New Electrification Technology

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ABSTRACT

Reducing Co_2 Emissions—Depending on the sources of electricity production, the use of electricity can be a contributing factor to net CO_2 emissions. What is less obvious is the fact that the increasing use of efficient end-use electric technologies has the potential to save energy and decrease overall CO_2 emissions substantially.

There are two main mechanisms for saving energy and reducing CO_2 emissions with electric end-use technologies: (1) upgrading existing electric technologies, processes, and building energy systems; and (2) expanding end-use applications of electricity. Upgrading existing electric end-use technologies embodies replacing or retrofitting older equipment with new, innovative, highly efficient technologies. It also includes improving controls and operations and maintenance practices, as well as reducing end-use energy needs by improving buildings and building processes. In essence, this first mechanism is comprised of what are commonly referred to as energy efficiency and demand-response measures.

The second mechanism, expanding end-use applications of electricity, involves replacing less efficient fossil fuel end-use technologies (existing or planned) with more efficient electric end-use technologies. It also encompasses developing new markets for electric end-use technologies that result in overall energy, environmental, and economic benefits.

There are many electric end-use technologies known to be superior in their performance, using much less overall (net) energy in performing the same function as a fossil fuel technology. This benefit of electricity use stems from several characteristics: (1) electricity is able to apply portions of the electromagnetic spectrum to a process or a task (e.g., microwaves to cook food or ultrasonic waves to enhance dyes); (2) electricity uses a mix of low-carbon primary energy sources, including nuclear, wind, solar, hydropower, etc.; and (3) electricity can provide motive power more efficiently than fossil fuel engines.

FACILITATING THE ADOPTION OF EFFICIENT TECHNOLOGIES

A number of state and federal institutions, as well as energy providers and consultants, have evolved some aspects of domain expertise relative to the development, demonstration, commercialization, and adoption of efficient technologies.

There are both a range of activities and a variation of technology transfer engagements that organizations can have. Figure 1 depicts the range of activities which can influence the availability of technologies.

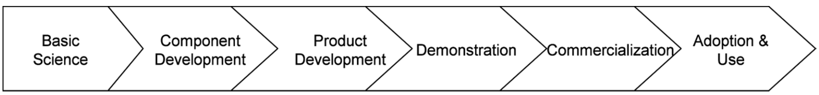

Figure 1. The Range of Activities Related to the Availability of Utilization Technologies.

These activities may include the following:

- Basic Science involves the fundamental research needed to provide the basis for the evolution of science that has the potential for increasing energy efficiency or evolving new applications of electricity.
- Component Development involves taking applications of basic science and converting them into technological components.
- Product Development involves combining combinations of components into an end-use, energy-consuming device or appliance, for application in a specific industrial or agricultural application.
- Demonstration involves the first and second of a kind *in situ* demonstration of the product.
- Commercialization involves engaging a manufacturer who will produce the technology and arrange for distribution, sale, and adoption and use.
- Adoption and Use involves the actual adoption and utilization of the technology by an industrial or agricultural concern.

Figure 2 depicts the variety of technology transfer opportunities which can support the evolution and adoption of advanced technologies.

