Chapter 7

The 1980s: Rapid Technology Development and Growth of an Industry

Program reviews at the end of the '70s indicated FSEC would need to broaden its technological agenda beyond solar thermal. So, in the early '80s, FSEC initiated and began to pursue support for programs in two technology areas with significant promise – photovoltaics and energy-efficient building design. With these programs active and growing by the mid '80s, FSEC began its hydrogen program. All three programs continue their vitality in large part because they attracted a number of talented staff members, who are noted in this chapter. They also set the base for future programs and activities.

The following review of FSEC during the '80s follows two tracks – the first covers technology programs, the second addresses state-related activities. The state activities of the 1980s also include initiation of the new building and site relocation, a most important part of FSEC's development.

Photovoltaics Program

Review of FSEC programs during the '80s begins with photovoltaics (PV) – the solar technology that then showed and still shows today the greatest promise for solar electrical generation in Florida.

PV House

PV research at FSEC began in earnest in June 1979, when staff undertook a feasibility study to determine the appropriateness and cost of designing and constructing an experimental photovoltaic residence on the Cape Canaveral site.

The concept of the PV house originated with PV staffers Art Litka, Jerry Ventre and Subrato Chandra, who took the idea to the Center Director. Initially, cost and funding appeared to be barriers. However, it became clear the concept had potential to provide FSEC with solid experience in the technology, with resulting public visibility and participation in the national R&D community. So, the administration decided to commit operating budget funds to construct the building and install the PV array.

FSEC staff began construction of the panelized house on the Cape site in early 1980. By December of that year, the house was completed, and its 5-kilowatt PV installation was ready for operation.

One goal of the PV house was to provide the first national data on the long-term reliability and performance of grid-connected photovoltaic systems. This was just the second PV house in the U.S. The first was built by John Long in Phoenix. Yet the FSEC

"Work day" of Governor Bob Graham during visit to FSEC (July 1980)

"Work day" of Governor Bob Graham during visit to FSEC (July 1980)

PV house under construction (January 1980)

PV house operated for a total of 15 years, until FSEC left the Cape Canaveral site in 1995. In contrast, Long's house operated with PV power only for three years, after which the PV system was removed and the house sold. The FSEC PV house holds the record as one of the best-performing PV systems throughout the world.

The five-peak-kilowatt photovoltaic system installed on the roof of the three-bedroom, panelized construction house comprised 168 ARCO Solar PV modules, each containing 35, four-inch-diameter solar cells (ARCO later became Siemens and is now owned by Shell). The PV system was designed to be utility interactive and to supply the house with about 8,000 kWh annually. The direct-current PV energy was converted to 60-cycle, line-synchronized alternating current through two four-kilowatt Gemini inverters. No on-site storage capabilities were designed into the initial system.

PV house under construction (January 1980)

The first year of operation yielded an energy output of 7,977 kilowatt hours, or 1,600 kWh per 1 kW of PV – within three percent of the annual performance predicted during design. At 1982 retail electrical rates, this output was worth approximately $600 annually. Today it would be worth approximately $780, which illustrates how little Florida utility prices have inflated.

Using the PV house, FSEC staff conducted experiments in the areas of power factor, harmonics and load management control. In later years, they installed and conducted experiments on battery-power storage options. The house also allowed staff to address many other technical and institutional issues, including system design, subsystem integration, system analysis, performance verification, maintenance needs, PV installation skill levels, utility interfacing, building codes and system economics.

PV house with 5-kw of PV

State Senator John Vogt and David Jopling of FPL at PV house dedication (December 1980)

Craig Maytrott on PV house roof (January 1983)

PV House with Shuttle lift off in background

During the first years of its operation, the PV system experienced only about four hours of down time, caused by open-circuit failures in three of the 168 modules. Staff detected some discoloration of cell connections and interconnections in the modules but no significant weather-related degradation in power output. [Reference 28]

The PV House was probably the most successful of any FSEC experimental program. The reliability of the PV system is still one of the best, if not the best, of any PV system. When the PV House arrays were disassembled for FSEC's move (15 years later), staff measured power output of the modules and found them still close to the same levels as when they were first installed. In addition, the PV House gave FSEC public and national R&D community exposure that could not have been achieved in any other way.

