L. Ray, "The Nation's Energy Future", Dec. 1, 1973 WASH 1281.

10. "ERDA Contingency Study - New Automotive Power Systems", July 1974, AEC.

- Report No. 8

I. Battelle Columbus Laboratories. Developing a Maximum Energy Efficiency Improvement Target for SIC 28: Chemicalsand Allied Products. Vol. I. Draft Target and Support Document, Battelle Columbus Laboratories, Columbus, Ohio. July 1976. Sponsored by FEA.

II. Technical and/or End-Use Focus

The focus of the study is to develop an energy conservaton target for the chemical and allied products industries which could be met by 1980. The emphasis was on determining near-term applications that could save energy, rather than determining where R&D could save energy in the long run.

III. Types of Information Provided

1. Fuels and electricity consumed in 1972 are given for each of the 4-digit industries within SIC 28. Some analyses showing energy use by unit operation are also given.

2. Specific savings from R&D were not identified.

3. No times to commercializatin were given.

4. No reserch programs were reviewed.

5. No methodology for identifying R&D opportunities was presented.

IV. R&D Opportunities

1. Process development for polymer production in SIC 2821, (pg. 84).

2. Developing less energy intensive processes for synthetic rubber production (pg. 88). Rubber production via slurry or bulk reaction could be significantly less energy intensive than solution processes currently used.

   - Potential saving of 50% of energy used in solution processes.

3. Specialized catalysts for solution processes (pg. 89).

   - Energy used in polymerization of butadiene can be reeduced 50% by proper catalyst selection, which may be a representative figure.

V. Critical Summary

The report is very comprehensive in its treatment of the near-term energy conservation potential within SIC 28. The level of detail in identifying where conservation is possible within each 4-digit industry is good. Because R&D does not generally have an impact on energy conservation in the short run, very few R&D opportunities are described.

The reviewed report was a draft that was assembled on a tight schedule. The authors point out that data available for estimating energy conservation potential were scarce, and that in many cases, inconsistency occurred in the data that were available.

VI. Comments

The energy consumption and other information in this report would be useful to a future study directed specifically at identifying R&D opportunities for SIC 28.

Reviewed by TAW.

• Report No. 9

I. Battelle Columbus Laboratories. Implementation of Energy Conservation Technology in the Steel Industry. Vols. I and II. Battelle Columbus Laboratories, Columbus, OH, August 1980.

II. Technical and/or End-Use Focus

As implied by the title, the focus of this report was on the steel industry. The study did not consider the mining of ore but did include all steps from the attainment of the ore to the shipping of the final product.

III. Types of Information Provided

1. End-use data relating to processes in the steel industry were reviewed.

2. Potential energy savings were thoroughly investigated.

3. Rough estimates of commercialization times were often given.

4. Existing programs were reviewed.

5. The project identification methodology was clearly described. Initially, previous studies were reviewed and contacts were made in the steel industry to generate a list totaling 93 potential projects. The first screening criteria consisted of two parts:

(1) The potential technology must conserve, or allow a fuel switch from a critical fuel to a less critical fuel of, at least 0.01 Quad. per year, and

(2) the technology must be capable of commercialization by 1985. The first screening step reduced the candidate technologies to 23. In the second screening, the candidates were analyzed in greater depth use four additional criteria:

(1) potential to conserve energy,
(2) level of investment required,
(3) user benefits, and
(4) other influences (regulatory, social, environmental, etc.)

The technologies were rated on a scale from one to five using each criteria and the product of the four scores yielded the overall rating. These scores were used as an aid, not a determinant, in narrowing the field further to seven technologies. This mode was chosen as a result of recognizing that the method of ranking was imperfect and that other factors may affect the appeal of a technology. These seven technologies were then evaluated relative to each other with consideration given to:

(1) energy benefits,
(2) costs to industry,
(3) operational risks, and
(4) timeliness.

As a result of this final comparison, three technologies were recommended.

IV. R&D Opportunities

Three technologies were recommended from the 93 considered. These suggestions were:

(1) • Energy Management by Computer Modeling and Control (p. 3-2, 8-31, 9-1).
This project was recommended because of its high overall apppraisal. The principals are well known and generic, but the application is very specific.

• The potential estimated energy savings are 0.20 Quad per year and the probable savings by 1985 above that which would be expected to occur without this program are 0.006 Quad per year.

• The implementation time is by 1985.

Current programs include:

• Inland Steel's energy model (p. 9-3).
Kashima Steel's energy management system (p. 9-4).
Purdue University systems control (p. 9-13).

(2) • Improved Forge Furnaces (p. 10-1).

This project was also selected due to its high overall appraisal. The technology is applicable to thousands of units and many forging businesses which qualify as small businesses.

• The potential energy savings are 0.10 Quad per year and the probable savings by 1985 above that which would be expected to occur without this program are 0.042 Quad per year.

• The implementation time is by 1985.

• Hague International design (p. 10-1).

(3) • High-Temperature Recuperators (11-1).

• Current recuperators are limited by temperatures well below those available in waste streams.

• The maximum potential energy savings are 0.05 Quad per year and the probable savings by 1985 above that which would be expected to occur without this program are 0.01 Quad per year.

• The implementation time is by 1985.

V. Critical Summary

The approach used to identify the energy conserving technologies was clearly and thoroughly explained. The authors emphasized the necessity of soliciting input from the steel industry both to better insure a comprehensive list and understanding of the technologies and to facilitate acceptance of the report within the industry.

Since the study was concerned with the near term implementation of a few projects, the limiting time frame quickly excluded technologies of interest to ECUT. In the first screening step, technologies which could not be implemented by 1985 were omitted from further evaluation. Thus ECUT candidate technologies were only treated cursorily.

The short time frame also necessitated that only proven technologies warrented consideration. Research and development needs were not included in the selection process while market penetration was a major factor.

In responding to the task of identifying three of the most promising technologies which can save a significant amount of energy by 1985, the authors chose a logical methodology and produced a lucid and well documented report.

VI. Comments

Reviewed by GJH.

ATTACHMENTS

Some of the companies known to be manufacturing and/or conducting research, development, and demonstration work on high-temperature recuperators are:

Ceramic Recuperators

British Steel Corporation, England
Coors Porcelain Company, Golden CO
General Atomic, San Diego CA
GTE Sylvania, Towanda PA
Hague International, South Portland ME
Midland Ross Corporation, Toledo OH
Priest Furnace Ltd., England
Solar Turbines, San Diego CA
Terra-Tek, Salt Lake City UT
Thermal Transfer Corporation, Monroeville PA

High-Temperature Metallic Recuperators

AiResearch Manufacturing Company, Torrance CA
GEFI, Krofeld, West Germany
Holcroft & Company, Livonia MI
Institute of Gas Technology, Chicago IL
Metallurgical Engineers Ltd., London, England
Rekuperator AG, Dusseldorf, West Germany

TABLE 8-2. STEEL INDUSTRY LAUNDRY LIST

October 31, 1979 (Revised)

Technologies are grouped by major process segments.

Numbering was purposely not consecutive, so that additions could be inserted at the proper place at later date.

Numbers in superior parentheses refer to references and notes at the end of the table.

Code for Step 1 Screening

* - Survives screening. Moves to Step 2.

XT - Screened out on basis that substantial implementation by end of 1985 is unlikely.

XE - Screened out on basis that amount of energy that will be conserved (or switched to a less-critical fuel) is likely to be less than 0.01 Quad annually.

XS - Screened out because of a special consideration. The nature of the special consideration is indicated by a superscript described at the end of this table.

Step 1 Results	Cokemaking
XT, XS[a]	(1) Formed coke[1]
*	(2) Charging of preheated coal to ovens[1,2]
XT	(3) Dry quenching of coke[1]
XT	(4) Automatic thermal control of coke batteries[5]
XE, XT, XS[b]	(5) Thermal stabilization of coke[5]
XT	(6) Thin-wall coke ovens[5]
XT, XS[b]	(7) Reduced-temperature coking (semi-coke)[5]
XT, XS[b]	(8) Partial (surface) coking (semi-coke)[5]

(continued)

TABLE 8-2. Continued

Step 1 Results	Agglomeration and Ironmaking
XT	(11) Self-reducing agglomerates (carbon-bearing) for BF[2]
XT	(12) Prereduction during final stages of agglomeration[5]
XE, XT	(13) Optimized fuel mix for agglomeration (sintering)[5]
XS[b]	(14) Substitution of semicoke or char for coke breeze for agglomeration[5]
XE, XT, XS[b]	(15) Recovery of heat from flue gas in agglomerating plant[5]
*	(16) Direct use of coal in manufacture of oxide pellets[11, 12] (replace oil or gas)
*	(17) Improved sintering process (McDowell-Wellman)[10]
XS[b], XT, XE	(21) Preheating of raw materials to BF[4]
XE	(22) Improved charging techniques for BF[5]
XE	(23) Increased use of basic sinter in BF[5]
XE	(24) Use of direct reduced iron in BF burden[2,5]
*	(25) Injection of coal into BF[1]
XS[c]	(26) Injection of hydrocarbons to BF[5]
XT	(27) Injection of hot reducing gases to BF[13] Zone-controlled modified BF.
XT	(28) Tar-bonded green briquetts charged to BF[5]
XE	(29) Evaporative cooling of BF[1,3]
XS[d]	(30) Improved effectiveness of BF blast stoves[4]
XE	(31) Enrichment of BF air with oxygen[5]
XT, XS[b]	(32) Blowing of BF with straight oxygen (instead of air)[5]
XE	(33) Bell-less top for high-pressure BF[14, 15]
XS[b], XT	(34) Cooling of combustion-zone parts with steam instead of water (steam superheater)[5]
XT, XE	(35) Use of BF top pressure to generate electricity[1]
*	(36) Computer control of BF thermal and metallurgical processes[5]
XS[b]	(37) Decreased slag volume (richer ore)[5]
XE, XS[b]	(38) Segregation of BF top gas[5]
*	(39) Increased recovery of BF top gas[5]

(Continued)

TABLE 8-2. Continued

Step 1 Results		Agglomeration and Ironmaking Continued
XE, XT, XS[b]	(40)	Stripping of N_2 and CO_2 from BF top gas[5]
XS[c]	(41)	External desulfurization of BF hot metal[1]
XE, XT, XS[c]	(42)	Direct reduction of iron ore[7]
XT	(43)	Biomass as a fuel/reductant for iron ore[2]
XE	(44)	Hydrogen as reductant for iron ore[2]
XT, XE	(45)	Alkaline carbonates as catalysts for reduction of iron ore[2]
XT	(46)	Recovery of heat from BF slags[16]
XE	(47)	Hydrometallurgical production of iron by electrolysis[2,8]
XT	(48)	Nuclear-derived heat for reduction of iron ore[2]
		Steelmaking
*	(51)	Increased use of BOF off gas[1] (suppressed combustion)
*	(52)	Induction furnace superheating of BF hot metal for BOF[6]
*	(53)	Preheating of scrap charges to steelmaking furnaces[5,28]
*	(54)	Use of EF top gas to preheat scrap[5]
*	(55)	Woolworth scrap preheater[17]
XE, XT	(56)	Plasma-arc steelmaking[2,8]
XT	(57)	Direct (continuous) ironmaking/steelmaking[2,8] (ore to steel in one step)
XT	(58)	"S" process; DR shaft over vertical shaft melter[8]
*	(59)	Conversion of regular-power EF's to high power[18]
XS[c]	(60)	Optimizing silicon content of hot metal from BF[5]
XS[e]	(61)	Optimizing temperature of hot metal from BF[5]
XE	(62)	Improved transportation of hot metal[5]
XT, XS[d]	(63)	Increased use of direct reduced iron[5].

(Continued)

TABLE 8-2. Continued

Step 1 Results		Steelmaking (Continued)
*	(64)	Computer optimization of power use in EF[3,5]
*	(65)	Preheating of ladles[19]
XT	(66)	Electric arc furnace modification[20]
		Casting, Heating, and Rolling
XT	(71)	Direct casting of thin-gage steel sheet[2,8]
XT	(72)	Continuous rheocasting of steel strip[3]
XT	(73)	Direct rolling of ingots and slabs[1]
*	(74)	High-temperature inspection and surface conditioning[3,5]
XE, XS[c]	(75)	Induction heating of slabs, billets, and bars[1]
*	(76)	Monobeam slab-reheating furnace[1]
XE, XT	(77)	Evaporative cooling of skids in reheat furnaces[1]
XT	(78)	Electric resistance heating of billets[21]
*	(79)	DC electric resistance heating of continuous sheets[22] (ValJim Corp.)
XS[c]	(80)	Nitrogen-based carburizing atmospheres[3,23]
XE	(81)	Direct firing for batch annealing (replace radiant)[1]
*	(82)	Improved slot forge furnace[3]
XE	(83)	Fluidized-bed heat treatment for parts[3]
XS[c]	(84)	Ceramic-fiber insulation[7,24]
XT	(85)	Steel sheet via powder metallurgy[2,8]
*	(86)	Heating furnace designs for increased efficiency [10] (Holcroft MPE)
*	(87)	Computerized annealing system for batch coil annealing [10] (Engineering Corp. of America)

(Continued)

TABLE 8-2. Continued

Step 1 Results		Foundry
*	(91)	Cupola modification to eliminate after-burners[3,25,26]
XE	(92)	Coal-fired rotary furnace for melting iron (replace oil) [27]
		General
XS[d]	(101)	Waste heat recovery[1]
XS[d]	(102)	Cogeneration[3,4]
XT	(103)	Gasification of coal to produce fuel[2]
XT, XS[a]	(104)	Gasification of coal in BF[9]
XT	(105)	Gasification of coal to produce reducing gas[7]
XT	(106)	Enrichment of combustion air in oxygen content[3] (by means other than addition of elemental oxygen)
XT, XE	(107)	COthane Process for making methane from waste CO[3]
XT	(108)	Air-fuel ratio controllers (multiburner combustors)[3]
XS[d]	(109)	High-temperature sensors[2]
*	(110)	Energy management through computer modeling and control[2]
XS[c.d]	(111)	Increase yield of various iron and steel processes[7]
*	(112)	Metallic counterflow recuperators[3]
*	(113)	Ceramic recuperators[3]
XS[c,d]	(114)	Increased recycling of scrap[7]
XT	(115)	High-temperature recuperator/burner/ducting[3]

(Continued)

TABLE 8-2. Continued

Notes for Step 1 Screening (Special Consideration)

XS[a]	Screening influenced by existence or plans for a major development or demonstration project.
XS[b]	Substantial question about technical feasibility.
XS[c]	Existing technology being implemented; may be subject to restraints imposed by technology or economics.
XS[d]	Generic technology is recognized as appropriate but specifics need to be developed.
XS[e]	A subset of Item (52), which has been retained.

References to Table 8-2.

(1) "Energy Conservation in the Steel Industry"; AISI; May 26, 1976.

(2) "Potential Technological Changes"; recent U.S. Government Agency report; currently restricted.

(3) "Program Description"; DOE Office of Industrial Programs; January, 1979.

(4) "Priority Listing of Industrial Processes by Total Energy and Potential for Savings"; Zonex Corporation for ERDA; 1977.

(5) "The Steel Industry"; Industrial International Data Base, Committee on the Challenges of Modern Society; prepared by Gordian Associates for ERDA, 1977.

(6) "How Induction Heating Bypasses Energy Mess"; John J. Obrzut; Iron Age; September 10, 1979; pp 55-58.

(7) Battelle Columbus Division

(8) "Toward Radical Changes in Steelmaking"; Julian Szekely; MIT Technology Review; February, 1979; pp 23-39.

(9) Awaiting approval and funding by Congress.

(10) Item submitted by R. Cilimberg; October, 1979.

(11) "The Bureau of Mines Looks at Coal Firing for Induction of Iron Ore Pellets", Part I by Donald W. Frommer, Skillings' Mining Review, 64, No. 16, April 19, 1975; Part II by John C. Nigro, Skillings' Mining Review, 64, No. 17, April 26, 1975.

(12) "Preliminary Experiments in Pellet Induration Using a Coal-Fired Cyclone Combuster"; Nigro, J. C., and Zahl, R. K.; Skillings' Mining Review; 65, No. 24; June 12, 1976.

(13) "Concepts for an Improved Blast Furnace System"; Chaflin, H. B.; Iron and Steel Engineer; November 1976; pp 25-29.

(14) "A Study of Improved Fuel Effectiveness in the Iron and Steel and Paper and Pulp Industries"; Gyftopoulos, E., Dunlay, J. B., and Nydick, S. E.; to National Science Foundation; by Thermo Electron Corporation; March, 1976; p 6-7.

(15) "Bell-less Top for High-Top Pressure Furnaces"; Heynert, G., and Legille, E.; Developments in Ironmaking Practice; Iron and Steel Institute Special Report, November 1972; No. 152.

References
(Continued)

(16) "Report of the Proceedings of the Energy Research and Development Administration Workshop on High-Temperature Waste Heat Recovery and Utilization"; to Department of Energy; by Washington Scientific Marketing; August 25 & 26, 1977; pp 43-44.

(17) Iron and Steel Engineer; July, 1979; p.33.

(18) "Energy Use By the Steel Industry in North America"; Group Study by Battelle Columbus Division; July 30, 1971; pp IV-6 to 9.

(19) Reference 16; p 44.

(20) DOE sponsored project with MIT; as per R. Sheneman, October 10, 1979.

(21) "Electric Conductive Billet Heaters"; Heine, H. G.; Iron and Steel Engineer; February, 1977; pp 38-42.

(22) "Direct-Current Electrical Heat Treatment of Continuous Metal Sheets in a Protective Atmosphere"; U.S. Patent 4,081,296; March 28, 1978.

(23) "Natural Gas Prices, Technical Problems Turn Heads to Nitrogen Atmospheres"; American Metal Market Heat Treating Report; August 20, 1979; p 18.

(24) "Lukens fights the natural gas battle by reducing its energy consumption"; 33 Magazine; September, 1976; pp 34-37.

(25) "The Cupola-Dying or Reviving"; Heine, H. J.; Foundry M & T; June, 1976; pp 102-109.

(26) "The New Economics of the Cupola"; Rehder, J. E.; Foundry M & T; January 1976; pp 102-109.

(27) "Clearfield Machine's Coal-Fired Furnace Saves on Melting Time, Maintenance, Fuel"; American Metal Market; July 9, 1979; p 15.

General

"Potential for Energy Conservation in the Steel Industry"; Battelle-Columbus to Federal Energy Administration; May 30, 1975; Contract No. CO-04-51874-00. NTIS No. PB 244,097/AS.

"Development and Establishment of Energy Efficiency Improvement Targets for Primary Metal Industries; SIC 33"; Battelle-Columbus to Federal Energy Administration; August 13, 1976; Contract No. CO-04-60609. NTIS No. PB 269,822.

- Report No. 10

I. Berg, Charles A. Energy Conservation in Industry: The Present Approach, The Future Opportunities. Council on Environmental Quality, May 1979.

II. Technical and/or End-Use Focus

As an example of the technological changes that can result in energy savings in industry, this report focused on the iron and steel industry.

III. Types of Information Provided

1. Energy-use data in major process steps were discussed.
2. Potential energy savings were occasionally mentioned but not always included as necessary motivation for the research.
3. Development times were occasionally estimated but were not generally included.
4. A review of relevant research programs was conducted.
5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

(1) Plasma Arc Steel Making (p. 44).

(2) Direct Steelmaking with Nuclear Energy (p. 44).

(3) Direct Electrolytic Reduction of Iron Ore (p. 44).

(4) Electrolytic Refining of Iron (p. 44)

- Smith, U.S. patent #3,118,816

(5) Direct Electrolytic Reduction of Iron Oxides to Pure Iron (p. 44).

- Vozhova, 1966. Russian patent.

(6) Produce Electric Power During Ox-Red Reaction (p. 50) also to generate H_2 as a reducing agent

(7) Powder Metallurgy (p. 57)

(8) Plasma Arc Spray Forming (p. 60)

(9) Electroforming (p. 60)

(10) Plasma Arc Steelmaking and Spray Forming together (p. 60)

(11) Direct Electric Resistance Heating (p. 62)

(12) Vacuum Furnace (p. 63)

(13) Coatings With High IR Reflectance and High Durability (p. 63)

(14) High Frequency Induction (p. 63)

V. Critical Summary

The author asserts several times in his report that he does not attempt to be comprehensive in his treatment of conservation potential in the iron and steel industry. Rather, the focus was on the potential for conceptual advances in industry, with iron and steel chosen for illustrative purposes.

The level of detail with which the author described the projects and conceptual advances was variable. Some concepts have been known for years, some are currently being developed, and others are not being matured and are only accorded brief description.

Justification for the projects was purposely not presented solely in terms of energy saved. The author believes that defining one's acceptance criteria in that way is too limiting. Instead the author proposes that the processes be judged by the more general criteria of economic efficiency, gauging the price of energy and all other required resources. In this way, the author feels that more energy saving opportunities may be found than if saving fuel by modifying conventional technology were the primary goal. As a result savings from advanced technologies are often reported in terms of material saved, increased production, or increased thermal efficiency. However, since the ideas mentioned in the report were not intended as concrete research projects, justifying the projects was of secondary importance.

VI. Comments

Reviewed by GJH.

References

Arthur D. Little, Inc., Research, Development and Demonstration for Energy Conservation: Preliminary Identification of Opportunities in Iron and Steelmaking, Department of Energy Contract No. EC-77-C-03-1962, January 1978.

Berg, Charles A., and Hague International, Efficient Operation of Slot Forging Furnaces, prepared for the U.S. Department of Energy, TID-27440, 1977.

Berg, C.A., "Process Innovation and Changes in Industrial Energy Use," Science, Vol. 199, Feb. 19, 1978, pp. 608-614.

Boltz, R.W., Production Processes: Their Influence on Design, Penton Press, Cleveland, 1949.

Boorstin, D.J., The Landmark History of the American People, From Appromattox to the Moon, Random House, New York, 1970.

Chenery, H.G., "Processes and Production Functions from Engineering Data," in Studies in the Structure of the American Economy, by W.W. Leontief, New York, 1953.

Cook, Earl, "Limits to Exploitation of Nonrenewable Resources," Science, Vol. 191, Feb. 20, 1976, pp. 677-682.

Crestani, A.B., Neumann, J.W., and Cruse, C.L., "Status of Armco's Reduction Process," American Iron and Steel Institute Technical Session, May 22, 1974.

Dancy, T.E., "Integrated Steelmaking Sidbec-Dosco Using Direct Reduction and Electric Furnaces," American Iron and Steel Institute Technical Session, May 22, 1974.

Douglas, P.H., Theory of Wages, Macmillan, New York, 1937.

Enos, J., "Innovation and Invention in the Petroleum Refining Industry," in The Rate and Direction of Inventive Activity: Economic and Social Factors, Princeton University Press, Princeton, N.J., 1962.

EPA (Environmental Protection Agency), Environmental Considerations of Selected Energy Conservaing Manufacturing Process Options, Vol. III, Iron and Steel Industry Report, EPA-600/7-76-034C, 1976.

Gabor, Dennis, "The Scientist in the New Society," Tykotchner Memorial Lecture, University of Illinois, Champaign-Urbama, May 1, 1972.

Hamberg, D., "Invention in the Industrial Research Laboratory," The Journal of Political Economy, Vol. LXXI, No. 2, April 1963.

Hatsopoulis, G., Widner, T., Gyftopoulos, E. and Sant, R., "A National Policy for Industrial Conservation," Thermo Electron Corporation, Waltham, Mass., 1977.

Heffernan, G.R., "Two Routes to Steel," IEEE Conference Record of the Eleventh Bicennial IEEE Conference on Electric Process Heating in Industry, 1973.

Hogan, W.T. (S.J.), and Koelble, F.T., Purchased Ferrous Scrap, United States Demand and Supply Outlook, study prepared for the American Iron and Steel Institute, Indistrial Economics Research Institute, Fordham University, New York, June 1977.

Hotelling, H., "A General Theory of Depreciation," Journal of the American Statistical Association XX, pp. 340-353, 1925.

Jewkes, J., Savens, D. and Stilerman, R., The Sources of Invention, Macmillan, London, 1958.

Lutz, F. and Lutz, V., The Theory of Investment of the Firm, Chapter VII, Princeton University Press, 1951.

National Science Foundation, Research and Development in Industry, 1975 NSF 77-324.

OTA (Office of Technology Assessment), Radically Innovative Steelmaking Technologies, a workshop held at the Massachusetts Institute of Technology, April 25, 1978, Chairman: Professor J. Szekeley.

Peck, M.J., Competition in the Aluminum Industry, Harvard University Press, Cambridge, Mass. 1961.

Pilkington, Sir Alastair, "The Development of Float Glass," The Glass Industry, February 1963, p. 80 & ff.

Pinkington, Sir Alastair, "The Float Process," Journal of the Institute of Fuel, /252/, July 1970.

Robinson, Joan, "The Production Function and the Theory of Capital," Review of Economic Studies, Vol. 21, No. 2, 1955.

RRN/A (Robert R. Nathan Associates), Iron and Steel Scrap: Its Accumulation and Availability as of December 31, 1975, prepared for the Metal Scrap Research and Education Foundation, Washington, D.C., August 1977.

Salter, W.E.G., Productivity and Technical Change, Cambridge University Press, 1966.

Samuelson, P., Economics, McGraw Hill Book Company, Inc., New York, 1952.

Samuelson, P., Economics, 9th edition, McGraw Hill Book Company, Inc., New York, 1973.

Smailer, R.M., Jensen, B.J., and Scott, W.W., Jr., "Utilization of Direct Reduction Iron in Electric Steel Making," American Iron and Steel Institute Paper, 22nd General Meeting, May 22, 1974.

Solow, R.M., "Technical Change and the Aggregate Production Function," The Review of Economics and Statistics, Vol. XXXIX, August 1957.

Sporn, P., Technology, Engineering and Economics, M.I.T. Press, Cambridge, Mass., 1969.

Stanford Research Institute (SRI), Patterns of Energy Consumption in the United States, prepared for the Energy Policy Staff, Office of Science and Technology, Office of the President, Washington, D.C., U.S. Government Printing Office, 1972.

Trinks, W., and Mawhinney, M.H., Industrial Furnaces, Vol. II, John Wiley & Sons Inc., New York, 1967.

U.S. Department of Energy, Criteria for Evaluating Conservation R&D Opportunities, 1978.

U.S. Department of the Interior, Minerals and Materials, a monthly survey, February 1978.

U.S. Steel Corporation, The Making, Shaping and Treating of Steel, Pittsburg, 1971.

Walker, B.H., and Fuss, L.N., "Manufacturing Processes for the Production of Near Net Superalloy Disk Shapes by Isothermal Forging," AFML report IR-278-5-III, Air Force Materials Laboratory, 1976; Net Shape Metalworking Program Review, Riviera Beach, Fla., Dec. 6-8, 1976.

• Report No. 11

I. Brookhaven National Laboratory. Future Raw Materials and Energy Use in Industry - A Research Agenda, A workshop sponsored by the Division of Industrial Energy Conservation, U.S. Department of Energy (DOE), November 9-10, 1978.

II. Technical and/or End-Use Focus

The focus of this report was industrial energy conservation. The research agenda is organized according to specific industries.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. No estimates of energy savings were given.

3. No estimates of times to commercialization were given.

4. No review of existing research programs was made.

5. The list of research needs was prepared by industry personnel and reflects their knowledge of their industries but does not represent any systematic attempt at identifying needed R&D.

IV. R&D Opportunities

This report did not address end-use energy flows, time to commercialization, process efficiencies, or further references relating to the R&D opportunities that were identified. Thus, items 2-5 in this outline are all empty. To save space, the R&D opportunities that follow are presented as a laundry list organized by industry.

A. Agriculture (p.18)

(1) Germ plasm research (preservation)

(2) Photosynthetic efficiency

(3) Fertilizer efficiency

B. Forest Products, Pulp and Paper

(1) Biological, genetic improvements in trees (p.27)

(2) Improved pest control (p.27)

(3) Water removal (p.29)

- dry forming
- fundamentals of fiber - fiber bonding
- fundamentals of fiber - solvent interaction
- high consistency forming/cleaning
- high temperature forming

(4) Drying (p.29)

- pressing
- physical displacement
- fluid displacement
- fluid displacement
- electromagnetic displacement

(5) Chemical cycle (p.29)

- chemistry of causticization
- new lime producing technology
- electrochemical regeneration using reducing power of black liquor
- plasma technology

(6) Power systems (p.30)

- fundamentals of wood combustion (gasification, cogeneration applications)

(7) Environmental (p.30)

- low level heat utilization
- low cost heat exchangers
- solid waste (sludge) utilization
- non-biological effluent treatment

C. Iron and Steel Processing

(1) Improved blast furnace process (p.38)

- distribution of gas & solids
- modeling of fluid flow in furnace, strength of materials that go into furnace, relative size of materials, etc.

(2) Improved particle reduction (low energy) (p.38)

- pelletizing
- sintering
- cokemaking

(3) Research that supports alternatives to blast furnaces (direct reduction, plasma steelmaking, nuclear steelmaking, direct refining...) (p.39)

- problem of containment (refractories)
- basic mechanisms of oxidation & reduction
- material requirements (severe in nuclear steelmaking)
- generating and maintaining plasma flows
- methods of applying energy, particularly electrical

(4) Impurities removal from scrap (p.40)

(5) Environmental questions (p.41)

- basic mechanisms of fume formation, fine particle technology, dust formation, gas cleaning mechanisms, slag processing, materials recovery.

(6) Solidification (form nearer to final product) (p.41)

- studies of effects on properties and processing of various heat transfer rates, cooling rates, and solidification rates
- modification of limiting factors (thermal diffusity...)
- basic properties of melts & slurries
- formation properties of surfaces
- effects of non-uniformities such as fluid-flow, heat transfer, fusion temperature, & compositional variations on processing and properties

(7) Heating solid steel

- pulse heating
- induction heating
- resistance heating
- basic research (electrical properties of steel, effect of heating rates & method of energy application on properties, methods of applying energy)

(8) Alternative techniques

- powder rolling
- electrodeposition (spraying to final shape)
- projectile forming
- codeposition of alloys

D. Glass, Cement and Ceramics

(1) High temperature phase composition studies would lead to high temperature processing units (p.51)

(2) More efficient heat exchangers to preheat raw materials using waste heat (p.51)

(3) Development of radically changed compound composition in cement (e.g., silicates and aluminates that form at lower temeratures) (p.51)

(4) Develop coal gasification units so that ash, sulfur and alkalies are not added to clinker composition (p.52)

(5) High temperature filtration to use 800-900 F waste heat from cement plants to produce electricity (p.52)

(6) Develop small non-rotating furnaces to produce portland cement (p.52)

(7) Study processes to produce high quality clinker from waste cement dust (p.52)

(8) Fundamental studies on the brittle nature of ceramic materials; success will permit use of high temperature stable materials for turbine applications yielding magnificantly higher efficiencies (p.53)

(9) Innovative glass melting process research, e.g., high energy concentration in a small area and with rapid transport of batch through the zone (p.53)

(10) Fundamental studies for increasing the fuel effectiveness in firing ceramic products; some processes are only 5-10% efficient (p.53)

(11) Fundamental system analysis for net process energy consumption, e.g., conversion to electricity from gas or oil for glass melting.

