EFFICIENT USE AND CONSERVATION OF ENERGY

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Contents

Summary

To avert the path of resource depletion that humans are currently on, considerable efforts are required to conserve finite resources. Resource conservation can come in many forms, including improved production and transport of energy, improved efficiency of equipment and processes, better operation and maintenance practices, increased application of alternative resources, and higher regard for matching energy quality with end-use requirements. This theme details the energy efficiency imperative—how we got into this predicament, and why we need to get out. It further highlights the results of recent worldwide efforts that were made in response to the energy efficiency imperative. The focus is on improved energy utilization in four primary end-use sectors: buildings, industry, transportation, and agriculture. In particular, this piece describes opportunities in each of the primary sectors for continuing proven paths and developing new paths toward a sustainable energized world. At the same time, this theme tries to highlight an over-arching concern—one where one-half the world's population is still using primitive biomass energy and has no access to electricity.

1. Introduction

It has taken the world about ten years to realize that energy is not an infinite resource. Prior to this, the illusion of infinite resources has supported and sustained a high standard of living. Over that period, it has become apparent that a variety of energy sources and efficiency options are necessary to achieve and maintain that standard of living as well as to provide economic stability and national security. The world has also come to realize that among all the measures that can be used as resources in meeting energy demand, deploying energy efficiency is the simplest option and the most rewarding in the near term with regard to benefits to the energy supplier and the energy consumer.

A strategy of using energy more effectively has the capability of saving all forms of nonrenewable and renewable energy resources. With little or no adverse environmental impact, it may lower the cost of living and improve the economy.

Is Energy Efficiency Cost-Effective?

But is energy efficiency really cost-effective? Does it cost society and the consumer less in the long run?

The question of whether end-use energy efficiency is cost-effective depends on both the type of energy efficiency investment, action, or program under consideration and on the energy system's characteristics. Certainly, energy efficiency programs and/or activities are specific to the energy form or supply and delivery system. Each must be evaluated on the basis of economics as applied to a particular system. On some systems, energy efficiency investments may be the cheapest source of energy; however, each investment must be evaluated in light of supply alternatives and other efficiency options that are available. What might be cost-effective in one application may not be for another due to variations in weather, demand characteristics, fuel costs, etc. When a system benefit is not achieved to offset the cost of an activity, the result will be higher charges for service, which will adversely impact the consumer. These evaluations do not, necessarily, include consideration of environmental externalities.

Individual consumers do not typically evaluate energy efficiency in terms of sophisticated formulas or models. They often decide based on instinct, opinion, or advice of colleagues. Larger consumers, in particular, may use an evaluation of investment decision criteria comparing energy efficiency to other investment opportunities.

For gas and electric utilities evaluating the benefits and costs of demand-side activities, one of the criteria generally used is life-cycle costing, or in a regulated environment, the impact on revenue requirements. Since end-use activities can impact a variety of costs, evaluation usually is accomplished by a modeling technique that stimulates the price of energy to a population of consumers. The revenue-requirement criterion is a product of long-standing utility economic theory. It is, without question, the proper criterion to look at alternative supply scenarios with different generation-resource options in a regulated environment. But it may not be the appropriate technique to use for decision making in an analysis of all energy efficiency alternatives. In many cases, life-cycle costing could be.

Why is Energy So Valuable?

Why is energy so valuable? Because it provides services? Facilitates product development and use? Engenders technology? Of course, but its value is not limited to narrow examples of its use. When attempting to quantify the economic value of energy, it helps to look at the “big picture” for a moment. From this vantage point, quantifying the value of energy may seem less daunting.

While the average consumer instinctively understands the value of flipping a switch and receiving instantaneous light, this consumer may not recognize additional evidence of its value. For example, does the average consumer appreciate energy’s impact on the world’s graphic, technological, and economic development? Early central generating station and electric distribution technology limited the spread of businesses; these businesses had to remain close to power stations because there was no way to “transport” electricity. However, technology advances in both electric transmission and distribution systems as well as power station design facilitated the growth of industry in cities all across the developed world.

The introduction of electricity to manufacturing processes revolutionized both factory designs and production methods. For example, by substituting electric motors for complicated belt-driven machine shop systems, a business could physically and technologically reorganize its manufacturing process to achieve greater efficiencies and economic benefits.

In the twentieth century, electricity has been used to develop and power some of the most basic technological developments, including the analog computer, the cathode-ray oscillograph, and the impulse voltage generator.

Interestingly, consumers do not always recognize the link between these technological developments, energy, and the industries that provide this service. They are even less likely to make this association for more advanced electric applications such as robotics and computer-aided production. Researchers create new generations of these products regularly and simultaneously the electroprocesses used to develop them evolve. Yet consumers still fail to equate energy with this technological development.

The availability of energy is the most significant technical advancement of all time.

Energy is fundamental to the quality of modern life. It can perform many tasks efficiently. In little over 100 years, energy and perhaps most significantly electricity has transformed the ways most people of the world live. Lighting, refrigeration, motors, medical technologies, computers and mass communications are but a few of the improvements it provides to an expanding share of the world's growing population.

Why save energy? In electrical terms, a kilowatt-hour of electricity can light a 100-watt lamp for 10 hours, or lift a ton 1,000 feet (305 meters) into the air, or smelt enough aluminum for a six-pack of soda cans, or heat 780 kg of water from 60 °F (15.6 °C) to 100 °F (37.8 °C). To save money and ease environmental pressures, can more mechanical work or light, more aluminum or more lukewarm water, be wrung from that same kilowatt-hour?