Photovoltaic Southeast Regional Experiment Station (SE RES)

FSEC's PV house proved to be a critical factor in attracting a $2 million award in late 1982 from the U.S. Department of Energy for the Photovoltaic Southeast Regional Experiment Station (SE RES). The SE RES was FSEC's largest externally funded program at the time and is now its longest-running such program.

The initial goal for the SE RES was to investigate all aspects of utility-interactive photovoltaic systems for Southeastern residences. Researchers were to test the most advanced solar cells, as well as various ways of mounting them on residential rooftops. In addition, staff were to study the performance of advanced photovoltaic systems and their components. This comprehensive research agenda offered FSEC the ability to recruit a strong technical staff and to maintain strong capabilities in the PV area over the years.

The original five-year SE RES project expanded DOE's national photovoltaics program. Two other PV research stations were already operating in the Northeast and Southwest. The Massachusetts Institute of Technology operated the Northeast station in Concord, Massachusetts, and New Mexico State University (NMSU) managed the Southwest station in Las Cruces, New Mexico. The initial RES goals were to compare performance, reliability and durability data from the three regions of the country and to determine the effects of climate differences on PV systems.

The SE RES effort began during the early years of the Reagan administration, at a time of sharply reduced federal solar budgets. With this reduction in federal dollars, MIT dropped its PV program to concentrate its research on defense activities. So, within two years of its creation, the SE RES operated as one of only two national PV research stations. After the close of the initial five-year contract, both the RES locations continued to be funded through congressional appropriations. Each received $2 million in the fiscal year 2003 appropriation passed by Congress and signed by President George W. Bush.

Efforts by Rudi Schoenmackers of New Mexico State University have been extremely critical in maintaining RES funding over the years. Dr. Schoenmackers and NMSU keep the RES partnership as a high priority. They actively pursue support from New Mexico Senator Pete Domenici to keep the RES in the Energy and Water Appropriations Bill. FSEC is grateful for Rudi's continuing efforts and his service on FSEC's Policy Advisory Board.

DOE's Albuquerque Operations Office administers the RES contracts. Sandia National Laboratories provides technical oversight, which has led to close interaction among Sandia and FSEC staff.

During the '80s, SE RES staff conducted three levels of residential photovoltaics testing. These included system testing using prototypes at FSEC and existing photovoltaic residences throughout the Southeast; component testing using FSEC's flexible test facility and selected field sites, and grid-interactive experiments at both FSEC and field sites. They also conducted building-energy-performance experiments to provide information for improved integration of photovoltaic systems into the design and construction process.

Rudi Schoenmackers, College of Engineering, New Mexico State University (2003)

SE RES Prototype house under construction (March 1983)

David Block with DOE Secretary Pat Collins, and Congressman and now U.S. Senator Bill Nelson at SE RES

SE RES Prototype dedication (December 1983)

SE RES prototype dedication (December 1983)

RES Project Manager Jerry Ventre commented in the 1982 FSEC Annual Report that the prototypes were a source of pride for the Center and for other SE RES team members. "They represent the first such project for which DOE allowed the contractor to act as building architect, system designer and general contractor. And we lived up to the task. Not only did we get the prototypes built right and on schedule, but we also did it under budget and at considerably less expense than it took to build prototypes at the other national photovoltaic experiment stations."

The FSEC prototypes were unique in other ways. Photovoltaic cells operate more efficiently and produce more electricity when they are cooler. So, the buildings were designed with passive cooling techniques to cool the photovoltaic arrays and the buildings. In this way, FSEC's low-energy building design program complemented the

FSEC built three residential system prototypes – quasi-residential structures with rooftop photovoltaic arrays – to support RES research. The three prototypes were built in 1983 and were dedicated in December of that year. DOE Undersecretary Pat Collins and Congressman Bill Nelson participated in the dedication. Nelson is currently one of Florida's U.S. Senators.