(12) New plants follow markets, need for local material and process variations to fit optimal model; basics of reformulation are not well established and research is necessary (p.53)

(13) Utilization of waste materials, tailings, recycle, etc., (p.53)

a) fly ash
b) calcium sulfate
c) slags and scorias
d) substitution for asbestos or other materials where there are environmental problems

(14) Alkali resistant glass applicable to reinforce concrete, (e.g., reactions of cement with other filler materials) (p.53)

(15) Reaction of materials thermal or chemical prior to processing (p.53)

(16) Reliable temperature measurement process diagnostics (p.53)

(17) Understand fine particle processes and characterization techniques (p.53)

(18) Lower temperature processes (p.53)

(19) Foamed ceramic materials; high strength at low density. (Low with construction group) (p.53)

(20) Glass and steel furnace refractories research to improve vessel life and product quality

(21) Heat storage, (high temperature regenerative process) encapsulation in stable refractory material of materials which will change phases

(22) Fundamental research on grinding processes

(23) Fundamental research on surfaces of ceramics

(24) Coating of fine mineral particles, e.g., coating of fluxing materials on aggregate materials of proper size distribution in order to develop better ceramic bodies at lower temperatures

(25) Fundamental research on fly ash

(26) Selected phase equilibrium diagrams

(27) Ability to predict fundamental properties of cement products - reduces the requirement for overdesign

(28) Change in standards from composition to performance standards - permits substitutional materials in cements

(29) Development of algorithms models for use in real industrial processes

E. Chemicals and Polymers

(1) Fundamental research in catalysis (p.67)

(2) Biomass conversion to chemicals & polymers (p.67)

(3) Coal liquefaction & gasification to provide chemical feedstocks (p.68)

(4) Fundamental research on corrosion (p.68)

(5) Fundamental research in surface chemistry (p.68)

(6) Utilization of government owned & operated high energy radiation sources for chemical process research (p.68)

(7) Polymer characterization in a fundamental sense (p.68)

(8) Provide (through NBS) continuing characterization of basic physical & thermochemical data on materials of interest to chemical & polymer industry (p.68)

Note: Items 5-8 are identified in the study as lower priority than items 1-4.

F. Textiles

Suggested general research areas to realize scenario of 2000 A.D. textile plant.

(1) Fiber and Raw Material
   a. Maximize use of raw material
   b. Separation; recovery, and reuse of fiber, chemicals

(2) Auxiliaries
  a. Improved process efficiency
  b. Product modification
  c. Improved in-plant environment for process control and workplace

(3) Machinery
  a. More efficient machines
  b. Continuous product flow
  c. Retrofits for improved efficiency

(4) Process Improvement
  a. New, more efficient routes from fiber to product
  b. Low-energy processing
  c. Reduce use of liquids
  d. Compressed process lines
  e. Continuous flow, improved materials handling

(5) Product Improvement
  a. Improve durability, useful life
  b. Improved performance
  c. Individualization of basic product through finishing versus construction

Additional specific topics suggested by panelists for research attention:

(1) Development of new generic fibers from renewable resources.

(2) Optimization of fiber blends and fabric finishes for both function and ease of separation and recycling.

(3) Development of economic recycling techniques for extraction of fibrous materials from finished fabrics.

(4) Development of new end uses for textile and apparel industry by-products.

(5) Development of new natural fibrous and auxiliary raw materials.

(6) Development of effective energy cost accounting by style, shade, etc.

(7) Improved screening and evaluation of developments and innovations, from within and without the textile industry, for possible implementation in material and energy conservation.

(8) Development of effective mechanical dewatering techniques to minimize energy required for drying (paper industry analogy).

(9) Development of pressurized hot water vs. steam for process heating systems (includes reuse of hot process liquors).

(10) Development of improved insulation and heat storage technologies to minimize heat energy requirements.

(11) Development of automatic power factor correction techniques for individual electric motors.

(12) Control and correction of high-frequency transient peaks by Zener diodes.

(13) Improved synchronous switching of heavy electrical loads.

(14) Development of more efficient electrical motors.

(15) Improved management and control of electrical energy demand.

(16) More effective manpower training in energy-conservative skills (possible new incentives for conservation).

(17) Minimize air cooling and humidification requirements for effective material performance in processing (example: condition only material and machinery area, not entire mill atmosphere).

G. Manufacturing

(1) Coal utilization for energy & raw materials (p.104)

(2) Cogeneration utilizing waste heat (p.104)

(3) Generic disciplines that boradly impact manufacturing (e.g., combustion research for low temps., powder metallurgy, net-shape forming, metal & plastic forming, wear, tribology, automatic welding processes, surface coatings) (p.104-105)

(4) Long-range research on inspection, non-destructive testing, product failure, mechanism & fracture mechanics (p.104)

(5) Factory automation, sensing & modeling (p.104)

H. Raw Materials, Exploration and Extraction

<u>Oil</u>

(1) Methods to find oil in stratigraphic traps (p.113)

(2) Ways to determine spatial distribution between drillholes of fluids (oil, gas, water) and rock (p.113)

(3) Improve ability of injected fluids to displace oil in reservoirs (p.,113)

(4) Cheaper, faster drilling (p.113)

(5) Means to mine depleted oil fields (p.114)

(6) Develop seafloor production and transport systems for use under permanent ice (p.114)

(7) Understand behavior of rock-fluid systems in outer 10,000 meters of earth's crust (p.114)

Coal, Oil Shale, Tar Sands

(8) Means to mine thick underground seams (p.114)

(9) Develop method of partial mining followed by underground gasification (coal), retorting (oil shale), or mobilization (tar sand) (p.115)

(10) Automate underground mining (p.115)

(11) Stabilize roofs ahead of underground working faces (p.115)

(12) Enhance recovery of coal (p.115)

(13) Methods for reclaiming land that has been mined (p.116)

Uranium

(14) Extraction of uranium from low concentrations (p.116)

(15) Solve support & environmental control problems of deep sandstone deposits (p.116)

(16) Improve methods of evaluating future supplies and costs (p.117)

Geothermal Fluids

(17) Develop new ways to find geothermal reservoirs (p.117)

(18) Means to evaluate quality of geothermal reservoirs before drilling (p.117)

(19) Improved drilling technology (p.117)

(20) Predict recharging rate of a geothermal reservoir & estimate total recoverable energy (p.117)

(21) Solve problems associated with disposal or reinjection of spent brine (p.117)

Non-Energy Minerals

(22) Develop new ways of making holes in the ground (p.117)

(23) Method to cheaply, quickly, continuously assay the walls of a drilling hole (p.118)

(24) Determine distribution of desired material between holes (p.118)

(25) Improve remote exploration & discovery tools (p.118)

- geophysical means to distinguish limestone from dolomite

- geophysical means to distinguish chalcopyrite from pyrite
- geophysical means of penetrating highly conducting or attenuating overburden w/o excessive power requirements
- airborne induced polarization unit
- induced polarization unit to penetrate below 1,000 ft. & electromagnetic unit to penetrate below 300 ft.
- means of determining breaking characteristics of rock from drill hole data

Extraction

(26) Determine rock properties & outline ore bodies ahead of drilling or mining face by indirect methods (p.119)

(27) Reduce waste breaking, handling & transport (p.119)

(28) Develop continuous self-adjusting mining system (p.120)

(29) Bioleach ore deposits & tight oil reservoirs (p.120)

(30) Find & recover seafloor nodules (p.120)

Processing

(31) Develop a data bank on the physical & chemical properties of metals & their compounds (p.121)

(32) Recover valuable minerals from waste products (mill tailings, smelter dust & slag, scrubber sludge, steel plant slag, thermal power plant ash, garbage) (p.121)

(33) Find better ways of fracturing rock (p.121)

(34) Improved understanding of fluid flow through static & dynamic particle systems (p.122)

(35) Augment understanding of the physics & chemistry involved in mineral processing (p.122)

(36) Improve flotation & flocculation processes by research on surface active agents (p.122)

(37) Improve separation of minerals by use of high-gradient, high-field magnets (p.122)

(38) Methods to extract minerals or metals from seawater P.122)

I. Construction

(1) State-of-art study or summary should be conducted on construction materials and methods with respect to energy utilization. An energy budget model should be developed, giving consideration to value engineering vs. energy engineering. Cost in dollars and kW to build, operate and salvage/recycle. Cost effectiveness vs. energy effectiveness. Emphasize energy savings (construct vs. operate) in design (p.127)

(2) Study of the effect of restrictive elements or labor, government, environmental, safety and codes with aim of standardization to improve energy efficiency and minimize restraints - reassess and recommend for legislation (p.127)

(3) Educational input of energy effectiveness to industry and owners (p.127)

(4) Scheduling - a greater percent of engineering and purchasing should be completed before bidding (p.127)

(5) Soil mechanics

- sonic quarrying, tunneling and drilling
- soil sampling
- in situ testing
- pile driving - pile replacement
- movement of earth, rock and similar materials
- earth compaction

(6) Site preparation - soil stabilization for site access (water, snow, mud consolidation)

(7) Concrete

- transportation/placement, e.g., air blown
- curing/stripping time reduction

(8) Improved tensile strength - reduced resteel, e.g., fiber concrete (p.128)

(9) Joint preparation - adhesive bonding (p.128)

(10) Strength measurement criteria and redefinition (p.128)

(11) Flammability studies - forms and scaffolding (p.128)

(12) Steel - splicing and tying methods (p.128)

(13) Material replacement (p.128)

- cement and concrete substitutions - blast furnace slag, fly ash, waste
- coatings for piping (cladding)
- aluminum wire termination research
- insulation for process industry and commercial buildings

(14) Adhesives - in lieu of welding or fasteners (p.128)

(15) Metals joining - e.g., diffusion bonding of structural steel, reinforcing steel and piping (p.128)

(16) Cutting techniques for concrete and steel using laser beams and plasma torches (p.128)

(17) Standardized connections - electrical (p.128)

(18) Explosive techniques - safety, precision (p.128)

(19) Destructive techniques - recycling, salvage (p.128)

(20) Waste product utilization - recycling (p.128)

(21) Heat storage and conservation (p.128)

(22) Non-destructive examination techniques (p.128)

(23) Quality assurance techniques (p.128)

(24) Centralized construction - float to location (p.128)

(25) Centralized location - industrial and power parks (p.128)

(26) Prefabrication - larger modules (p.128)

(27) Equipment handling systems (p.128)

(28) Instrumentation - sensing of primary elements - pressure, temperature, moisture, 3-dimensional strain measurements (p.128)

(29) Fracture mechanics and structural analysis (p.128)

(30) Temporary power sources (p.128)

(31) Temporary heating sources - replace petroleum (p.128)

J. Non-Ferrous Metal Processing

(1) Direct reduction of aluminum (p.133)

(2) Inert anodes (p.133)

(3) Replacement of petroleum coke w/coke from coal in anodes (p.133)

(4) Purification technology for recycling aluminum alloys (p.133)

(5) Develop alternative processes for extracting copper, lead, zinc, and nickel from sulfide ores (p.136)

(6) Study of impurity element distribution between slag, metal, matte and gas phases (p.137)

(7) Basic research in grinding (only about 5% efficient) (p.138)

V. Critical Summary

This report is basically a set of lists of needed research projects put together by groups of knowledgeable persons from various industries. There is no tight structure or methodology that binds the lists together. Thus, while this report presents a massive "laundry list" of industrial energy conservation ideas, it does not attempt to justify them in either end-use or technical terms.

VI. Comments

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Reviewed by WJH

• Report No. 12

I. Committee on Nuclear and Alternative Energy Systems. Energy in Transition 1985-2010. National Academy of Sciences, Washington, D.C., W.H. Freeman: San Francisco, 1979.
- funding from NAS and ERDA.

II. Technical and/or End-Use Focus

The focus of the study is on development of alternate energy supply and demand scenarios. R&D needs come out of the discussions of demand scenarios, presented in the Report of the Demand and Conservation Panel.

III. Types of Information Provided

1. A fairly detailed review of energy use is made in the Report of the Demand and Conservation Panel and models of energy use in the various sectors are utilized to project alternate consumption scenarios.

2. Specific savings from R&D not identified.

3. No estimates of times to commercialization were given.

4. No review of existing research programs was made.

5. Whatever methodology that was utilized was not made explicit in the reports. The R&D needs were presented as "obvious good ideas".

IV. R&D Opportunities

Buildings and Appliances

(1) Basic Studies of Properties of Materials (p. 117).

(2) Basic Studies of Automatic Control Technology (p. 117).

(3) Automatic Setback Thermostats (p. 117)

(4) Pilot/Burner Retrofit (p. 117).

(5) Reinsulation Methodologies (p. 117).

(6) Solar Water Heating and Passive Design

(7) Metering for Time-Dependent Utility Pricing

(8) Automatic Ventilation Control for Building and Appliances (e.g. clothes dryer)

(9) High Performance Electric and Heat Driven Heat Pumps

(10) Solar Space Cooling

(11) Sophisticated Appliance Controls and Integrated Appliance Design

(12) More Sophisticated Design of Buildings to Provide Desired Amenities at Low Energy Demand.

Buildings and Appliances References

Authur D. Little. 1975. An Impact Assessment of ASHRAE Standard 90-75; Energy Conservation in New Building Design. Cambridge, Mass.: Arthur D. Little.

Bligh, T. P., and R. Hamburger. 1974. Conservation of Energy by Use of Underground Space. In Legal, Economic and Energy Considerations in the Use of Underground Space, pp. 103-118. Papers presented at a workshop organized by Standing Committee No. 3 (Demand Forecasting, Use of Sub-surface Space, Legal Requirements, and Standards), U. S. National Committee on Tunneling Technology, National Research Council, held in conjunction with the Engineering Foundation conference on Need for National Policy for Use of Underground Space, June 24-29, 1973, South Berwick, ME. Washington, D. C.: National Academy of Sciences. Available from National Technical Information Services, Springfield, Va. (PB236-755).

Cohn, S., E. Hirst, and J. Jackson. 1977. Econometric Analyses of Household Fuel Demands. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-3).

Doel, S. H. 1975. Energy Use and Conservation in the Residential Sector: A Regional Analysis. Santa Monica, Calif.: Rand (R-1641-NSF).

Energy Research and Development Administration. 1976. The Electrodeless Fluorescent Lamp Fact Sheet. Washington, D. C.: Energy Research and Development Administration.

Federal Energy Administration. 1976a. Technical Background Information for Appliance Efficiency Targets for Kitchen Ranges and Ovens. Draft, Washington, D. C., April.

Federal Energy Administration. 1976b. Technical Background Information for Appliance Efficiency Targets for Water Heaters. Draft, Washington, D. C., April.

Fraker, H., and E. Schorske. 1973. Energy Husbandry in Housing: An Analysis of the Development Process in a Residential Community, Twin Rivers, N. J. Center for Environmental Studies. Princeton, N. J.: Princeton University.

General Services Administration. 1975. Energy Conservation Design Guidelines for New Office Buildings. Washington, D. C.: General Services Administration.

Herendeen, R. A., and J. Tanaka. 1975. Energy Cost of Living. Center for Advanced Computation. Urbana, Ill.: University of Illinois (CAC 171).

Hirst, E. A., and R. Hoskins. 1977. Energy Cost Analysis of Residential Water Heaters. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-10).

Hirst, E. and J. Jackson, 1977. Historical Patterns and Residential and Commercial Energy Uses. Energy 2(2):131-40.

Hirst, E., W. Lin, and J. Cope. 1976. An Engineering-Economic Model of Residential Energy Use. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/TM-5470).

Hirsh, E., J. Cope, S. Cohn, W. Lin, and R. Hoskins. 1977. An Improved Engineering-Economic Model of Residential Energy Use. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-8).

Hise, E. C., and A. S. Holman. 1975. Heat Balance and Efficiency Measurements of Central, Forced Air, Residential Gas Furnaces. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/NSF-EP-88).

Hise, E. C., J. C. Moyers, and H. C. Fisher. 1976. Design Report for the ACES Demonstration House. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-1).

Hittle, D., and B. Sliwinski. 1975. CERL Thermal Loads Analysis and System Simulation Programs. Vols. 1 and 2. Champaign, Ill.: Construction Engineering Research Laboratory (Interim Report E-81).

Hittman Associates. 1972. Residential Energy Consumption: Phase 1 Report. Columbia, Md.: Hittman Associates (HUD-HAI-1).

Hoskins, R., and E. Hirst. 1977. Energy and Cost Analysis of Residential Refrigerators. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-6).

Jackson, J. R., S. M. Cohn, J. Cope, and W. S. Johnson. 1978. The Commercial Demand for Energy: A Disaggregated Approach. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-15).

Jackson, J. R., and W. S. Johnson. 1978. Commercial Energy Use: A Disaggregation by Fuel, Building Type, and End Use. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-14).

Katona, C. 1975. Psychological Economics. New York: Elsevier Scientific Publishing Co.

Lin, W., E. Hirst, and S. Cohn. 1976. Fuel Choices in the Household Sector. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/CON-3).

Morrison, B. M. 1976. Residential Energy Consumption: Socio-Physical Determinants of Energy Use in Single Family Dwellings. Institute for Family and Child Studies. East Lansing: Michigan State University.

Moyer, J. C. 1973. The Room Air Conditioner as an Energy Consumer. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL-NSF-EP-59).

Mutch, J. J. 1974. Residential Water Heating: Fuel Conservation, Economics, and Public Policy. Santa Monica, Calif.: Rand (R-1498-NSF).

Newton, G. C. 1976. Energy and the Refrigerator. Technology Review 78(3):57-63.

Peoples, G. 1975. Sealed Oil Furnace Combustion System Reduces Fuel Consumption. Dallas: Lennox Industries.

Peterson, S. R. 1976. Economic Optimization in the Energy Conservation Design of Single-Family Housing. Draft for Discussion at the American Society of

Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Symposium, Dallas, February 1-5.

Pilati, D. A. 1975a. The Energy Conservation Potential of Winter Thermostat Reductions and Night Setback. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL-NSF-EP-80).

Pilati, D. A. 1975b. Room Air Conditioner Lifetime Cost Considerations: Annual Operating Hours and Efficiencies. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL-NSF-EP-85).

Pilati, D. A. 1976. Residential Energy Savings Through Modified Control of Space-Conditioning Equipment. Energy 1(3).

Salter, R. G., R. L. Petruschell, and K. Wolf. 1976. Energy Conservation in Non-Residential Buildings. Santa Monica, Calif.: Rand (R-1623-MSF).

Shick, W. L. and R. A. Jones. 1976. The Illinois Lo-Cal House. Small Homes Council, Building Research Council. Urbana, Ill.: University of Illinois.

Socolow, R. H. 1976. Energy Conservation in Existing Residences: Your Home Deserves a House Call. Paper presented at the Conference on Energy Efficiency as a National Priority, Washington, D. C., May 20.

Thompson, P. T., and I. Mactavish. 1976. Energy Problems: Public Beliefs, Attitudes, and Behaviors. Urban and Environmental Studies Institutes. Allendale, Mich.: Grand Valley State College.

U. S. Department of Commerce. 1975a. Projections of the Number of Households and Families: 1975-1990. Population Estimates and Projections, Series P-25, No. 607. Bureau of the Census. Washington, D. C.: U. S. Government Printing Office.

U. S. Department of Commerce. 1975b. Projections of the Population of the United States: 1975 to 2050. Population Estimates and Projections, Series P-25, No. 601. Bureau of the Census. Washington, D. C.: U. S. Government Printing Office.

Wheeler, J., M. Grabaud, and J. P. Acton. 1975. How Business in Los Angeles Cut Energy by 20 Percent. Santa Monica, Calif.: Rand (p-5417).

Wurm, J., G. Panikker, and W. Staats. 1976. Seasonal Performance Evaluation of Small Engine-Driven Heat Pumps. Chicago: Institute of Gas Technology.

Transportation

(1) Basic Studies of Materials Properties (e.g. strength-to-weight) (p. 117).

(2) Thermodynamics of Internal/External Combustion Engines (p. 117).

(3) Chemical Energy Storage (p. 117).

(4) Automatic Control Technology (p. 117).

(5) Specific Data on Factors that Influence Fuel Economy of Existing Cars

(p. 117).

(6) Improved Power-to-Weight Ratios, as well as Interior Volume-to-Weight Ratio

(7) Instrumentation to Provide Driver with Real-Time Data on Fuel Efficiency

(8) Improved Traffic Control

(9) New Motors

(10) Improved Aerodynamic Design for Cars and Trucks

(11) New Primary Energy Sources (liquid, electric) (p. 117)

(12) Improved Intermodel Transfer Technology (p. 117)

(13) Technology for Improved Energy Efficiency in Air Transport. (p. 117)

(14) Applied Engine Combustion Research (p. 185, Report of the Demand and Conservation Panel)

(15) Electric Vehicles, including R&D on Batteries, Fuel Cells, Controls, Electrical Supply Structures, and New Engines for Autos and Trucks (p. 185)

(16) Aircraft Engines with Higher Efficiencies and Lower Emissions (p. 185)

(17) Lighter Weight Materials/Structures Using Composite and Non-Ferrous Materials, Improved Structural Designs, etc. (p.185)

(18) Alternative Energy Sources (synthetic fuels from coal and biomass, hydrogen, fuel cells, etc. (p. 185)

(19) Basic Research on Combustion, Materials for Electrochemical Processes, and Systems. (p. 185)

Transportation References

Abelson, Philip H., and Allen L. Hammond. 1977. The Electronics Revolution. Science 195:1085.

Altendorf, J. P., and A. Kalberlah. 1976. A Comparison Between the Primary Energy Consumption of Electric and Gasoline Powered Vehicles. Paper presented at Fourth International Electric Vehicles Symposium, Dusseldorf, Germany, August 31-September 2.

American Public Transit Association. 1976. Transit Fact Book. Washington, D. C.: American Public Transit Association.

Ayres, R., R. M. Doggett, et al. 1975. Automobile Forecasting Models. Prepared for the Office of Technology Assessment, United States Congress. Draft, International Research and Technology, McLean, Va., September.

Ayres, R., et al. 1976. Automobile Forecasting Models. Draft Working Paper.

McLean, Va.: International Research and Technology (IRT-446-12).

Bernard, Martin J. III, and Joseph L. Shofer. 1975. Policy Search Model for Evaluating Future National Transportation Strategies Under Energy and Environmental Constraints. Paper presented at the Third Intersociety Conference on Transporation. Technical Session on Resource/Energy Strategies, Atlanta, July 16.

Boeing Commercial Airplane Co. 1975. Intercity Passenger Transportation Data. Vol. 1: Service and Economic Comparisons; Vol. 2: Energy Comparisons.

Carley, William. 1976. Nation's Airlines Face Key Problem. Wall Street Journal. October 22.

Civil Aviation Advisory Group. 1976. Air Transportation: Comparative Assessment of Its Public Benefits.

Coon, C. W., et al. 1974. Technological Improvements to Automobile Fuel Consumption. Prepared for the U. S. Environmental Protection Agency and the U. S. Department of Transportation. San Antonio, Tex.: Southwest Research Institute.

DeLeuw Cather and Co. 1975. Case Studies of Transit Energy and Air Pollution Impacts. Prepared for the U. S. Environmental Protection Agency. Washington, D. C.: DeLeuw Cather and Co. (68-01-2475).

Dickerson, Stephen L., and Raymond E. Goodson. 1975. A Low Cost/High Performance Resolution of the Urban Transportation Problems of Congestion, Energy, and Pollution. Paper presented at the Third Inter-society Conference on Transportation, Atlanta, July 14-18.

Difiglio, Carmen, and Damain Kulash. 1976. Marketing and Mobility. Marketing and Mobility Panel, Interagency Task Force on Motor Vehicle Goals Beyond 1980, U.S. Department of Transportation, Washington, D.C.

Drake, John W. 1974. Social, Political, and Economic Constraints on Airline Fuel Optimization. Transportation Research 8(4/5).

Eltinge, Lamont. 1973. 1970's Development of 21st Century Mobile-Dispersed Power. Portland, Ore.: Society of Automotive Engineers.

Friedman, K. M. 1977. Telecommunications and Transportation Energy Demand: Opportunity and Caveats. Energy Communications 3(6):555-600.

Goodson, R. E. 1976. Energy Utilization by Various Modes of Transportation. Address to the Automobile and Manufacturing Meeting, Society of Automotive Engineers, Detroit, October 15. In Energy and Transportation. Warrendale, Pa.: Society of Automotive Engineers (SP-406).

_______. 1977a. Conservation and Transportation: The Primary Issues. Paper presented at Joint Resources for the Future/Electric Power Research Institute Workshop on International Energy Consumption, Washington, D. C., September 15-16.

_______. 1977b. Federal Regulation of Motor Vehicles: A Summary and

Analysis. Institute for Interdisciplinary Engineering Studies, Purdue University. Washington, D. C.: U. S. Department of Transportation (230-5867).

______. 1977c. A Statement on the Potential for Transportation Energy Conservation. Prepared for the Hearings of the Subcommittee on Energy Conservation and Regulation, Committee on Interior and Insular Affairs, U. S. Senate, April 4.

______, et al. 1977. Opportunity and Risks Assessment for Electric and Hybrid Vehicles. Institute for Interdisciplinary Engineering Studies, Purdue Unversity. Washington, D. C.: U. S. Department of Transportation.

Goodson, R. E., K. M. Friedman, et al. Transportation Energy Conservation/Demand Options to 2010. Purdue University. Prepared for the Demand and Conservation Panel, Committee on Nuclear and Alternative Energy Systems, National Research Council, Washington, D. C.

Hagey, Graham, and William Hamilton. 1976. The Future of Electric Land Transportation in the United States. Warrendale, Pa.: Society of Automotive Engineers (760118).

Harkness, Richard C. 1976. Technology Assessment of Telecommunications/Transportation Interaction, Vol. 1: Introduction, Scenario, Development, and Policy Analysis. Draft, Stanford Research Institute. Prepared for the Office of Exploratory Research and Problem Assessment, National Science Foundation, September.

Harvey, D. G., and W. R. Menchen. 1975. A Technology Assessment of the Transition to Advanced Automotive Propulsion Systems. Columbia, Md.: Hittman Associates (HIT-541).

Hirst, E. 1974a. Direct and Indirect Energy Requirements for Automobiles. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL-NSF-EP-64).

______. 1974b. Direct and Indirect Energy Use for Commercial Aviation. Transportation Research 8(4/5).

Hittman Associates. 1974. The Automobile, Energy, and the Environment. Columbia, Md.: Hittman Associates.

Hurter, D. A., and W. D. Lee. 1975. A Study of Technogical Improvements to Optimize Truck Configurations for Fuel Economy. Arthur D. Little. Springfield, Va.: National Technical Information Service (PB-238693).

Jet Propulsion Laboratory. 1975. Should We Have a New Engine? An Automobile Power Systems Evaluation: Technical Report, Vol. 2. Pasadena: California Institute of Technology.

Kendall, E. T. 1975. Fuel Economy/Emission Tradeoff Study. Working Paper, Transporation Systems Center. Cambridge, Mass.: U. S. Department of Transportation (409-75-01).

Lathy, Charles E. 1975. Telecommunications Substitutability for Travel: An Energy Conservation Potential. Office of Telecommunications. Washington, D. C.: U. S. Department of Commerce.

MITRE. 1974. Energy and Environmental Aspects of U. S. Transportation. In Energy Primer. Transportation Systems Center. Cambridge, Mass.: U. S. Department of Transportation.

Motor Vehicle Manufacturers Association. 1976. Motor Vehicle Facts and Figures '76. Detroit: Motor Vehicle Manufacturers Association.

National Academy of Engineering. 1969. Telecommunications for Enhanced Metropolitan Function and Form. Committee on Telecommunications. Prepared for the Director of Telecommunications Management, Office of Emergency Preparedness, Executive Office of the President. Washington, D. C.: National Academy of Engineering.

National Aeronautics and Space Administration. 1975. Aircraft Fuel Conservation Technology. Washington, D. C.: National Aeronautics and Space Administration.

National Research Council. 1974. The Relationship of Emissions to Ambient Air Quality. Vol. 3 of Air Quality and Auto Emissions Control. Coordinating Committee on Air Quality Studies, National Academy of Sciences-National Academy of Engineering. Prepared for the Committee on Public Works, U. S. Senate. 93rd Cong., 2d sess. Washington, D. C.: U. S. Government Printing Office (93-24), p. 8.

National Research Council. 1976. Criteria for Energy Storage R&D. Committee on Advanced Energy Storage Systems, Energy Engineering Board, Assembly of Engineering. Washington, D. C.: National Academy of Sciences.

Nilles, Jack M., R. Roy Carlson, Jr., Paul Gray, and Gerhard Hanneman. 1976. Telecommunications-Transportation Tradeoffs: Options for Tomorrow. New York: Wiley-Interscience.

Office of Technology Assessment, U. S. Congress. 1975. Energy, the Economy, and Mass Transit. Springfield, Va.: National Technical Information Service (PB-250624).

Piasetzki, J. 1976. On the Substitutability of Communications for Transportation: A Selectively Annotated Bibliography. Council for Planning Librarians Exchange Bibliographics. Monticello, Ill.: Council of Planning Librarians (1099).

Pikarsky, Milton, and Daphne Christensen. 1976. Urban Transportation Policy and Management. Lexington, Mass.: D. C. Heath.

Pilati, David. 1974a. Airline Energy Use and Conservation Strategies. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL-NSF-EP-69).

_______. 1974b. Energy Use and Conservation Alternatives for Airplanes. Transportation Research 8(4/5):433-41.

Pollard, J., D. Hiatt, D. Rubin. 1975. A Summary of Opportunities to Conserve Transportation Energy. Transportation Systems Center. Cambridge, Mass.: U. S. Department of Transportation (DOT-TSC-OST-75-22).

Povinelli, F. P., J. M. Klineberg, and J. J. Kramer. 1976. Toward a National

Objective: Improving Aircraft Efficiency. Astronautics and Aeronautics 14 (February): 18-31.

Real Estate Research Corporation. 1974. The Costs of Sprawl. Prepared for Council on Environmental Quality, U. S. Department of Housing and Urban Development, and U. S. Environmental Protection Agency. Washington, D. C.: U. S. Government Printing Office (041-011-0022).

Sheridan, David C., John J. Bush, and William R. Kuziak. 1976. A Study of the Energy Utilization of Gasoline and Battery-Electric Powered Special Purpose Vehicles. Warrendale, Pa.: Society of Automotive Engineers (760119).

Staley, J. L. 1979. A Transportation Energy Use Forecasting Model: An Integrated Model Approach. New York: Garland Publishing.

Steiner, John E. 1976. Future Technology in Commercial Airplanes. Paper presented to the American Society of Civil Engineers, Philadelphia, September 30.

Strobotne, R. L. 1974. Evolution and Effects of Energy Conservation in the Transportation Sector. Paper presented at annual meeting of American Association for the Advancement of Science, San Francisco.

Stuntze, Mayo S., Jr., and Eric Hirst. Energy Conservation Potential of Urban Mass Transit. Federal Energy Administration Conservation Paper No. 34. Springfield, Va.: National Technical Information Service (PB-245 336/9BA).

Transportation Association of America. 1976. Transportation Facts and Trends. Washington, D. C.: Transportation Association of America.

U. S. Department of Commerce. 1975. Statistical Abstract of the United States. Bureau of Census. And earlier editions. Washington, D. C.: U. S. Government Printing Office.

U. S. Department of Transportation. 1974a. Highway Travel Forecasts. Office of Highway Planning, Federal Highway Administration. Springfield, Va.: National Technical Information Service (PB-239169).

______. n.d. Automobile Standards for 1981-84. Rule-making support paper, National Highway Traffic Safety Administration. Washington, D. C.: U. S. Government Printing Office.

