HVACR Research for the 21st Century:

Expanding the Plan

ARTI anticipates and plans for the future.

By Kenneth E. Hickman, PhD and Glenn C. Hourahan, PE

The Air-Conditioning and Refrigeration Technology Institute (ARTI) recently completed a major strategic planning initiative. The mission was to identify the research needed to enable the HVACR industry to develop technology, products, and innovative applications and services for the next decade and beyond. This article highlights the initiative, and explains the research opportunities that were identified during the process.

Why This Study At This Time?

The HVACR industry experienced evolutionary change until the early 1990s. Then the industry entered a period of unprecedented transformation. The pressures driving these changes — protection of the environment and conservation of natural resources — continue to grow in importance.

In 1988, the Air-Conditioning and Refrigeration Institute (ARI) launched ARTI as a not-for-profit organization to undertake scientific research in the public interest, principally to assure that industry could safely, reliably, and cost-effectively change to new refrigerants and lubricants in response to stratospheric ozone depletion and the ensuing Montreal Protocol.

In 1997, ARI's Research and Technology Committee held a workshop to respond to a new public concern — global climate change — by establishing new research directions for the air conditioning and refrigeration industry. The result was the establishment of the *HVAC&R Research for the 21st* Century (21-CR) program. The 21-CR program is an industry-government collaboration for identifying, prioritizing, and undertaking research that focuses on decreasing energy consumption while improving indoor environmental quality (IEQ) within buildings.

By January 2001, 21-CR committees had defined, approved for funding, and placed 32 projects valued at $4.1 million under contract. These initial projects came forward for many good reasons, but the 21-CR participants stepped back to check their focus and vision. They wanted to review the program's strategic objectives to define a long-term matrix of goals to be met as ongoing projects are completed and new projects are begun. Thus, the 21-CR program launched a strategic planning initiative.

Strategic Planning Process

The strategic planning initiative began with a series of meetings in which a core group of 18 experts from industry, academia, national laboratories, and consulting firms followed a facilitated and structured process. The process concluded with an industry workshop in September 2001, with 65 attendees. Reports summarizing the initiatives resulted, and may be downloaded for free from www.arti-21cr.org.

The strategic planning initiative categorized research needs by three user sectors:

- Commercial buildings (offices and institutional facilities)
- Residential buildings (low rise, high rise, detached)
- Commercial refrigeration (supermarkets, warehouses, commercial transport).

The geographic focus is the North American HVACR

market, with consideration of global issues that may affect the North American industry. The timeframe focus is on the research needed to support products, applications, and services that will be in the market during 2010-2015.

The first step in the strategic planning initiative was to identify the present-day events, future trends, and drivers that are likely to impact the HVACR industry in significant ways.

The present-day events believed to be most important are:

- Advancing technologies in many related fields
- Changes in energy availability and cost
- Embedded industry practices in architecture, construction, and refrigeration
- Expanding government mandates and requirements
- Food safety concerns
- Lifestyle changes
- Impact of international initiatives
- Increased awareness of IEQ and its link to health and productivity
- Public pressures to improve the environment
- Shortage of skilled installation and service people.

The most important future trends and drivers that are recognized are:

- Environmental concerns and regulations
- Expanding global food supply chains
- Food safety issues from field to table
- Growing demand for energy efficiency and source diversity
- Impact of globalization
- Increasing customer expectations
- Increasing integration of building technologies
- Increasing requirements for indoor environmental control
- Shortage of qualified labor
- Urbanization.

Five over-arching themes emerged during this process; they are highlighted throughout the rest of this article. While there are others, these five have a particularly strong relationship to future trends.

Current Sponsors, Supporters, and Endorsers

21-CR Sponsors*

- U.S. Department of Energy (DOE)
- Air-Conditioning & Refrigeration Institute (ARI)
- Copper Development Association (CDA)
- New York State Energy Research and Development Authority (NYSERDA)
- California Energy Commission (CEC)

21-CR Supporters*

- Refrigeration Service Engineers Society (RSES)
- Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI)

21-CR Endorsers

- Air Conditioning Contractors of America (ACCA)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc. (ASHRAE)
- Association of Home Appliance Manufacturers (AHAM)
- Edison Electric Institute (EEI)
- Energy Center of Wisconsin (ECW)
- Geothermal Heat Pump Consortium (GHPC)
- Iowa Energy Center (IEC)
- Plumbing-Heating-Cooling Contractors (PHCC) National Association
- Thermal Technology Center (TTC), National Research Council Canada (NRC)

*List in order of contribution %

Expanding The Offer

The demise of commodity HVACR

This theme focuses on innovations that increase the value received from our products and services. We need to respond to energy concerns and regulatory responses that can expand the market for higher-performance comfort system solutions.

