

U.S. HVAC&R RESEARCH PROGRAMS

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ABSTRACT

This paper presents an overview public and public-private sector HVAC&R research programs in the United States.

Key Words: *HVAC&R research, ASHRAE, ARI, ARTI, ASERTTI, ASHRAE, CEC, DOE, HUD, MCLR, NYSERDA, PATH, PIER, 21CR*

1 INTRODUCTION

1.1 Funding Organizations vs. Research Organizations

In reviewing HVAC&R research programs in the U.S. it is important to understand the roles and relationship between funding organizations and organizations that actually perform the research. The funding organizations generally define what areas of research are to be funded - while the research organizations generally perform the research for the funding organizations. There is of course some interplay between the two in defining research to be conducted. Many funding organizations have developed technology roadmaps outlining the path from research to product development and market transformation. In many cases these roadmaps are developed with input from the research, manufacturing and regulatory sectors.

Funding organizations are generally federal or state governmental agencies, technical societies, or trade organizations. The U.S. Department of Energy (DOE), the U.S. Department of Housing and Urban Development (HUD), the U.S. Environmental Protection Agency (EPA), the Department of Defense (DoD) are examples of federal funding agencies. The California Energy Commission (CEC) and the New York State Energy Research and Development Authority (NYSERDA) are examples of state funding agencies. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) and ARI's research arm the Air-Conditioning and Refrigeration Technology Institute (ARTI) are examples of technical society and trade association funding organizations.

Each funding organization may have its own focus or slant on the research to be conducted. The U.S. Department of Energy and state energy agencies, like CEC and NYSERDA, generally focus on energy. Their HVAC&R research programs are targeted towards development of more energy efficient systems or systems that reduce peak electric power loads. The EPA on the other hand might focus more on indoor air quality in buildings, and HUD might focus more on affordable housing. Technical societies, such as ASHRAE, tend to have a broader range of research interests. Trade associations tend to support research that will prepare their members for developing successful products for tomorrow's market place.

Research organizations generally include the national laboratories, universities, private-sector research laboratories and engineering consulting firms.

DOE has a number of national laboratories, the following of which perform HVAC&R research.

- Brookhaven National Laboratory (BNL)
- Lawrence Berkeley National Laboratory (LBNL)
- Oak Ridge National Laboratory (ORNL)
- National Renewable Energy Laboratory (NREL)
- National Energy Technology Laboratory (NETL)
- Pacific Northwest Laboratory (PNL)

The U.S. Department of Commerce also has a “national” laboratory, the National Institute of Standards and Technology (NIST) with campuses at Gaithersburg, Maryland and Boulder, Colorado. Much of NIST’s work on HVAC&R and building systems research is conducted by the Building and Fire Research Laboratory in Gaithersburg. Thermophysical and transport properties measurements of refrigerants are conducted at NIST’s Boulder Colorado campus.

The General Services Administration is responsible for most of the buildings occupied by the federal government and typically sponsors research to characterize the performance and/or indoor air quality of those buildings. The Department of Defense also has a number of laboratories. The Army Corps of Engineers is generally responsible for the planning and construction of buildings on government installations, while much of the research on air-conditioning and refrigeration systems for ground tactical vehicles and equipment is done at Fort Belvoir, Virginia. NASA and the U.S. Navy also conduct research and develop specialized equipment for use in spacecraft and naval vessels.

Many universities in the U.S. have capabilities to conduct a broad range of HVAC&R research and are often used to industry and industry-government sponsored research.

1.2 Driving Factors for Collaborative HVAC&R Research

In recent years there have been a number of driving factors for collaborative HVAC&R research. They can be grouped into three general categories - environmental concerns, electric power grid reliability concerns, and indoor environmental quality concerns. These drivers have spawned collaborative research in several specific areas as identified below.