______. 1974b. Potential for Motor Vehicle Fuel Economy Improvement. With the U. S. Environmental Protection Agency, joint report to Congress. Washington, D. C.: U. S. Department of Transportation.

______. 1974c. A Report for Energy Conservation Through Public Mass Transportation Improvements. Washington, D. C.: U. S. Department of Transportation.

______. 1975a. Climatic Impact Assessment Program Report. Springfield, Va.: National Technical Service.

______. 1975b. Potential for Motor Vehicle Fuel Economy Improvement. Report No. 7: Truck and Bus Panel. With the U. S. Environmental Protection Agency. Washington, D. C.: U. S. Department of Transportation.

______. 1976a. Aviation Forecasts: Fiscal Years 1977-1978. Federal Aviation Administration. Washington, D. C.: U. S. Department of Transportation.

______. 1976b. Commercial Vehicle Post-1980 Goals Study. Inter-agency Task Force. Washington, D. C.: U. S. Department of Transportation.

______. 1976c. Energy Impact Analysis Resource Information. Federal Highway Administration. Washington, D. C.: U. S. Department of Transportation.

______. 1976d. Energy Statistics. Transportation Systems Center. Cambridge, Mass.: U. S. Department of Transportation (DOT-TSC-OST-76-30).

______. 1976e. Motor Vehicle Goals Beyond 1980. Air Quality Panel, Interagency Task Force. Washington, D.C.: U.S. Department of Transportation.

______. 1976f. Motor Vehicle Goals Beyond 1980. Main Vol., Executive Summary, and Panel Report. Washington, D. C.: U. S. Department of Transportation.

______. 1976g. Motor Vehicle Goals Beyond 1980. Draft, Vols. 1 and 2. Washington, D. C.: U. S. Department of Transportation, September 2.

______. 1976h. National Transportation Trends and Choices to the Year 2000. Draft, Washington, D. C., June 1.

______. 1976i. Proposed Programs for Aviation Energy Savings. Federal Aviation Administration. Report to the Congress. Washington, D. C.: U. S. Department of Transportation.

______. 1976j. Summary of National Transportation Statistics. Transportation Systems Center. Washington, D. C.: U. S. Government Printing Office.

______. 1977. National Transportation Trends and Choices: To the Year 2000. Washington, D. C.: U. S. Government Printing Office (050-000-00124-5).

U. S. House of Representatives. 1975. Electric Vehicle Research, Development, and Demonstration Act of 1975. Hearings before the Subcommittee on Energy Research, Development, and Demonstration, Committee on Science and Technology, June 3-6. Washington, D. C.: U. S. Government Printing Office (94-27).

U. S. Senate. 1975. Electric Vehicle Research, Development, and Demonstration Act of 1975. Hearings before the Special Subcommittee on Science, Technology, and Commerce, Committee on Commerce, October 7 and 10. Washington, D. C.: U. S. Government Printing Office (94-96).

Urban Systems Research and Engineering. 1976. Baseline Energy Forecasts and Analysis of Alternative Strategies for Airline Fuel Conservation. Federal Energy Administration Conservation Paper No. 48. Springfield, Va.: National Technical Information Service (PB-255 351/9BA).

Watkins, Robert, and G. Scott Rutherford. 1975. A Survey of Urban Transportation Control Strategies for Reducing Energy Consumption. Paper presented at the Third Intersociety Conference on Transportation, Atlanta, July 14-18.

Wildhorn, S., B. Burright, J. Enns, and T. Kirkwood. 1975. How to Save Gasoline: Public Policy Alternatives for the Automobile. Prepared for the National Science Foundation. Santa Monica, Cal.: Rand (R-1560-NSF).

Industry

(1) Materials Properties at High Temperature (p. 117).

(2) Characteristics of Industrial Combustion (p. 117).

(3) Heat Transfer and Recovery Methods (p. 117).

(4) Automatic Control Technology (p. 117).

(5) Improved Methods for Energy Monitoring and Housekeeping (p. 117).

(6) Improved Methods for Scrubbing Combustion Gases (p. 117).

(7) Process Retrofit Technologies (p. 117).

(8) Improved Combustion of Marginal Fuels (p. 117).

(9) Cogeneration of Heat and Electricity (p. 117).

(10) Automatic Monitoring of Energy Performance (p. 117).

(11) Low-Temperature Heat Utilization (p. 117).

(12) Basic New Processes that Reduce Overall Requirements for Energy and Other Resources (e.g. recycling, durability) per unit output.

(13) Modification of Material Properties to Enable Replacement of Energy-Intensive Materials with Less Energy-Intensive Material in Specific Applications.

Industrial References

Ayers, R. U., and M. Narkus-Kramer. 1976. An Assessment of Methodologies for Estimating National Energy Efficiency. Arlington, Va.: International Research and Technology Corporation.

Barnes, R. W. 1976. The Potential Industrial Market for Process Heat from Nuclear Reactors. Dow Chemical Co. Oak Ridge, Tenn.: Oak Ridge National Laboratory (ORNL/TM-5516).

Battelle Columbus Laboratories. 1975. Potential for Energy Conservation in the Steel Industry. Prepared for the Federal Energy Administration. Columbus, Ohio: Battelle Columbus Laboratories.

Board of Governors, Federal Reserve System. 1977. Industrial Production: 1976 Revisions. Washington, D. C.: Board of Governors, Federal Reserve System.

Booz-Allen and Hamilton. 1975. Energy Consumption in the Food System. Bethesda, Md.: Booz-Allen and Hamilton.

General Motors. 1977. Industrial Energy Conservation: 101 Ideas at Work. Energy Management Section. Detroit: General Motors.

Gordian Associates. 1975. The Potential for Energy Conservation in Nine Selected Industries. 9 vols. Prepared for the Federal Energy Administration. Washington, D.C.: Gordian Associates.

Hall, E. H., W. J. Hanna, L. D. Reed, J. Varga, Jr., D. N. Williams, K. E. Wilkes, B. E. Johnson, W. J. Mueller, E. J. Bradbury, and W. J. Frederick. 1975. Evaluation of the Potential for Energy Conservation in Seven Basic Industries. Battelle Columbus Laboratories. Springfield, Va.: National Technical Information Service (PB-244772).

Industry Week. 1977. New Rate Plan to Hike Industry Electric Bills. September 12, p. 135.

Institute for Energy Analysis. 1976. Economic and Environmental Implications of a U. S. Nuclear Moratorium 1985-2010. Prepared for the U. S. Nuclear Regulatory Commission. Oak Ridge, Tenn.: Institute for Energy Analysis (ORAU/IEA-76-4).

Nydick, S. E., J. P. Davis, J. Dunlay, S. Fain, and R. Sukhuja. 1976. Study of In-Plant Power Generation in the Petroleum, Chemical and Paper Industries. Thermo Electron. Springfield, Va.: National Technical Information Service (PB-255659).

Resource Planning Associates. 1977. The Potential for Cogeneration Development in the Chemical Industry by 1985. Interim report to the Federal Energy Administration. Cambridge, Mass.: Resource Planning Associates, June.

Spencer, R. S., <u>et al</u>. 1975. Energy Industrial Center Study. Prepared for the National Science Foundation. Midland, Mich.: Dow Chemical Co.

Starr, C. 1975. A Strategy for National Electricity Production. Paper presented at the National Research Council Energy Engineering Board Summer Session, Woods Hole, Mass.: July-August.

U. S. Department of Commerce. 1975a. Historical Statistics of the United States: Colonial Times to 1970. Bureau of Census. Washington, D. C.: U. S. Government Printing Office (003-024-00120-9).

______. 1975b. Statistical Abstract of the United States: 1975. Bureau of the Census. Washington, D. C.: U. S. Government Printing Office (0324-01050-0).

von Hippel, F., and R. Williams. 1976. Energy Waste and Nuclear Power Growth. Draft, Center for Environmental Studies. Princeton University Princeton, N. J. August.

Williams, R. H. 1978. Industrial Cogeneration. Center for Environmental Studies, Report No. 66. Princeton, N. J.: Princeton University.

V. <u>Critical Summary</u>

Quite apart from its well-publicized difficulties as a major energy study, the CONAES Study represents a very weak R&D needs study. It falls into the frequent trap of simply presenting a "laundry list" of research needs, many of which appear quite reasonable, with almost no justification or explanation of why the research is needed. The research needs are presented as if it is perfectly obvious that they are necessary from both a technical and an energy conservation standpoint. While they may have been obvious to the CONAES Panel, many persons are likely to want more justification than the opinion of the authors of the study before they accept the R&D needs. Thus, the CONAES Report represents at best a "tickle list" of ideas for consideration in an R&D Needs study. To do a complete job, one would have to examine the energy flows addressed by the research, identify specific technical barriers, survey the extent to which the research is being covered in existing programs, and prioritize R&D needs according to their appropriateness for federal funding. Clearly, the CONAES work represents only a small step toward completion of a full-blown R&D needs identification effort.

VI. Comments

To glean all of the R&D needs in CONAES, one must consult the Report of the Demand and Conservation Panel (a separate document), as well as the main report. The main report is an incomplete summary of the other reports.

Reviewed by WJH.

- Report No. 13

I. Cremers, C. J. "Environmental and Conservation Research Needs in the Eighties", American Society of Mechanical Engineers Publication 76-WA/RGPC-2. American Society of Mechanical Engineers, New York, 1976.

Summary of contribution by the Research and Goals Committee of ASME.

II. Technical and/or End-Use Focus

Research opportunities focus on environmental and conservation research addressable by mechanical engineers. Conservation is broken down into energy and materials.

III. Types of Information Provided

1. No energy use data were reviewed.

2. No energy savings data were given.

3. No estimate of time to commercialization.

4. No review of existing research.

5. No methodology presented.

IV. R&D Opportunities

(1) Waste heat utilization (from power generation plants) - assessments of the previous and existing state of the art need to be made before an assessment of most likely directions for R&D can be made.

(2) Heat Exchangers (single-phase HX, oil coolers, evaporators, and condensers). - There is insufficient knowledge of details of flow and tranfer mechanisms, as well as the effects of manufacturing tolerances and geometric perturbations on the performance of the heat exchanger, the role of contaminants, and the effect of fouling.

(3) Internal combustion engines - Alternative engine cycles, more efficient carburation of fuel injection, computer control, stratified charges and higher operating temperatures are all areas needing further R&D. Better and more rapid means of heat exchange and regeneration in Stirling engines must be found.

(4) Industrial gas turbines - have not been exploited to their full potential.
   - Design data are needed for advanced turbine and compressor configurations.
   - High temperature materials needed to withstand higher temperatures - research needed on composites, ceramics, and metals.

(5) Alternates to petroleum fuels - e.g. hydrogen from water by thermochemical means, methanol from coal, fuel cells.

(6) Heat Pump Systems - lack of information on seasonal operation.

Need modeling of system and load to determine economics of operation.

(7) Furnace Systems - frequently have low efficiencies. Suggest studies of furnace operation, draft control, heat exchange design and controls.

(8) Waste heat recovery from buildings - computer modeling of systems and control strategies.

(9) Insulating materials - cheaper and more efficient. Insulative panels for inside mounting in retrofit applications where between the walls insulation may not be attractive.

V. Critical Summary

A laundry list of R&D opportunities. Apparently accurate technically, but not well justified. No references.

VI. Comments

Useful as a shopping list to be investigated in the process of determining ECUT R&D needs.

Reviewed by WEG.

- Report No. 14

I. Department of Energy. Department of Energy Program Objectives, Fluid Waste Heat Recovery and Utilization. TID-28393. Department of Energy, Washington, D.C., February 1978.

II. Technical and/or End-Use Focus

This report discussed fluid waste heat recovery in both the industrial and residential/commercial end use sectors, with the emphasis on the former.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. Conservation potential for may of the suggestions was included.

3. Expected development times were usually included.

4. Projects undertaken as the result of a workshop in 1976 were described.

5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

See the review of the parent report, Workshop on Fluid Waste Heat Recovery and Utilization, November 17-19, 1976.

V. Critical Summary

This report is a response to action taken as a result of a workshop held in 1976.

This report is a companion to a more complete document (1976) which describes each conservation need. Both documents are the result of a workshop involving persons from industry and agriculture who gathered to recommend government sponsored development projects related to conserving energy by utilizing waste heat.

Though many suggestions were presented, all deal with short-term projects ranging from several months to a few years. The approach at identifying projects was very use specific and few suggestions with generic motivation were put forth. This feature allowed the workshop participants to quantify the energy potential and expected effort for each project.

Since that workshop in 1976 several projects have been undertaken and the status of the projects are described here.

VI. Comments

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Reviewed by GJH

- Report No. 15

I. Department of Energy. Report of the Proceedings of the DOE Workshop on Energy Conservation in the Textile Industry. TIC-10007. Division of Industrial Energy Conservation, Department of Energy, January 24 and 25, 1978.

II. Technical and/or End-Use Focus

As implied by the title, this report focuses on the textile industry.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. Potential savings were estimated for most of the projects proposed.

3. Approximate R&D times were estimated for most of the project.

4. Programs funded by the conservation office were briefly reviewed.

5. The workshop participants were identified from various trade and professional contacts. They were then assembled in informal round-table discussions to explore near-term needed research.

IV. R&D Opportunities

See attached pages.

V. Critical Summary

The professional backgrounds of the workshop participants likely aided in a comprehensive survey of salient needs within the four subcategories: 1) textile energy management systems, 2) preparation and dyeing, 3) finishing, 4) textile yarn and fabric. The time frame of the research and development was very much in the near term, several months to a few years. The projects were therefore suggestions of incremental improvement rather than of major change.

Most of the projects recommended were specific to various textile processes. However, a few projects such as drying and cogeneration did have greater generic utility.

Due to the short nature of the workshop, energy use data wasn't well researched. To estimate the energy savings the panelists were limited to a "best guess". A fair amount of uncertainty thus surrounds these values.

The attached tables list the projects suggested by the workshop participants and also provide a prioritization within each working group. Even though this is a useful feature, the method used to assign the ratings wasn't explained in the report.

VI. Comments

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Reviewed by GJH

TEXTILE ENERGY MANAGEMENT SYSTEMS

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Heat Recovery of Contaminated Exhausts	High	25% of dryer energy consumption	R-2 yrs D-1 yr D-1 yr		R-100% D- 75% D- 50%	Page 37
Development of Co-generation System	High	30% of mill electric demand	D-2 yrs D-2 yrs	D-$1 MM D-$500 M	D- 50% D- 50%	37
Energy Analysis of Textile Processes	High		R-3 to 5 yrs	R-9 man yrs	R-100%	38
Development of Coal Boiler	High		R-1 yr D-2 yrs D-2 yrs	R-2 man yrs D-20 man yrs D-$3.5 MM	R-100% D-100% D- 75%	38
Improvement of Drying Technology	High	20% of drying energy	R-1 yr D-2 yrs D-1 yr	R-4 man yrs D-$250 M D-$150 M	R-100% D- 75% D- 75%	39

PREPARATION AND DYEING

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Moisture Analyzer	1	.0025 Quad	R-2 yrs D-1 yr D-1 yr	R-$180 M D- $90 M D- $90 M	R- 85% D- 85% D- 0%	43

PROJECT OVERVIEW MATRIX

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Exhaust Gas Incineration	2	1.1×10^{13} Btu's	R-1 yr	R-$250 M	R-100% D-100% D- 20%	43
Pad/Batch Preparation and Dyeing	3	.0033 Quads	R-2 yrs D-2 yrs D-1 yr	R-$250 M D-$250 M D-$500 M	R- 80% D- 60% D- 50%	44
Energy Optimization in Textile Scouring	4	.0576 Quads	R-2 yrs D-1 yr D-1 yr	R-$500 M D-$500 M D-$1 MM	R-100% D- 80% D- 60%	44
Energy Efficient Moisture Removal Systems	5	10-25% of energy consumed for moisture removal	R-2 yrs D-1 yr D-1 yr	R-$200 M D-$100 M D-$200 M	R-100% D- 90% D- 50%	45
Cleaning Exhaust Emissions for Heat Recovery	6	7.1×10^{12} Btu's	R-1 yr D-1 yr D-1 yr	R- $50 M D- $50 M D-$200 M	R-100% D-100% D- 50%	46
Direct Application of Process Chemicals	7	0.4×10^{6} BOE	R-4 yrs D-2 yrs D-1 yr	R-$400 M D-$200 M D-$200 M	R-100% D- 80% D- 50%	46
Low-Energy Continuous Dye Systems	8	.0268 Quads	R-2 yrs D-1 yr D-1 yr	R-$500 M D-$500 M D-$1 MM	R- 80% D- 65% D- 50%	47
Sludge Incineration	9	1.4×10^{12} Btu's	D-2 yrs		D-100% D- 20%	47
Anerobic Digestion of Sludge	9	1.5×10^{12} Btu's	D-2 yrs	D-$500%	D-100% D-100%	47

TEXTILE YARN AND FABRIC

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
State-of-the-art Review of Energy Use in Textiles	High	2.5×10^9 kWh	R-1 yr		R-100%	53
Power Measurement Equipment	High		R-1 yr D-1 yr D-1 yr	R- $50 M D-$150 M D- $50 M	R-100% D-100% D-100%	53
Energy Conservation in Weaving	Medium	0.8×10^9 kWh/yr	R-1 yr D-1 yr D-1 yr	R- $60 M D- $60 M D- $60 M	R-100% D-100% D-100%	54
Energy Conservation in Texturing	Medium	1.8×10^9 kWh/yr	R-1 yr D-1 yr D-1 yr	R- $50 M D- $80 M D- $80 M	R-100% D-100% D-100%	55
Energy Conservation in Yarn Forming & Preparation	High	2.0×10^9 kWh/yr	R-1 yr D-1 yr D-1 yr	R- $60 M D- $70 M D-$100 M	R-100% D-100% D- 90%	55
Low Energy Sizing	High	4.0×10^9 kWh/yr	R-2 yrs D-3 yrs D-2 yrs	R-$250 M D-$500 M D-$300 M	R-100% D-100% D- 80%	56
Curriculum for Fixers & Changers	High		D-2 yrs D-1 yr	D-$100 M D-$537 M	D-100% D- 80%	56
Electrostatic Waste Removal	High			D- $85 M D- $15 M		57
Computer Model of Energy Needs of a Mill	Medium	10^7 kWh/yr	R-½ yr D-1 yr D-½ yr	R- $25 M D- $50 M D- $25 M	R-100% D-100% D-100%	57

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Optimizing Power Needs of Greige Mill	High	675×10^6 kWh/yr	D-1 yr	D-$250 M	D- 75%	57
Energy Conservation via Lubricants	Medium	5% of textile mill energy use	R-1 yr D-1 yr D-1 yr	R- $50 M D-$100 M D- $50 M	R-100% D-100% D- 80%	58
Tuft to Yarn System	High		R-3 yrs D-2 yrs D-1 yrs			59
Electrostatic Spinning	Medium	30% of energy used by present Equipment	R-3 yrs D-2 yrs D-1 yr			59

FINISHING

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Low Temperature Curing	High	0.6×10^6 BOE/yr	R-2 yrs D-1 yr D-1 yr	R-$320 M D-$160 M D-$100 M	R- 75% D- 75% D- 50%	63
Optimization of Drying Techniques	High	2.5×10^6 BOE/yr	R-1 yr D-1 yr D-1 yr	R- $75 M D- $75 M D- $75 M	D- 95% D- 95% D- 95%	63
Metering Techniques for Finishing Agents	High	2.25×10^6 BOE/yr	R-1 yr D-2 yrs D-1 yr	R- $80 M D-$400 M D-$100 M	R- 75% D- 75% D- 50%	63

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Exhaust Incineration	High	1.2×10^6 BOE/yr	R-1 yr D-1 yr D-2 yrs	R-$500 M D-$500 M D-$500 M	R-100% D- 75% D- 50%	64
Effluent Neutralization Via Flue Gases	Medium	0.4×10^6 BOE/yr	R-2 yrs D-2 yrs D-2 yrs	R-$500 M D-$500 M D-$1.5 MM	R-100% D- 75% D- 50%	64
New Size Development	Medium	1200-1600 Btu/lb	R-3 yrs D-1 to 2 yrs			65
Study of the Machnozzle	Medium	2.5×10^6 BOE/yr	R-1 yr D-1 yr D-1 yr	R- $50 M D- $25 M D- $25 M	R-100% D-100% D- 50%	65
Radiation Curing	Medium	9×10^6 BOE/yr	R-2 yrs D-1 yr D-1 yr	R-$170 M D-$800 M D-$800 M	R- 80% D- 65% D- 55%	65
Systems Analysis of a Finishing Plant	Medium			R-$100 M		66
New Bleaching Technology	Medium	0.46×10^6 BOE/yr	R-1 yr D-1 yr D-1 yr	R-$150 M D-$100 M D-$100 M	R- 70% D- 60% D- 50%	66
Alternate Fuels for Finishing	Medium					66
Microwave or Dielectric Heating	Low					67

Project	Priority	Estimated Energy Conserved	Time Frame	Cost	Federal Role	Reference
Modification of Steam Can Technology	Low					67
Flame Curing Finishes	Very Low					67

• Report No. 16

I. Department of Energy. Research Workshop on Energy Conservation Through Enhanced Heat Transfer. COO-4649-8. U.S. Department of Energy, October 1979.

II. Technical and/or End-Use Focus

The focus of the report is on heat transfer problems in the industrial end use sector.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. No estimates of energy savings from research were made.

3. No estimates of times to commercialization were given.

4. Existing research programs sponsored by DOE in heat recovery and heat exchangers were reviewed. The four categories are: 1) performance and reliability penalties inflicted by heat exchanger environment, 2) efficient, economical high temperature heat recovery, 3) poor economics in recovery of low temperature waste heat, and 4) test and evaluation of improved heat exchangers.

5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

AIR CONDITIONING AND REFRIGERATION

(1) Augmented surfaces are needed to yield enhanced performance under dehumidifying, frosting, or icing conditions.

(2) Contact resistance in the use of augmented fin surfaces must be reduced.

(3) The maldistribution of fluid needs to be studied.

(4) Fouling factors must be better understood.

CHEMICAL AND PROCESS INDUSTRIES

(1) Fouling data must be improved.

HEAT RECOVERY

(1) Fouling of augmented surfaces must be understood.

(2) The aging effect of boiling needs to be understood.

(3) The influence of tube row, tube spacing, fin height, and upstream turbulence on tubes with low fins in cross flow must be understood.

(4) The performance of finned tubes with shroud shapes needs to be determined.

(5) Heat exchangers with variable fin density.

(6) Augment tubes with thermoelectric elements.

(7) Heat pipe exchanger evaluation.

(8) Finned plastic heat exchangers and plastic coated exchangers.

V. Critical Summary

This report is a good overview of current government funded research programs in heat transfer and of further research opportunities as percieved by members of the technical field.

Due to the workshop format used to generate the report, the document isn't comprehensive, but many of the salient needs in heat transfer are described. The discussion is predominately technical and many specific needs are included. Energy conservation potential was not included as a point of discussion.

As seen in Section four, many of the research suggestions are for basic rather than applied research.

In addition to the presentations from the work groups, the document also included the question and answer periods following the presentations. The comments offered were often interesting supplements to the information provided by the work groups.

VI. Comments

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Reviewed by GJH.

• Report No. 17

I. Energy Research and Development Administration. Agricultural Processing Industry Workshop on Energy Conservation. CONF-760355. Division of Industrial Energy Conservation, Energy Research and Development Administration, Washington, D.C., March 4-5, 1976.

II. Technical and/or End-Use Focus

As implied by the title, the focus of this report was on the agricultural processing industry.

III. Types of Information Provided

1. No review of end-use data was made.
2. Savings were estimated for most of the projects recommended by the workshop participants.
3. Estimates for most projects were given along with estimates of funding.
4. No review of existing research programs was made.
5. No methodology for identifying R&D opportunties was presented.

IV. R&D Opportunities

See attached sheets.

V. Critical Summary

The focused topic of the workshop allowed the participants to be comprehensive within these limits. The suggestions for research and development were applied to very specific needs in agricultural processing. These needs predominately involved short-term research efforts; hence, most projects included in the report were expected to bear fruit in several months to a few years.

To further specify the projects, anticipated levels of funding were also included. To further justify the projects, estimates of potential energy savings were often given; however, the sources of these estimates were usually not cited.

VI. Comments

Reviewed by GJH

ATTACHMENTS

APPENDIX B - CHAIRMEN'S SUMMARY REMARKS

Chemicals	23
Dairy	25
Fruits and Vegetables	29
Grain	33
Meats	37
Textiles	41

APPENDIX C - RECOMMENDED PROJECTS

Chemicals 47

1. Alternate sources of feed stocks for ammonia plants to replace natural gas with coal
2. Conservation of energy during production of phosphoric acid
3. Use of coal as a fuel for ammonia plants instead of natural gas
4. Study total energy consumption of marketing systems for anhydrous ammonia versus nitrogen solution
5. Conservation of energy in granulation plants
6. Improve heat recovery in existing ammonia plants
7. Conserve energy in phosphate rock mining by extracting P_2O_5 directly from rock-clay matrix
8. Combine the operations of an anhydrous ammonia plant and a steel blast furnace
9. Conservation of energy through minimum tillage
10. Improve efficiencies of pollution control equipment in fertilizer plants
11. Conservation of electrical power in granulation plants

Chemicals (continued)

12. Efficient marketing and distribution of fertilizers and agricultural chemicals

13. Use of byproducts in agriculture

14. Solar evaporation of potash brines to concentrate and crystallize potash

15. Wet grinding of phosphate rock

Dairy 53

16. Development and dissemination of technical educational materials and technology transfer

17. Development of alternatives to current package sealing techniques

18. Integrated energy systems for dried food products

19. Utilization of heat pumps in current manufacturing processes

20. Utilization of solid wastes as an energy source

21. Development of a 2:1 sterile concentrate milk beverage

22. Identification and evaluations of constraints on energy utilized by the dairy products industry

23. Improvement of energy efficiency of in-plant clean-up practices

24. Phase I: Feasibility study of sterile fluid milk as a major conservation measure; Phase II: Development and demonstration of a pilot system

Fruits and Vegetables 57

25. Heat recovery - gases and water

APPENDIX C - RECOMMENDED PROJECTS

Fruits and Vegetables (continued)

26. Methane production and anaerobic digestion of wastes

27. Improved steam traps

28. "Good management"

29. Systems studies of industrial parks

30. Fuel Substitution

31. Improved combustion efficiency

32. Improved refrigeration equipment and processes

33. Bulk reduction to decrease handling, warehousing and transportation costs

34. Earth covered and/or underground storage of cold and/or frozen products

35. Packaging

36. Water removal

37. Sterilization

38. Equipment ratings

39. Evaluation of current practices in food processing firms

40. Education of the public

Grain 63

41. Improved heat transfer and heat recovery capability of drying systems

42. Improved technology for process and moisture control

43. Liquid concentration

44. Improved heat recovery systems

Grain (continued)

45. Alternate fuels to replace natural gas

46. Alternate processing and formulation methods to reduce energy consumption

47. Improved equipment design

Meats 65

48. Systems analysis of energy use in the meat industry

49. Automatic air/fuel ratio control for small boilers

50. Recycle waste water effluents through reclamation system to produce crystal clear potable water certifiable by U.S. Health Dept. laboratories

51. Re-use of hot and/or tempered water through filtration

52. Reduce energy used in beef and hog viscera inspection tables

53. Reduce energy used in high pressure and high temperature water beef carcass washer

54. Substitution of sanitation for refrigeration energy to reduce energy used in chilling red meats

55. Elimination of after-burners

56. Investigate use of outside winter air for refrigeration in northern plants

57. Recovery of lost heat escaping plant in waste effluent

58. Reduce natural gas consumption in hog singeing operation

59. Develop means of eliminating condensation on plant ceiling that is less energy intensive than current procedure

APPENDIX C - RECOMMENDED PROJECTS

Meats (continued)

60. Hot deboning

61. Industrial boiler system

62. Minimize packaging material for meats

63. Development of alternate methods for chilling carcasses

64. Develop alternate method of removing water from material to be rendered inedible

65. Better ammonia and freon refrigeration systems and controls for defrosting

66. Raise low pressure steam to 100 psig level by compression cycle

67. Elimination of steam traps with introduction of a sump at lower physical level and pumping of condensate under pressure to steam generator

68. Improving scalding and de-hairing methods for hogs, on-line with mechanical equipment and chemicals

69. Microwave for processing - new construction

70. Pressurize meat processing smoke houses

71. Reduce energy use in refrigerated transport

72. Demonstration of energy conservation measures

73. Vacuum chilling and storage of red meat

74. Immersion chilling of red meats

75. Reduction of the amount of water used in all meat and poultry processing plants

76. 4-day, 40-hour work week effect on energy consumption, and effect on economies of various plant capacities

APPENDIX C - RECOMMENDED PROJECTS

Textiles

77. Conversion from pneumatic to mechanical materials handling at gins

78. Ginning waste as a substitute fuel for drying

79. Generation of power for cotton gins by using gin waste

80. Compression process using hydraulic power instead of steam power

81. Reduction of energy consumption in wool scouring

82. Reduction of hot water usage in wet-processing of cotton-containing textiles

83. Elimination of drying processes in wet-processing of cotton-containing textiles

84. New fiber-to-yarn techniques for agricultural fibers

85. Field cleaning of seed cotton

86. Improved lint cleaning at gins

87. Improvement of efficiency of gin seed cotton dryers

- Report No. 18

I. Energy Research and Development Administration. ERDA Workshop on Energy Conservation in Agricultural Production. CONF-760763. Energy Research and Development Administration, Washington, D.C., July 15-16, 1976.

II. Technical and/or End-Use Focus

As implied by the title, this report focuses on agricultural production.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. The potential for energy savings was included for each suggested project.

3. Times to commercialization (or research development times) were estimated.

4. No review of existing research programs was made.

5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

See attached pages.

V. Critical Summary

The time focus of the projects suggested by the workshop participants was very near term: several months to a few years. Given this frame, the projects were generally directed at specific uses and few generic activities were recommended. The report nonetheless provides a good overview of immediate needs in agricultural production.

Though the workshop members were probably comprehensive in their netting of salient needs, justification in terms of energy conservation potential is uncertain because the sources were not cited.