SE RES prototype 1 (December 1983)

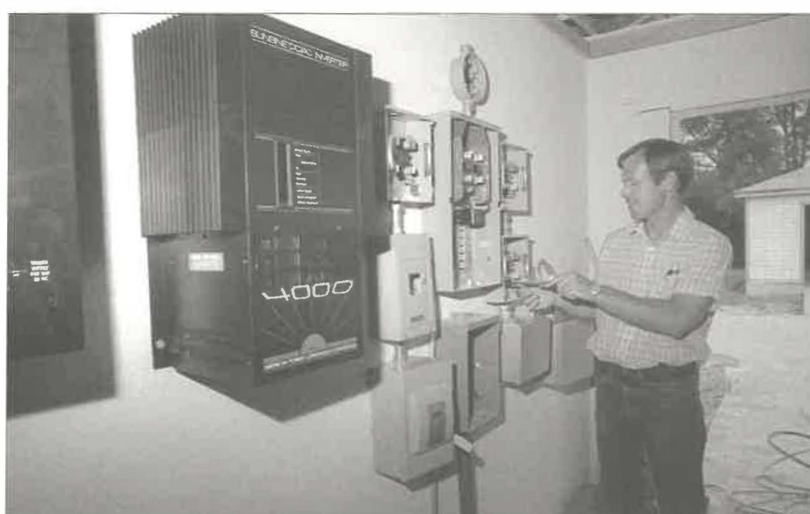
RES project, allowing it to better match the electrical demand of the prototypes with the amount of electricity supplied by the photovoltaic systems.

Each of the three prototype homes used different cell technologies and array mounting schemes. In two of the buildings, the photovoltaic modules replaced conventional roofing materials to become the roof structure itself. The third module array was mounted to stand off from the conventional roof. [Reference 29]

In addition to conducting experiments on the FSEC prototypes, researchers also monitored the performance of systems at multiple field sites in six geographic locations representing four states and a diversity of Southeastern climates. Other research centers and utility companies assisting with the RES research included Georgia Institute of Technology, Alabama Solar Energy Center, Alabama Power Company, Florida Power & Light Company, Florida Power Corporation, Georgia Power Company, Jacksonville Electric Authority, Southern Company Services, Inc., Tampa Electric Company and the Tennessee Valley Authority.

SE RES Prototype 2 (December 1983)

SE RES Prototype 3 (December 1983)



Don Kilfoyle at SE RES (September 1983)

PV Flexible Test Facility (January 1984)

PV Flexible Test Facility (January 1984)

Flexible Test Facility

FSEC added a flexible PV test facility to its SE RES research complex in 1984. With two kilowatts of PV on its roof, the facility was designed to be highly flexible, allowing for rapid interchange of a variety of photovoltaic system components. [Reference 30]

The facility included four PV tracking arrays. Each array tracked the sun in a different manner, allowing staff to compare tracking arrays with each other and with stationary PV arrays. FSEC purchased commercially available trackers similar to those used by SEGS in its California desert installation. The PV arrays installed on FSEC's trackers produced approximately two kilowatts of power under bright sun conditions. Experiments using these facilities provided comparative results for four types of PV array orientations – two degrees of freedom tracking vs. horizontal tracking vs. latitude tracking vs. stationary. Compared with stationary, power output increased by 34 percent with two degrees of freedom tracking, 12 percent with horizontal tracking and 15 percent with latitude tracking. [Reference 31]

PV tracking test stands – Henry Healey (1985)

Solar trackers – Joe Harris and crew (July 1984)

Other PV Projects

The Center undertook several other notable photovoltaic projects during the '80s. These included solar-powered signal light experiments for the Florida Department of Transportation (FDOT), long-term exposure testing of photovoltaic modules for the Jet Propulsion Laboratory (JPL), PV water pumping tests, and installation and monitoring of a 15 kW PV array at a Florida Power Corporation substation in Orlando.

The FDOT project involved design and reliability monitoring of PV-powered traffic aids for use in remote areas of Florida highways. The project first installed a PV-powered railroad crossing safety system in Cocoa, Florida. Staff installed a PV system as a battery charger for safety devices at a Florida East Coast Railroad line near the intersection of U.S. 1 and the Beeline Highway. Vandals damaged the system, and it was removed after about 10 years.

FSEC's initial effort for FDOT was followed by one of FSEC's most successful PV projects installation of PV-powered lights on a remote section of the Beeline Highway – Highway 528 between Cocoa and the Orlando airport. Completed in 1988, the Beeline PV light system is still operating today. [Reference 32]

FSEC's work for JPL involved investigation of the degradation effects on modules exposed for long periods to FSEC's hot, humid, coastal climate. For many years, FSEC researchers studied PV modules produced by six different manufacturers. The tests were finally dismantled during the move to new facilities in 1995.