Systems must become responsive to real-time energy costs and take advantage of multiple fuel sources, waste heat, local power generation, and load shifting. Cooling, heating, and power generation systems will become integrated systems for a number of applications. In fact, building design increasingly will become a process that simultaneously considers the structure's design, its envelope, the HVAC systems, lighting, and other energy and load generation systems to achieve high performance, comfort, and productivity.

Our society is becoming more concerned about quality-of-life issues. This means that the relationships among indoor air quality parameters, comfort, and human productivity in a number of settings must be studied and better understood. The best commercial and residential systems will control humidity and temperature independently under all load and ambient conditions. We will be required to provide better air treatment in tighter spaces. Health issues associated with the indoor environment will increase in importance. We will have to give attention to securing buildings and homes from biological or chemical assaults.

New controls and sensors will be developed to deliver high IEQ while minimizing energy consumption. Natural ventilation will be used together with mechanical conditioning.

Equipment-generated noise will become a quality-of-life issue. Quieter equipment is perceived to be quality equipment, justifying higher costs for product differentiation.

Buildings generally outlive their original HVACR systems. Buildings are also subject to changing patterns of use in their interior spaces. Both situations create needs for retrofit/replacement equipment and services. Research needs for replacement systems may sometimes be different than for new buildings and new HVACR systems.

Some research examples include:

- Documenting the benefits of healthy, productive environments and developing the means to provide them
- Improved installations through integration of building architecture and mechanical systems
- Equipment designs tailored to reduce energy use in replacement/retrofit applications.

Mass Customization

Creating and satisfying a better-informed customer

HVACR users are developing higher expectations in areas such as choice, comfort, health, safety, efficiency, and reliability. Characteristics of these more demanding users include:

- Likely to use information technology to search for product-related information in a variety of places. As a result, users

are better informed and more involved with purchasing decisions, and users will examine a wider range of alternatives before buying a product.

- Less likely to be swayed by the influence of others, whether it is a company or a brand, because they are better educated and informed.

This means that new systems of the future will be customized for owners or users. Many options will be available and systems will be tailored to specific applications to achieve the best performance. Computer models will be needed to allow customers to compare the benefits of different combinations of energy sources, equipment combinations, and control approaches for their unique applications and load characteristics. The models are essential to show the customer the additional value they will receive by investing in high-end systems. Therefore, these models must generate accurate estimates of life-cycle cost for each system alternative and level of desired indoor environmental quality.

The models must allow the customer to compare systems using equipment from many sources, and must be easy to update as new equipment or control strategies become available. They will require data on equipment performance based on tests in the laboratory or in field installations. A standard format for generating and certifying data for models may be required.

The characteristics of our increasingly influential and involved users have led to a number of research recommendations. For example:

- Analysis tools to support HVACR system comparison and selection
- Decision tree/matrix tool that compares alternative current and new HVACR technologies
- Projects to document alternative system design strategies and their energy, comfort, and environmental advantages
- Expert systems and analysis tools focusing on life-cycle cost to "sell" value-added products.

Keeping It All Together

Technologies changing the scope of the business and the ways end users are served

Information technologies are radically transforming business processes and changing the interaction between product suppliers, customers, and end users. HVACR infrastructure opportunities related to customer support and delivery/installation/maintenance systems are expanding. At the same time, we need to maintain system efficiencies and avoid downtime, all with a limited skilled-labor force. While systems actually become more complex, they must appear to be simpler to operate to the user.

Demand will grow for common communication protocols across the industry, with components from any vendor able to "plug and play" with those of other vendors. System controls must be easy to set up, commission, and continue to reprogram without extensive training. Operators will routinely use the Internet to check control settings and make changes remotely if desired.

Expert systems will be applied to monitor HVACR system operation and predict when maintenance will be needed. In the event of a breakdown, the expert system will diagnose the nature of the problem and alert service personnel, perhaps through the Web, to respond with the right repair parts. Instructions will be available on-line to show how to make the repair. The expectation will be that problems will be fixed on the first call.

We will need to address the educational needs to support future HVACR equipment. Operators and service personnel need to understand the system's functions and purpose, installation procedures, and service requirements if optimum performance is to be achieved. The education and training will need to include IEQ control as well as basic HVACR system operation.

Research Results Becoming Available

Many of the early 21-CR projects are nearing completion, and final reports are becoming available in each of the five focus areas. Reports may be downloaded for free from the ARTI Web site (www.arti-21cr.org). The Web site also describes each project (i.e., objectives, information expected, how results are likely to be applied, contractor identification, and brief status).