Environment Concerns - Ozone Depleting Substances (ODS) Greenhouse Gases and Global Warming Potential (GWP)

- Development and use of more environmentally benign refrigerants
- Systems with smaller refrigerant charges
- Tighter systems and leak detection equipment
- Development of recovery and recycling equipment
- Assessment of alternative cooling technologies – thermoacoustic, thermoelectric, water-vapor, magnetocaloric, etc.
- Energy efficiency improvements to HVAC&R component - compressors, heat exchangers and other components

Electric Power Grid Reliability - Peak Electric Load

- Higher efficiency of HVAC&R equipment at high temperature/peak load conditions
- Load shifting alternative to alternative energy sources
- Load shifting through thermal storage
- Better integration of HVAC with buildings/homes
 - Load reduction through tighter insulated building envelopes
 - More efficient thermal distribution systems
 - Reducing internal heating/cooling loads

Indoor Environmental Quality – Comfort, Productivity, and Health of Building Occupants

- Moisture and condensation control for control of indoor mold
- Mold detection technology
- Detection and inactivation, neutralization, dilution or removal of indoor air pollutants:
 - Bioaerosols and allergens
 - Carbon dioxide
 - Carbon monoxide from combustion appliances
 - Volatile organic compounds (VOC)
 - Fine particulates
- Reduced indoor noise levels
- Thermal comfort
- Energy efficient means of providing increased ventilation rates

2 KEY HVAC&R RESEARCH PROGRAMS AND FUNDING ORGANIZATIONS

2.1 U.S. Department of Energy

The U.S. Department of Energy (DOE) is the federal government's largest funders for public-private collaborative HVAC&R research. That effort is centered in the Office of Energy Efficiency and Renewable Energy's (EERE) Building Technologies Program. This program works with the building industry and HVAC&R manufacturers to sponsor research and development on energy efficient technologies and practices. Research under this program may be conducted by several national laboratories, universities, commercial research organizations, or research consortia through open solicitations, grants and cooperative agreements.

DOE, working with industry and other stakeholders, has developed several Roadmaps to guide research in selected technology areas:

- *Vision 2020: The Lighting Technology Roadmap* (March 2000)
- *High Performance Commercial Buildings - a technology Roadmap* (October 2000)
- *Building Envelope Technology Roadmap* (May 2001)
- *Solar and Efficient Water Heating* (Draft 2005)

For HVAC&R technology research DOE sites the industry developed roadmap – *Basic Research Driving the Future of America's Heating, Ventilation, Air Conditioning and Refrigeration Technologies* (November 2004) – published by the Air-Conditioning and Refrigeration Technology Institute (ARTI).

The joint development of technology roadmaps help to articulate research goals and provide the groundwork for focusing public-private research efforts.

Open solicitations under the Building Technologies Program are normally issued by the National Energy Technology Laboratory (NETL). Those solicitations seek proposals for innovative technologies that have the potential for significant energy savings in residential and commercial buildings, by supporting projects that advance energy efficient equipment, envelope, and whole building technologies. The objective this program is to accelerate high-payoff technologies that, because of their risk, are unlikely to be developed in a timely manner without a partnership between industry and the Federal government. In 2004, NETL had approximately \$11 million available for research in the following four areas:

- Building Envelope

- Space Conditioning, Water Heating and Appliances
- Lighting
- Whole Buildings

Putting Research and Technology into Practice

The U.S. Department of Energy has a number of programs to assist in moving technology from the laboratory into buildings and homes.

Zero Energy Homes (ZEH) is a DOE research initiative that combines state-of-the-art energy-efficient construction and appliances with commercially available renewable energy systems, such as solar water heating and solar electricity, with the objective of net zero energy consumption. The ZEH initiative capitalizes on the expertise and technology that already exists within DOE and its industry partners to dramatically reduce the amount of energy consumed by single-family homes. Only about 10% of new homes in the United States are built significantly above the minimum efficiency standards. The ZEH initiative seeks to build more homes that perform at least 50% more efficiently than those built to current minimum efficiency standards, while also increasing the number of new homes that can meet their own energy needs. One key to the reducing energy consumption in homes is to build tighter, better insulated homes that result in reduced heating and cooling load requirements.