Center staff began to investigate PV-powered water pumping in 1987. The project objective was to determine the best design configurations for PV-powered water pumping systems. The project used a 2-kW PV array to power 1-HP pumps in an experimental setup. Experiments employed both AC and DC and investigated maximum power utilization. Staff used data from three operating systems to develop an optimized system. They then developed a computer model that allowed designers to optimize system component choices using array performance specifications, pump specifications, and climate and load data. The resulting model has been used to optimize PV pumping installations, both nationally and internationally. [Reference 33]

PV-powered railroad crossing – Cocoa, Florida (June 1982)

Jim Dunlop, Kirk Collier, David Block at Beeline Highway (SR 528) signs (August 1988)

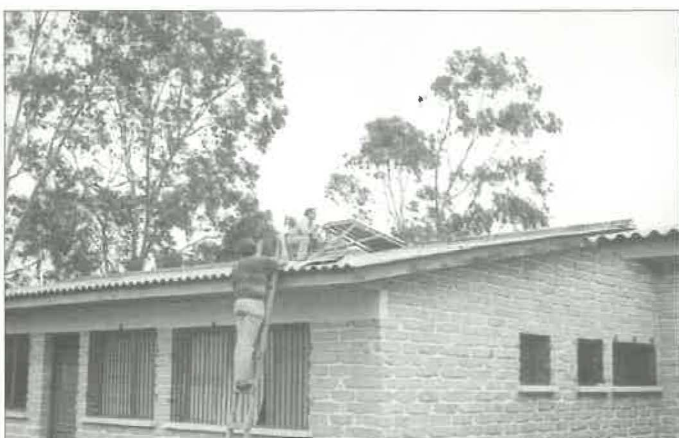
PV signs on Beeline Highway

FSEC began work with Florida Power Corporation (FPC) on a 15-kW utility PV installation in Orlando during 1987. The system, which used ARCO thin-film amorphous silicon modules, was completed in 1988. FSEC collected data from it for many years, carefully studying degradation of the amorphous silicon modules. In addition to FPC, Sandia National Laboratories and the Electric Power Research Institute sponsored this utility system experiment, which was headed by FSEC's Gobind Atmaram. Located approximately two miles west of UCF on University Boulevard in Orlando, the system components are still in place but not operational. [Reference 34]

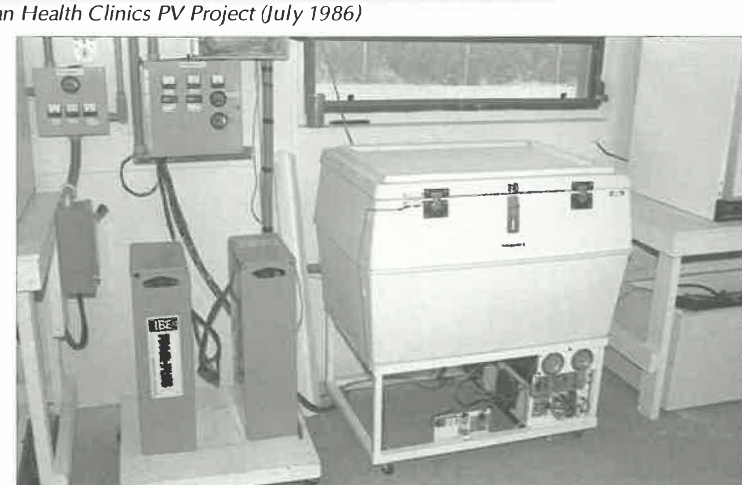
Over the years, the RES program grew many offshoots. Two very notable ones were accomplished in Latin America.

The first involved a vaccine refrigeration program conducted in the mid-'80s in cooperation with the World Health Organization. For this program, FSEC researchers tested three types of PV-powered vaccine refrigerators at FSEC. The selected refrigerators and PV systems were then installed in small village health clinics in Honduras, Guatemala, El Salvador and Costa Rica. FSEC's Jerry Ventre and Don Kilfoyle traveled to each of these countries to assist in the installations. [Reference 35]

The second project resulted in a PV power installation in the mountainous jungles of Belize. This project began when FSEC engineer Jim Dunlop met with UCF archaeologists Drs. Diane and Arlen Chase in 1987. The Chases were in charge of a long-term archaeological dig at Maya ruins in Caracol, Belize. They had already spent years studying the ruins, but their progress had been slowed by lack of power for lights, communications equipment, mapping devices and batteries. They could operate their generator for only about three hours each night. Along with the expense of buying fuel and maintaining the generator, they spent valuable research time traversing winding jungle paths to transport the fuel.