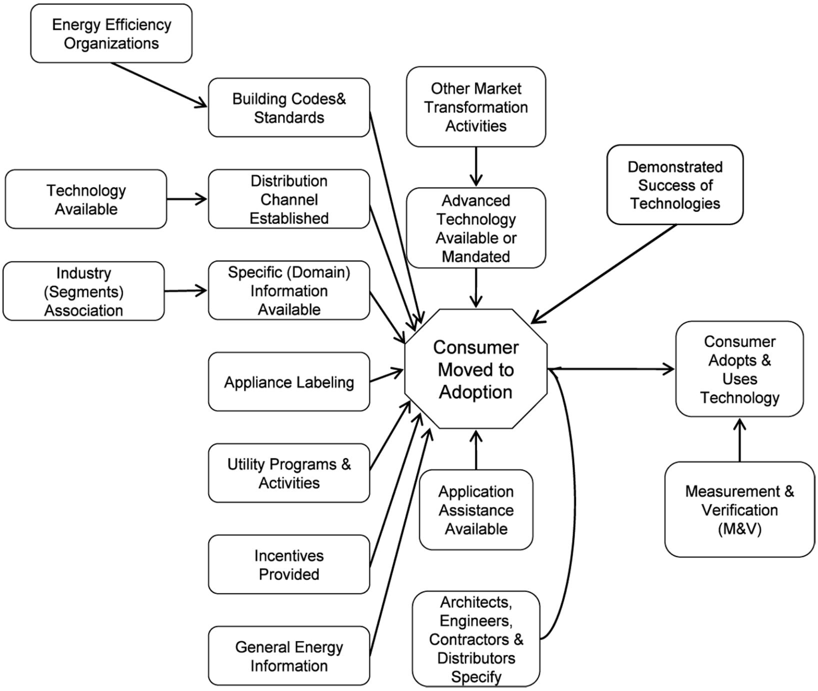

Figure 2. The Technology Transfer Opportunities and Activities Which Influence Technology Availability and Adoption

There are clearly a number of policies, technology development actions, and activities which can play a key role in the evolution and eventual adoption of efficient technologies. However, the demonstrated success of new technologies in real-world applications is among the most critical and relatively nascent activities.

Demonstrations of advanced technology provide a first-hand assessment of the technology. This facilitates a means to assess new technologies and to evaluate opportunities for improvement or enhancement of those technologies. This may include undertaking or facilitating improvements or enhancements. Demonstrating technologies involves addressing issues of integration of these technologies into real-world settings and includes the assessment of advanced technologies developed overseas, as well as the evaluation of these technologies for application in the U.S. Demonstrations facilitate commercialization of new technology.

Importantly, demonstrations also facilitate the acceptance and adoption of advanced and improved technologies. Demonstrations enable availability of information on the installation, allowing specific (domain) expertise to be available and enabling technical assistance. For specific technologies, this may also facilitate the knowledge necessary to develop sales and distribution channels to establish value propositions and to facilitate customer acceptance.

In addition, demonstrations provide insight on understanding and assessment of how individual technologies and services may relate to utility and regulatory interests in energy efficiency, load building, demand response, rate design, regulatory incentives, and legislation.

DEMONSTRATION OF NEW USES OF ELECTRICITY IN BUILDINGS

A nationwide demonstration of technologies which involve new uses of electricity applied to buildings is already underway. EPRI is undertaking a major collaboration to test energy efficient equipment for both the residential and commercial sectors.

This three-year endeavor will demonstrate residential "hyper-efficient" appliances, domestic heat pump water heaters, and residential ductless heat pumps. Commercial-sector technologies that are part of the test are variable-refrigerant-flow heat pump air conditioning systems and efficient power conversion, cooling, and computing systems for data centers. (See www.epri.com for more information.)

PROPOSED NATIONAL DEMONSTRATION OF INDUSTRIAL TECHNOLOGIES

Background

In addition to the application of beneficial new uses in buildings, there are also many opportunities for demonstration of beneficial electricity in the industrial sector. Electric technologies in industrial processes use electricity to make or transform a product. Many electrotechnologies are used for heating applications like heat treating, drying, curing, melting, and forming. Others are used for applications like motive power, separation, machining, and welding.

Such technologies generally have good controllability, superior product quality, cleanliness, and efficiency. In many cases, electrotechnologies are chosen for technical reasons, while in other cases, the relative price of natural gas (or other fuels) and electricity is the deciding factor. In some cases, the application cannot be done effectively without an electrotechnology.

Electrotechnologies are generally accepted within industries because of their efficiencies, energy control capabilities, low material waste, and processing and production rates. The fact that they reduce CO_2 emissions as well should provide an added incentive for their development and use.

However, there are a number of other electrotechnologies that are not fully deployed which reduce or eliminate other adverse environmental impacts often associated with gas-fired processes. For example, drying liquid automobile paints with gas ovens releases volatile organic compounds (VOCs) into the atmosphere. New powdered paints, dried using electrotechnology, eliminate these hazards.

Beneficial new uses have emerged which can reduce CO_2 emissions in industrial processes by applying energy efficient technologies, with a primary focus on the food processing, chemicals, and pulp and paper industries. These include heat recovery using heat recovery chillers, heat recovery heat pumps (including closed-cycle heat pumps using advanced refrigerants), and air-to-air heat exchangers. Predominantly, these applications involve reclaiming otherwise "waste" heat from one process or application and applying it to another where heat is required.