Building America works with members of the home-building industry to produce quality homes that use less energy without costing more to build. Building America program views the house as a system and then looks at re-engineering that house; rather than making isolated changes in one part of the house. It also brings together all segments of the housing industry: designers, builders, developers, financial institutions, materials suppliers and equipment manufacturers. The Building America goals are to:

- Design and construct more energy efficient homes
- Reduce construction costs to provide more affordable housing
- Improve comfort
- Improve health and safety and indoor air quality
- Increase resource use efficiency
- Increase building durability

Rebuild America is a growing network of community-driven voluntary partnerships that foster energy efficiency and renewable energy in commercial, government and public-housing buildings. The program's goals are to: conserve energy, accelerate the use of the best energy technologies, save money, reduce air pollution, lower U.S. reliance on energy imports, help revitalize aging city and town neighborhoods, and create "smart energy" jobs. Rebuild America works to overcome market barriers that inhibit use of the best technologies through:

- Disseminating knowledge
- Developing projects to stimulate market change
- Providing analyses and advice in support of the best technologies
- Developing networks with state and local governments and the private sector

2.2 U.S. Department of Housing and Urban Development (HUD)

Partnership for Advancing Housing Technology (PATH) provides funding to spur innovative background research, which includes conducting technical investigations and creating new areas of knowledge or actual products, including innovation in housing materials, systems, construction processes, and management techniques. PATH sponsors research on advanced housing technologies that support PATH strategic goals in the areas of affordability, durability, disaster resistance, safety, quality, and energy efficiency and environmental impact. A number of universities are partners in the PATH program:

- Clemson University
- Massachusetts Institute of Technology
- Michigan State University, Construction Management Program
- Michigan State University: Housing Education and Research Center
- Penn State University: Pennsylvania Housing Research Center
- Purdue University
- University of Central Florida
- University of Missouri-Rolla
- University of Southern California
- Villanova University
- Virginia Polytechnic Institute and State University: Virginia Center for Housing Research

2.3 California Energy Commission

One of the largest state run research programs is the California Energy Commission's Public Interest Energy Research (PIER) program. The PIER program supports energy research, development and demonstration (RD&D) projects that will help improve the quality of life in California by bringing environmentally safe, affordable and reliable energy services and products to the marketplace. The PIER program annually awards up to \$62 million for research through partnerships with RD&D organizations including individuals, businesses, utilities, and public or private research institutions. PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy Innovations Small Grant Program
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally-Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies

HVAC&R research under the PIER program normally falls within the area of Building End-use Energy Efficiency.

2.4 New York State Energy Research and Development Authority

The New York State Energy Research and Development Authority (NYSERDA) is a public benefit corporation created by the New York State Legislature. NYSERDA has conducted a multifaceted energy and environmental research and development program since its inception in 1975. NYSERDA's research and development program supports the development and commercialization of innovative energy and environmental products, technologies, and processes that improve the quality of life for New York's citizens and help New York businesses to compete and grow in the global economy.

NYSERDA research and development activities in five primary program areas:

- Energy Resources
- Transportation and Power Systems
- Environment
- Industry
- Buildings

NYSERDA issues annual or periodic project solicitations for innovative building technologies in the following areas:

- Heating and Cooling - to develop and commercialize innovative, energy efficient environmentally-friendly heating and cooling technologies for the home and business. New products include a high-efficiency, pulse combustion, gas-fired, commercial boiler; a 95% efficient, aluminum, gas-fired residential boiler; fluorescent leak detection technologies for air conditioning systems; and an electric heat pump water heater.
- Lighting - to develop energy-efficient lighting products, such as fixtures to accommodate high efficiency light sources, fiber-based plasma display panels, photovoltaic-powered exterior fixtures, and ultraviolet germicidal systems. NYSERDA also partners with the Rensselaer Polytechnic Institute's Lighting Research Center (LRC), assisting manufacturers with programs such as the National Lighting Product Information Program (NLPIP), Design and Evaluation of Lighting Technologies and Applications (DELTA), the Hybrid Skylight Program, and numerous training seminars.
- Building Envelope – to develop new building construction products, such as advanced windows, panelized wall systems, and industrialized construction methods. Other projects include integrated systems to optimize building energy and environmental impacts, such as building-integrated solar technologies and advanced indoor air quality systems.
- Controls and Meters – to develop and demonstrate innovative control, sensor, and metering technologies for residential and commercial building systems. Technologies seek to improve power quality, reliability, and efficiency, as well as the indoor environment, such as variable speed air conditioners, wireless submeters, remote HVAC diagnostic equipment, advanced indoor environmental quality monitors, web-enabled systems for price sensitive load management, and power quality and conditioning equipment.
- Distributed Generation/Combined Heat and Power – to promote innovative distributed generation applications - the on-site generation of electricity. In particular, the program promotes combined heating and power (CHP) -- electric generation from heat recaptured from space or domestic water heating.