South American Health Clinics PV Project (July 1986)



PV-powered vaccine refrigerator for Latin American project (July 1986)

Dunlop designed a photovoltaic system for the dig using 48 PV modules no longer needed at FSEC. Just reaching the ruins taught Jim the difficulty of routinely carting conventional fuels to the dig. "It took us about five hours to drive 120 miles from the nearest city," he said. "When we reached the end of one of the country's few paved roads, we had to drive the rest of the way over rocky, rutted mountain trails." [Reference 36]

With local labor, Dunlop cut logs to construct a rack for the photovoltaic array, assembled materials and dug trenches for wiring. Then he wired the system, installed switches and area lights, and checked out the system's operation. The power was a go.

Dunlop conducted his own information exchange by teaching the staff how to operate and maintain the photovoltaic system. He also demonstrated the system to archaeologists from a nearby site and explained its operation to reporters from a Belizian television network.

Upon his return to the U.S., Dunlop suffered for weeks from pneumonia – finally diagnosed as being caused by a rare tropical virus. But he insists it was worth the trip, and said, "If you can imagine how important this system is to those scientists, you can grasp why they needed it so badly. Photovoltaics has literally brought an ancient civilization into the modern day."

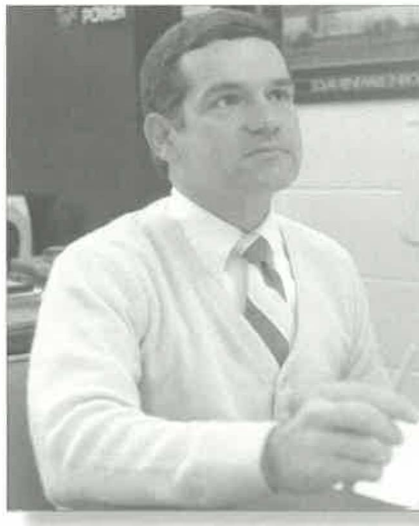
The SE RES initially concentrated on utility-interactive residential systems. In the late '80s, the project was renamed the Regional Experiment Station, and its focus shifted to stand-alone PV systems, with work concentrating on batteries and charge controllers. In recent years, utility-interactive systems have come back into the RES picture.

Jim Dunlop in Belize (May 1987)

Jim Dunlop using PV-powered communications equipment (May 1987)

People of the Photovoltaics Division

The Center's success in photovoltaic systems research can be attributed to the talent, knowledge, skills and experience of FSEC staff members involved in the research. The following individuals are noted for their work during the '80s:

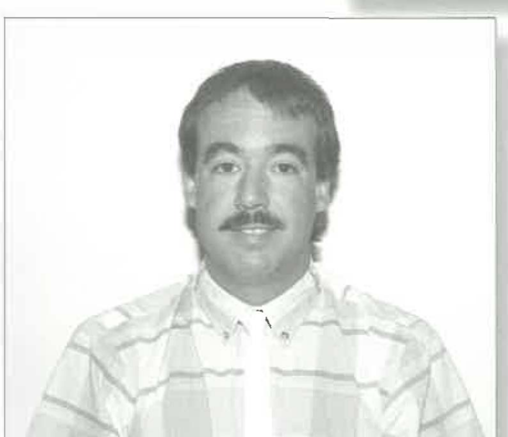


Jerry Ventre
(January 1983)

- *Dr. Jerry Ventre – Jerry was the long-term PV Division Director and first FSEC Deputy Director. He began work at FSEC on December 23, 1977, and retired on October 31, 2003. Jerry's name is synonymous with PV activities at FSEC. He elevated the PV program to national recognition through his outstanding leadership and research abilities.*

- *Dr. Gobind Atmaram – Gobind is a long-time PV researcher and task leader who came to at FSEC on February 27, 1981. Gobind specializes in utility-interactive systems and laboratory accreditation.*

Gobind Atmaram and Jerry Ventre
(January 1983)



Jim Dunlop
(June 1988)

- *Jim Dunlop – A longtime PV researcher and task leader, Jim began work at FSEC on May 20, 1985, and is now the RES Project Manager. His specialties include system analysis, applications, monitoring, education and a bit of everything else. When a PV application is needed, Jim is the individual to see.*

- *Donard Metzger – Donnie was hired as a student assistant on September 12, 1986, and became an FSEC staff member on August 15, 1991. He is a versatile PV technologist who has been involved with all aspects of system and component testing, along with PV installer training programs.*

Donnie Metzger (July 1996)

Kirk Collier, PV&AT Division Director from June 1988 to August 1993. Photo taken July 1988.