VI. Comments

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Reviewed by GJH

APPENDIX B - Chairmen's Summary Remarks

Crop Production Systems 21
Animal Production Systems 25
Greenhouses and Other Production Systems 29
On-Farm Processing 31
Water Resources 35
Utilization of Agricultural By-Products 39

APPENDIX C - Recommended Projects

Crop Production Systems 45

1. Reduction of Transport Energy in Crop Production
2. Energy Conservation through Reduced Tillage
3. Cropping for More Energy-Efficient Food Chains
4. Loss Reduction in Harvesting
5. Multiple Cropping for Energy Efficiency
6. Reduced Weather Vulnerability
7. Alternate Portable Fuel Systems for Agricultural Production
8. A Systems Approach to Energy Conservation in Agricultural Production
9. Effect of Continuous Crop Residue Removal on Soil Productivity
10. Agricultural Utilization of Non-Agricultural By-Products
11. Energy Conservation through Genetic Improvement
12. Increase Efficiency of Nutrient Utilization
13. Energy Reduction through Increased Pesticide Efficiency

APPENDIX C - Recommended Projects (continued)

Crop Production Systems (continued)

14. Biological Nitrogen Fixation

Animal Production Systems 53

15. Improvement of the Energetic Efficiency of Animals By Physiological and Nutritional Means

16. Matching Animal Production with Processing or Manufacturing Process

17. Recovery and Development of Energy from Animal Excreta

18. Conservation of Energy Used for Handling Livestock Waste

19. Conservation of Energy in the Construction and Use of Buildings for Livestock Production

20. Conservation of Energy Used to Control the Environment in Livestock Housing

21. Improve Motor Efficiency and Make More Efficient Use of Motors in Farmstead Equipment

22. Energy Conservation in Feed-Handling Equipment

23. Minimizing Energy Costs of Environmental Modifications of Animal Production Systems

24. Energy Self-Sufficient Animal Production Systems

25. Future Requirements for Energy in Animal and Poultry Production

26. Conserving Energy in Transport

27. Integrated Milk Production and Sanitation Systems

APPENDIX C - Recommended Projects (continued)

Animal Production Systems (continued)

28. Feasibility of the Utilization of Industrial Low Temperature Waste Heat

29. Develop and Demonstrate Forage and Grain Handling Systems

30. Promotion, Acceptance, and Adoption of Energy-Saving Methods of Livestock Production

31. Potential for Energy-Flexible Systems

32. The Facts of Meat Animals and Energy Use

33. Development of Effective Animal Manure Management Systems

34. Improved Milk-Handling Procedures

Greenhouses and Other Production Systems 65

35. Energy-Effective Use of Lighting Systems for Heating and Constant Year-Round Production

36. Reducing Heat Losses in Greenhouses

37. Reducing Energy Consumption for Cooling Greenhouses

38. Improved Greenhouse Heating Systems

39. Greenhouse Orientation and Shape

40. Increased Space Utilization in Greenhouses

41. Development of New Construction Materials for Greenhouses

42. Biological and Physiological Alterations of Crops

43. Systems Analysis of Intensive Vegetable, Grain and Flower Production for Energy Conservation

APPENDIX C - Recommended Projects (continued)

Greenhouses and Other Production Systems (continued)

44. Reduction of Energy Use in the Transportation and Marketing of Vegetables, Fruits, and Flowers

45. Substitution of Scarce Fuels

46. Combination Systems

47. Increasing Efficiency of Materials-Handling Systems in Aquacultural Production

48. Utilizing Low Grade Waste Heat in Aquacultural Production

49. Improving Efficiencies of Vehicle Use in Aquacultural Production

50. Domestic Aquacultural Production

51. Combination Systems for Aquacultural Production

52. Establishing Data Base for Energy Conservation in Controlled-Environment Agriculture

On-Farm Processing 73

53. Annual Cycle Energy Systems Applied to Farm Processing

54. On-Farm Milk Volume Reduction Systems

55. Demonstrating Energy Conservation through Recycled Heat from Dairy Farm Milk Refrigeration Units

56. Energy Conserved and Effect on Electrical Demands Resulting from Peak Load Shifting

57. Establishing Energy Use Patterns for Livestock Feed Processing/Handling Systems

58. Grain Dryer Fuel from Non-Grain Plant Parts

On-Farm Processing (continued)

59. Heat Recovery Systems for Crop Dryers

60. Low Temperature Grain Drying

61. Innovative Design of Grain Dryers

62. Investigation of the Technical and Economic Feasibility of a Coal-Fired Grain Dryer

63. Evaluation of Technical and Economic Feasibility of Heat Pumps for Grain Drying

64. Direct Oil-Fired Burner for Crop Drying

65. Utilization of Lined Tunnels Below Grade as a Heat Exchanger

66. Preservatives to Delay Drying as Applied to Cereal Grains

67. Development and Demonstration of Dryeration

68. Use of Industrial Waste Heat for Crop Drying

69. Containerization for Low-Energy Grain Handling

Water Resources 81

70. National Impacts of Energy Conservation in Water Resources

71. Energy Limitations for Reclamation of Submerged Lands

72. Irrigation Management

73. Energy Conservation Due to Improved Pumping Plant Efficiencies

Water Resources (continued)

74. Development of Educational Material for Evaluating Alternatives to Improve Pumping Plant Efficiency

75. Alternate Sources of Energy for Pumping Water

76. Alternate Source of Energy - Coal-Fired Steam Turbine

77. Wind as a Source of Energy for Pumping Water

78. Solar Energy as an Alternate Source of Energy for Pumping Water

79. Improvement of Motor and Engine Efficiencies

80. Improvement of Pump Efficiency

81. Development of New Well Screens and Gravel Pack Procedures to Reduce Drawdown in Wells

82. Irrigation System Efficiency

83. Water Application Efficiency

84. Crop Response to Limited Water and Nitrogen Input

85. Use of Waste Water to Replace Pumped Water

86. Energy Conservation in Agricultural Drainage Installation

87. Energy Conservation by Improved Drainage Pumping Plant Efficiencies

88. Drainage Materials and Design Practices for Energy Conservation

89. Development of a Simplified Flow Meter

90. Measures for Retaining Water on Land to Reduce Irrigation Pumping

APPENDIX C - Recommended Projects (continued)

Water Resources (continued)

91. Water Harvesting as an Alternative to Pumped Irrigation

92. Recharge of Aquifiers to Reduce Lift for Pumped Irrigation

Utilization of Agricultural By-Products 91

93. Development of Methods for Harvesting, Storing and Transporting Crop Residues Considering Off-the-Farm Use

94. Availability of Field Crop Residues for Specific Crops and Regions

95. Definition of Economical Methods of Whole Crop Harvesting for Optimum Grain Quality, Energy Use, and Residues Collection

96. Practicality of the Redesign of Grain Crops to Maintain Grain Yield But Increase Total Biomass

97. Demonstration of Direct Combustion of Field Crop Residues for On-the-Farm Use

98. Demonstration of Direct Combustion of Field Crop Residues for Off-the-Farm Use

99. Define and Demonstrate Gas-Generating Systems for Farm and Off-the-Farm Use

100. Define and Demonstrate Optimum Liquid Fuel Production Systems

101. Define and Demonstrate Optimum Systems for Production of Industrial Chemicals from Collected Agricultural Residues

102. Increase Developmental Efforts on the Enzymatic Hydrolysis of Cellulosic Residues to Sugars

103. Demonstration of Practical Methods of CO_2 Enrichment for Increasing Crop Growth

APPENDIX C - Recommended Projects (continued)

<u>Utilization of Agricultural By-Products</u> (continued)

104. Integration of Animal Feeding, Fuel Production and Fertilizer Use in the Use of Crop Residues and Animal Wastes

105. Use of Mineral Content Derived from Crop Residues

106. Relative Efficiency and Economic Aspects of Utilizing Manure

107. Development of Energy-Efficient Equipment to Collect, Process, Store and Re-Feed Livestock Wastes

108. Health and Consumer Aspects in the Feeding of Animal Wastes to Livestock

109. Demonstration of Cascade Feeding Systems for Poultry, Steers, and Brood Cattle

110. Feasibility of Converting Feedlot Wastes to Industrially Useful Oxychemicals

• Report No. 19

I. Energy Research and Development Administration. ERDA Workshop on Fluid Waste Heat Recovery and Utilization. CONF-761157. Division of Industrial Energy Conservation, Energy Research and Development Administration, Washington, D.C., November 17-19, 1976.

II. Technical and/or End-Use Focus

The majority of the workshops concerned segments of the industrial sector: agriculture, chemicals, food processing, metals, petroleum, pulp and paper, and textiles. An additional group discussed community systems.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. For each suggested project, energy savings were estimated.

3. R&D times for many of the projects are estimated.

4. No review of existing research programs was made.

5. The workshop participants were chosen from those recommended from professional societies and industry. The participants did not discuss the methods used to arrive at their suggestions.

IV. R&D Opportunities

See attached sheets for general descriptions of R&D needs.

V. Critical Summary

The techical and professional backgrounds of the participants contributed toward presenting a comprehensive sampling of salient low temperature heat recovery needs in the various industries.

The R&D projects recommended were directed at specific end uses and were generally short-term efforts - several months to a year. The participants did not investigate the generic potential of the projects suggested, but most of the projects can be classified in one of eight broader headings: 1) system studies, 2) decontamination, 3) heat exchangers, 4) augmentation techniques, 5) enhancement techniques, 6) environmental conditioning, 7) storage and transport, and 8) process modification.

Though potential energy savings were estimated for each of the projects the sources of the estimates were not given. The numbers thus involve a fair degree of uncertainty.

VI. Comments

This workshop and document motivated the work reported in the report titled DOE Program Objectives, Fluid Waste Heat Recovery and Utilization, February, 1978.

Reviewed by GJH

APPENDIX B - CHAIRMEN'S SUMMARY REMARKS

Agriculture	27
Chemicals	31
Community Systems	35
Food Processing	39
Metals	43
Petroleum	49
Pulp and Paper	53
Textiles	57

APPENDIX C - RECOMMENDED PROJECTS

Agriculture 63

1. Heat and Mass Transfer in Soils as Applied to Soil Warming

2. Distribution for Piping Systems for Soil Warming and Subsurface Irrigation

3. Crop Variety Testing in Waste Heat-Warmed Soil Conditions

4. Utilization of Area Waste Heat by Area Agricuture

5. Intensive Integrated Fish Production Utilizing Waste Heat

6. Utilizing Waste Heat from Steam Electric-Generating Plants in the Culture of Aquatic Food

7. Development of Intensive Catfish Fingerling Production System Utilizing Power Plant Discharge Water

8. Large Scale Environmental Control Complexes

9. Heating Greenhouse Crop-Rooting Media and Enhancement of Greenhouse Above Root Media Atmosphere with CO_2 from Relatively Clean Stack Heating

10. Utilizing Power Plant Waste Heat for Greenhouse Environmental Control

11. Utilization of Waste Heat in Closed-Loop, Dehydration-Pelletizing Systems

12. Methods for Waste Heat Transport with Distance Limitations

13. Identification of Potential Areas of Using Waste Heat for Crop Drying

14. Heat Storage for Agricultural Uses

15. Design Equations for Heat Pipes/Heat Exchangers

16. Mechanisms for Utilizing Waste Heat to Dry Agricultural Crops

17. Economic Feasibility of Soil Warming Systems

18. Production of Fresh Water in Arid Regions Using Waste Heat

19. Environmental Control of Poultry Houses Utilizing Waste Heat Contained in Liquid Streams

20. Environmental Control of Swine Houses Utilizing Waste Heat Contained in Liquid Streams

21. Use of Low Grade Energy Contained in Liquid Effluents for Dairy Operations

22. Survey of Waste Heat Recovery and Utilization for Agricultural Applications

23. Technology and Information Transfer

24. Advancement of Refrigeration and Air Conditioning Technologies Utilizing Waste Heat

25. Systems Approach to Utilizing Waste Heat in Intensive Crop Production and Marketing

26. Utilization of Waste Heat to Enhance Biogas Production

27. Frost Control via Waste Heat Sources

28. Waste Heat Utilization to Improve Quality of Inland Water Streams

29. Improvement of Biogas Production System Reliability

30. Enhanced Water Plant Production for Food, Feed, and Biomass via Waste Heat

31. Use of Waste Heat to Enhance Composting

Chemicals 81

32. Handbook on Waste Heat Recovery Systems and Applications

33. Study of Possible Modes for Federal Incentives Regarding Energy Conservation

34. Lower Cost Heat Exchangers

35. Low Cost Chilled Water

36. Industrial Heat Pumps

37. Expander Technology

38. Exchanger Coolant Flow Control

39. Pipe Tracing, Monitoring and Control

40. Determination of Fluid Physical and Thermodynamic Properties

41. Study of Insulation Characteristics

Community Systems 87

42. Inventory of Energy Sources and Energy Needs

43. Impact of Waste Heat Utilization on Power Plant Engineering

44. Energy Transport and Storage

45. Utilizing Effluent Waste Energy in Heating/Cooling Buildings

46. Waste Heat Utilization for Multiculture Biological Systems

47. Recreational Use of Waste Heat

48. Waste Heat for Desalination

Food Processing 95

49. Refrigeration Waste Heat Recovery

50. Dryer Exhaust Recovery with Fouling Control

51. Heat Storage in Small Volumes

52. Vapor Compression with Wetter Steam

53. Improve the Efficiency of Absorbers for 140°F. Input Water

54. Heat Pump or Heat Pipe for 250°F. Waste Heat Elevated to 400°F. in Cereal Manufacturing

55. Waste Water 100°F. to 180°F. for Sanitizing and Thawing

56. Increase of Water Temperature for Clean-up Using Solar Augmentation

57. Heat Exchanger Cleaning and Filtering for Fouling Prevention

58. Reuse of Hot or Tempered Water Through Filtration

59. Recovery of Contaminated Condensate for Reuse

60. Electrical Production During Generation of Low Pressure Steam

61. Fuel Cell Application

Metals 103

62. Heat Exchanger Development

63. Flexible Membrane Heat Exchanger Development

64. Bleedwater Chemical Treatment

65. Vapor Recompression of 125°F. Steam

66. Recover Energy from Spent Bauxite Discharge

67. Source-Sink Location Coordination

Petroleum 107

68. Low Level Waste Heat Recovery Evaluation

Pulp and Paper 109

69. Converting Waste Heat in Low Temperature Water to Higher Temperature Water via Heat Pump

70. Conserving Hood Waste Heat via Heat Pumps

71. Improved Low Temperature Heat Exchangers

72. ASME Coding of Compact Heat Exchangers

73. Application of Fluidized Bed Heat Exchangers to Waste Heat Recovery

74. Investigation of Feasibility of Bark Drying for Heat Recovery

75. Utilization of Heat Sinks or Balancing Condensers

76. Economics of Solar Augmentation and Conceptual Design of System for Waste Stream Heat Recovery in Pulp and Paper Industry

77. Improved Paper Machine Hood Economizers

Textiles 115

78. Development of a Moisture Meter

79. Mass and Energy Flows in a Textile Finishing Plant

80. Wet Process Modification

81. Tenter Frame Drying

82. Dewatering Processes

83. Heat Pump Utilization of Waste Heat Streams

84. Application of Heat Pumps to Specific Textile Processes

85. Heat Recovery from Boiler Stack Gas

86. Anaerobic Digestion of Concentrated Waste

87. Projection of Future Solar Collector Costs

88. Foam Dyeing

89. Wet-on-Wet Dyeing and Finishing

90. Spray Dyeing and Finishing

91. Vapor Dyeing and Finishing

92. Electrostatic Deposition of Dyes and Finishes

93. Radiation Curing

• Report No. 20

I. Energy Research and Development Administration. ERDA Workshop on High Temperature Waste Heat Recovery and Utilization. Division of Industrial Energy Conservation, Energy Research and Development Administration, Washington, D.C., August 25 and 26, 1977.

II. Technical and/or End-Use Focus

The majority of the workshop sessions concerned segments of the industrial sector: cement and ceramics, chemicals, glass, non-ferrous metals, petroleum, and iron and steel. An additional group discussed integrated industrial parks.

III. Types of Information Provided

1. No review of energy end-use data was made.

2. Potential energy savings were occasionally included with each of the project suggestions.

3. Expected R&D times were estimated for each of the suggested projects.

4. No review of times to commercialization was made.

5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

See attached sheets for a summary.

V. Critical Summary

Industrial representatives contributed to this workshop by presenting a comprehensive sampling of salient high temperature heat recovery needs in the various industries.

The R&D projects recommended were directed at specific end uses and were generally short term; a few years. The participants did not attempt to investigate the generic potential of the projects suggested, but most projects can be classified under one of the three broader headings: 1) systems studies, 2) process modification, and 3) heat recovery technology.

Though potential energy savings were estimated for each of the projects, the sources of the estimates were not given. The numbers thus involved a fair degree of uncertainty.

VI. Comments

The format of this workshop is very similar to a previously held workshop, Fluid Waste Heat Recovery and Utilization, November 17-19, 1976 (CONF-761157). The fluid waste heat workshop concerns potential energy savings in low temperature streams, thus complementing the information provided in this high temperature workshop.

Reviewed by GJH

Index to Topics of Broad Interest

Topic	Industry Group	Project Number
Systems Studies		
• thermodynamic analysis of energy-intensive processes	Glass	11
	Industrial Parks	30,34
• thermal audit of waste heat sources	Chemicals	12
	Glass	18,19,20
• energy storage and transport	Cement & Ceramics	7
	Chemicals	17
	Industrial Parks	31,32
	Non-Ferrous Metals	39
	Petroleum	48
	Iron & Steel	52,54
• energy optimized design	Glass	24,27
	Petroleum	41
• waste heat stream metering	Industrial Parks	33
Process Modification		
• absorption-refrigeration	Chemicals	16
	Petroleum	43
• stack gas heat recovery	Chemicals	10
	Glass	28
	Industrial Parks	35
	Petroleum	47
• high temperature preheated combustion air and burners	Cement & Ceramics	5
	Chemicals	19
	Non-Ferrous Metals	37
	Petroleum	46
	Iron & Steel	52
• oxygen-enriched combustion air	Glass	26
• co-generation	Cement & Ceramics	5,6
	Glass	25
	Iron & Steel	53

Topic	Industry Group	Project Number
Heat Recovery Technology		
• heat exchangers	Cement & Ceramics	1,2,3,6,7
	Chemicals	10,15
	Glass	21,22,23, 29,28
	Industrial Parks	35
	Non-Ferrous Metals	36,38
	Petroleum	44,45,47
	Iron & Steel	49,50,51, 52
• heat pumps	Cement & Ceramics	4
	Petroleum	42
• bottoming cycles	Cement & Ceramics	6
	Chemicals	10,15
• electrical power generation	Cement & Ceramics	8,9
	Chemicals	13,14
	Petroleum	40,44
	Iron & Steel	49

- Report No. 21

I. Energy Task Group, Committee on Materials (COMAT). Federal Council for Science and Technology, Needs for Energy-Related Materials Research and Development. Volume 1. Near-Term Energy Program. ERDA 76-28V1 (Preliminary Version), ERDA Technical Information Center, Oak Ridge, Tennessee. Has 5 appendices. Executive Summary published in 1977 as NP-21665. Available from National Technical Information Service, Springfield, VA. 1976.

II. Technical and/or End-Use Focus

Seven study panels addressed the following areas:

- Fossil Energy
- Nuclear Energy
- Solar and Geothermal Energy
- Energy Conversion, Storage, and Transmission
- Conservation and Recovery of Materials and Energy
- Materials Supply and Management
- Multi-Impact Basic Research and Exploratory Development

III. Types of Information Provided

1. Energy end use data not reviewed.
2. Energy savings from research not estimated.
3. Time to commercialization not considered.
4. Existing research programs reviewed broadly in main text. Some specific programs and funding levels are reviewed in the Appendices.
5. Report did not present a methodology for identifying research. Panels of experts reviewed existing research programs and then recommended changes in program levels and priorities.

IV. R&D Opportunities

- The list of R&D opportunities is, by necessity, long and broadly stated. They are summarized in the Executive Summary. Somewhat more detail, although still general, is available in the body of the report and Appendices.
- Existing research funding levels for various areas are summarized in the attached tables. The report and Appendices contain some additional detail and discussion.
- References for the four panel reports that have the most relevance to energy conservation R&D are attached.

V. Critical Summary

This COMAT report presents a broad view of materials R&D opportunities for energy supply, conversion and use. This report covers R&D opportunities through 1985. No report was issued on intermediate term (to 2000) and long-term R&D opportunities. Several earlier reports had described the needs for energy-related materials R&D, such as the following reports by the National Academy of Sciences:

- Materials Technology in the Near Term Energy Program. 1974.
- Materials and Man's Needs. 1974.
- Mineral Resouces and the Environment. 1975.

The intent of the subject COMAT report was to complement previous materials R&D opportunities reports by specifying and setting priorities on the materials R&D efforts needed to meet the objectives of the national energy plans (ERDA-48 and later ERDA 76-1). To meet these objectives the COMAT report has very little detail. Technical accuracy is not assessable based upon the information provided in the report itself, but it does appear to be very good. The stated R&D opportunities are not justified in the COMAT report; they are based upon programmatic goals (e.g., demonstrated a new process or device by year X) and the knowledge of the individual panel members. It is noteworthy that the panels were composed exclusively of personnel from government agencies; no private industry participation is evident.

VI. Comments

The report represents the broad government view of energy related materials R&D opportunities in the year 1976. While little justification of R&D opportunities is given, their list provides a useful check list to compare against lists coming from other R&D opportunties lists which originate more directly from studies of material using devices and processes.

Reviewed by WEG.

Report of Energy Conversion, Storage, and Transmission Panel

Table 1—PRIORITY RATING AND BUDGET ANALYSIS OF ENERGY CONVERSION MATERIALS R&D PROGRAM (NEAR-TERM)

Item	Sponsor	Current support FY 76, $K	% of total	Priority rating	Recommended support FY 77, $K	% of total	Justification
Mobile Systems							
Open-cycle gas turbines							
Ceramic turbines	DOD	5,975	18.0	NA	NA		Technology applicable to stationary plants. Ceramics not strategic materials. Thermal barriers permit use of nonexotic materials.
Aircraft turbines*	DOD, NASA	15,200	45.8	NA	NA		
Automotive turbines	ERDA	1,000	3.0	1	1,200	7.3	
Total OCGT		22,175	66.8		1,200		
Closed-cycle gas	DOD	175	0.5	NA	NA		Technology proved in Europe. Can use any heat source.
Thermionics	ERDA/NE	745	2.2	NA	745	4.5	Space power systems.
Generators/motors	DOD/ARPA	400	1.2	NA	NA		Compact power systems.
	DOD/USN	500	1.5				
		900	2.7				
Stirling engine	ERDA			2	150	0.9	Phillips/Ford engine to be unveiled in 1976. Reserve judgment re degree of gov't participation.
Stationary Systems							
Open-cycle gas turbines							
Ceramic components	ERDA/FE†	100	0.3	1	2,400	14.6	Required for combined-cycle plants. Ceramics nonstrategic materials.
Closed-cycle gas turbines	ERDA/NE	(900)‡					
	ERDA/CONS	200	0.6	4	300	1.8	Technology proved in Europe. Can use any heat source.
		200	0.6				
Rankine cycles							
Alkali-metal topping	ERDA/FE	300	0.9				
Organic bottoming, waste-heat HX	ERDA	55	0.2				
High-temp. heat-pipes	ERDA	160	0.5				Technology widely applicable.
Total Rankine		515		3	1,000	6.1	
Other cycles	ERDA	50	0.2	5	600	3.7	Start Stirling development, pursue Lysholm.
Fuel cells	ERDA	580	1.7	2	1,800	11.0	Efficiency not Carnot-limited. Distributed generation mitigates transmission problems.
Thermionics	ERDA			7	75	0.5	Topping cycle potential.
Generators/motors	ERDA			6	130	0.8	Increased efficiency reduced materials requirements.
Supporting Technology*							
Heat pipes	NASA	700	2.1				
Ceramics	DOD, NSF, NBS, ERDA	1,800	5.4				
Metals	DOD, NASA, NSF	2,590	7.8				
Fuel-cell	ERDA, NBS	550	1.7				
Superconducting materials	DOD	1,400	4.2				
General support	ERDA	700	2.1				
Total		7,810	23.3		8,000	48.8	Basic to many programs.
Total		33,180	100				
Total less DOD/NASA mobile systems		10,930			16,400	100	

*DOD data incomplete.
†Estimate of S. Friedman, ERDA/FE.
‡Not expected to continue, therefore not included in the totals.

REFERENCES

1. Creating Energy Choices for the Future, A National Plan for Energy Research, Development and Demonstration, Vol. 2, Program Implementation, p. 58, ERDA Report ERDA-48, 1975.
2. Ref. 1, p. 171.
3. Ref. 1, p. 7.
4. An Analysis of the ERDA Plan and Program, pp. 68-69, U. S. Congress, Office of Technology Assessment, October 1975.
5. Ref. 1, p. 78.
6. *Record of the Tenth Intersociety Energy Conversion Engineering Conference*, August 18—22, 1975, IEEE Catalog No. 75CHO 983-7 TAB, pp. 496-512.
7. The Stirling Automotive Power System, Chap. 6 in Should We Have a New Engine? An Automobile Power System Evaluation Vol. 2, Technical Reports, Report JPL-SP43-17, pp. 6-27, California Institute of Technology, August 1975.
8. Ref. 7, pp. 6-28.
9. Ref. 1, p. 65.
10. Ref. 1, pp. 78-79.
11. Ref. 1, p. 68.
12. Ref. 1, p. 61.
13. Ref. 1, p. 63.

Report of Conservation and Recovery of Materials and Energy Panel

Table 8—BUDGET ANALYSIS—NEAR-TERM PROGRAM

Item or program	Approximate budget for FY 76, $1000	% of total	Recommended budget for FY 77, $1000	% of total
I. Reduced energy consumption in the materials cycle	(19,850)*	(92)*	(28,500)*	(88)*
A. Management of the materials cycle	(4,549)*	(21)*	(7,200)*	(22)*
Systems study of the cycle	685	3	2,000	6
Development of substitute materials	1,717	8	2,200	7
Improve the data base on energy use in the cycle	1,440†	7	1,800	6
Integrated studies to support policy implementation	707	3	1,200	4
B. Reduced energy use in materials production	(6,560)*	(30)*	(10,300)	(32)*
Assessment of alternate processes	2,121	10	3,500	11
R&D on new and improved processes	3,876	18	5,800	18
Materials science and engineering	563	3	1,000	3
C. Resources from wastes	(8,741)*	(41)*	(11,000)*	(34)*
Materials from urban wastes	1,189	6	(1,400)	4
Energy from urban wastes	2,289	11	3,500	11
Energy and resources from agricultural wastes	1,180	6	1,300	4
Energy from wood wastes	278	<1	500	2
Material from combustion and conversion wastes	1,440	7	(1,600)	5
Energy and materials from waste-water sludges	665	3	1,000	3
Energy and materials from industrial waste	878	4	(1,200)	4
All	822	4	500	2
II. Materials for improving efficiency in end uses of energy	(1,684)*	8*	(3,800)*	(12)*
A. Materials property assessment for emerging energy technologies	105	(<1)*	500	2
B. Materials development to support energy conservation	(1,579)*	(7)*	(3,300)*	(10)*
Buildings and consumer products	530	2	1,000	3
Industrial end use	1,024	5	2,000	6
Transportation systems and vehicles	25	<1	300	1
Totals	21,534	100%	32,300	100%

*Subtotal.

†The figure for data collection includes about $250K that overlaps with the Materials Supply and Management Panel program.

REFERENCES

1. Energy Research and Development Administration, A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future, Volume I: The Plan. Washington, D.C., U.S. Government Printing Office, ERDA-48, June 1975.
2. Ref. 1, p. III-1.
3. Energy Research and Development Administration, A National Plan for Energy Research, Development, and Demonstration: Creating Energy Choices for the Future, Volume II: Program Implementation. Washington, D.C., U.S. Government Printing Office, ERDA-48, June 1975.
4. Ref. 3, p. 70.
5. Office of Emergency Preparedness, Energy Conservation, A Staff Study Prepared for the Energy Subcommittee of the Domestic Council, July 1972.
6. Federal Energy Administration, Project Independence Report, November 1974.
7. Energy Policy Project of the Ford Foundation, *A Time to Choose: America's Energy Future*, Ballinger Publishing Co., Cambridge, Mass., 1974.
8. R. Herrendeen and C. Bullard, Energy Cost of Goods and Services, 1963 and 1967, Document 140, Center for Advanced Computation, University of Illinois, November 1974.
9. P. F. Chapman, Energy Costs: A Review of Methods, *Energy Policy*, 2(2): 101 (June 1974).
10. National Science Foundation, Report of the NSF-Stanford Workshop on Net Energy Analysis, Aug. 25–28, 1975.
11. International Federation of Institutes for Advanced Study, *Energy Analysis Workshop on Methodology and Conventions*, Aug. 25–30, 1974, Stockholm, Sweden.
12. National Academy of Sciences, Materials Technology in the Near-Term Energy Program: Report of the Ad Hoc Committee to the Science Advisor to the President, p. 51, National Academy of Sciences, Washington, D.C., September 1974.
13. John B. Wachtman, *The Office of Technology Assessment: Overview and Materials Programs*, West Coast Meeting, Society of Automotive Engineers, Inc., Warrendale, Pa., August 1975.

Report of Materials Supply and Management Panel

Table 4—FUNDING ESTIMATES FOR FEDERAL PROGRAMS ON MATERIALS SUPPLY AND MANAGEMENT

Research program	Sponsor	FY 76 funding, $ millions
Uranium resource assessment	ERDA	14.0
Nuclear processing development (gas diffusion, isotope fuels, laser separator, gas centrifuge)		14.8
Nuclear waste management		25.9
Materials research (substitution)		0.9
Minerals and materials information and analyses	DOI/BOM	15.2
Metallurgy (processes and substitution)		22.0
Minerals and materials resource information and analyses	DOI/USGS	2.5
Geological research on mineral deposits		12.0
Metal substitutes		Included elsewhere
Seabed assessment, structural materials, resources, geology	NSF	8.6
Conservation of materials, new production processes	NSF/RANN	3.3
Efficiency of wood processing	DOA/FS	6.2
Extraction and harvesting of wood		1.8
Metallurgical materials properties and composition analysis	NBS	4.0
Development of efficient power plants and designs for ships	DOC	4.0
Use of secondary woods, supply of copper	DOS	0.2
Minerals Attaché Program		0.3
Com-Ply products and innovative piping	HUD	0.1
Chromium, magnesium, manganese, etc.	Nat. Mat'l Advisory Board	Included elsewhere
	Federal Preparedness Agency	0.3
TOTAL		136.1

REFERENCES

1. A National Plan for Energy Research, Development & Demonstration: Creating Energy Choices for the Future, Vol. 2, Program Implementation, ERDA Report, ERDA-48, June 1975.
2. Federal Energy Administration, Project Independence Report—Task Force Report, Availabilities, Requirements, and Constraints on Materials, Equipment and Construction, 1974.

BIBLIOGRAPHY

Albers, John P., and Walter J. Bawiec, Non-Fuel Minerals and Materials Needed by the United States Energy Industry—A Preliminary Report, U. S. Geological Survey open-file report, 1975.

Bennethum, Gary, and L. Courtland Lee, Is Our Account Overdrawn?, *Mining Congr. J.*, 61(9): 33-48 (1975).

Brobst, Donald A., and Walden P. Pratt (Eds.), United States Mineral Resources, U. S. Geological Survey Circular 682, 1973.

Calkins, J. A., Olaf Kays, and E. K. Keefer, CRIB—The Mineral Resources Data Bank of the U. S. Geological Survey, U. S. Geological Survey Circular 681, 1973.

Carlson, Jack W., Reliable Mineral Supply for the Future?, *Mining Congr. J.*, 61(11): 42-47 (1975).

Council on International Economic Policy, Special Report—Critical Imported Materials, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1974.

Energy and Hydrocarbons in the U. S. to 1985, Vol. 2, The Pace Company.

Environmental Quality—5th Annual Report on Environmental Quality, Council on Environmental Quality, 1974.

Mineral Resources and the Environment, National Research Council, February 1975.

Minerals Yearbooks, U. S. Department of Interior.

National Academy of Sciences—National Research Council, Mineral Resources and the Environment, National Academy of Sciences, Washington, D. C., 1975.

Office of Business Economics—Economic Research Service, Projections, U. S. Water Resources Council, 1972.

Statistical Abstracts, Bureau of the Census.

U. S. Bureau of Mines, The Bureau of Mines Minerals Availability System and Resource Classification Manual, U. S. Bureau of Mines Information Circular 8654, 1974.