2.5 Association of State Energy Research and Technology Transfer Institutions (ASERTTI)

Several other states also have their own research programs, work jointly on federally funded cooperative programs, or through research consortia such as the Association of State Energy Research and Technology Transfer Institutions (ASERTTI). ASERTTI was established in 1990. Its mission is to increase the effectiveness of energy research efforts in contribution to economic growth, environmental quality, and energy security. ASERTTI does this by collaborating on research projects with state, federal, and private partners and by sharing technical and operational information among members and associates. While ASERTTI works with the National Association of State Energy Offices (NASEO), ASERTTI does not officially represent the governors, though some ASERTTI members are also State Energy Offices (SEO). ASERTTI activities include applied research, technology development, demonstration and deployment, with a strong interest in end use efficiency and conservation and supply side interests, including fossil fuels and renewable resources.

2.6 The American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE)

ASHRAE is a technical society whose mission is to advance the arts and sciences of heating, ventilation and, air conditioning, refrigeration, and related human factors to serve the evolving needs of the public and ASHRAE members. ASHRAE membership is comprised of individuals. ASHRAE has been a long standing sponsor of HVAC&R research. Since the 1960's, ASHRAE has funded more than 1300 research projects [ASHRAE Insights – Dec 2004]. ASHRAE annual research budget is between \$2 and \$3 million per year. For its 2004 fiscal year, it was budgeted at \$2,185,837. The research program supports the needs of over 100 of ASHRAE technical committees. To provide overall direction for its research priorities, ASHRAE formed its Research Advisory Panel in 1999. This panel has conducted a number of workshops to develop its Strategic Plan for Research, which will be finalized in 2005. The ASHRAE Strategic Plan for Research will identify goals for the following broad research opportunity themes:

- Energy and Sustainability
- Indoor Environmental Quality
- Tools and Applications
- Equipment, Components and Materials

2.7 National Center for Energy Management and Building Technologies (NCEMBT)

The National Center for Energy Management and Building technologies (NCEMBT) is a relatively new organization focusing on building energy performance, indoor environmental quality, and building security. The NCEMBT was organized in 1999. Its partners include: the U.S. Department of Energy; University of Nevada at Las Vegas (UNLV); the National Energy Management Institute (NEMI); University of Illinois at Chicago (UIC); the Building Diagnostics Research Institute (BDRI); the International Training Institute (ITI); the Sheet Metal Workers' International Association (SMWIA); and the Sheet Metal and Air Conditioning Contractors National Association (SMACNA). In the past two years it has launched several projects including measurement and verification of building performance characteristics; underfloor air distribution application testing; high performance/zero energy buildings in cold climates; Integrated advanced humidity controls to reduce energy; reduced energy use through the reduced indoor contamination in commercial and residential buildings; practical scheduled maintenance for energy reduction

2.8 ARI and ARTI Research Programs

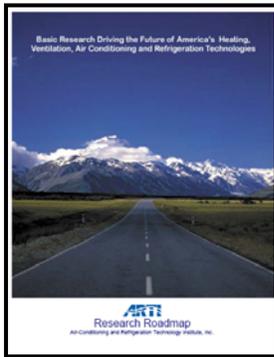
The Air-Conditioning and Refrigeration Institute (ARI) is a North American association of HVAC&R equipment manufacturers. Its members are manufacturing companies. With over 200 member companies, ARI members manufacture over 90% of the air conditioning and commercial refrigeration equipment produced in North America. Primarily formed for the establishment of industry performance standards and certification programs, ARI also supports and directs industry cooperative research. This research may be wholly funded by its own members or jointly funded in public-private programs managed by the Air-Conditioning and Refrigeration Technology Institute (ARTI). Since 1991 ARI and ARTI have directed a number of major research efforts.