Paul Freen and Jim Huggins (April 1986)

- *Leighton (Demi) Demetrius – A former PV system integrator, Demi joined FSEC on July 17, 1990, and has played a major role in PV module, battery and chargecontroller testing.*

Leighton (Demi) Demetrius (May 1990)

With the exception of Jerry Ventre, all these individuals still work in the PV program. Notable PV staff members who are no longer with FSEC include Art Litka, Don Kilfoyle, Paul Freen, Kirk Collier and Bill Marion.

Passive Cooling Lab under construction (June 1981)

Buildings Research

The buildings research program was built on the philosophy that proof of concepts could be achieved only through analytical work, coupled with both laboratory and field experiments. Over the years, this combination of approaches has produced outstanding results.

Energy use in buildings accounts for about 41 percent of Florida's total energy consumption. Residential structures account for fully 22 percent of energy use in the state. This consumption profile placed building energy use at the top of FSEC's research agenda beginning in 1980. Over the years, it has grown to become the Center's largest and highest-impact program.

At its start, the national building energy program was directed at use of energy for heating, with little to no effort directed at building energy use in hot, humid climates. At the same time, the nation was beginning to experience a population shift to the southern tier of states, with the majority of the nation's new home starts in the hot, humid Southeast. These facts made FSEC's hot, humid climate program important and unique. By 1983, FSEC had established itself as a leader in passive-hybrid cooling research.

State Representative Fran Carlton and David Block at Passive Cooling Lab dedication (September 1981)

The objective of the energy-efficient buildings program is to reduce energy consumption in buildings. Research in the '80s focused on radiant barriers, vent-skin walls and roofs, natural ventilation, cooling systems and daylighting.

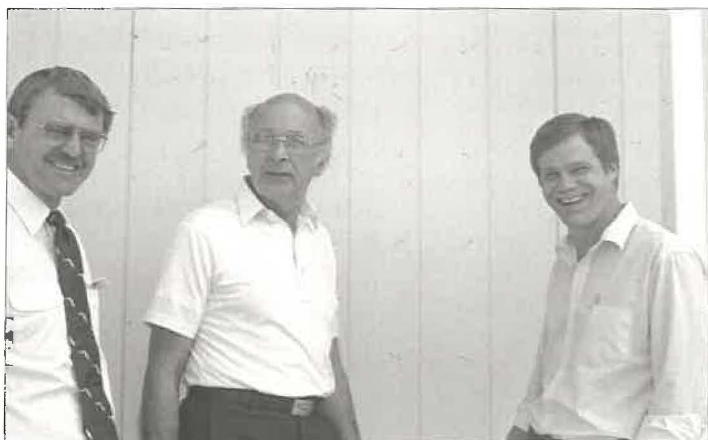
Construction of Passive Cooling Lab

The Passive Cooling Laboratory (PCL), designed by Philip Fairey, was the heart of the buildings program. Philip was a new employee at the time, and the PCL was his first task. It was completed in 1981. A key individual in the buildings program, Philip was named FSEC Deputy Director on August 8, 1990.

The PCL had a unique design that allowed its walls, roofs, ceilings, floors and interior spaces to be easily reconfigured. It was developed specifically for experimental testing, measurement and analysis of passive-hybrid cooling designs and construction alternatives for hot, humid climates. [Reference 37]

Efforts in the PCL were directed at reducing the energy required for cooling through a variety of heat-gain prevention techniques, heat-rejection strategies and thermal storage options. Side-by-side testing in the PCL allowed for quantitative comparison of frame vs. concrete block construction, and evaluation of the effectiveness of ventilated-skin envelopes, radiant barriers, exterior insulation, various shading devices and many other concepts.