U. S. Department of the Interior, Mining and Minerals Policy, 1975, and Commodity Data Summaries, 1975, Annual Report of the Secretary of the Interior under the Mining and Minerals Policy Act of 1970 (P.L. 91-631), Parts 1 and 2, Superintendent of Documents, U. S. Government Printing Office, 1975.

The U. S. Energy Problem, Vol. 2, Appendices, Part B, Inter Technology Corporation, RANN, November 1974.

U. S. Geological Survey, Mineral Resource Perspectives 1975, U. S. Geological Survey Professional Paper 940, 1975.

U. S. National Commission on Materials Policy, Material Needs and the Environment Today and Tomorrow, Superintendent of Documents, U. S. Government Printing Office, Washington, D. C., 1973.

Table 1—PROGRAM FOR BASIC RESEARCH FOR NEAR-TERM GOALS
(Parentheses enclose Materials Sciences, DPR, ERDA, total for topic)

	Funding, millions of dollars (1976)					
	FY 76	77	78	79	80	81
Metals and alloy development	(13.4)					
Fracture	0.5	1	1.5	2	2.5	3
Creep mechanisms	0.5	2	3	3	3	3
Stress rupture life		2	3	3	3	3
Stress rupture life with cyclic loading	0.4	1	1	1	1	1
Stress corrosion cracking	0.5	3	4	5	6	7
Thermodynamics		1	1.5	2	2.5	3
Coatings development	0.3	2	2	2	2	2
Theory/modeling (lifetime pred'n)	0.3	1	1.5	2	2.5	3
Erosion mechanisms	0.4	2	2.5	3	3	3
Corrosion mechanisms	0.5	3	3.5	4	5	6
Thermodynamics	0.5	1	1.5	1.5	1.5	1.5
Kinetics	0.5	3	3	3	3	3
Hydrogen embrittlement	0.5	2	3	4	5	5
Thermodynamics	0.3	2	3	4	4	4
Hydride (structures)	0.5	1	1.5	2	2	2
Metals and alloys (for light-water reactors)						
Stress corrosion cracking	0.5	3	3	3	3	3
Radiation effects	7	8	9	10	10	10
Welding and joining	0.2	1.5	2	2.5	2.5	2.5
Ceramics	(5.6)					
Slag properties	0.5	2	2.5	3	3	3
Refractories (corrosion)		0.5	1	1.5	2	2
Thermodynamics	0.5	0.5	1	1.5	2	3
Kinetics	0.2	0.5	1	1.5	2	3
Microstructure effects	0.2	0.5	1	1.5	2	3
Temperature-gradient effects	0.2	0.5	1	1	1	1
Erosion	0.2	0.5	1	1.5	2	2
Thermal shock studies	0.1	0.5	1	1.5	2	3
Fracture mechanics	0.2	0.5	1	1.5	2	3
Microstructure development	0.5	1	1.5	2	2.5	3
Nonoxide ceramics	0.5	2	2.5	3	3.5	4
Processing	2	2.5	3	3	3	3
Mechanisms of flaw formation		1.5	2	3	3	3
Scale-up		1	1.5	2	2.5	3
Single-crystal growth	0.3	1	1	1	1	1
Crack-growth mechanisms		0.5	1	1.5	2	3
Variable environments		0.5	0.5	0.5	0.5	0.5
Design techniques (brittle)		1	1.5	2	2	2
Design techniques (composites)		0.5	1	1.5	2	3
Thermal-insulation studies						
Bulk conductivity	0.2	0.5	1	1.5	2	3
IR coating materials		0.5	1	1.5	2	2.5
Measurement developments		0.5	1	1	1	1
Polymers	(0.3)					
Processing:structure:property relations		2	3	4	5	5
Ultraviolet degradation mechanisms		0.5	1	1.5	2	2.5
Corrosion		0.5	1	1.5	2	2.5
Crazing		0.5	1	1.5	2	2.5
Coal chemistry		3	4	4	4	4
Coal structure		0.5	1	1	1	1
Amorphous carbons		0.5	1	1.5	2	2.5
Composites	(1.0)	2	3	4	5	6
Fiber development		2	3	4	4	4
Interface bonding		1	1.5	1.5	1.5	1.5
Micromechanics		0.5	1	1.5	1.5	2
Surfaces	(3)					
Corrosion films		2	3	4	5	5
Catalysis		2	3	4	5	5
Equipment/instruments		15				
Totals	23	90	105	129	147	163.5

REFERENCES

1. A National Plan for Energy Research, Development and Demonstration, ERDA Report ERDA-48, Vols. 1 and 2, 1975.
2. Exploring Energy Choices, Ford Foundation, 1974.
3. Materials Technology in the Near-Term Energy Program, National Academy of Sciences, 1974.
4. Materials and Man's Needs (COSMAT Report), National Academy of Sciences, 1974.
5. Report of the Committee on Structural Ceramics, Report AB-320, National Academy of Sciences, 1975.
6. Critical Needs and Opportunities in Fundamental Ceramics Research: MIT Meeting Summary, ERDA Report ERDA-9, 1975.
7. Thermodynamics and National Energy Problems, National Academy of Sciences, 1974.
8. Report on the Federal R&D Program for FY 76, Federal Council for Science and Technology, Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 1975.
9. Materials Sciences Programs, FY 1975, Division of Physical Research, ERDA Report ERDA-55, July 1975.
10. Inventory of Federally Supported Materials R&D for FY 76, COMAT Report, Federal Council for Science and Technology.

- Report No. 22

I. The Engineering Societies Commission on Energy (ESCOE). Basic Research in Engineering: Advanced Industrial Technology. U.S. Department of Energy, Washington, D.C., February 1979.

II. Technical and/or End-Use Focus

This report focused on energy conservation methods in industrial technology. Specific areas addressed were: design methods, manufacturing processes, industrial sensors and measurement techniques, and tribology.

III. Types of Information Provided

1. Energy end-use data were discussed qualitatively as certain manufacturing processes were discussed. The primary emphasis for data presentation was an energy supply source.
2. No energy savings were estimated.
3. No times to commercialization were given.
4. No review of existing research programs was made.
5. Research opportunities were chosen by committee concensus according to the following criteria:
   - potential for major breakthrough
   - potential for fast commercialization
   - critical information for filling technology gaps
   - energy and economic advantages
   - significant advance in engineering technology base.

   However, methods for analyzing energy distributions and uses in industrial processes were recommended for further study.

IV. Individual Research Needs Were Described as Follows :

1. Design
   - Data bank and advanced Methodology Handbook incorporating life cycle energy accounting.
   - Greater incorporation of computer-aided design, computational methods, and optimization techniques.
2. Manufacturing Processes
   - Advance physical understanding and mathematical modeling techniques.
   - Analysis of energy required for various materials and processes to produce a specific part.
   - Methods to assess and reduce net energy content of manufactured parts (i.e. starting with new net shape forms in machining processes).
3. Sensors and Measurement Techniques
   - Real-time process control for manufacturing operations.
   - Quantitative NDE for energy conservation, transmission and and production systems.
   - Automated inspection systems for remote hazardous environments.
   - Sensors for well logging and minerals exploration.
   - Self powered sensors for remote monitoring.
4. Tribology

   Research opportunities were reviewed from "Strategy for Energy Conservation through Tribology" by Pinkus and Wilcock.

V. Critical Summary

The qualitative nature of much of this report indicated that the understanding of basic industrial processes is insufficient in many cases to adequately define needed research. Therefore, recommendations were made for further study to classify these processes and develop methodologies in relation to energy use analysis.

Instrumentation and measurement systems were considered to have sufficient technological basis to recommend specific programs and estimate costs.

The emphasis of the report was on energy conservation for the production of small discrete batches of manufactured components, since 75% of all metal parts are produced in this manner.

The report in general was oriented toward long term research goals.

VI. Comments

None.

Reviewed by REW.

- Report No. 23

I. The Engineering Societies Commission on Energy (ESCOE). Basic Research in Engineering, Fluid Dynamics and Thermal Processes. FE-2468-54. Department of Energy, Washington, D.C., August 1979.

II. Technical and/or End-Use Focus

As the title implies, the technical focus of the paper is fluid dynamics and thermal processes. End-use discussions include the industrial and transportation sectors with most examples relating to the former.

III. Types of Information Provided

1. No end-use data were reviewed.

2. No estimates of energy savings were given.

3. No times to commercialization for technologies were given.

4. No detailed review of existing programs was described.

5. The methodology used was that of a survey. Initially, ASME sections relating to the topic were consulted. 600 questionnaires were sent out from which 170 'useful' responses were received. The information was categorized into general areas and presented by groups of ESCOE members.

IV. R&D Opportunities

See attached pages.

V. Critical Summary

This is a very technically oriented report concerning basic research needs in fluid dynamics and some thermal processes. The research was not suggested with energy conservation as a primary goal. Increased energy efficiency was assumed to be a natural consequence of a greater basic understanding of a process of phenomenon. This can be seen in the R&D need summaries attached, in which the reason for the needs is technical justification.

Through the survey/workshop method used in generating the report, a wide breadth of activities was collected. The descriptions of the activities are thorough and are equivalent to the "Research Activity" or "task" level.

As a technical document, this report rates highly. The primary deficiency of the report is the lack of more in depth reasons for needs in terms of end use energy or process improvements.

VI. Comments

Reviewed by GJH

Table 2.4: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Multiphase Flows
Secondary Research Category: Fundamental Understanding

Research Needed	Application	Reason for Need
Field Equations	General	Determine once and for all the proper form for the space - time averaged field equations to resolve questions of consistancy
General extension of single-phase theories to multiphase flows (Poiseuille, Covette, rotating, stability, etc.)	All future applications where multiphase flows are of potential usefulness	Virtually all work done to date has been emperical or semiempirical in nature with a specific need in mind. Practically no directed fundamental work has been undertaken towards simple extension of single phase ideas to multiphase flow fields
Flow pattern extension of range	Mixers, separators, liquid metal MHD generators, geothermal wells	Improve efficiency of given systems by artifically extending a flow regime of enhanced or efficient characteristics
Flow pattern stability with heat transfer	Condensors and reheaters	Condensation-induced flow regime collapse reduces heat transfer rate and changes flow rates causing oscillation
Flow pattern transition and stability	All multiphase flow systems	All mass, momentum, and energy exchange processes are governed by the flow configurations which govern contact area and gradients
Laminar and turbulent transport	Injectors, jets, furnaces, combustors	Improved product design and efficiency
Modeling of turbulent transport	Coal utilization	Developing improved systems for processing and burning of coal
Regions of laminar separation	Aerodynamic hardware and artificial organs	To prevent failure by proper design for safety and economic purposes
Turbulent dispersion	Contactors	Prevention of stable emulsion production of radioactive waste
Turbulent transport droplets and particles	Fuel injectors, soot transport	Dominant behavior in numerous processes requiring energy utilization optimization with little knowledge available
Unsteady flow effects on pressure drop and heat transfer in multi dimensional systems	Particulate combustion, heat exchangers	Improve efficiency of particulate or heterogeneous combustion systems and to improve knowledge regarding coal dust explosions
Unsteady flow effects	Heat exchangers, high temperatures multiphase devices (combustors)	For startup and shut down predictions as well as cyclic behavior for energy system optimization.

Table 2.4 (Cont.): BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Multiphase Flows
Secondary Research Category: Fundamental Understanding

Research Needed	Application	Reason for Need
Unsteady flow effects in multidimensional boundary layers	Compressors and other turbomachinery.	Greatly improve efficiency in rotating machinery
Unsteady flow effects	Fusion reactor blankets and confinement systems	Improve design and optimize blanket regions especially with pulsed intermittent flows and energy deposition in complex geometrice
Pressure drop in packed beds	Contactor, distillation towers, gas absorption systems, cooling towers	Improve throughput rates thereby reducing process energy requirements
Improved understanding of pressure losses	Oil wells, pipelines, geothermal wells	Improve performance predictions, increase yield, improve efficiency
Packed bed behavior	Filters	Improve efficiency of filters used in containment or environmental protection areas
Motion of granular materials	Transport and processing systems for cool, agricultural products, ores, chemicals, etc.	Reduction in transport and process costs and energy requirements
Fluid profile effects voids, velocities, temperatures in both steady and transient flows	Generalized advanced energy systems and components	Need more detailed information for accurate predictions and calculations for improved efficiency, reduced margins, reduced conservatism with maintained safety
Multidimensional experimental data	All multiphase equipment	Improved understanding leading to better computational methods for improved design capability, reduced conservatism, and better efficiency
Boundary layer and secondary flows	Turbomachinery	Improved efficiency
Heat transfer	Nuclear reactors, heat exchangers, refrigeration systems, etc.	Optimize equipment size relative to duty
Bubble dynamics	Contactors	Design improvements to improve efficiency in gas-liquid systems
Interactions with solid structure from erosion or damage standpoint	All current and advanced energy systems having two-phase flow fields - coal liquefaction, geothermal turbines, nuclear turbines, fusion power plants, etc.	Extension of equipment life and improved safety through elimination or reduction of destructive potential of multiphase flows due to droplet erosion, cavitation, vibration, deformation, etc.

Table 2.5: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Multiphase Flows
Secondary Research Category: Interphase Transfers and Nonequilibrium

Research Needed	Application	Reason for Need
Improved understanding of interfacial transfer of mass, momentum, and energy	All advanced energy system application having multiphase flow fields	Development of advanced predictive tools for development, design and optimization
Improved understanding of transient and steady state transfer mechanisms	All advanced energy system application having multiphase flow fields	Development of advanced predictive tools for development, design, and optimization
Improved understanding of interface formation, deformation, and renewal mechanisms	All advanced energy system application having multiphase flow fields	Prediction of phenomena based on interface transfer laws will require not only a understanding of the transfer laws themselves but an understanding of factors affecting the transfer areas
Molecular scale modeling	Many current and advanced energy system divices	Almost impossible to predict rates in areas where safety or performance are affected
Improved understanding of cavitation phenomena	High speed multiphase flows, propellar efficiency, flashing impellor efficiency	Improve efficiency, reduce erosion, reduce noise in systems where the potential for cavitation exists
Improved understanding of cavitation phenomena	Pumps and components	Reduce potential for flow induced vibration and resultant damage
Improved understanding of cavitation phenomena	Flow control devices	Design optimization and reduce damage potential noise reduction
Improved understand of cavitation phenomena in entering passages	High speed pumps and turbines	Damage and noise reduction, improved efficiency
Direct contact condensation - limit of condensing rates	Many current and advanced energy system devices	A high penalty is paid in terms of size and efficiency due to our lack of understanding
Vapor release in suddenly expanded systems	Nuclear reactor safety, LNG transport	Safety analysis of power generation and LNG transport systems
Transient phase geometry determination	Steam generators	To determine potential for pocket formation and rate of pocket collapse condensing induced water hammer
Particulate or droplet continuum coupling	Power generation systems, polution treatment systems, gasification processes, coal transport, etc.	Improve efficiency of particulate or droplet transport and combustion systems, remove or eliminate polutants
Establishment, maintenance and boiling in thin films	OTEC, waste heat, recovery systems, low potential transfer device	Very high heat transfer rates may be obtained with thin films resulting in large improvements in efficency but mechanisms are not well understood

Table 2.6: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Multiphase Flows

a) SECONDARY RESEARCH CATEGORY - MULTIDIMENSIONAL AND ORIENTATIONAL EFFECTS

Research Needed	Application	Reason for Need
Fundamental analysis and data in general internal flow systems as diffuses, bends, around obstructions, etc.	General multiphase fluid flow systems	Information lacking for future developments in all areas where multidimensional fields must be considered
General multidimensional behavior in laminar and turbulent flows	All advanced multiphase flow systems	Advanced energy applications designs need methods for assessment of efficiency and optimization
Flow mixing due to strong and weak cross flows	Many multiphase flow systems	Little is known regarding more complicated aspects of multiphase systems beyond single geometries such as round tubes and annuli
General multidimensional modeling in turbulent flows including general stability criteria	Almost all advanced energy systems and components including heat exchangers, fusion systems, OTEC, etc.	No information available
Inside blades and passages, multidimensional flow fields, branches	Two-phase turbomachinery	Advanced energy application designs need methods for assessment of efficiency and optimization
Relative velocity and phase distribution in horizontal and inclined ducts	Nuclear reactor systems	Virtually no information available
Fundamental analysis and data in general internal flow systems as diffuses, bends, around obstructions, etc.	General multiphase fluid flow systems	Information lacking for future developments in all areas where multidimensional fields must be considered
Flow mixing due to strong and weak cross flows	Many multiphase flow systems	Little is known regarding more complicated aspects of multiphase systems beyond simple geometries such as round tubes and annuli
General multidimensional modeling in turbulent flows including general stability criteria	Almost all advanced energy systems and components including heat exchangers, fusion systems, OTEC, etc.	No information available
Relative velocity and phase distribution in horizontal and inclined ducts	Nuclear reactor systems	Virtually no information available
Develop theory and data in rotating flows	Advanced steam turbines	Two-phase turbines appear attractive for use in advanced energy conversion systems such as solar waste heat or automotive, geothermal, and marine power systems
Steady and unsteady flow behavior in blades and passages	Turbomachinery, pumps	No information available for design of advanced multiphase equipment

Table 2.6 (Cont.): BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Multiphase Flows

a) SECONDARY RESEARCH CATEGORY - MULTIDIMENSIONAL AND ORIENTATIONAL EFFECTS

Research Needed	Application	Reason for Need
Steady and unsteady flows in orifices, entrances, exits, branches	All internal multiphase systems - refrigeration, air conditioning, turbomachinery nuclear reactor accident analysis	Little or no information is available to enable accurate designs, development, or optimization calculations to be undertaken
Theories for flashing flows through valves and orifices	Nuclear reactor systems - other two-phase systems	For design determination of back pressures and stresses in piping systems
Movement of droplet fields through nozzles	Geothermal power recovery systems	Design of advanced two-phase flow turbines
Multidimensional particulate and granular flows	Pneumatic or slurry transport systems, blood flows, spray systems	Improve design capabilities in areas where particle or granule trajectones are important especially for spray cooling
Flows around tubes and baffles	Heat exchangers	Method currently used are largely empirical. Significant improvements in efficiency may result from better understanding
Three-dimensional flows with shocks	Advanced propulsion systems	Improve existing methodology for design and development to achieve improved efficiency
Develop two-phase "Reynolds" flow methods	Two-phase bearings	Little information available which will allow development of multiphase bearings to eliminate complicated and costly external and separated lubrication systems for turbines

b) SECONDARY RESEARCH CATEGORY - COMPUTATIONAL METHODS

Research Needed	Application	Reason for Need
General multidimensional behavior in laminar and turbulent flows	All advanced multiphase flow systems	Advanced energy application designs need methods for assessment of efficiency and optimization
Inside blades and passages, multidimensional flow fields, branches	Two-phase turbomachinery	Advanced energy application designs need methods for assessment of efficiency and optimization
Around tubes, plates, and baffles	Heat exchangers, air cleaners, etc.	Improved design methods, reduce cost due to elimination of experiments

Table 2.7: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Multiphase Flows

a) SECONDARY RESEARCH CATEGORY - MISCELLANEOUS NEEDS

Research Needed	Application	Reason for Need
Particulate or droplet behavior in liquid slurries and gas/vapor carriers	Spray systems, combustors, filters, nuclear reactor systems, MHD generators, transport systems	Behavior from size and trajectory standpoint is not well known and, therefore, advanced system development and optimization is difficult. De-entrainment of liquid drops on structure is important in emergency cooling considerations
Pressure drop, concentration, wear, abrasion relationships in slurries	Coal transport and other particulate or granular slurry systems	Improved efficiency and structural integrity of such systems
Optimize mixture and particle size in coal slurries	Coal transport	Minimize losses in particulate transport systems
Study effects of liquid or particulate impacts on materials	All multiphase applications esp. rotating machinery	Equipment life extension and safety improvements
Cavitation-corrosion interactions	Rotating equipment, valves, orifices	Improve life and safety of such equipment

b) SECONDARY RESEARCH CATEGORY - BODY FORCE EFFECTS

Research Needed	Application	Reason for Need
Magnetic field effects	Liquid metal MHD, coal-fired plasma MHD	Performance of advanced MHD generators is critical to the overall cycle efficiencies and depends heavily on such interactions
Pulsed magnetic field effects	Fusion power systems	Properly design and optimize fusion blankets and magnetic and inertial confinement systems
Centrifugal separation effects	Turbomachinery and rotating instrumentation	Design and optimization of advanced energy systems components - reduced stress on turbomachinery blades
Electrostatic field effects	Electrostatic precepitates	Improve efficiency of particulate removal systems

Table 2.8: BASIC RESEARCH INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Fluid-Structure Interactions

Research Needed	Application	Reason for Need
• Mean effects • Instantaneous local effects • Integrated effects	Design of buildings, large structures. Bridges, solar-collectors, power towers, wind turbine supports OTEC pipes and support structures	Proper designs, earthquake energy conservation, prevention of failures and damages to collector fields and wind turbines. Placement and design of cold water pipe in OTEC
Broad basic research in flow separation, re-attachment, vortex shedding and fluid structure interactions. Flow over tube bundles and in nuclear reactor cores	Design of heat exchanges, nuclear reactors, turbines, rotating machinery	Higher efficiencies and lower cost in heat exchange equipment, better rotating machinery, safer nuclear reactors

Table 2.10: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Biological, Geological, and Environmental Fluid Flow

Research Needed	Application	Reason for Need
Basic understanding of flow phenomena in porous media including pressure drop, and heat transfer	Oil recovery (secondary) filtration clean up of oil spills, geothermal heat recovery, thermal insulation	Not enough information is available, little possibility for using data for design, no verification
Determine mechanism of processes involving fouling of heat exchangers especially in marine environments	Improve heat exchanger performance for OTEC application	Economic feasibility of closed cycle OTEC depends on size of heat exchangers. Must size them correctly
Basic studies of flow and stability of stratified fluid with body forces. Experimental verification on large scale	Solar ponds atmospheric phenomena inversion layers geophysical fluid mechanics	Improved design, control of instabilities or activation of instabilities to break up inversion layers
Non-Newtonian flow in capillaries	Blood flow	Medical

Table 2.11: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flows
Primary Research Category: Facilities and Instrumentation
Secondary Research Category: Instrumentation

Research Needed	Application	Reason for Need
Develop remote field velocity sensors and flow visualization techniques	Turbomachines, pumps, large fluid machinery	It is now extremely difficult to visualize and measure flow fields that are inaccessible and thus to improve understanding of motion and losses in such situations
Develop remote particle or droplet sensing and sizine techniques	All particulate and slurry systems	Improve data base upon which understanding and design optimization of failure energy systems must be based
Develop remote bubble velocity and sizing methods	All multiphase downs in advanced energy systems	Improve data base upon which understanding and design optimization of failure energy systems must be based
Develop local phase volume fraction and velocity measuring systems for intermediate and high speed flow	All advanced energy system components utilizing multiphase flow fields	No methods currently exist for adequately measuring phase velocities above 1-2 m/s. Almost all flow systems have higher speeds. This information is desperately needed for advanced development methods
Develop inexpensive sensors for consumer use	All consumer devices	For measurement and control of flow temperature, valve, mass, heat transfer, etc. of devices on the consumer level to improve consumer product efficiency
Develop dam flow monitor	Ground water storage systems	Present techniques are cumbersome, expensive, time consuming, and not particularly useful
Development of various instruments for extreme environments (pressure, temperature, dynamics)	Advanced energy conversion systems, plasma MHD generators, advanced nuclear reactor safety studies, gas turbine studies	Data on behavior of materials under extreme conditions are almost nonexistant. Yet super design and reliable operation of advanced systems requires such data
Develop inexpensive, portable, reliable Laser anemometer	General flow measurement	A cheap portable Laser anemometer would be a powerful tool in many areas of fluid mechanics
Process and reaction monitors - improvement	General chemical and thermal processes	Much conservatism in todays process control leads to increased residence time and overutilization of energy needs. Improved monitoring and control instrumation could greatly reduce process energy needs
Transient and unsteady flow and pressure measurement	Tubomachinery	Present dependence on strain gauges does not give information on flow and causes of exitation and failure
Develop interphase transport measuring devices	All multiphase flows and flow systems	Advanced predictive tools are relying more and more on interphase transfer descriptions but little data exist to quantify such descriptions

Table 2.11 (Cont.): BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Facilities and Instrumentation
Secondary Research Category: Instrumentation

Research Needed	Application	Reason for Need
Develop improved velocity measuring devices for difficult environments	Basic fluid flow studies	LDV's or hot wires are accurate but not useful in opaque or corrosive/erosive environments (such a high pressure/temperature water)
Devices for measuring flow phenomena in rotating passages at transonic conditions	Turbomachinery research	Improved instrumentation is a key link in improving understanding for development of flow models and accurate prediction techniques for improved performance and optimization in advanced energy systems components
Devices for measuring components and phase flow rates in multiphase flows	All multiphase flow systems and components	None currently exist that are reliable but the most balance in steady and transient flows is a fundamental basis for comparison of predictive techniques with experimental results
Particulate or droplet velocity and size classification methods	All dispersed particulate and droplet flows	Only rudimentary methods currently exist but much research is needed in these areas

Table 2.12: BASIC RESEARCH NEEDS INVENTORY
Fluid Dynamics and Thermal Processes, Fluid Flow
Primary Research Category: Facilities and Instrumentation
Secondary Research Category: Facilities

Research Needed	Application	Reason for Need
General, multipurpose research facility for basic studies in multiphase steady and unsteady flows	Improved understanding of multiphase flow behavior	Develop improved predictive tools for development, design, and optimization of advanced energy systems
Research facility for high temperature, high pressure studies for fussion studies	Development of fussion blanket designs	No flexible facility is available for such studies
Research facility for use in aerospace, meterological, and combustion research	General studies	A national facility does not currently exist and is needed for advanced studies supporting meteorological and combustion process studies
Research facility for general multiphase flow studies	Advanced energy system development	Improve data base for fundamental understanding of multiphase flows
Calibration facility for single and multiphase gas, liquid and/or particulate flows	Advanced energy system development	Providing of national standards facility for new instrumentation development is crucial for improved measurement techniques in all fluid flow areas. None currently exists
Ultra high Reynolds number flow facility	Advanced energy conversion system such as OTEC	Determine forces on bluff bodies at $Re>10^6$ for OTEC and other offshore studies

The major priorities appear to be ordered as follows:

- Multiphase and Multicomponent Flows
  - Application to and experimental verification of extensions of single-phase flow theory to multi-phase, multicomponent turbulent flows.
  - Detailed studies of nucleation phenomena and of interfacial structure and transfers. This should be done in simple and multidimensional geometries and free field flows. Objective determination of flow regimes and of phase and/or component spacetime distributions should be undertaken in laminar and turbulent flows.
  - Fundamental studies regarding effects of scaling laws building on knowledge gained in the previously defined studies.
- Fluid Structure Interactions
  - Research should be undertaken in energy-related problems of flow-induced vibrations due to both periodic and stochastic loadings. Such loadings may be due to such effects as vortex shedding or turbulent interactions in both free fields and boundary layers. Attention should be given to both coupled and uncoupled interactions. Areas of concern include, but are not limited to, tubes in heat exchangers and blades in turbines and compressors.
  - Fluid/structural coupling in cases of both impulsive and aperiodic loadings should also be investigated. Such situations include condensation-induced water hammer, and transient decompressive reactions, for instance.
- Shear, Mixing, and Reactive Flow Effects
  - In spite of current and continuous emphasis in boundary layer research, the difficult problems dealing with real systems still exist. The area of separation and reattachment remains unresolved and appears to be of central importance affecting performance, lifetime, and safety of turbomachinery, among others. Significant gains in pre-service energy utilization appear possible with improved understanding which could be gained through such research.
  - Fundamental studies into the flow patterns about road vehicles are needed and can be of great benefit. These flows involve three-dimensional bluff bodies, in extremely close proximity to a ground plane, with strong vortical wakes. Both wind-tunnel and analytical modeling studies are recommended.
  - Research needed in internal flow with chemical reactions leading to a detailed understanding of the coupled processes which enable the development of more efficient, cleaner combustion systems. In this category, particular emphasis

should be placed on advanded analysis techniques and instrumentation to study internal combustion automotive engines and others.

Table 3.2 CRITICAL RESEARCH AREAS AND SPECIFIC TASKS

PARTICLE REMOVAL FROM LIQUIDS

- Particle removal from synthetic liquid fuels
- Extension of sedimentation theory to a wide range of particle sizes and to hindered settling regimes
- In situ particle size measurements at high temperatures and pressures
- Surface properties of particles in synthetic liquid fuels
- Electrically-induced agglomerates of suspended fission products
- Electrical enhancement of liquid filtration
- Concentration of solids in coal liquids by distillation

TRACE POLLUTANT REMOVAL

- Determination of adsorbent selectivity and regeneration methods for hydrocarbon removal from water
- Selective precipitation of trace heavy metal species
- Mechanisms of electrostatic precipitation

SEPARATIONS IN HOT GASES

- Regenerable mixed oxide sorbents for use in hot gases
- Particle removal from hot gases

RESOURCE BENEFICIATION

- Mechanisms of coal flotation
- High gradient magnetic separation of pyrites from coal

CRYOGENIC SEPARATIONS

- Mechanisms in cryocondensation pumping of hydrogen isotopes
- Studies of cryosorption separation of synthetic gas mixtures

REDUCTION OF ENERGY LOSSES IN SEPARATION PROCESSES

- Systems analysis for minimizing energy losses in Distillation Systems

Table 3.3 ADDITIONAL RESEARCH AREAS

DIFFERENTIAL SOLUBILITY

- Vapor-liquid equilibrium data for synthetic fuels
- Transport data for drying
- Asphaltene crystallization
- Supercritical extraction

SURFACE-SELECTIVE PROCESSES

- Effects of surface adsorption on particle stability (both aqueous and nonaqueous environments)
- Mechanisms of solvent deashing

IMPOSED GRADIENTS

- Mechanisms of electrostatic coalescence
- New concepts for continuous electrophoresis
- Theory of density gradient centrifugal separation
- Transport mechanisms in continuous centrifuges
- New concepts for self-cleaning continuous centrifuges

BARRIERS

- Septum Filtration
  - Investigate new concepts for continuous filtration
  - Study new filtration media particularly for small particles
  - Investigate the use of biological membranes for selective transport
  - Study selective membrane permeability

BED FILTRATION

- Study particle interactions in fixed and fluidized beds including the effects of particle shape
- Investigate methods of enhancing particle capture
- Develop a theory to describe the inital part of the filtration curve where the filtration equation is inadequate for cake filtration
- Investigate filter precoats that are most suitable for non-aqueous systems
- Relate permeability and compressibility of filter cakes to particle characterization parameters
- Couple the study of particle penetration into substrates and cyclic methods to restore the original surface
- Investigate methods of displacing valuable product from the interstices and surfaces of precoats and cakes

Table 3.3 (Cont.)

SUPPORTIVE RESEARCH

- Create a clearinghouse for information on novel separation techniques
- Investigate surface charges of particulates in nonaqueous environments
- Investigate instrumentation concepts for on-line, dispersed particulate characterization particularly at high temperatures

The following pages from the report summarize the major specific R&D needs and the research gaps they address.

4.7.1.3 Nature of Work

- Theoretical studies of appropriate cycles and suitable fluids.
- Experimental verification of heat transfer coefficient correlations.
- Experimental testing of chemical stability and corrosion.
- Design studies of suitable machinery.