The ARTI Material Compatibility and Lubricants Research (MCLR) program was a 10-year, \$10.8 million cooperative research program between industry and the U.S. Department of Energy that began in 1991. Its objective was to provide basic research needed to assist the HVAC&R industry in phasing out the use of ozone depleting CFC refrigerants. As the name indicates, the primarily focus of this program was to examine and solve material compatibility and lubricant issues associated with the introduction of

HCFC and HFC refrigerants. An industry Advisory Committee provided the direction and oversight of research that was subcontracted to universities, national laboratories and commercial research organizations. Forty-seven projects were completed under the MCLR program leading the way for the successful phase out of CFC refrigerants in the U.S.

The ARI Alternative Refrigerant Evaluation Program (AREP) was an industry cooperative research program that included HVAC&R equipment manufacturers from the North America, Asia and Europe. Under this program manufacturers conducted performance screening tests on a number of proposed refrigerants and refrigerant blends designed to replace R-22 and R-502 in a broad range of applications. This program was unique in that the manufacturers divided up the refrigerants to be tested among themselves and then shared results with each other. This program identified several refrigerant blends that have since gained widespread acceptance by manufacturers to include R-134a, R-407C, R-404A, and R-410A.

HVAC&R Research for the 21st Century (21CR) is an industry-government cooperative research program with funding provided by industry associations, state energy agencies and the U.S. Department of Energy. This six-year program (1999-2005) addressed a board range research in five areas: energy efficient equipment, working fluids, system integration, indoor environmental quality and emerging technology. An industry-government Steering Committee and over 80 technical experts provided the direction and oversight of research that was subcontracted to a number of universities, national laboratories and commercial research organizations. Forty-five projects were launched under this program. The program is coming to a conclusion at the end of 2005.



The ARTI Research Program is industry's latest program for cooperative research. This program is currently funded by the Air-Conditioning & Refrigeration Institute (ARI), the Copper Development Association (CDA), the Heating, Refrigeration and Air Conditioning Institute (HRAI) and the New York State Energy Research and Development Authority (NYSERDA). The ARTI Research Roadmap outlines ambitious goals in four market sectors, with additional subgoals in each sector. The roadmap serves as a guide, not only for ARTI sponsored projects, but also for others as well. Under the ARTI Research Program, a concerted effort is being made to co-sponsor research projects with other organizations.

HVAC&R Research Sector Goals

	<p>Residential Buildings</p> <p>Achieve a 50% reduction in HVAC&R annual energy consumption and peak electric energy demand in new buildings by 2020.</p>
	<p>Commercial Buildings</p> <p>Realized energy consumption and peak energy demand reductions of 25% in new buildings by 2020.</p>
	<p>Refrigeration</p> <p>Reduce refrigerant leakage in supermarkets refrigeration systems by 90% and reduce energy consumption in supermarkets by 25% by 2020.</p>
	<p>Emerging Technologies</p> <p>Continually review and monitor research in the HVAC&R arena and elsewhere for breakthroughs that could contribute to achieving the roadmap's goals.</p>

3 CONCLUSIONS

Even though federal funding for HVAC&R research programs has been declining since 911, the U.S. still has vibrant and active programs for collaborative public-industry HVAC&R research. The development of industry technology roadmaps has helped to articulate and focus those research programs. The expanding use of internet-based websites have aided in rapidly disseminating research information and made coordination efforts among the various research sponsors much easier.