Passive Cooling Lab (1981)



David Block, Hub Hubbard (NREL Director) and Philip Fairey at Passive Cooling Lab (March 1985)

Philip Fairey and Mike Houston at Passive Cooling Lab (January 1983)

Early side-by-side tests in the PCL showed that an aluminum foil layer (called a radiant barrier) placed in the airspace between a building's roof and ceiling surfaces significantly impeded radiant heat transfer. In conventional construction, radiant heat in the attic heats up the insulation layer and, eventually, the room ceiling surfaces below it. Occupants then feel that radiated heat, even though the actual air temperature may not rise. A radiant barrier stops the heat before it reaches the insulation. FSEC's experimental results led to their use in residential construction.

Philip Fairey, Mike Houston and Subrato Chandra (January 1983)

PCL researchers also collected data on the thermal performance of eight types of wall systems, and designed and fabricated data acquisition and control systems. In the process, they improved temperature measurement techniques, analyzed the performance of air conditioners at various humidity levels, and validated computer programs important to the research.

Muthusamy Swami, Dave Beal, Charlie Cromer, Alp Kerestecioglu, Ingrid (Melody) Norberg, Philip Fairey, Rob Vieira and Subrato Chandra at PCL (February 1987)

Wind ventilation test (March 1982)

Natural Ventilation

The first major funded effort in the buildings area was a $400,000 contract on passive cooling by natural ventilation received in 1981 from the U.S. Department of Energy. This project, under the direction of Subrato Chandra, involved ventilation testing in the PV house, in a retrofitted house in Eustis, Florida, and in the PCL. In addition, the Center also investigated thermal stack ventilation and how it might best be combined with other ventilation strategies to reduce the need for mechanical air conditioning to produce comfort in buildings.

Project activities included the development of computer models, experimental monitoring of naturally ventilated homes; prediction of energy use and comfort indexes, and development of a manual for architects, home designers and builders. The research culminated in 1983 with a handbook for designing naturally ventilated buildings, including floor plans for compact, well-ventilated houses suitable for Florida. [Reference 38]

Orange High School ventilation model – Dave LaHart, Subrato Chandra and Ross McCluney (June 1985)

Subrato Chandra and Doug Balcomb of NREL during visit to FSEC (April 1986)

Charlie Cromer (January 1984)

Side-by-Side Testing of Mobile Homes

A mobile home project initiated FSEC's capabilities in field testing and remote data acquisition. Led by Charlie Cromer, staff instrumented two side-by-side mobile homes – one of conventional design and one with energy efficiency improvements – at a mobile home sales site in Tallahassee. A computer program operated equipment to simulate lived-in conditions, such as turning lights and appliances on and off, and then collected data on the daily time-of-day performance of the two homes. The project was FSEC's first application of telephone data transmission from a remote site to FSEC – a method used extensively over the years for FSEC data collection projects. The mobile home testing project was sponsored by the Florida Public Service Commission and Mobile Home Industries, Inc. [Reference 39]

Daylighting

Daylighting research has also been a long-term buildings-related activity at FSEC. It has enjoyed enduring DOE support under the direction of FSEC daylighting expert Ross McCluney. Initially, this research program measured the effectiveness of awnings, shades and screens to protect windows from unwanted sunlight.

Daylighting Laboratory (1985)

Carol Emrich and Ross McCluney (April 1986)

Carol Emrich and Ross McCluney at Daylight Availability Measurement Station (August 1988)

The daylighting program was aimed at achieving an optimal balance between use of daylight as a light source and prevention of solar heat gain. The fenestration project's long-term goal was to design buildings that could optimize the use of both natural and artificial light, without adding heat to and increasing the cooling energy use of buildings. It promoted product testing and development and accompanying numerical analysis.