4.7.2.3 Research Gaps

- Research is needed to improve our understanding of the basic phenomena involved in high flux heat transfer and prevention of burn-out.
- Knowledge of how materials perform in high heat flux systems must be developed. Improved materials may be needed.

4.7.3.3 Research Needs

- Development of an inexpensive low-energy method of producing crude oxygen or enriched air. Possible methods should be surveyed in planning the research. Possible techniques might make use of absorption, diffusion, and para-magnetic separation.

4.7.4.3 Research Needs

Superior processes are needed. Fundamental research might be performed in response to surveys of promising methods. Means that should be considered are: novel batteries; processes that produce a chemical fuel from waste energy which is, in time, used in a fuel cell to produce electricity during peak periods; suitable reversible chemical reactions where heat is absorbed with an endothermic reaction at the surplus heat location and the reaction is reversed at a distant location or different time period with the release of heat; and methods of storage of thermal energy by freezing (crystallization) and melting of high freezing point materials.

4.7.6.3 Research Needs

- Means to achieve higher gas convective heat transfer coefficients without increased energy expenditure of high-intensity turbulence. Possible methods include:
  - Surface roughness
  - Boundary layer thinning techniques
  - Vibration
  - Electrostatic fields

- Focusing of heat transfer to achieve selective transfer, through the use of electrostatic or magnetic fields

4.7.7.3 Research Needs

- A better fundamental understanding of the effects of turbulence on combustion, especially of solid fuels, flame shaping, effects of combustion variables on flame heat transfer, and on pollution

- Development of furnace design methodology, especially with regard to heat transfer, to make furnace design more of a science than an art and to reduce dependence on empirical design of limited applicability.

- Develop scaling methods for fluid bed coal combustors and kinetics of coal combustion at high pressures

4.7.8.3 Gaps

Fundamental research directed toward determining lateral running rates of particles in the combustion bed, and combustion rates of fluid particles offers the possibility of predicting the required spacing of fuel feed points, and hence the number of feed points required.

Mixing rates are one aspect of the problem of scaling the mechanical behavior of fluidized beds, and fundamental research might be directed to the problem of developing reliable scaling methods.

Combustion rates could be studied separately on a relatively small scale. The spacing of fuel feed points is then determined by the requirement that lateral running times be short compared with combustion times.

For the basic research program, it is recommended that reactions and turbulence models be chosen when detailed experimental verification of resulting models can be obtained. Research on instrument techniques is also appropriate.

Hydrocarbon oxidation under conditions where rates are such that incomplete oxidation is a problem is suggested as a high priority starting point. Practical problem areas are lean combustion, hydrocarbon destruction in the freeboard space of fluidized bed combustion and hydrocarbon emissions in transportation power plants.

- Mechanics and chemistry of char consumption and the interaction with ash under both combustion and gasification conditions

- Relative rates of thermal and catalytic reactions in hydrogenation catalyst particles

- Reactions and transport processes and solid state transformations in limestone particles under combustion, gasification and coal pyrolysis conditions

- Hydrogen/hydrocarbon reactions in slurry reactors

- Solid/hydrocarbon interactions in fluidized bed pyrolysis

- Localized temperature fluctuations in fluidized bed combustion and gasifiers as related to ash and agglomeration

- Reactions of nitrogen and sulfur species in fluidized bed combustion

- Electrode reaction mechanisms including gas nucleation and evolution, dissolution and precipitation reactions and solid transformations

- Transport phenomena such as ionic transport in membranes and solid electrolytes and heat and mass transfer in porous electrodes

- Understanding and improvement of electrode catalyses with emphasis on aging processes in oxygen, hydrogen and chlorine electrodes, and electrocatalysis

- Report No. 24

I. Georgia Institute of Technology. Energy Conservation in the Paper and Allied Products Industry, Phase I. DOE/CS/4098-T1. Department of Energy, Washington, D.C., October 1979.

II. Technical and/or End-Use Focus

Paper and Allied Products Industry

III. Types of Information Provided

1. No mention of end use data was made.
2. Fairly detailed energy savings analysis of two specific technologies was given.
3. No estimate was made of times to commercialization but the study did discuss barriers to implementation, such as manufacturability and cost. (Machnozzle, high feedstock temperatures).
4. No review of existing research was made.
5. No methodology for identifying research opportunities.

IV. R&D Opportunities

1. Higher feedstock temperatures - allows for reducted viscosity and surface tension (and increased drainage reduces pumping losses) also means less heat would be needed in the drying section

    - Energy Savings
      20×10^6 (tons of paper and board)
      (0.4 ton & 0.4 tons) (steam saved) = 16×10^6 tons of dryer steam saved

      16×10^6 tons * 2000 lb/ton * 1000 Btu/lb =
      32×10^{12} Btu saved/yr

    - Immediately available for commercialization except for cost problems

    - Higher temperatures create problems:
      - corrosion
      - formation
      - scales, deposits
      - machine room temperature/insulation of pipes
      - etc.

    - References attached

2. Machnozzle - aids in the dewatering (or drying) part of paper making. The paper sheet laid down requires much less drying. pg. 2,3

- Energy Savings
  98,000 lbm/day steam saved

  98,000 lbm/day 350 days/yr * 1000 Btu/lb = 3.5 x 10^{10} Btu/yr

  -- VERY ROUGH ESTIMATE -- 100 plants = 3.5 x 10^{12} Btu/yr

- Nozzle available now
  - cost possible problem
  - plugging
  - operability/down time

- References attached

V. Critical Summary

The detail was good in this report. However although the title sounds good, the discussion is completely limited to the two technologies discussed above. Most of the report discusses experiments done with the Machnozzle. Information given seemed good.

VI. Comments

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Reviewed by SGA.

- Report No. 25

I. Gordian Associates. IEA Steel R&D Report, Final Report. ALO-5076-TI. May 31, 1979.

II. Technical and/or End-Use Focus

Cooperative international research concerning the steel industry is the focus of this report.

III. Types of Information Provided

1. No review of end-use energy data was made.

2. No estimates of energy savings from research were made.

3. Rather than specify a time to commercialization, a funding period and expected effort were given for each of the research suggestions.

4. Existing programs were not mentioned.

5. In this study, the methodology consisted of steel representatives from the participating IEA countries being solicited for suggestions.

IV. R&D Opportunities

All of the research and development suggestions were summarized in Appendix B.

A. Surface Inspection

(1) Ultrasonic Methods

- development time - 2 yrs.

(2) Eddy Current Methods

- development time - 2 yrs.

(3) Optical & Other Methods

- development time - 2 yrs.

(4) Development Program (selection of the most promising methods)

- funding period - 2 yrs.

B. Surface Conditioning

Hot Grinding

C. Heat Recovery

(1) Fluid Bed Cooling

- development time - 4 yrs.

(2) High Temperature Heat Exchangers and Recuperators

(3) Dry Coke Quenching

(4) Ceramic Heat Wheel

(5) Scrap Preheating

(6) Heat Recovery from Slag

(7) Low Temperature Heat Recovery

D. Energy Conversion & Combustion

(1) Continuous Gasification of Coal

- development time - 2 yrs.

(2) Coal Injection with Plasma Burner

- development time - 1 yr.

(3) Pyrolysis of Low Grade Coals

(4) Heavy Fuel Oil Combustion

(5) Blue Flame Burner

E. Material Properties

(1) Continuous Casting Slurries

(2) Hot Working & Heat Treatment

- development time - 4 yrs.

V. Critical Summary

Since this document describes planned activities in an end use area, the justification of needs has apparantly been settled. Whether the suggested projects came about from a formal assessment of needs or a consensus of industrial contacts is not clear, but the latter is implied.

Member countries do not support all the activities but only those of national interest. For example, the U.S. is only planned to support the surface inspection development program, high temperature heat exchangers and recuperators, dry coke quenching, and scoop preheating.

This document fulfills the requirement of an activities report, but does not attempt to explain why the countries are supporting the projects. As a result, the report is very short, 5 pages of text.

VI. Comments

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Reviewed by GJH.

- Report No. 26

I. Grey, Jerry, Sutton, George W. and Zlotnick, Martin, "Fuel Conservation and Applied Research". Science 200, No. 4338, April 14, 1978, pp. 135-142.

II. Technical and/or End-Use Focus

The real focus of this paper is on the need for and the nature of applied research. In end-use terms, it focuses on automobiles.

III. Types of Information Provided

1. A very nice breakdown of where energy is used in an automobile was presented.

2. Estimates were given for specific improvements in terms of their impact on auto fuel use and national fuel use.

3. No estimates of times to commercialization were made.

4. No review of existing research programs was made.

5. The methodology used is to see that the research opportunities are selected to address major losses in automobile.

IV. R&D Opportunities *

(1) Low air draft design (33% reduction in auto drag) (p. 140). Current drag coefficients are 0.45 to 0.55. Experts estimate 0.25 to 0.3 as a practical goal. Many gaps exist in the engineering information related to ground effect, influence of wheels and wheel wells, effects of intakes and cooling ducts, effects of flow control devices, such as dams, vanes, spoilers, flaps, and vents, and basic airflow over auto bodies. Increased understanding of three dimensional flows is necessary for improved aerodynamic performance.

- Could result in 8% reduction in auto energy consumption, 1% national reduction.

- References

  Program Plan Report for Applied Research in Road Vehicles (TRW Energy Systems Planning Div., ERDA Contract E-1-76-C-03-1182, Task 17, 2a, July 1977.

(2) Piston ring-cylinder friction reduction (reduction of 25%) (p. 140). 12% of mechanical work of engine is lost in this region because of friction and blow-by at this seal.

- Could result in 2.4% savings in automobile energy and 0.4% of total national energy (70,000 barrels of oil per day).

- References

  O. Pinkus, D. F.. Wilcock, Strategy for Efficient Energy Utilization Through Tribology (Research Committee on Lubrication of the American Society of Mechanical Engineers, New York, 1977).

(3) Adiabatic Diesel Engine (efficiency increase of 60%) (p. 140).

- Could result in 40% reduction in auto energy consumption, 8% reduction in national energy consumption.
- References

  Same as item (1).

(4) Continuously Variable Transmission with Conventional Engine (p. 140) Need to achieve high efficiency and durability. The lubricant of the traction drive is a key component of developing the CVT.

- Could result in 20% reduction in auto energy consumption, 4% reduction in total national energy consumption.
- References

  Same as items (1) and (2).

(5) Continuously Variable Transmission with Regenerative Braking (p. 140).

- Could result in 35% reduction in auto energy, 7% reduction in total energy.
- References:

  Same as items (1) and (2).

(6) Improved Engine and Driveline Lubricants (p. 140). 25% reduction in engine friction. Low viscosity lubricants offer promise but are expensive and exhibit behavioral anomalies.

- Could result in 5% reduction in auto energy consumption, 1% reduction in total national energy consumption.
- References

  Same as item (2).

(7) Low Drag Tires (50% reduction in rolling resistance) (p. 140).

- Could result in 13% reduction in auto energy consumption, 2.5% reduction in national energy consumption.
- References

  Same as item (1).

(8) Diesel Engines, Stirling Cycle, Gas Turbine (p. 140).

- Could result in 30% reduction in auto energy, 6% reduction in national energy.
- References:

Same as item (1).

(9) Improved Otto Cycle (p. 140).

- Could result in 25% reduction in auto energy, 5% reduction in national energy.
- References:

  Same as item (1).

(10) Valve Resizing (reduction of 60% in pumping loss) (p. 140).

- Could result in 13% reduction in auto energy, 2.5% reduction in national energy.
- References:

  Same as item (1).

(11) Xylan Coating (halves valve friction) (p. 140).

- Could result in 15% reduction in auto energy, 3% of national total.
- References:

  Same as items (1) and (2).

(12) Idle-off System (cuts idle loss) (p. 140).

- Could result in 12% reduction in auto energy, 2.4% reduction in national total.
- References:

  Same as item (1).

*It should be recognized that the savings from the various technologies discussed are not additive. The paper calculates total savings for various combinations of technologies (p. 141). Basically the maximum reduction results from combination of low air drag design, CVT with regenerative braking, low drag tires, and a diesel, stirling cycle, or gas turbine engine (assuming any are 30% more efficient than conventional engines), which increases the efficiency over current automobiles by 67 percent without reducing weight or size of the vehicles.

V. Critical Summary

Although this paper is very narrowly restricted to energy conservation in automobiles, it provides a very good model for how to go about identifying R&D opportunities. The breakdown of where energy goes in a conventional automobile gives the analyst a valuable checklist of possible types of conservation techologies and highlights areas where major improvements are possible. A potential improvement on this approach would be to look at the efficiency of each component of the device or process in 2nd law terms as opposed to 1st law. However, even if such an improvement is made, one must take care in using the approach of identifying R&D opportunities in response to a breakdown of energy flows in a conventional process or device. The results may tend to be unimaginative because the approach does not encourage investigation of radically different means with which to achieve the same end use. It must be remembered that the end-use service is transportation, not automobiles. Thus, communications may be a substitute for some auto travel. Special attention needs to be given to radical approaches, although it is not clear how this can be done systematically. The approach given in this paper provides a good beginning for developing an R&D needs identification methodology.

VI. Comments

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Reviewed by WJH.

• Report No. 27

I. Hollander, Jack M. Basic Research Needs in Energy Conservation. LBL, 99939. Lawrence Berkeley Laboratory, University of California, October 1979.

II. Technical and/or End-Use Focus

This report discussed needs in the following end use areas: industrial processes, combustion systems, energy storage, conversion, and transmission, buildings, transportation, thermodynamics and system studies, and environmental impacts.

III. Types of Information Provided

1. Little end-use data were used. The report cites the need for more specific and thorough end-use data.

2. No estimates of energy savings from research were made.

3. Time to commercialization was not discussed, though the division between short and long term research was.

4. No review of existing research programs was made.

5. No methodology for identifying research opportunities was given; however, the report seemed to point to the need for a more comprehensive methodology.

IV. R&D Opportunities

INDUSTRIAL PROCESSES

A. Basic materials processing
-(paper, steel)

B. Basic mechanical studies

(1) Friction, lubrication

(2) Control of fluid flow

(3) Separation processes (osmosis, absorbtion)

(4) Heat transfer (at surfaces, boiling, two phase flow)

(5) Study of sensors (automatic control)

C. Process Control

(1) Catalytic Mechanisms
Relating to less severe and more selective reaction conditions for coal liquification and gasification.

(2) In-situ Processing
Fluid flow in porous media of low void fraction.

(3) Control and Dynamic Interaction of Processes

(4) Effective Use of Heat Exchange Through Control

D. Direct Coal Use
Fuel gas desulphurization must be improved

E. Processes
Fundamental chemical or mass transport mechanisms

F. Separation
In chemical and food processing, 80% of the energy use is attributed to distillation, evaporation, and drying.

G. Material Containing Devices

(1) Gas to gas heat exchangers.

(2) Vapor liquid contacting devices often over designed.

H. Electrochemical Processes

(1) Electrode geometry

(2) Surface Potential

(3) Boundary-Layer Control

(4) Non-aqueous Ionizing Media

(5) Corrosion Resistant Material

COMBUSTION SYSTEMS

A. Diesel Engines

(1) Soot

(2) In-situ on-line monitors to characterize particle emissions, combustion nuclei and gases.

B. Coal

(1) Understanding of chemical and physical phenomenon of caol combustion, gasification, and liquefaction.

(2) Rates and mechanisms releasing heat and pollution.

(3) Coupling of heat release and pollutant chemistry to turbulent field mechanisms.

(4) Flammability, flamespeed, toxicity.

(5) New diagnostic instruments to facilitate in identifying high temperature kinetics and turbulent fluid mechanics.

ENERGY STORAGE, CONVERSION, AND TRANSMISSION

(1) Long distance power transmisison lines.

(2) Hydrogen storage, transmission, and use.

(3) Basic electro- and thermo-chemical studies for batteries.

BUILDINGS

(1) Heat pumps.

(2) Better hot/cold storage.

(3) Community heating.

(4) Controlling solar insolation through windows.

- Optical shutter with a variable solar transmission.
- Optical active materials
  For example, photothermochromic and electrochromic, liquid crystal, colloidal suspensions, absorbtion edge shifts, solid state phase transformation, electrolytic precipitation of metals.

TRANSPORTATION

(1) Fundamental properties of fluids which might be used in advanced engines.

(2) Air drag.

(3) Telecommunication.

THERMODYNAMICS AND SYSTEM STUDIES

(1) Second law efficiency analysis

ENVIRONMENTAL IMPACTS OF ENERGY CONSERVATION STRATEGIES

(1) Ventilation systems

(2) Heat exchangers to tranfer both latent and sensible heat.

(3) Pollutant release from insulation.

(4) Formaldehyde release from particle board/plywood.

(5) Pollutant release from new building techniques.

- Nitric acid under pressure.

(6) Health effects of fiberglass

(7) Radon gas release from concrete bricks.

V. Critical Summary

The thrust of the paper appears to be a justification of governmnet sponsored technical, social, and environmental research related to energy conservation. The author's examples of research needs thus take the form of an overview of the breadth of potential rather than an exhaustive list. The examples provided are a mix of general and specific activities. However, since research activities are emphasized rather than specific needs for energy research in certain areas, an assessment of energy savings in each area is not attempted.

The report was very readable and provides a good introduction to the breadth of possible energy conservation research efforts. For a 25 page paper, the author was amazingly thorough in his treatment. In general, a good summary.

V. Comments

Reviewed by GJH

VI. REFERENCES

1. National Academy of Sciences. Report of the Committee on Nuclear and Alternative Energy Systems (CONAES). Chapter 2. NAS_NRC, Washington, D.C., 1979 (in press).

2. National Academy of Sciences. Report of the CONAES Panel on Energy Demand and Conservation. 1979 (in press).

3. Brooks, H. and Hollander, J. M. "United States Energy Alternatives to 2010 and Beyond: The CONAES Study." Annual Review of Energy, 4, 1979.

4. Schipper, L. "Another Look at Energy Conservation," Papers and Proceedings, American Economic Review. May, 1979.

5. National Academy of Sciences. Report of the CONAES Panel on Energy Supply and Delivery (1979) (in press).

6. J. H. Gibbons, "Long Term Research Opportunities," in Conservation and Public Policy, J. C. Sawhill, ed., Prentice-Hall, Inc. Englewood Cliffs, N. J. (1979).

7. W. R. Grimes et al, "Assessment of Basic Research Needs and Priorities in Support of Fossil Energy," Preliminary Draft (April 1979).

8. R. S. H. Mah (ed.), "Innovative Design Techniques for Energy-Efficient Processes," National Science Foundation Workshop Report, March 1975.

9. G. T. Rochelle, "Process Synthesis and Innovation in FGE," Report FP-463-ST, Electric Power Research Institute, Palo Alto, July 1977.

10. T. W. Mix, J. S. Dweck, M. Weinberg and R. C. Armstrong, "Energy Conservation in Distillation," Chem. Eng. Prog., 74, (4) 49 (1979).

11. S. G. Unger, "Energy Utilization in the Leading Energy-Consuming Food Processing Industries," Food Technology 29 (12), 33 (1975).

12. C. D. Hollowell et al, "Chemical and Physical Characteristics of Vehicle Emissions," Lawrence Berkeley Laboratory Report LBL-5214, p. 54 (1976).

13. Chin Fu Tsang, "A Review of Current Aquifer Thermal Energy Storage Projects," Lawrence Berkeley Laboratory Report LBL-9211, May 1979. See also: Proceedings of Workshop on Thermal Energy Storage in Aquifers, LBL-k431, CONF-7805140, May, 1978.

14. Some references on photochromic materials:
    a. Schulman, J. H., Compton, W. D., "Color Centers in Solids," MacMillan, M. Y., 1962;

b. Megla, G. K., Applied Optics, 5, 6 (June 1966).

c. Seitz, F., Reviews Mod. Physics, 23,4 (October 1951)

15. K. M. Friedman and R. M. Obermann, "Transportation and Telecommunications: The Energy Implications." Annual Review of Energy, 4 1979 (in press).

16. A. B. Lovins, "Soft Energy Technologies," Annual Review of Energy, 3, p. 477 (1978).

17. C. C. Hollowell, J. V. Berk and G. W. Traynor, "Impact of Reduced Infiltration and Ventilation on Indoor Air Quality in Residential Buildings," LBL-8470, EEB-Vent 78-6, November 1978; ASHRAE Journal, 1979 (in press).

18. R. J. Budnitz, J. V. Berk, C. C. Hollowell, W. W. Nazaroff, A. V. Nero, and A. H. Rosenfeld, "Human Disease from Radon Exposures: The Impact of Energy Conservation in Buildings," LBL-7809, EEB-Vent 78-5, August, 1978; Energy and Buildings, 1979 (in press).

19. L. Schipper and A. Lichtenberg, "Efficient Energy Use and Well Being: The Swedish Example," Science, Dec. 3, 1976, 194, 1001-1013.

20. A. Doernberg, Energy Use in Japan and the United States. BNL 50713, UC-95c. August 1977. Upton, New York: Brookhaven National Laboratory.

21. T. V. Long and L. Schipper, "Resource and Energy Substitution," Energy, No. 1, 1978, 3, 63-79.

22. Griffin, J. 1979. Energy Conservation in OECD Countries. Cambridge, Mass.: Ballantine Books.

23. National Academy of Sciences. Report of the CONAES Resource Group on "Consumption, Location, and Occupation Patterns." Washington, D. C. (1979).

- Report No. 28

I. Johnson, R. M., "Tribology: Research and Development Needs in Advanced Energy Technology," HEDL-SA-1191, 1977.

II. Technical and/or End-Use Focus

The report is focused on advanced energy technologies (fossil, nuclear, solar, etc.) with strong emphasis on nuclear, and the LMFBR in particular.

III. Types of Information Provided

1. No review of energy end-use data was made.
2. No estimates of energy savings from research were made.
3. No times to commercialization were given.
4. The "ERDA National Friction, Wear, and Self-Welding Program" was discussed.
5. No methodology for identifying research opportunities was given.

IV. Research Opportunities Were Established in General Terms:

1. Characterize long-term stability materials in high temperature, harsh environments.
2. Develop knowledge of properties of wear resistant materials, especially at higher temperatures.
3. Standardize wear testing methods and materials.
4. Organize existing and future data to be of maximum design use.
5. Establish a Tribology Information Center.
6. Support a National Tribology Testing Center.

Specific data needs are:

1. Characterize the time-temperature effects on hard surfacing materials.
2. Correlate microstructures and materials properties with friction and wear behavior.
3. Establish a list of reference properties for wear technology related materials.

- For additional references, see attached sheet.

V. Critical Summary

This report appears to be moderately comprehensive and detailed for the narrow scope it addresses. Research needs were justified only in the most general terms, primarily on technical merit.

VI. Comments

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Reviewed by REW.

- Report No. 29

I. Klaus, E. E. "Energy Conservation in Road Transportation through Lubricant Technology," Lubrication Engineering. Vol. 34.11, November 1978, pp. 611-617.

II. Technical and/or End-Use Focus

Discussion of end use was concentrated on automative applications in engines and transmissions.

III. Types of Information Provided

1. End-use energy consumption was reviewed.
2. Energy savings from research were estimated.
3. No estimates of times to commercialization were made.
4. Brief mentions of past technological advances were made in general to provide perspective, but no specifics were given.
5. Research opportunities were identified strictly by technical merit.

IV. Research Opportunities were Outlined in General Terms :

1. Improved understanding of the mechanics of boundary friction (sliding wear).
2. Improved understanding of chemistry of interactions among lubricant additives (compatibility and formulation techniques).
3. Improved understanding of relationships among viscosity, volatility, temperature, and wear.
4. Improved understanding of Non-Newtonian viscosity improvers.
5. Development of traction drive lubricant if this device is considered for implementation.
   - Potential energy savings were estimated at 1% for improved viscometrics and 1% for improved boundary lubrication.
   - For additional information, see attached references.

V. Critical Summary

This article gives an excellent and concise explanation of the technical and some nontechnical problems encountered in developing improved automatic lubricants. Items discussed ranged from the different types of lubrication occurring in various parts of the engine, to the base stocks required for new lubricant development. Of interest is the fact that viscometrics and boundary lubrication developments are independent of each other. Research needs were discussed in terms of technical advances required to achieve goals. Energy savings were quoted, but no details of the deviation of these estimates were provided.

VI. Comments

Good report for background reading (seven pages long).

Reviewed by REW.

REFERENCES

1. Zolotnik, M., "Role of Tribology in ERDA's Mission and Programs," Tribology Workshop, February 1977, Washington, D.C.

2. Hays, D.F., "Gaspeth Sealing," Tribology Workshop, February 1977, Washington, D.C.

3. Pinkus, O. and Wilcok, D. F., "Strategy for Energy Conservation through Tribology," 174 pages, The American Society of Mechanical Engineers, N.Y., 1977.

4. Haviland, M. L. and Davison, E. D., "Lubricant Viscosity Effects on Passenger Car Fuel Economy," SAE Trans., Paper 750675, 84 (1975).

5. Kanno, R., "The Adiabatic Diesel," Tribology Workshop, February 1977, Washington, D.C.

6. Stewart, R. M. and Selby, T.W., "The Relationship Between Oil Viscosity and Engine Performance -- A Literature Search," pp. 1-19, ASTM STP 621, SAE Warrendale, Pennsylvania, 1977.

7. Stambaugh, R. L. and Kopko, R. J., "Behavior of Non-Newtonian Lubricants in High Shear Rate Applications," SAE Trans., Paper#730487, 82 (1973).

8. Appeldoorn, J. K., "The Present State of Lubrication and Its Relation to Rheology," ASME Paper#68-LKII-5, ASME-ASLE-ASTM Symposium on Lubrication and Lubricant Rheology, 1968.

9. Ambrose, H. A. and Taylor, J. E., "Wear, Scuffing and Spalling in Passenger Car Engines," SAE Trans., pp. 192-2a03, 63 (1955).

10. Willn, J. E. and Brett, P. S., "An Investigation into Piston Ring Scuffing During Running In," SAE Paper 750861, 1975.

11. Nutt, H. V., Lanen, E. W. and Edgar, J. A., "Effect of Surface Temperature on Wear of Diesel-Engine Cylinders and Piston Rings," SAE Trans., pp. 694-703, 63 (1955).

12. Klaus, E. E. and Fenske, M. R., "Some Viscosity-Shear Characteristics of Lubricants," Lubr. Eng.., II, March-April (1955).

13. Stewart, R. M., Spohn, C. R. and Meyer, W. A. P., "Some Factors Contributing to Winter Hot Starting Difficulties in Automative Engines," SAE Trans., pp. 1453-65, 77 (1969).

14. Stewart, R. M., Spohn, C. R. and Meyer, W. A. P., "Influence of Lubricating Oil Formulation on Winter Hot Starting Torque Requirement," SAE Trans., pp. 722-35, 78 (1970).

15. Klaus, E. E., Tewksbury, E. JJ. and Fenske, M. R., "Preparation, Properties, and Some Applications of Super Refined Mineral Oils," ASLE Trans., 5, No. 1, pp. 115-25 (1962).

16. Klaus, E. E. and Bieber, H. E., "Effect of Some Physical and Chemical Properties of Lubricants on Boundary Lubrication," ASLE Trans., 7, pp. 1-10 (1964).

17. McMillan, M. I., "Engine Oil Viscosity Classifications -- Past, Present and Future," SAE Paper 770-73, pp. 21-32, ASTM STP 621, SAE, Warrendale, Pennsylvania, 1977.

18. So, B. Y., "Visosity-Pressure Correlations for Liquid Mixtures," Ph.D. Thesis, The Pennsylvania Stae University, University Park, Pennsylvania, August 1975.

19. Dubois, G. B., Oovirk, F. W. and Wehe, R. L., NACA Contract No. NAW6197, Progress Report 9 (Revised), August 1953.

20. Anonymous, "Sonic Shear Stability of Polymer Containing Oils," ASTM Test Method D2603-76, pp. 562-6, Annual Book of ASTM Standards, ASTM, Philadelphia, Pennsylvania, 1976.

21. Klaus, E. E. and Jolie, R. M., "Effect of Polymer Structure on the Viscosity Properties of Polymer Solutions," ASME Paper No. 58-A-294, ASME, 1958.

22. Smalheer, C. V. and Smith, R. K., "Lubricant Additives," Lezius-Hiles Co., Cleveland, Ohio, 1967.

23. Hewko, L. O., "Traction Drives," Tribology Workshop, February 1977, Washington, D.C.

• Report No. 30

I. May, E. Kenneth, and Hooker, Douglas W. Reducing Fuel Usage Through Applications of Conservation and Solar Energy. SERI/TP-733-665, April 1980.

II. Technical and/or End-Use Focus

The focus was on the industrial end-use sector.

III. Types of Information Provided

1. Process heat demand in various temperature ranges as percentages of the total process heat demand for 1974 was graphed.

2. No direct energy savings were estimated, though examples of savings in a few plants were given.

3. No estimates of times to commercialization were given.

4. No review of existing research programs was made.

5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities

(1) Less expensive heat exchangers operating at low differential temperatures (p. 4)

(2) Corrosion problems (p. 4)

V. Critical Summary

This is a very brief report describing the potential for solar energy in generating low temperature industrial process heat. The national potential was discussed first, then several case studies were described.

The report deals with the topic at a general level. Research and development needs are mentioned cursorily and conservation potential was not discussed thoroughly.

This paper was delivered at the Western Plant Engineering Conference and the presentation was clearly flavored for this audience. The authors mention several times that plant management and plant supervisors were critical to the implementation and success of solar IPH. Increasing energy costs, a list of factors favoring solar IPH and case studies were selected to be relevant for this audience.

VI. Comments

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Reviewed by GJH.

- Report No. 31

I. MITRE Corporation. An Agenda for Research and Development on End-Use Energy Conservation. Volumes I and II. Mtr-6577. McLean, VA, December 1973.
   - Funded by Office of Energy R&D Policy, National Science Foundation.

II. Technical and/or End-Use Focus

The main focus of this report is to recommend R&D programs to enhance energy conservation at the point of use. It examines the Residential/Commercial, Industrial, Agricultural, and Transportation sectors. However, because it is aimed at recommending budgets, the report gives a great deal of attention to non-technical R&D, such as studies of incentives, etc.

III. Types of Information Provided

1. A review of old (1960-68) energy data was made.

2. Energy savings from research were estimated only in general terms, such as "better insulation reduced heating energy requirements by 18.6".

3. No estimates of times to commercialization for technologies were given.

4. No review of existing research programs was made.

5. The methodology used in this study is pretty much an "educated assessment" of the problem with the results presented as opinions rather than justifiable outcomes.

IV. R&D Opportunities

(1) Develop a more efficient automobile engine (Stirling, Diesel, Rankine, DISC, Brayton) (p. III-76).

- Could save 15% of transportation fuel.

(2) Develop an improved transmission (e.g., continuously variable) (p. III-76).

- Could save 10% of transportation fuel.

(3) Reduce Vehicle Drag (Aerodynamic and Rolling Resistance) (p. III-76).

- Could save 8-10% of transportation energy.

(4) Reduced Accessory Power (reduced capacity, constant speed drives) (p. III-76).

- Could save 5% of transportation energy.

(5) Reduced Vehicle Weight (p. III-77).

- Could save 6% of transportation energy.

(6) Develop High Performance Batteries for Electric and Hybrid Vehicles (p. IV-18).

(7) Develop a Transportable Heat Engine Van capable of Delivering Steam and Refrigerant to Part-Time Food Processing Plants During Harvest. (p. III-62).

(8) Develop Improved Fluidized Bed Combustors (p. III-40).

- Increased efficiency of furnace and kiln operations for 30% to 50%.