4 REFERENCES AND WEB LINKS

- ARTI, *Basic Research Driving the Future of America's Heating, Ventilation, Air Conditioning and Refrigeration Technologies* (November 2004)
- DOE, *Vision 2020: The Lighting Technology Roadmap* (March 2000)
- DOE, *High Performance Commercial Buildings – A Technology Roadmap* (October 2000)
- DOE, *Building Envelope Technology Roadmap* (May 2001)
- DOE, *Solar and Efficient Water Heating* (Draft 2005)

4.1 Links to HVAC&R Related Trade Organizations and Technical Societies

Air-Conditioning and Refrigeration Institute (ARI) <http://www.ari.org>

Air-Conditioning and Refrigeration Technology Institute (ARTI) <http://www.arti-research.org>

Air Conditioning Contractors of America (ACCA) <http://www.acca.org/>

Air Movement and Control Association International (AMCA) <http://www.amca.org/>

Alliance for Responsible Atmospheric Policy (Alliance) <http://www.arap.org/>

American Council for an Energy-Efficient Economy (ACEEE) <http://aceee.org/consumerguide/>

American Council of Engineering Companies (ACEC) <http://www.acec.org/>

American Indoor Air Quality Council (IAQ Council) <http://www.iaqcouncil.org/>

American Society of Civil Engineers (ASCE) <http://www.asce.org/>

American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
<http://www.ashrae.org>

ASHRAE Research

<http://www.ashrae.org/template/TechnologyLinkLanding.jsessionid=aaa954L77p1Gk5?category=1596>

Architectural Engineering Institute (AEI) <http://www.aeinstitute.org/intro.cfm>

Association of Home Appliance Manufacturers (AHAM) <http://www.aham.org/>

BACnet Manufacturers Association <http://www.bacnetassociation.org/>

Civil Engineering Research Foundation (CERF) <http://www.cerf.org/indexjs.htm>

Consortium for Energy Efficiency (CEE) <http://www.cee1.org/>

Continental Automated Buildings Association (CABA) <http://www.caba.org/>

Copper Development Association (CDA) <http://www.copper.org/>

Council on Tall Buildings and Urban Habitat <http://www.ctbuh.org/>

Gas Appliance Manufacturers Association (GAMA) <http://www.gamanet.org/>

Home Ventilating Institute (HVI) <http://www.hvi.org/>

Hydraulic Institute <http://www.pumps.org/index.html>

Indoor Air Quality Association (IAQA) <http://www.iaqa.org/>

International Council of Air-Conditioning and Refrigeration Manufacturers' Association (ICARMA)
<http://www.icarma.org/index.shtml>

Global Refrigerant Environmental Evaluation Network (GREEN) <http://www.icarma.org/green/>

International Institute of Ammonia Refrigeration (IIAR) <http://www.iiar.org/>

International Institute of Refrigeration (IIR) <http://www.iifir.org/>

National Association of Home Builders (NAHB) <http://www.nahb.org/>
NAHB Research Center
<http://www.nahbrc.org/index.asp?category=0&TrackID>

National Center of Energy Management and Building Technologies (NCEMBT) <http://www.ncembt.org>

National Energy Management Institute (NEMI) <http://www.nemionline.org/>

National Electrical Manufacturers Association (NEMA) <http://www.nema.org/>

North American Insulation Manufacturers Association (NAIMA) <http://www.naima.org/main.html>

Plumbing-Heating-Cooling Contractors National Association (PHCC) <http://www.phccweb.org/>

Refrigeration Service Engineers Society (RSES) <http://www.rses.org/>

Sheet Metal and Air Conditioning Manufacturers' National Association (SMACNA) <http://www.smacna.org/>

Society of Automotive Engineers International (SAE) <http://www.sae.org/servlets/index>

Sustainable Buildings Industry Council (SBIC) <http://www.sbicouncil.org/>

The Infrastructure for Security Partnership (TISP) <http://www.tisp.org/>

4.2 Intergovernmental

Intergovernmental Panel on Climate Change (IPCC)
IPCC Data Distribution Center <http://ipcc-ddc.cru.uea.ac.uk/>