For example, many industrial facilities require cooling in one part of the campus while simultaneously generating hot water for process use elsewhere. Cooling is typically provided by a system using compressors / condensers, evaporators, and cooling towers. In the same facility, hot water is often generated by a fossil fuel, usually natural gas. The cooling system may only be rejecting 95°F hot water to send to the cooling towers—not typically viewed as a valuable energy source. Meanwhile, 150°F water is being generated by gas-fired boilers for process heating in another part of the facility. In this case, a heat recovery chiller could be used to reduce the water in the chiller loop from 95°F to 85°F and coincidentally generate 150°F water, thus eliminating the operation of the boilers.

An excellent example is an application facilitated by Alabama Power Company at GKN Aerospace Services (GKN), a manufacturer of composite parts for the aeronautical industry. GKN used propane-fired hot water boilers to make 150°F hot water for heat, dehumidification, and curing processes. GKN also needs a minimum of 300 tons of cooling for HVAC and industrial processes. The company installed a 560-ton heat recovery chiller (HRC) that recovers waste heat currently being sent to the cooling towers. The HRC generates 155°F water by use of the compression cycle by reducing cooling tower inlet water temperature. The HRC displaced 350 hp of propane-fired hot water boilers. By operating at 400% efficiency, it resulted in an annual net energy savings of $350,000 while reducing net CO_2 emissions by 3.3 million pounds per year.

Similar applications could use heat pumps to provide leverage of energy in recovering heat. Results from a 2009 study conducted by the Electric Power Research Institute (EPRI) indicate that the potential for saving energy and reducing CO_2 emissions by expanding end-use applications of electricity is significant. [1] As the study showed, converting existing and anticipated residential, commercial, and industrial equipment and processes from traditional fossil fuel technologies to more efficient electric technologies can result in annual energy savings in 2030 of 5.32 quadrillion Btus per year and CO_2 reductions of 320 million metric tons per year. Another recently completed report identified promising research and development opportunities for electric technologies in industrial applications. [2]

The use of heat pumps to recover waste heat in industrial applications represents one of these opportunities. Heat pumps are systems that operate in a cyclic manner. They absorb heat of low temperature from an energy source, apply external energy, and deliver heat to a higher-temperature load, as illustrated in Figure 3. The external energy is usually supplied by an electric motor.

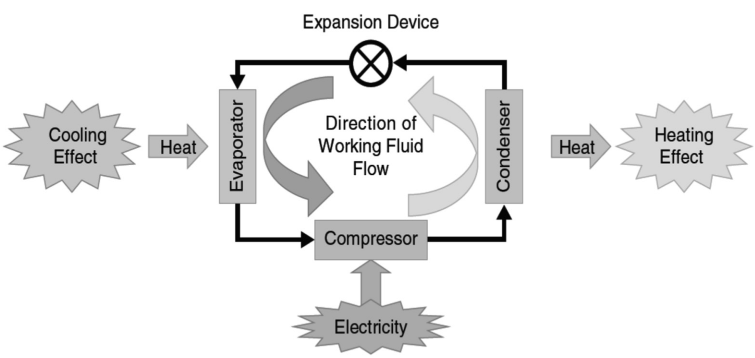

Figure 3. Operation of Closed-cycle Mechanical Heat Pump

There are four common types of industrial heat pumps:

- **Closed-cycle mechanical heat pumps** use mechanical compression of refrigerant. They are used for lumber drying, space heating, and heating water and process liquids (Figure 3).

- **Open-cycle mechanical vapor recompression (MVR) heat pumps** use mechanical compression to increase the pressure of waste vapor. They are used in evaporation and distillation processes commonly found in the petroleum, chemical and petrochemical, pulp, and food and beverage industries.

- **Open-cycle thermo compression heat pumps** use high-pressure steam to increase the pressure of waste vapor. They are used in evaporators and flash-steam recovery systems, such as paper dryers.

- **Closed-cycle absorption heat pumps** use a two-component working fluid and the principles of boiling-point elevation and heat absorption. They can deliver a much higher temperature rise than other heat pumps and have the ability to provide simultaneous cooling and heating. They are typically used in chilling applications.