(9) Heat Pipes (p. III-40).

V. <u>Critical Summary</u>

This report is rather old (1973), and is therefore based on pre-embargo data. Thus, in 1980, many of the quantitative conclusions may no longer be accurate. However, the general tone of the report is quite contemporary and the conclusions are reasonable although not rigorous. In general, this is a good study for 1973 but has largely been displaced by other more recent studies.

VI. <u>Comments</u>

Reviewed by WJH.

• Report No. 32

I. Office of Technology Assessment. Residential Energy Conservation. Vol. I. Office of Technology Assessment, Washington, D.C., 1978 est. (No date given).

II. Technical and/or End-Use Focus

Very Specific Focus on Residential (some commercial) Uses. Parallel reports are currently being prepared by the same office for Transportation and Industrial Energy Conservation.

III. Types of Information Provided

1. Very detailed review and summary of end-use data.

2. No estimates of energy savings were made, although some generalizations were made.

3. Times to commercialization were estimated for several technologies.

4. A brief review of existing research was made.

5. The study mentioned several times about having contacted manufacturers. Many of the opinions given seem to be from these contacts. This would seem to constitute some form of methodology.

IV. R&D Opportunities (See Table 7s in Report)

3.0 Heating and Cooling Equipment

3.1 Direct Fossil-Fired Heating Equipment

3.2 Oil and Gas Furnace Efficiency Improvements

- reduce burner firing rate (by 25%)
- boiler water temperature reduction (35°F)
- burner efficiency adjustment
- retention head burner
- vent damper
- stack heat reclaimer
- low input/variable firing rate burners
- ducting combustion air from outdoors
- modern high-efficiency burner-boiler
- blue flame burner-boiler
- outdoor boiler installation
- combustion air humidification
- water-oil emulsion

3.3 Advanced Fuel-Fired Equipment

- Pulse Combustion furnaces and boilers
- fuel-fired heat pumps

3.4 Electric Air-Conditioners and Heat Pumps

- more efficient compressors
- multiple compressors (enhance part-load efficiency)

- improved heat exchangers
- more efficient motors
- automatic fan controls
- improved airflow

3.5 Gas-fired Heat Pumps and Air-Conditioners

- Absorption Air-Conditioners
- Absorption Heat Pumps
- Other gas fired heat pumps
    - gas turbine
    - Stirling engine
    - diesel engines
    - Rankine engines

4.0 Integrated Appliances

4.1 Air conditioner/water heater

4.2 Furnace/water heater

4.3 Refrigerator/water heater

4.4 Drain water heat recovery

5.0 Controls and Distribution Systems

- controls for individual equipment (lights, etc.)
- controls for space heating and cooling

6.0 Passive Solar Designs

- thermal storage
- indirect and direct gain

V. Critical Summary

The review was very comprehensive. Parts were sketchy, but it was meant to be a summary, not an exhaustive study. Technically it was sound. It did not attempt to justify R&D needs, it merely assessed the current state.

VI. Comments

I felt it was by far the most comprehensive summary of residential energy conservation I've read. It very accurately portrayed where current energy conservation potential exists.

Reviewed by SGH.

• Report No. 33

I. Oppenheim, A. K. and F. J. Weinberg, "Combustion R&D - Key to Our Energy Future", Astronautics and Aeronautics. November 1974, pp. 22-31.

II. Technical and/or End-Use Focus

Technical Focus - Combustion processes related to emissions and efficiency, principally in view of auto and aircraft engines.

III. Types of Information Provided

1. No energy end-use data were reviewed.

2. No estimate of energy savings was made.

3. Times to commercialization were not considered

4. Existing research programs (as of 1973) were mentioned and referenced.

5. No methodology for identifying R&D opportunities was given.

IV. R&D Opportunities (Given on Page 30)

(1) Experimental Investigators - facilities which should include:

- Molecular beams
- Shock tubes
- Explosion vessels
- Single pulse compression-expansion machines
- Flow combustion chambers

(2) Development of auxilliary apparatus and instruments.

(3) Theoretical and analytical studies.

(4) Hardware development testing.

(5) Evaluation.

V. Critical Summary

A good quick, well-referenced introduction to combustion R&D. The exact needs, energy savings, pollution reduction are not given , but it is assumed that review of the 38 references would give a good "feel" for these things.

VI. Comments

Useful for idea collection for basic R&D topics on combustion. Much sifting will be done before a good set of fundable projects is arrived at.

Reviewed by WEG.

- Report No. 34

I. Pinkus, O. and Wilcock, A. F., "Strategy for Energy Conservation through Tribology," Published by ASME, 1977.

II. Technical and/or End-Use Focus

This report discussed potential energy savings via tribology technology in the transportation, industrial, and utilities sectors. Important end-use applications identified were: automotive vehicles (engines, lubricants and transmissions), steam and gas turbines (bearings and seals), general industrial friction and wear, and heavy metal forming operations.

III. Types of Information Provided

1. Energy end-use data were reviewed in fair detail.
2. Energy savings were calculated.
3. Time to complete research was tabulated, but time for commercialization was estimated in passing in only a few cases.
4. Existing research programs were reviewed only in passing while discussing specific project objectives. No organized tabulation of existing research was given.
5. Project selection was based on five criteria: level of potential energy savings, technical feasibility, economic feasibility, response by industry and public, and national interest. Specific project areas were classified into "Recommended Projects" and "Study Panels" by the members of the workshop and advisory group.

IV. R&D Opportunities

See attached sheet.

V. Critical Summary

This is in general a fairly comprehensive survey that is frequently referenced. Energy statistics are briefly reviewed in relation to tribology and are used in selecting specific projects to be recommended. Then background and supporting information is given in sufficient detail for each primary technical area considered, and potential energy savings are summarized. Finally, a detailed qualitative description is provided for each project recommended. The R&D justification was established in part by opinion survey of technical experts. The weak points of the report appear to be the occasional unclear sources of reference energy savings data, and sometimes confusing computation or presentation of potential energy savings for specific projects. This is particularly evident in the areas of "general industrial friction and wear" and "metal procesing."

VI. Comments

Reviewed by REW.

I.D.	Program Area	Technology	Project Number	Project Title	Estimated R&D Cost $/Yr. Thousands	Estimated R&D Cost Yrs.	Criteria: A. Potential Energy Savings* % U.S. Consumption	A. Bbl/Yr. Millions	A. Type of Fuel	B. Technical Feasibility	C. Economic Feasibility	D. Response by Ind. & Public	Project Priority
I	Road Transportation	Transmissions	P-1	Traction Contact Study	250	4							
			P-2	Rheology of Traction Fluids	150	3							
			P-3	Traction Fluid Development	200	3							
			P-4	Concepts and Designs of Traction Drives	300	2	4.5	560	Oil	Medium	High	High	A
			P-5	Thrust Bearing for CVT	150	2							
			P-6	Materials For Traction Drives	300	3							
			P-7	Traction CVT Prototype Development and Testing	600	3							
		Piston Rings	P-8	Analytical Model of Ring Lubrication	100	3				Medium			
			P-9	Piston Ring Optimization Studies	200	3	0.2	25	Oil	Medium	High	High	A
			P-10	Measurement of Piston Ring Losses	250	3				High			
			P-11	Piston Ring Materials and Coatings	200	4				Medium			
		Adiabatic Diesel	P-12	Coatings for Extreme Temperatures	200	4							
			P-13	Concepts and Techniques for Extreme High-Temperature Lubrication	200	3	3.0	390	Oil	Low	Medium	Medium	A
			P-14	Lubrication System for Adiabatic Diesel	200	3							
			P-15	Gas Floated Pistons for Adiabatic Diesel	150	3							
		Viscometrics	P-16	Automotive Engine Lubricants I	375	2							A
			P-17	Automotive Engine Lubricants II	500	2	1.8	220	Oil	Medium	Medium	Medium	A
			P-18	Automotive Engine Lubricants III	100	3							B
II	Power Generation	Low Friction Turbulent Bearings	P-19	Water Lubricated Bearings for Utilities	200	4				High	Medium	Low	
			P-20	High Temperature Babbitt-Like Materials	100	3	0.1	12	Non-Oil	Low	High	High	B
			P-21	Reduction of Power Loss in Turbulent Bearings	200	2				High	High	Medium	
			P-22	Mechanism of Turbulence and Inertia in Hydrodynamic Bearings	100	2				High	High	Medium	
		Gaspath Seals	P-23	Active Control of Labyrinth Seal Concentricity	100	4	0.13	16	Non-Oil	Medium	Medium	Medium	B
III	Turbomachinery	Rolling Element Bearings: $DN>3.0x10^6$	P-24	Cage Design and Lubrication for Small High Speed Ball Bearings	150	3				High			
			P-25	Development of Rolling Element Bearing Materials Having High Fracture Toughness	150	3	0.5	60	Oil	Low	Medium	Medium	B
			P-26	Analysis and Development of Cylindrical Roller Bearings for Three Million DN Operation	125	3				Medium			
			P-27	Tapered Roller Bearings for 3.5 Million DN	150	4				Medium			
			P-28	Series Hybrid Bearing	100	3				High			
		Process Fluid Bearings	P-29	Refrigerant Lubricated Bearings	100	3				Medium	Medium	High	
			P-30	Bearings for Oxygen Compressor Service	300	2	0.1-1.0	12-120	All	High	Medium	Medium	A
			P-31	Foil Bearing Materials	200	4				High	Low	Medium	
		Gaspath Seals	P-32	Abradable Blade Tips and Shrouds	250	3	0.1	10	All	Medium	Medium	Medium	B
			P-33	Active Control of Blade Tip Clearance	150	4							
IV	Industrial Machinery and Processes	Wear	P-34	Mechanism of Foreign Particle Wear	100	5	1.3	160	All	Medium	High	High	A
			P-35	Wear Control Handbook	50	3							
		Metal Processing	P-36	Mechanism of Metal Rolling	100	5	1.5-3.0	180-360	Non-Oil	Low	Low	Low	C
			P-37	Metal Processing	500	5							
V	Support		P-38	Documentation of Energy-Tribology Statistics	50	6							
			P-39	Applications Workshops	30	6							A
			P-40	Advisory Board	100	6							

A. REFERENCES

1. Meyers, B., et al, "A Topping Cycle for Coal Fueled Electric Power Plants Using the Ceramic Helical Expander", paper presented at Symposium on Environment & Energy Conservation, sponsored by EPA & ERDA, September 1975.

2. "Lubrication" Education and Research; A Report on the Present Position and Industry's Needs", Department of Education and Science, HMSO, London, G.B. 1966.

3. "Tribologie" Bundesministerium für Forschung und Technologie. Forschungsbericht T76-38, Postfach 860 880, München 86, W. Germany, July, 1976.

4. Pinkus, O., Tribology Workshop, February 7-9, 1977, Washington, D.C. (MTI, Latham, N.Y.)

5. Wilson, R.F., and Tierney, W.T., "Optimization of the Vehicle-Fuel-Refinery System", API 41st Mid-year Meeting, May 10-13, 1976, Los Angeles, Cal.

6. Zlotnick, M., "Role of Tribology in ERDA's Mission and Programs", Tribology Workshop, February 7-9, 1977, Washington, D. C. (ERDA, Washington, D. C.)

7. Hays, D.F., "Gaspath Sealing", Tribology Workshop, February 7-9, 1977, Washington, D. C. (G.M. Research Labs., Warren, Mich.)

8. Tierney, W.T., Johnson, E.M., and Crawford, N.R., "Energy Conservation Optimization of the Vehicle-Fuel-Refinery System", SAE Paper 750673, Fuels & Lubricants Meeting, June 3-5, 1975, Houston, Texas.

9. Rice, R., "Energy Efficiencies of the Transport System", Int. Aut. Engineers Congress, SAE, January 1973, Detroit, Mich.

10. Pinkus, O., Decker, O., and Wilcock, D.F., "How to Save 5% of Our Energy", Mechanical Engineering, September 1977.

11. "Energy Consumption in Manufacturing", by the Conference Board, Ballinger Publishing Co., Cambridge, Massachusetts, 1974.

12. Booser, E.R., "Fluid Film Bearings", Tribology Workshop, February 7-9, 1977, Washington, D. C. (General Electric Co., Schenectady, N.Y.)

13. Anderson, W.J., "Rolling Element Bearings", Tribology Workshop, February 7-9, 1977, Washington, D. C. (NASA-Lewis Res. Ctr., Cleveland, Ohio.)

14. Miller, D.R., "Traction Fluids", Tribology Workshop, February 7-9, 1977, Washington, D.C. (Monsanto Co., St. Louis, Mo.)

15. Hewko, L.O., "Traction Drives", Tribology Workshop, February 7-9, 1977, Washington, D. C. (New Departure, Sandusky, Ohio)

16. Lemanski, A.J., "R&D Needs in Power Transmission Technology", Tribology Workshop, February 7-9, 1977, Washington, D. C. (Boeing Vertol Co., Philadelphia, Pa.)

17. Jost, H.P., "Economic Impact of Tribology", Mechanical Engineering, August 1975.

18. Haviland, M.L., "Automotive Fuel Economy Gains Through Lubrication Technology", Tribology Workshop, February 7-9, 1977, Washington, D. C. (G.M. Research Labs, Warren, Mich.)

19. Kamo, R., "The Adiabatic Diesel", Tribology Workshop, February 7-9, 1977, Washington, D. C. (Cummins Engine Co., Columbus, Ind.)

20. DOD Industry Metal Chip Removal Conference, February 8-10, 1977, Daytona, Fla.

21. Seireg, A., University of Wisconsin, Madison, Wis., Oral Communication.

22. Johnson, R.N., "Research and Development Needs in Advanced Energy Technology" Tribology Workshop. February 7-9, 1977, Washington, D.C. (Westinghouse-Hanford Co., Richland, Washington)

- Report No. 35

I. Resource Planning Associates. Implementation of Energy Conservation Technology in the Pulp and Paper Industry. Department of Energy, Washington, D.C., September 1980.

II. Technical and/or End-Use Focus

Pulp and Paper Industry - in general

III. Types of Information Provided

1. A brief overview of energy was presented (p. 12).
2. Energy savings were presented, (p. 33, 34, C.20, C.52).
3. Times to commercialization were given for technologies.
4. No review of existing research programs was made.
5. See attached pages for methodology used.

IV. R&D Opportunities

General list: (see attachments)
Three technologies were looked at in detail:

A. Advanced air/fuel ratio control systems.
   1. Automatic control of excess air to boilers by monitoring CO, O_2, HC, and/or opacity. Controls were not justified when many of the boilers were installed years ago (with cheap fuel) see pg. 10.
   2. See attached (up to 9×10^{12} Btu total).
   3. Available now.
   4. None discussed.
   5. None.

B. Heat recovery from paper dryers using heat wheels - involves the recovery of sensible heat from dryer exhaust air.
   2. See attached (up to 22×10^{12} Btu total).
   3. Available now
   4. None
   5. None

C. Extended Slip Press
   - removes more water from paper mechanically before going to dryers
   2. See attached (up to 32×10^{12} Btu total)
   3. Available now

V. Criticality Summary

The study began very comprehensively by interviewing 33 companies for new technologies. However, the study was based on an agreement that the technologies must be available and influence the market significantly by 1985. Thus the long term ideas were out in the first pass. For the three main technologies looked at, the detail was amazing. Everything was considered. They even developed a program plan for implementation. It's unfortunate they didn't look at all of the ideas more closely.

VI. Comments

They seem to be rather convinced on the necessity for government involvement in the near term projects.

Reviewed by SGH.

Exhibit B.1

Study Methodology

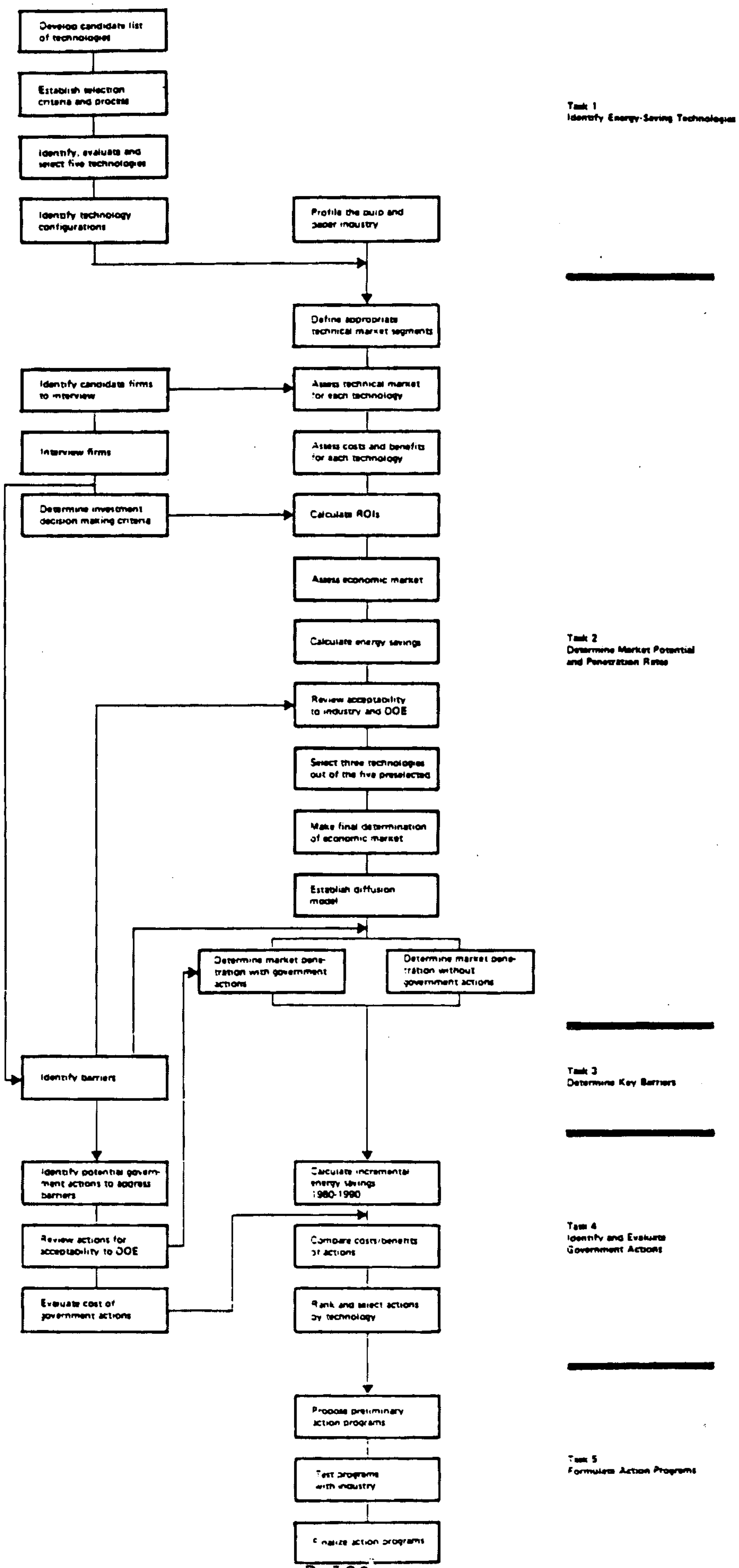


Exhibit B.2

Results of Preliminary Screening of Technologies

Score	Technology
4.75	Advanced air/fuel ratio controls
4.65	Cogeneration
4.55	Automatic control bleaching
4.55	Automatic control digester
4.55	Automatic control recovery boiler
4.40	Vapor compression
4.25	Heat recovery from existing dryers
4.25	Use of hot water from flue gas scrubbing to eliminate steam usage in the bleach plant
4.15	Extended nip press
4.05	Corrosion-resistant economizers
4.00	Hot water from flue gas scrubbing
3.95	Bark and hog fuel preparation
3.90	Increased end product moisture
3.85	Paper pressing
3.75	Steam distillation of methanol
3.70	Mechanical pulping
3.70	Waste paper characterization (subsequently, expanded to pulp fiber characterization)
3.60	Paper drying using mach air nozzle
3.55	Computer applications to energy management
3.50	Batch-digester heat reuse
3.50	Waste-paper recycling
3.50	Bark separation from chips
3.45	High-consistency forming
3.35	Dry forming
3.35	Microwave drying
3.30	Fluidized bed
3.10	Energy management handbook
3.05	Pulp washing
3.00	Hydropyrolysis
3.00	Reuse of low-value heat to heat chips
2.90	Pulp pressing
2.65	New recovery technology
2.55	Clean-burning bark burners
2.25	Rankine and electric heat pump
2.25	Solid waste disposal
2.25	Reradiant recuperator
2.15	Technical information
2.15	Gasifier
2.15	Freeze crystallization of black liquor
2.05	Pressurized fluidized bed
2.05	Resource recovery logistics
1.95	Reduce water to recovery boiler
1.90	Mechanical dewatering
1.90	Membrane technology for air enrichment
1.90	Coal-derived fuels for combined gas steam turbines
1.30	Alternative fuels for lime kilns

Exhibit B.3

DOE-Supported Technologies Not Included in Set of Candidate Technologies for Immediate DOE Implementation Actions

DOE-Supported Technology	Primary Reason for Not Including
Cogeneration	DOE is already conducting major programs related to cogeneration implementation.
Corrosion-resistant economizers	There is no known supplier of the special metallurgical materials needed.
Paper-drying using mach nozzle	Technical problems currently being encountered may prevent implementation of the mach nozzle before 1985.
High-consistency forming	The new design of the high-consistency forming headbox has not been tested in actual operating conditions. The resulting perception of high technical risk would likely delay market introduction beyond 1985.
Microwave drying	Health and safety standards for a high-energy microwave system operated in proximity to mill workers will impose design and operating constraints that will probably delay implementation a number of years.
Hydropyrolysis	Uncertainty regarding project economics in a joint demonstration between government and industry will probably delay implementation beyond 1985.
Rankine and electric heat pump	Scale-up of available heat pump designs to a size and reliability appropriate for industrial applications is expected to delay implementation. Currently available heat pumps have limited application in the pulp and paper industry.
Reradiant recuperators	Reradiant recuperators have been designed primarily for high-temperature applications such as an aluminum remelt furnace. Units suitable for the pulp and paper industry are not expected to be commercially available by 1985.
Freeze crystallization of black liquor	Technical feasibility issues, questionable economics, and a possible thermal pollution problem all indicate long-term implementation prospects (6-7 years).
Mechanical dewatering	Translation of mathematical modeling results into useful hardware is not likely to occur in the near term.

Exhibit B.4

Factors Considered in Market Analysis

	Market Segmentation Factors	Technical Market Factors	Economic Market Factors
Advanced air/fuel ratio controls	• Boiler fuel	• Boiler fuel	• Boiler size
Heat recovery from dryers using heat wheels	• Paper mills • Paperboard mills	• Higher basis-weight products • Type of dryer hood • Paper machines with open or closed hoods	• Degree of hood enclosure • Paper machine capacity
Extended nip press	• Paper mills • Paperboard mills	• Higher basis-weight and low freeness products • Linerboard, solid bleach board, semichemical, newsprint products • Paper machine width	• Paper machine capacity (size, speed, basis weight)
Energy management systems	• Multiple-boiler power plants	• Number of boilers	• Power plant configuration (boilers, turbines, cogeneration) • Total steam production
Pulp fiber characterization using an automatic imagery-pattern recognition system	• Pulp mills	• Pulping process (mechanical, thermomechanical, and kraft)	• Quantity of pulp produced • Number of pulping units

Exhibit 9

Energy Savings from Advanced Air/Fuel Ratio Controls

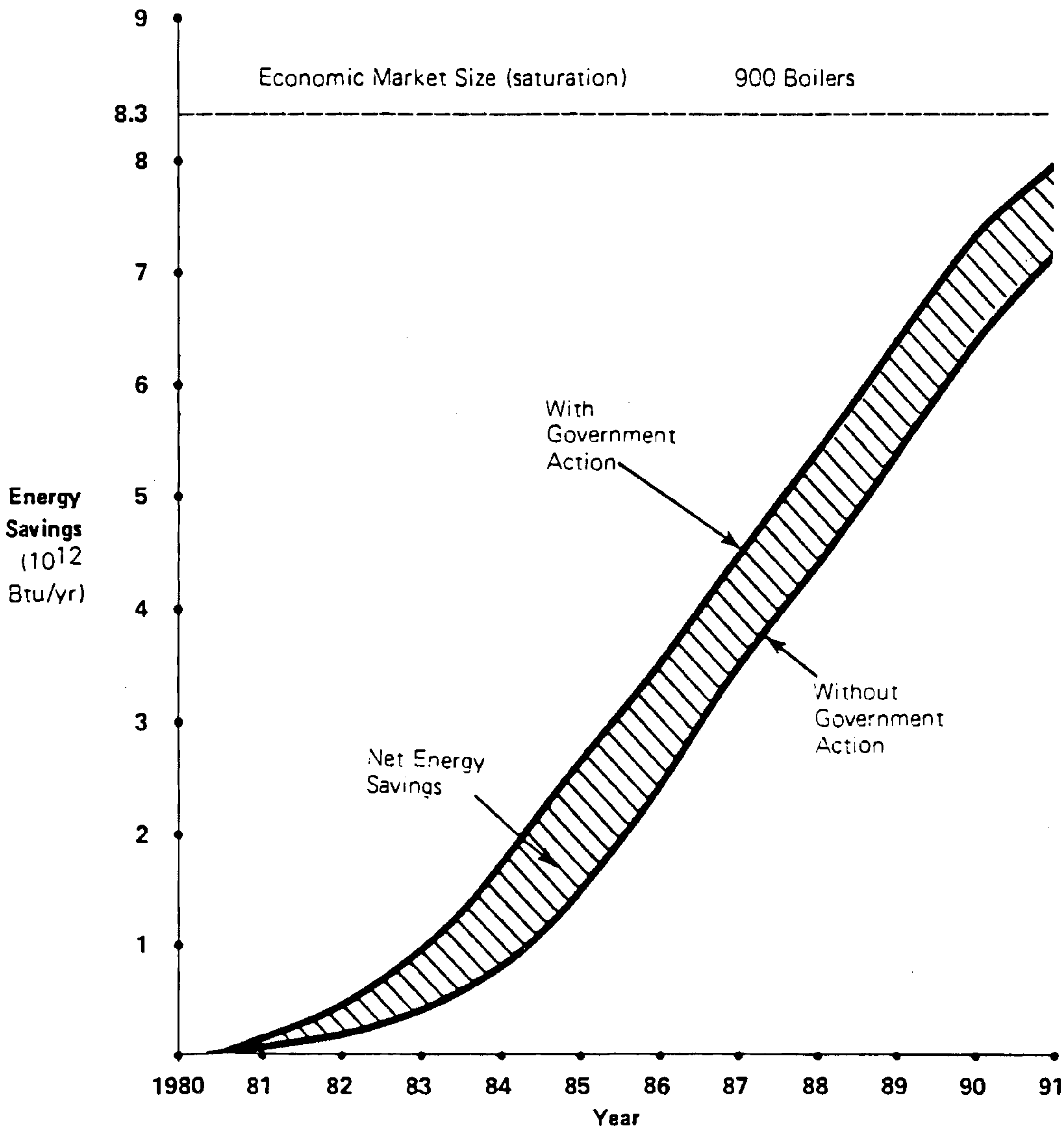


Exhibit C.4

Energy Savings from Heat Wheels

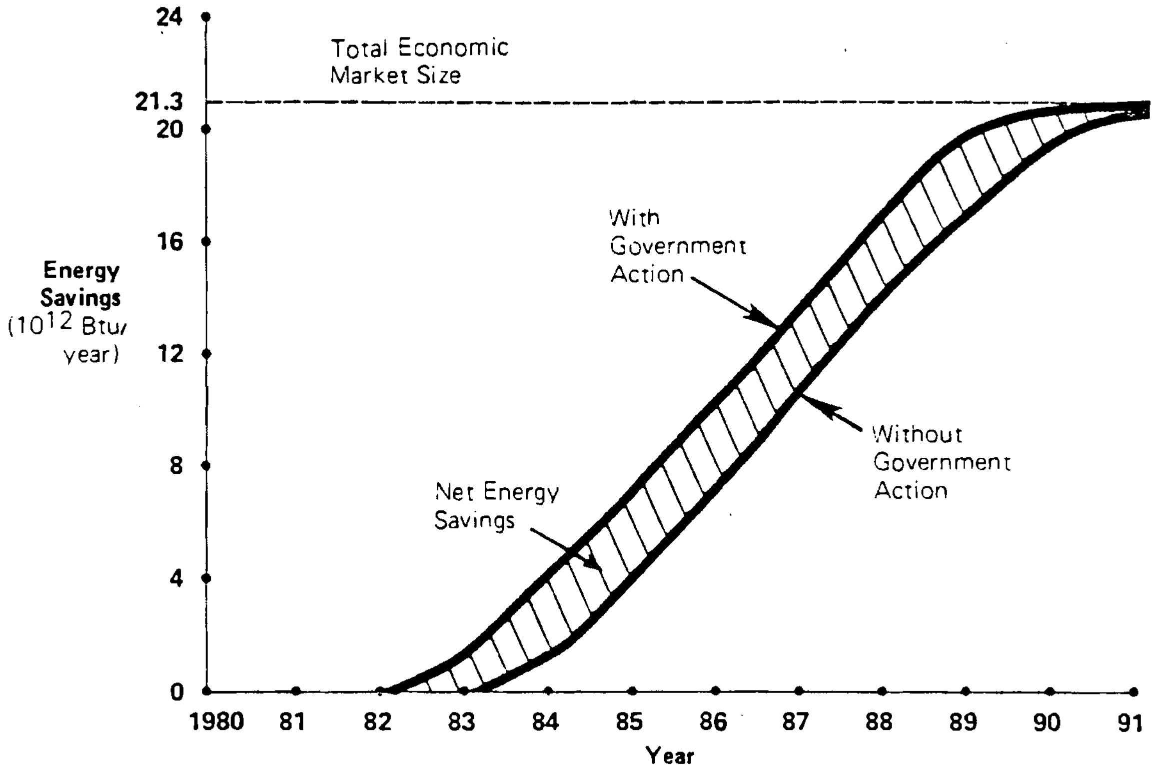
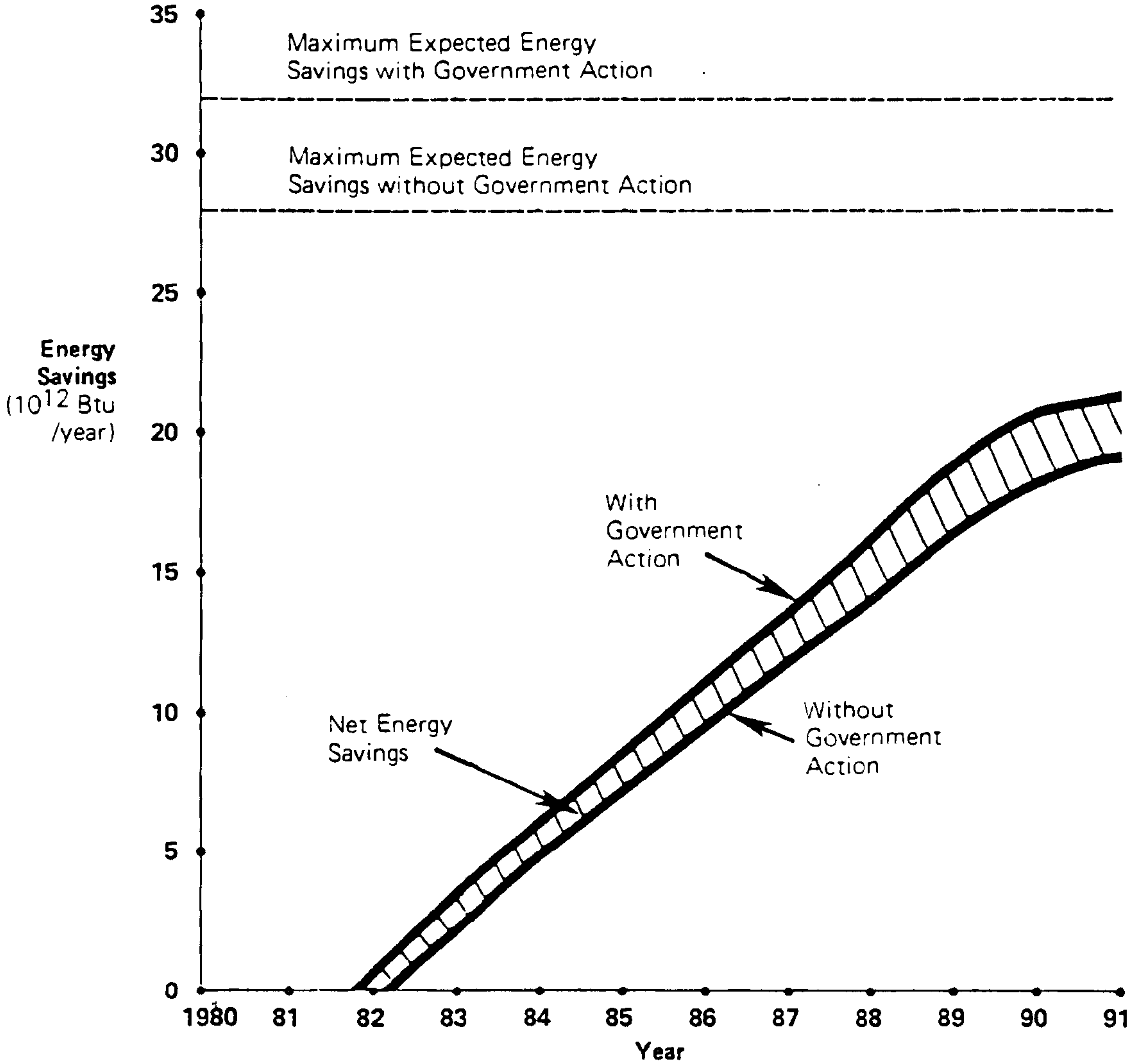


Exhibit C.10

Energy Savings from the Extended Nip Press



- Report No. 36

I. Ross, Marc H., Williams Robert H. Our Energy: Regaining Control, McGraw-Hill, New York, 1981.
- independent funding sources

II. Technical and/or End-Use Focus

End-Use Orientation - focus on residential housing, industrial cogeneration, and automobile transportation.