International Energy Agency (IEA) <http://www.iea.org/>

IEA Heat Pump Program
IEA Heat Pump Centre <http://www.heatpumpcentre.org/>

US National Team IEA Heat Pump Program http://www.ornl.gov/sci/engineering_science_technology/usiea/

United Nations Environmental Program (UNEP) <http://www.unep.ch/>

4.3 U.S. Federal Agencies

Federal Research Search Engines

Government Science Portal – Science.gov <http://www.science.gov/>

DOE Office of Scientific and Technical Information (OSTI)
Information Bridge <http://www.osti.gov/bridge/>

U.S. Department of Energy
DOE Energy Efficiency and Renewable Energy <http://www.eere.energy.gov/>

DOE Commercial Buildings Energy Consumption Survey (CBECS)
<http://www.eia.doe.gov/emeu/cbecs/contents.html>

DOE National Labs

Brookhaven National Lab (BNL) <http://www.bnl.gov/world/>
Lawrence Berkeley National Lab (LBNL) <http://www.lbl.gov/>
National Energy Technology Lab (NETL) <http://www.netl.doe.gov/>
National Renewable Energy Lab (NREL) <http://www.nrel.gov/>
Oak Ridge National Lab (ORNL) <http://www.ornl.gov/>
Pacific Northwest National Laboratory (PNL) <http://www.pnl.gov/>

U.S. Department of Commerce

National Institute of Standards and Technology (NIST) <http://www.nist.gov/>
NIST Virtual Library <http://nvl.nist.gov/>

NIST Laboratories http://www.nist.gov/public_affairs/labs2.htm

Building and Fire Research Lab (BFRL) <http://www.bfrl.nist.gov/>
Chemical Science and Technology Lab <http://www.cstl.nist.gov/>
Electronics and Electrical Engineering Lab <http://www.eeel.nist.gov/>
Information Technology Lab <http://www.itl.nist.gov/>
Manufacturing Engineering Lab <http://www.mel.nist.gov/>
Material Sciences and Engineering Lab <http://www.msel.nist.gov/>
Physics Lab <http://www.physics.nist.gov/>

Federal Emergency Management Administration (FEMA) <http://www.fema.org/>

U.S. Environmental Protection Agency (EPA) <http://www.epa.gov/>

EPA Research Programs <http://www.epa.gov/epahome/program2.htm>
EPA Indoor Air Quality <http://www.epa.gov/iaq/>

U.S. Housing and Urban Development (HUD) <http://www.hud.gov/>

Partnership for Advancing Technology in Housing (PATH) <http://www.pathnet.org/index.asp>
ToolBase Services <http://www.toolbase.org/index-toolbase.asp>

U.S. Department of Health and Human Services <http://www.hhs.gov/>

Center of Disease Control and Prevention (CDC) <http://www.cdc.gov/>
National Institute for Occupational Safety (NIOSH) <http://www.cdc.gov/niosh/homepage.html>

National Science Foundation (NSF) <http://www.nsf.gov/>

NSF Engineering Research Centers <http://www.nsf.gov/pubs/2000/nsf00137/start.htm>

4.4 State Agencies

Association of State Energy Research and Technology Transfer Institutions (ASERTTI)

<http://www.asertti.org/>

California Energy Commission <http://www.energy.ca.gov/>

Research Info <http://www.energy.ca.gov/research/index.html>
Public Interest Energy Research (PIER) <http://www.energy.ca.gov/>

New York State Energy Research and Development Authority (NYSERDA) <http://www.nyserda.org/>

4.5 University Research Centers

Center for the Built Environment

University of California Berkeley's Building Science Laboratory <http://www.cbe.berkeley.edu/>

Center for Environmental Energy Engineering (CEEE)

University of Maryland <http://www.enme.umd.edu/ceee/>

National Building Controls Information Program (NBCIP)

Iowa Energy Center, Iowa State University <http://www.buildingcontrols.org/>

The Ray W. Herrick Laboratories

Purdue University

<http://www.ecn.purdue.edu/Herrick/Welcome/index.whtml>