Heat pumps are extremely beneficial in recovering low-temperature waste heat. It is ordinarily not practical to extract work from waste heat sources in the low-temperature range, and many applications of low-temperature waste heat are limited to using the waste heat for preheating liquids or gases by means of heat exchangers. Under many circumstances, however, heat pumps enable the economic use of low-temperature waste heat in industrial applications requiring higher-temperature heat. Examples of industrial waste heat sources in the low-temperature range include process steam condensate (~130-170°F) and cooling water from various industrial machines, furnaces, internal combustion engines, and hot-processed liquids and solids (~90-450°F). [3]

There are numerous industrial applications of heat pumps and heat recovery chillers. Industrial heat pumps are predominately used by the lumber, petroleum refining, chemical and petrochemical, pulp and paper, and food and dairy industries. Common industrial processes benefiting from heat pumps include drying, evaporation, and distillation.

Heat pumps are also employed across most industrial sectors for water heating and space conditioning, similar to how heat pumps are used in residential and commercial buildings. Additionally, the application of absorption heat pumps for chilling is emerging. Heat recovery chillers are less popular. Engineering practice has been to keep cooling and heating process flows separate, thus not examining industrial process flow in a holistic way. There are tremendous opportunities for use of heat recovery chillers.

The use of closed-cycle heat pumps for drying of leather, foodstuff, and paper is a relatively popular application, but these tend to be small-scale applications. Other closed-cycle applications are generally of a larger scale, but they are typically low energy-intensive applications, such as heating process water or process fluids and heating water for cleaning purposes.

In contrast, evaporation and distillation applications are highly energy-intensive and often involve large-scale systems. Distillation and evaporation lend themselves extremely well to open-cycle mechanical vapor recompression (MVR) heat pumps. In the evaporation process, MVR heat pumps are mainly used for water-based solutions where the vapor produced by the evaporation of liquor is compressed and used to drive the evaporator. The distillation process is a physical separation process that involves the separation of mixtures based on differences in their volatilities. It is an extremely energy-intensive process found in numerous industries, including food and beverage, chemical and petrochemical, oil production, and refineries. For example, distillation separation of propylene and propane is extensively used b y the chemical industry to produce propylene, a key material in the production of many chemical products.

Because of the many advantages of open-cycle heat pumps, a detailed analysis of the benefits associated with the use of an MVR heat pump in a chemical plant has been conducted. The MVR heat pump is used in a distillation column to separate propylene and displaces steam generated by a natural gas boiler. [4] The primary plant-level benefits associated with this heat recovery heat pump application are summarized in Table 1.

Advanced Refrigerants

There are seven new refrigeration units available for use in heat recovery installations from Japanese manufacturers. These systems use

Table 1. Benefits Associated with Use of an MVR Heat Pump

Industry	Chemical/petrochemical (NAICS 325)
End-use	Separation of propylene and propane in distillation column
Electric Technology	50.2 MW open-cycle MVR heat pump, COP = 8
Electricity Requirement	50,400 MWh per hear (172,000 MMBtu per year)
Displaced Technology	Natural gas boiler for steam generation, 75% efficient
Natural Gas Savings	1,824,000 MMBtu per year
Net On-site Energy Savings	1,652,000 MMBtu per year (91% savings)

CO_2 as a refrigerant. One manufacturer (Toyo Engineering Works, Ltd.) has demonstrated an industrial heap pump which recovers heat from low-temperature waste hot water that would have been discarded in the past. The recovered heat is then used to generate steam and hot water for process use (www.h.toyo-ew.co.jp).

Another Japanese firm, Mayekawa Manufacturing Co., Ltd., has demonstrated the application of the popular Japanese "Eco Cute" heat pump technology for industrial applications. Their product is ideally suited for industries which use gas-fired boilers to generate hot water. They claim coefficients of performance (COP) of over 3.0 in units that are designed to produce 10 tons of hot water in 10 hours.

Target Industries

Demonstrations of heat recovery technology should be generally targeted toward industrial segments with applications where the demonstration would offer examples for many other industries to follow. Food processing, chemicals, and pulp and paper are industrial segments that are generally ubiquitous in technology opportunities.

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