III. Types of Information Provided

1. Fairly detailed review of gross energy consumption and market sizes (e.g. # houses in year 2000) were given.

2. Maximum potential energy savings were calculated for each sector, but energy savings from specific R&D were not identified.

3. No estimates of times to commercialization were given.

4. No review of existing research programs was made.

5. A systematic methodology was inherent in this study. Overall energy consumption patterns were examined to identify the three areas of primary concentration noted in (II.) Also, a second-law approach was used to identify areas of large potential savings and to justify efforts in particular areas.

IV. R&D Opportunities

(1) Develop Hydraulic Transmission Systems to replace less efficient mechanical drives in machine power tools. (p. 198)

- Would result in 20% savings in energy use in machine power tools.

- References:

J. Chase, NJD Lucas, W. Murgatroyd, "Industrial Energy Use - I: Power Losses in Electrically Driven Machinery", p. 179-196, Energy Research, Vol. 2, 1978.

N. Ladomatos, NJD Lucas, W. Murgatroyd, "Industrial Energy Use - II: Energy Use in a Light Engineering Factory," p. 375-388, Energy Research, Vol. 2, 1978.

N. Ladomatos, NJD Lucas, W. Murgatroyd, "Industrial Energy Use - III: The Prospects for Providing Motive Power in a Machine Tool Shop from a Centralized Hydraulic System," p. 19-28, Energy Research, Vol. 3, 1979.

(2) Develop Alternating Current Synthesizer for improving efficiency of industrial motors (p. 198).

- Would produce 50% savings in electricity used in industrial electric motors.

- References

D. J. BenDaniel, E. Z. David Jr., "Semiconductor Alternating Current Motor Drives and Energy Conservation, Science 206, November 16, 1979, p. 773.

(3) Heat Transfer in Turbulent Flow (p. 220)

- References:

Efficient Use of Energy, A Physics Perspective, Vol. 25, American Institute of Physics Proceedings, 1975.

Jerry Grey, George W. Sutton, Martin Zlotnick, "Fuel Conservation and Applied Research," Science 200, p. 135, April 14, 1978.

Marc H. Ross, Robert H. Williams, "The Potential for Fuel Conservation," Technology Review, February 1977, p. 48.

(4) Thermal Response of Buildings of Various Materials to Changing Weather Conditions (p. 220).

- References:

Same as item (3).

(5) Friction and Lubrication (p. 220).

- References

Same as item (3).

(6) Air Drag on Surface Vehicles

- References:

Same as item (3).

V. Critical Summary

The Ross and Williams book is much more than an R&D opportunities study. It devotes a good deal of effort to non-technical issues affecting energy conservation. This broadness of perspective gives the study's treatment of R&D opportunities (albeit brief) a sense of realism. By carefully examining energy flows, demographic shifts, and degrees of saturation for various products, the authors make a plausible assessment of the overall role that energy conservation can occupy in future energy strategies. Indeed, because of their pessimistic evaluation of the potential for customary estimates of energy demand in the future to be met by either nuclear or solar technologies, energy conservation is the cornerstone of the energy policy recommended by the authors. However, while this study sets the stage for R&D opportunities assessment exercises, it does not complete the task. As can be seen from the R&D opportunities that are listed in Section IV, a great deal of additional specification is necessary to justify the R&D opportunities that were suggested by the authors.

IV. Comments

This study should be read with the AIP study and the Ross and Williams Technology Review paper that are cited in item (3) in Section IV. In essence, the three pieces are a part of an overall study of energy conservation energy savings (potential and R&D opportunities).

Reviewed by WJH.

- Report No. 37

I. Schurr, Sam H., et.al. Energy in America's Future: The Choices Before Us, Johns Hopkins University Press, Baltimore, 1979.
   - research by Resources for the Future, funding at least partially from the Ford Foundation.

II. Technical and/or End-Use Focus

End-use orientation with focus on three segments of national energy use: residential space heating (about 10 percent of U. S. consumption), automotive transport (between 13 and 14 percent) and industrial process steam (about 10 percent).

III. Types of Information Provided

1. Study takes a very broad view of national energy use. Although formal justification of the three areas of concentration is not made, they appear sensible in light of the earlier discussions in the report, particularly in Chapter 2.

2. Energy savings are estimated only in broad terms. Savings are the result of a variety of research concepts, as well as public policy measures.

3. No estimates of times to commercialization are given, although many of the technologies considered are essentially available now and are simply in need of appropriate application.

4. No review of existing research programs was made.

5. An explicit methodology was not given in this study, but it did discuss the role of second law efficiencies and did review end use energy flows, making it more than a simple "laundry list."

IV. R&D Opportunities

Residential Space Heating

- Efficiency of heating system could be cost-effectively improved by 20 percent (from 55 to 69 percent thermal efficient) Measures include:

(1) Electric Pilot for Gas Furnace (p. 130).

- Saves 6 million Btu/yr or about 5% of space heating energy.
- Some already available.

(2) Flue Damper for Gas Furnace (p. 130).

(3) Study of Air Infiltration (p. 131).

(4) Specially coated windows to inhibit radiative transfer (p. 131).

- Some already on market.

(5) Movable Window Insulation (p. 131).

(6) Air to Air Heat Exchangers for Introducing Fresh Air (p. 131).

- Already in use in Sweden.

(7) Zoned Temperature Control (p. 131).

- Already in use to a small extent.

(8) Improved Heat Pumps (extraction of heat from water and use of combustible fuel instead of electricity) (p. 131).

(9) Cogeneration (p. 131): correct e/s ratio, down-scaling.

- Can save as much as 30 percent of "base" fuel use.

(10) Solar Heating: economics, seasonal storage, solar cogeneration of heat and electricity (p. 132).

(11) Passive Solar (p. 132).

(12) Integrated Appliance Use to Serve Multiple Applications (e.g. internal venting of dryer to provide heat) (p. 132).

Automotive Transport

(1) Electric Vehicles (lightweight batteries and materials) (p. 197).

(2) Substitution of Communications for Travel (p. 198).

(3) Crashworthiness of Small Autos (p. 155).

- DOT Highway Traffic Safety Administration Program is performing research.

*However, report concludes that automotive R&D is advancing at a pace which suggests that no bold policy initiatives are required. The government should not be involved in demonstration of technologies. Specifically, the government should <u>not</u> support efforts at engineering to improve automobile engine design. (p. 977).

Industrial Process Steam

Cogeneration**

(1) Fluidized Bed Combustors (including residential scale) (p. 165).

- References

  A. B. Lovins, <u>Soft Energy Paths</u>, Harper 1977, pp. 46-48.

(2) Coal Fired Gas Turbines (p. 165).

(3) Coal-Fired Diesel Engines (p. 165).

(4) Coal-Fired Stirling or Ericsson Engines (p. 16).

**The need for these technologies arises from the fact that generation technology with high electricity-to-steam ratios is not ready to use coal as a fuel. Cogeneration is more economical with high e/s ratios, provided industry can sell excess electricity (p. 170).

General R&D Opportunities

(1) Reduction of Friction Research (Tribology): broad application (p. 477).

V. Critical Summary

The RFF Study is a massive, information-packed energy study that offers a wealth of useful data for performing energy analyses. However, it is not primarily an R&D needs study. Where R&D opportunities are discussed, they are generally peripheral to discussions of policy or the appropriate role for government. Also, the discussions of R&D are plainly taken from the work of Ross and Williams and one might as well get these results direct from the horse's mouth by reading Ross and Williams' book and the AIP study. This does not mean that the RFF study is not useful in studying R&D opportunities. On the contrary, the study goes a long way toward establishing the context for an R&D opportunities study through its review of end-use energy consumption and discussions of non-technical barriers to energy conservation. The following list of non-technical barriers to residential energy conservation is crucial to market penetration and ultimate conservation potential of any residential conservation technology.

Residential Conservation Barriers

1. Conservation equipment is purchased by builders rather than homeowners.
2. Building codes are often based on specifications rather than performance.
3. Building industry has low capitalization and is therefore sensitive to first cost rather than life cycle cost.
4. Building industry is fragmented and horizontally stratified.
5. Building industry is craft oriented and resistant to change.
6. Feedback to residents is slow and difficult to interpret.
7. Dweller often does not directly pay utility bills.
8. Variety of buildings makes retrofits hard to standardize.
9. Conservation is generally compared to average energy costs rather than social replacement of marginal costs.

VI. Comments

This book is complementary to the work of Ross and Williams (indeed it was based on it). Reading them together gives good coverage to the areas of residential space heating, auto transport, and industrial process steam, although both stop short of a really thorough technical analysis of R&D opportunities in these areas.

Reviewed by WJH

- Report No. 38

I. Stephens, J. R., W. R. Witzke, G. K. Watson, J. R. Johnson and W. J. Croft. Materials Technology Assessment for Stirling Engines. NASA TM-73789. NASA Lewis Research Center, Cleveland, Ohio, 1977.

II. Technical and/or End-Use-Focus

Assesses current state of the art of metals and ceramic with respect to Stirling engine and recommends materials R&D programs needed.

III. Types of Information Provided

1. No energy and use data were reviewed.

2. No energy savings were estimated.

3. No time to commercialization estimates were made.

4. Existing research was not reviewed.

5. Engine design temperatures and stresses and related to existing material properties to point out needed areas of data development and property improvements.

IV. R&D Opportunities

(1) Improved (Metal) Engine (pp. 3-6) - The heater head is the most critical component. Mechanical property data and required for candidate alloys under anticipated engine operating conditions. Hydrogen compatibility, permeation, and effects on properties need to be measured for uncoated and coated alloys. Lower costs, non-strategic alloys need to be substituted.

- References 3 thru 12 attached.

(2) Advanced (Ceramic) Engine (pp. 748) - A paucity of data on candidate ceramic materials under estimated engine operating conditions exists. Because of its high temperature the air preheater is considered to be the most critical component. "Long term stability data at the air preheater temperature and long-term mechanical property data under operating conditions of the heater head are needed. Environmental effects (hydrogen and combustion gases) must be evaluated. Low cost fabrication technology must be developed for the various ceramic components - - in the advanced Stirling engine.

- Reference 5 of attachment.

V. Critical Summary

This is a summary paper with a low level of detail but a few good sounding references on the details of Stirling engine design. Economic and competitive (with respect to other engines) analysis not included. Justification of needed R&D apparently assumed.

VI. Comments

A good, basic reference for materials work required for Stirling engines.

References

1. Ragsdale, R. G.: Stirling Engine Project Status. ERDA Highway Vehicle Systems Contractor Coordination Meeting Held in Dearborn Mich., Oct. 4-6, 1977.

2. Should We Have a New Engine? An Automobile Power Systems Evaluation. Jet Propulsion Laboratory, JPL-SP 43-17, Vols. I and II: SAE-SP-399 and SAE-SP-400, 1975.

3. Blankenship, C. P,; and Schulz, R. B.: Opportunities for Ceramics in the ERDA/NASA Continuous Combustion Propulsion Systems Program. NASA TM X-73597, 1977.

4. Postma, Norman D.; Van Giessel, Rob; and Reinink, Frits: The Stirling Engine for Passenger Car Application. SAE paper 730648, Sept. 1973.

5. Tomazic, William A.; and Cairelli, James E.: Ceramic Applications in the Advanced Stirling Automotive Engine. NASA TM X-73623, 1977.

6. van Beukering, H. C. J.; and Foller, H.: Present State of-the-Art of the Philips Stirling Engine. SAE paper 730646, June 1973.

7. Commodity Data Summaries, 1977: Bureau of Mines, U. S. Department of the Interior, 1977.

8. Shewmon, P. G.: Hydrogen Attack of Carbon Steel. Effect of Hydrogen on Behavior of Materials, A. W. Thompson and I. M. Bernstein, eds., AIME, 1976, pp. 59-69.

9. Nelson, Howard G.; and Stein, James E.: Gas-Phase Hydrogen Permeation Through Alpha Iron, 4130 Steel, and 304 Stainless Steel from Less than 100 C to near 600 C. NASA TN D-7265, 1973.

10. Louthan, M. R., Jr.; and Caskey, G. R., Jr.: Hydrogen Transport and Embrittlement in Structural Metals. Int. J. Hydrogen Energy, Vol. 1, Oct. 1976, pp. 291-305.

11. Harris, J. A., Jr.; and Van Wanderham, M. C.: Properties of Materials in High Pressure Hydrogen at Cryogenic, Room, and Elevated Temperatures. (FR- 5768, Pratt and Whitney Aircraft; NASA Contract NAS8-26191.) NASA-CR-124394, 1973.

12. Klima, Stanley, J.; Nachtigal, Alfred J.; and Hoffman, Charles A.: Preliminary Investigation of Effect of Hydrogen on Stress-Rupture and Fatigue Properties of an Iron-, a Nickel-, and a Cobalt-Base Alloy. NASA TN D-1458, 1962.

Reviewed by WEG.

B.3 BIBLIOGRAPHY OF ENERGY CONSERVATION RESEARCH OPPORTUNITIES

• 1. A.D. Little, Inc. Environmental Considerations of Selected Energy-Conserving Manufacturing Process Options. Vol. X. Cement Industry Report. EPA-600/7-76-034j. U.S. Environmental Protection Agency, Cincinnati, Ohio. 1976.

• 2. A.D. Little, Inc. RD&D for Energy Conservation Preliminary Identification in Iron and Steelmaking. SAN/1692-1. Division of Industrial Energy Conservation, U.S. Department of Energy, January 1978.

• 3. Aerodyne Research, Inc. An Assessment of the Potential Impact of Combustion Research on Internal Combustion Engine Emissions and Fuel Consumption. PB-0290953. Aerodyne Research, Inc. Bedford, MA, January 1979.

4. Aerospace Corp. Light-Duty Diesel Engine Development Status and Engine Needs. The Aerospace Corporation, August 1980.

• 5. American Institute of Physics. Efficient Use of Energy: AIP Conference Proceedings No. 25. American Institute of Physics, New York, 1975.

6. American Society of Mechanical Engineers. Heat Transfer in Energy Conservation. Heat Transfer Division, Energetic Division, November 27 - December 2, 1977.

• 7. American Society of Mechanical Engineers. Research Needs Report: Environmental and Conservation Research, American Society of Mechanical Engineers Task Force on Environmental and Conservation Research, American Society of Mechanical Engineers, New York, 1979.

• 8. American Society of Mechanical Engineers. Research Needs Report: Fundamental Research Needs. American Society of Mechanical Engineers Task Force on Fundamental Research, American Society of Mechanical Engineers, New York, 1978.

• 9. Anderson, Carl J. Research and Development Needs for Transportation, Lawrence Livermore Laboratory, April 10, 1975.

10. Bahadar, S. "Near Research and Development", J. Lubr. Tech., Trans Asme, V. 100, n. 4, October 1978, p. 449-454.

• 11. Battelle Columbus Laboratories. Developing a Maximum Energy Efficiency Improvement Target for SIC 28: Chemicals and Allied Products. Vol. 1. PB269869. Battelle Columbus Laboratories, Columbus, OH, July 1976.

• 12. Battelle Columbus Laboratories. Implementation of Energy Conservation Technology in the Steel Industry. Vols. I and II. Battelle Columbus Laboratories, Columbus, OH, August 1980.

• 13. Berg, Charles A. Energy Conservation in Industry: The Present Approach, The Future Opportunities. Council on Environmental Quality, May 1979.

• 14. Brookhaven National Laboratory. Future Raw Materials and Energy Use in Industry - A Research Agenda. A workshop sponsored by the Division of Industrial Energy Conservation, U.S. Department of Energy (DOE), November 9-10, 1978.

15. Burte, Wilfred J. Possible Energy Savings With the Help of Tribology, Especially in the Case of Motor Vehicles. Tech. Akad Esslinjen, Ger. (Erdoel Kohle Erdgus Petrochem Ver Brennst Chem V33 N. 2 Feb. 1980, p. 78-87).

16. Chakrabarty, A.M. "Which Way Genetic Engineering?" Industrial Research, Jan. 1976, pp. 45-50.

17. Cheng, H.S. List of Theses Topics in Tribology. American Society of Mechanical Engineers Publication, n. 76-Lub-G, 1976.

• 18. Committee on Nuclear and Alternative Energy Systems. Energy in Transition 1985-2010. National Academy of Sciences, Washington, D.C., W.H. Freeman: San Francisco, 1979.

• 19. Cremers, C.J. "Environmental and Conservation Research Needs in the Eighties", American Society of Mechanical Engineers Publication 76-WA/RGPC-2. American Society of Mechanical Engineers, New York, 1976.

20. Department of Energy. Cogeneration: Technical Concepts, Trends, Prospects, DOE-FFU-1703. Department of Energy, Washington, D.C., September 1978.

• 21. Department of Energy. Department of Energy Program Objectives, Fluid Waste Heat Recovery and Utilization. TID-28393. Department of Energy, Washington, D.C., February 1978.

• 22. Department of Energy. Report of the Proceedings of the DOE Workshop on Energy Conservation in the Textile Industry. TIC-10007. Division of Industrial Energy Conservation, Department of Energy, January 24 and 25, 1978.

• 23. Department of Energy. Research Workshop on Energy Conservation Through Enhanced Heat Transfer. COO-4649-8. U.S. Department of Energy, October 1979.

24. Dufek, V. Tribology Consolidates its Position. Rept. No. FTD-HC-23-1488-71. Foreign Tech. Div., Wright-Patterson AFB, 1971.

• 25. Energy Research and Development Administration. Agriculture Processing Industry Workshop on Energy Conservation. CONF-760355. Division of Industrial Energy Conservation, Energy Research and Development Administration, Washington, D.C., March 4-5, 1976.

• 26. Energy Research and Development Administration. ERDA Workshop on Energy Conversion in Agriculture Production. CONF-760763. Energy Research and Development, Washington, D.C., July 15-16, 1976.

• 27. Energy Research and Development Administration. ERDA Workshop on Fluid Waste Heat Recovery and Utilization. CONF-761157. Division of Industrial Energy Conservation, Energy Research and Development Administration, Washington, D.C., November 17-19, 1976.

• 28. Energy Research and Development Administration. ERDA Workshop on High Temperature Waste Heat Recovery and Utilization. Division of Industrial Energy Conservation, Energy Research and Development Administration, Washington, D.C., August 25-26, 1977.

29. Energy Research and Development Administration. A Federal Look at the Needs for Energy-Related Materials Research and Development. ERDA 76-28V1 (Prelim. Version), ERDA Tech. Info. Center, Oak Ridge, TN. (Vol. 2 Intermediate and Long-Term Program appeared as a draft but apparently never was officially published). 1976.

30. Energy Research and Development Administration. Industrial Applications Study, Vol. III, Technology Data Base Evaluation of Waste Recovery Systems. COO-2862-3. Energy Research and Development Administration, Division of Conservation Research and Technology, Washington, D.C., January 1977.

31. Energy Research and Development Administration. Materials Sciences Overview, Vol. II Workshop Reports. ERDA 77-76/2. Energy Research and Development Administration. NTISD, Springfield, VA, 1977. (Vol. 1 of this is an Executive Summary).

• 32. Energy Task Group, Committee on Materats (COMAT), Federal Council for Science and Technology, Needs for Energy-Related Material Research and Development. Vol. 1. Near Term Energy Program. ERDA 76-28V1, NTIS, Springfield, VA, 1976.

• 33. The Engineering Societies Commission on Energy (ESCOE). Basic Research in Engineering, Advanced Industrial Technology. FE-2468-56. Department of Energy, Washington, D.C., February 1979.

• 34. The Engineering Societies Commission on Energy (ESCOE). Basic Research in Engineering, Fluid Dynamics and Thermal Processes. FE-2468-54. Department of Energy, Washington, D.C., August 1979.

35. Fox, J. L. "Biological Solutions to Industrial Energy Reduction," presented at the 1981 IECTC. Houston, TX, April 26-29, 1981.

36. General Electric Corporation. Cogeneration Technology Alternative Study Summary Report. Vol. 1. DOE/NASA/0031-80/1. Prepared for NASA-Lewis, Cleveland, OH, April 1980.

37. General Electric Corporation. Cogeneration Technology Alternative Study Industrial Processes. Vol. 3. DOE/NASA-0031-80/3. Prepared for NASA-Lewis, Cleveland, OH, April 1980.

38. General Energy Associates, Inc. Relevance of the Second Law of Thermodynamics to Energy Conservation. Vols. I and II. DOE/CS/40178. 000-01. National Bureau of Standards, Cherry Hill, NJ, January 1980.

• 39. Georgia Institute of Technology. Energy Conservation in the Paper and Allied Products Industry, Phase 1. DOE/CS/40098-T1. Department of Energy, Washington, D.C., October 1979.

40. Gordian Associates. Heat Pump Technology. HCP/M2121-01. Buildings and Community Systems Division, U.S. Department of Energy, June 1978.

• 41. Gordian Associates. IEA Steel R&D Report, Final Report. ALO-5076-TI. May 31, 1979.

42. Gorman, R. and K. L. Heitner, "A Comparison of Costs for Automobile Energy Conservation versus Synthetic Fuel Production," presented at the 5th International Automobile Propulsion Systems Symposium, April 14-18, 1980.

• 43. Grey, Jerry, Sutton, George W. and Zlotnick, Martin. "Fuel Conservation and Applied Research," Science 200. No. 4338, April 14, 1978, pp. 135-42.

44. Haines, L. F. and G. R. Morley, "Lubricant Development on British Rail," Proceedings of Institute of Mechanical Engineers. Vol. 192, December 1978, p. 333-342.

45. Halling, J. Tribology in Manufacturin Engineering. Institute of Mechanical Engineers (Cond.), Proc. v. 192, June 1978, p. 189-196.

• 46. Hollander, Jack M. Basic Research Needs in Energy Conservation. LBL-99939. Lawrence Berkeley Laboratory, University of California, October 1979.

47. Ivkovic, B. Z. "Tribological Characteristics of Cutting Fluids and Machining Costs," 2nd International Conference on Lubricating Challenges in Metalworking and Processing. IIT Research Institute, Chicago, IL, June 27-29, 1971.

48. Jet Propulsion Laboratory. Should We Have a New Engine, An Automobile Power Systems Evaluation. Pasadena, CA, August 1975.

• 49. Johnson, R. M. Tribology: Research and Development Needs in Advanced Energy Technology. (REPT NO: CONF-770237-1) HEDL SA-1191. Hanford Engineering and Development Laboratory, Richland, WA, 1977.

50. Jost, H. Peter. Economic Impact of Tribology. National Bureau of Standards Specifications Publication, 423, April 1976.

• 51. Klaus, E. E. "Energy Conservation in Road Transportation Through Lubrication Technology," Lubrication Engineering. Vol. 34 n. 11, November 1978, pp. 611-617.

52. Ku, P. M. "Energy and Materials Conservation Through Tribology," Lubrication Technology. Vol. 34, n. 3, March 1978, pp. 131-134.

53. Larsen, R. M. "Tribology: The Little Known Science of Friction and Wear," Iron Age. v. 221, n. 44, November 1978, pp. 51-54.

• 54. May, E. Kenneth and Hooker, Douglas W. Reducing Fuel Usage Through Applications of Conservation and Solar Energy. SERI/TP-733-665, April 1980.

55. McDonald, C. F. "The Role of the Ceramic Heat Exchanger in Energy and Resource Conservaation," Journal of Engineering for Power. Vol. 102, April 1980, pp. 303-315.

56. McNab, I. R. "Recent Advances in Electrical Current Collection," Wear. Vol. 59, n. 1, March 1980, pp. 259-a276.

57. Miller, H. R. New Lube Oils and Fuel Economy. (Edwin Cooper, Inc.) Proc., American Petroleum Institute, Refining Department: 71. 73(1978).

58. Miller, P., et. al. Plastic Heat Exchangers: A State-of-the-Art Review. ANL-79-12. Prepared by Argonne for the Department of Energy, Washington, D.C., July 1979.

• 59. MITRE Corporation. An Agenda for Research and Development on End-Use Energy Conservation. Volumes I and II Mtr-6577. McLean, VA, December 1973.

60. Mujumdar, Arun. Drying '80. Vol. I & II. Hemisphere Press, Washington, D.C., 1980.

61. NASA-Lewis. Cogeneration Technology Alternative Study (CTAS), Summary. Vol. 1. DOE/NASA/1062-80/4. Prepared for DOE, Washington, D.C.,

62. Newcomb, T.P. "Energy Dissipated During Braking", Wear. Vol. 59, n. 2, March 1980, pp. 401-407.

63. O'Callaghan, Paul. Energy for Industry. Pergamon Press, Oxford. 1979.

64. Office of Technology Assessment. Changes in the Future Use and Characteristics of the Automobile Transportation System. GPO, Washington, D.C., February 1979.

65. Office of Technology Assessment. Impact of Advanced Air Transport Technology, Part 1: Advanced High Speed Aircraft. GPO, Washington, D.C., April 1980.

66. Office of Technology Assessment. Impacts of Applied Genetics: Microorganisms, Plants, and Animals. GPO, Washington, D.C. April 1981.

• 67. Office of Technology Assessment. Residential Energy Conservation. Volume I, Office of Technology Assessment, Washington, D.C., 1978 est. (No date given).

68. Office of Technology Assessment. Technology and Steel Industry Competitiveness. Office of Technology Assessment, GPO, Washington, D.C. June 1980.

• 69. Oppenheim, A.K. and F.J. Weinburg. "Combustion R&D - Key to Our Energy Future", Astronautics and Aeronautics. November 1974, pp. 22-31.

70. Perez-Blanco, H., and F.C. Chen. "Some Concepts for Residual Heat Removal". Alternate Energy Sources Conference. CONF-801210-11, December 1980.

71. Pinkus, Oscar, Donald F. Wilcock. "Role of Tribology in Energy Conservation, Lubr. Eng. V34, n. 11, November 1978, p. 599-610.

• 72. Pinkus, Oscar, Donald Wilcox. Strategy for Energy Conservation Through Tribology, Publ. by ASME, 1977.

73. Plevy, T.R.H. "The Role of Friction in Metal Working With Particular Reference to Energy Savings in Deep Drawing," Patterns of Tribology. Vol. II, p. 361-379 (also in Wear, Vol. 58 n. 2, p. 359-380, Feb. 1980).

• 74. Resource Planning Associates. Implementation of Energy Conservation Technology in the Paper and Pulp Industry. Department of Energy, Washington, D.C., September 1980.

75. Resource Planning Associates. Technical Overview of Cogeneration: The Hardware, the Industries, the Potential Development. SAN-1223-TI. Resource Planning Associates, Washington, D.C., prepared for the Department of Energy, December 1977.

• 76. Ross, Marc H., Williams, Robert H. Our Energy: Regaining Control. McGraw-Hill, New York, 1981.

• 77. Schurr, Sam H., et. al. Energy in America's Future: The Choices Before Us, Johns Hopkins University Press, Baltimore, 1979.

78. Semler, T.T., et. al. Potential Industrial Applications for Direct Contact Waste Heat Recuperator Systems. EGFG-CS-5328. Prepared by EG&G for Department of Energy, Washington, D.C., February 1981.

79. Solar Energy Research Institute, Committee on Energy and Commerce. Building a Sustainable Future. Vols. I, II. Committee Print 97-K, Washington, D.C., April 1981.

80. Somasundaran, P. and D.W. Fuerstenau. Research Needs in Mineral Processing. PB-260735. Available from NTIS, Springfield, Va., 1976.

81. Steering Committee for the Study of Research Applied to Naional Needs. Priorities for Research Applicable to National Needs. National Academy of Engineering, Washington, D.C. 1973.

• 82. Stephens, J.R., W.R. Witzke, G.K. Watson, J.R. Johnson, W.J. Croft. Materials Technology Assessment for Stirling Engine. NASA TM-73789. NASA Lewis Research Center, Cleveland, Ohio, 1977.

83. Szekely, Julian. "Radically Innovative Steelmaking Technologies," Howe Memorial Lecture, Metallurgical Transaction B. Vol. 11B, September 1980, pp. 353-371.

84. Tribological Consideration in the Hot Rolling of Low Carbon Steel, (Author, etc., unknown.)

85. TRW. Program Plan Report for Allied Research in Road Vehicles. Energy Systems Group, TRW, July 29, 1977.

86. United Technologies Corp. Cogeneration Technology Alternative Study Summary Report. Vol. 1. DOE/NASA/0030-80/1. Prepared for NASA-Lewis, Cleveland, OH., January 1980.

87. United Technologies Corp. Cogeneration Technology Alternative Study Energy Conversion System. Vol. 3. DOE/NASA/0030-80/3. Prepared for NASA-Lewis, Cleveland, OH, January 1980.

88. Westinghouse. Industrial Cogeneration Optimization Program. Vol. 1. DOE/CS/05310-1. Department of Energy, Washington, D.C., January 1980.

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