Some research examples identified during the planning process include:

- System commissioning — upfront and continuous
- System self diagnostics and prognostics
- "Plug-and-play" components for refrigeration equipment
- Technologies that ensure peak performance of systems under all operating conditions
- Expert systems that support lower service and maintenance skill levels.

Emerging Global Marketplace For Commercial Refrigeration

Creating new business opportunities; influencing value delivered

The growing number of democratic countries that increasingly participate in international trade exchange enhances opportunities for the HVACR industry to flourish in new global markets. Food preservation and transportation is a good example of a global market with excellent growth potential.

Commercial refrigeration equipment will need to be capable of using varied energy resources. Refrigeration must be maintained effectively when the primary source is interrupted or becomes unavailable. Better capability to use off-peak energy is needed.

To supply high-quality food to consumers, equipment must have the capability to monitor and control temperature, humidity, and perhaps the atmosphere surrounding the food. A seamless product history should be generated throughout the process from grower to consumer. Refrigeration systems should be adaptable to provide a variety of foods when, where, and how consumers want those foods.

System controls should be easy to install and operate. The external appearance of refrigeration equipment should exude quality to bolster consumer confidence.

As is the case for comfort conditioning systems, computer models will be needed for commercial refrigeration systems to allow customers to compare systems of different types with respect to performance and life-cycle cost. These computer models will show the value of new technologies and new features.

Computer models may be able to help users optimize system performance during the pull-down and holding

of food in refrigerated containers. Models may also be able to optimize food transportation steps.

Refrigeration equipment for the global market must be designed to require lower skill levels for installation, operation, maintenance, and decommissioning. Expert systems will allow monitoring of system operation, call for preventive maintenance, and detect system breakdowns and their causes. Expert systems also can guide service people through the steps required to repair the systems and put them back in service. The Internet can be a communication vehicle for service and operating personnel. However, components will be required to use common communication protocols and permit easy installation ("plug-and-play").

We need to elevate the status of refrigeration service personnel and create incentives for people to choose refrigeration as a career. Accessible, effective teaching aids, training tools, and programs are needed.

Strategies may be developed to broaden the food refrigeration industry to encompass food preservation in general. This would improve the industry's market reach and prepare for situations in the future where refrigeration may be impractical.

Some of the research opportunities that were identified are:

- Alternative food preservation techniques for end users who have uncertain energy availability
- Development of reusable cold containers to provide portable refrigeration for third world areas that have limited power grids
- Change in food packaging designs/containers that enable dehydration before shipment overseas
- Develop a surface coating for food products to increase food safety and storage life.

Sustainability

Moving from selling heating and cooling boxes to ecosystem services

Sustainability is defined by the United Nations World Commission on Environment and Development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." To meet this commitment and prosper, our industry must broaden its thinking. The goal of eco-efficiency is to reduce the ecological costs of a product or service. At the heart of this emerging requirement is a systems point of view that considers the impact products have on the environment and natural resources from "birth" to "death."

Many decision makers will come to prefer environmentally responsible products, systems, and services. Additionally, regulations will be imposed and will have to be met. We need to expand explorations of system solutions that minimize impact on the environment. These solutions may include new working fluids, systems that do not leak, and systems that use the most environmentally friendly energy sources. Choices need to be made with intelligent input from computer models that evaluate life-cycle energy consumption, environmental impact, and risks.

"We need to expand explorations of system solutions that minimize impact on the environment."

We may need to provide HVACR equipment that requires fewer natural resources to manufacture. Possible solutions include new cooling technologies and new system architectures such as distributed systems or the use of secondary coolant loops. We will need to consider disposal of equipment, including recovery of resources where possible. We will need to design equipment with consideration for disassembly and recycling. Facilities may be needed for the disassembly and recovery process, and the destruction of elements that are environmentally undesirable. Can recycled content be used in new products in the future?

Here are a few examples of research relating to the theme of sustainability:

- Reduction of waste (materials, energy, chemical byproducts, and atmospheric emissions) generated from manufacturing HVACR products
- Sensor technology and controls that increase the reliability of HVACR products, detect refrigerant leaks, and notify the end user when energy use exceeds expectations
- Invent systems that use less new energy (e.g., utilize waste heat).

What Happens Next?

The material generated from the strategic planning process will form the basis for a future-oriented research agenda. ARTI members are identifying efforts that 21-CR is best suited to address, and those that would be better served by other organizations.

In 2002, the ARTI 21-CR Subcommittees will use the reports generated from the planning process to identify/prioritize efforts that should be undertaken during the next five years. The 21-CR Steering Committee will review and coordinate these "mini" research plans to minimize gaps and overlaps. The result will be a five-year actuation plan.

The two reports that summarize the planning process may be downloaded free from www.arti-21cr.org. ■

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