The answer is clearly yes. Estimates as to how much more range from 30 to 500%. The higher number relates to replacing short circuit water heaters with heat pumps. Also at issue is how fast efficiency can be improved, and at what cost.

Since the oil embargo of 1973, energy intensity – the amount of energy required to produce a dollar of gross national product– has fallen by over 30% in the United States. Plugged steam leaks, caulk guns, duct tape, insulation, and cars whose efficiency has increased by many miles per gallon (or kilometers per liter) have helped to extract more work from each unit of fuel. Applications of electricity, too, have made important contributions to productivity and to a more information-based economy. Electricity accounts for a growing fraction of energy demand. Technologies and implementation techniques now exist for using electricity more efficiently while actually improving services. Harnessing this potential could get society off the present treadmill of ever-higher financial and environmental risks and could make affordable the electric services that are vital to global development.

Historical patterns have already changed. California reduced its electric intensity by 18% from 1977 to 1986. Nevertheless, in such major industries as cars, steel and paper, Japan's electric use per ton is falling while the United States' is rising – chiefly because American companies are still adopting new fuel-saving "electrotechnologies" already common in Japan. But companies there are improving their efficiency at a faster rate.

Other industrialized nations are also setting higher standards for efficiency. Sweden has outlined ways to double its electricity efficiency. Denmark has vowed to cut its carbon dioxide output to half the 1988 level by 2030 and West Germany to 75% of the 1987 level by 2005; both nations emphasize efficiency.

These encouraging developments reflect rapid progress on four separate but related fronts: advanced technologies for using energy more productively; new ways to finance and deliver those technologies to consumers; expanded and reformulated roles for utilities; and innovative regulation that rewards efficiency.

The technological revolution is most dramatic. The 1980's created a flood of more powerful yet cost-effective electricity-saving devices. If anything, progress seems to be accelerating as developments in materials, electronics, computer design, and manufacturing converge. Also, by making the second law of thermodynamics, i.e. the exergy concept, into industrial practice will further add to an accelerating efficiency improvement.

Contents of the Theme

This theme deals with energy conservation and efficiency. First, the impetus for conservation and efficiency is put into perspective in Chapter 2 where the factors pertaining to the imperative for energy efficiency are highlighted. Next, in Chapter 3, trends that depict historical energy use patterns and reactions to the energy efficiency imperative are described to show the progress that has been made, and to illustrate the need for continued efficiency efforts. Chapter 4 provides the basic knowledge of energy conversion and measures of efficiency that is required before one can understand and improve the efficiency of energy conversion. Chapter 5 describes two approaches to energy management at the demand side. This chapter shows how energy management activities yield lists of specific energy efficiency opportunities. Examples of energy efficiency opportunities in buildings, industrial processes, transportation, and agriculture are provided in Chapter 6. Chapter 7 discusses the costs and benefits of energy efficiency for four primary groups: consumers, participants and non-participants of energy efficiency programs, utilities, and society at large. Finally, Chapter 8 discusses issues related to obtaining a sustainable energy future. Throughout the text, references are made to topic and article level contributions to direct the reader to more detailed treatments of the specific subjects introduced herein.

The terms *energy conservation* and *energy efficiency* are typically identified with the improved utilization or use of energy. As such, the topics typically included in treatment of this subject include the primary uses of energy in industry, in buildings, in agriculture, and in transportation—as is the case in this theme. It should be noted, however, that there are other opportunities for efficiency in the system of production and transport of energy, which are equally important to consider and are covered in other parts of this encyclopedia. Efficiency as it pertains to the extraction, refining, and transport of petroleum products, particularly oil and natural gas, and efficiency in the production and transport of electricity can be found in other themes of EOLSS On-Line.

Please note that *energy use* and *energy consumption* are used loosely throughout this theme to represent the actual quantity of energy from a source converted to another energy form to perform a given task. For example, it is common to say that a 100 W light bulb *uses* 0.1 kWh in one hour. However, the energy is not really *consumed*; rather, it is converted from electric energy to heat and light energy. The concept of energy conversion, rather than utilization, is further developed in Chapter 4.

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Biographical Sketch

Clark Gellings’ 30-year career in energy spans from hands-on wiring in factories and homes to the design of lighting and energy systems to his invention of “demand-side management” (DSM). Mr. Gellings coined the term DSM and developed the accompanying DSM framework, guidebooks, and models now in use throughout the world. He provides leadership in EPRI, an organization that is second in the world only to the Department of Energy (in dollars) in the development of energy efficiency technologies. Mr. Gellings has demonstrated a unique ability to understand what energy customers want and need and then implement systems to develop and deliver a set of R&D programs to meet the challenge. Among Mr. Gellings’ most significant accomplishments is his success in leading a team with an outstanding track record in forging tailored collaborations—alliances among utilities, industry associations, government agencies, and academia—to leverage R&D dollars for the maximum benefit. Mr. Gellings has published 10 books, more than 400 articles, and has presented papers at numerous conferences. Some of his many honors include seven awards in lighting design and the Bernard Price Memorial Lecture Award of the South African Institute of Electrical Engineers. He has been elected a fellow in the Institute of Electrical and Electronics Engineers and the Illuminating Engineering Society of North America. He won the 1992 DSM Achiever of the Year Award of the Association of Energy Engineers for having invented DSM. He has served as an advisor to the U.S. Congress Office of Technical Assessment panel on energy efficiency, and currently serves as a member of the Board of Directors for the California Institute for Energy Efficiency.