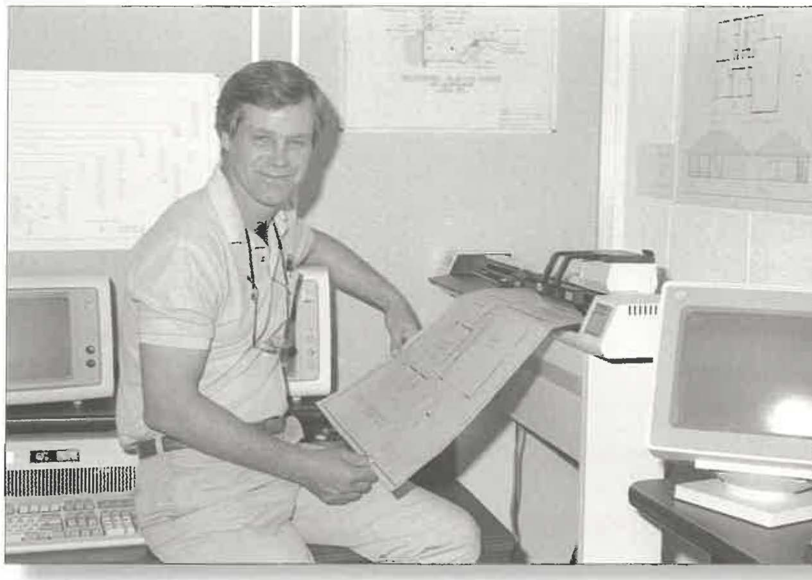
In 1982, FSEC constructed its Daylight Availability Measurement Station. The station measured 36 channels of solar radiation and daylight, including direct beam radiation, global horizontal radiation, diffuse sky radiation, and radiation falling from the sun on vertical planes facing north, south, east and west. [Reference 40]

Over the years, FSEC daylighting and fenestration staff have worked closely with the Windows and Lighting Group at Lawrence Berkeley Laboratory in California through DOE-funded activities.

Cooling Research Program

In 1986, FSEC began a major building research program when the U.S. Department of Energy contracted the Center to lead its national solar cooling program. DOE selected FSEC to lead this five-year, $7 million effort based on the Center's already-extensive research on the subject. Philip Fairey was the principal investigator, and guidance was provided by the project's steering committee.

The project's main research objective addressed the complex problem of how to measure, analyze and predict the combined flow of moisture and heat into and out of building materials and furnishings. The research would help to answer the important question of how moisture and heat flows affect energy consumption in buildings in the hot, humid climate of the Southeast. The solution would set the basis for filling data gaps in complex computer programs that predict building energy use and would allow for building designs better suited to Southern climatic conditions. It would provide knowledge on how to improve the performance of both conventional and innovative cooling systems.



Philip Fairey (August 1988)

Diurnal test facility (March 1989)

The cooling research program also led to a building design concept known as DESRAD (DESiccant-enhanced, night-sky RADiation). In this concept, desiccant materials in an attic would adsorb moisture at night from the interior air and raise the temperature of a building's roof. The roof, in turn, would radiate this heat to the cooler night sky. During the day, the roof would use the sun's energy to dry the desiccant in the attic in preparation for another nighttime adsorption cycle. Computer analysis of DESRAD yielded promising results. Computed seasonal savings in cooling energy requirements of houses in Miami and Atlanta were shown to be 65 percent and 96 percent, respectively. Staff conducted laboratory testing of a small-scale model, but material issues precluded full-scale testing. Staff were unable to identify a desiccant material that would perform as desired on the 24-hour cycle and still be operative over an extended period of time.

By 1988, the Solar Cooling Research project broadened its funding base with support from the U.S. Department of Energy, the Gas Research Institute and Florida Power & Light Company. The program, now focused on ways to enhance the energy efficiency of buildings, made significant advances in three areas: moisture research and analysis, integrated cooling and dehumidification, and radiant barrier systems. [Reference 41]

Alp and Didem Kerestecioglu (April 1987)

Determining the moisture absorbtion and desorption properties of building materials was one of the most significant results of the cooling research. Philip Fairey and David Beal conducted the research in a large environmental chamber located in the FSEC auditorium. The chamber was so large that Testing and Operations staff had to tear out a wall of the auditorium to bring the chamber into the interior and then again to remove it. Data taken from these tests are still one of the few sources of such information. [Reference 42]

Radiant barrier system studies conducted by Philip Fairey were another major component of the Solar Cooling Research Project. PCL testing showed that a radiant barrier glued to the roof deck with the reflecting side facing down worked as well as one draped under the roof decking. In 1988, FSEC constructed an attic radiant barrier test facility at its auxiliary test site. The facility gave researchers the ability to measure ceiling flux and attic temperatures on six side-by-side attic sections and for extended periods of time. Fairey drafted a comprehensive report on radiant barriers, but the report was never published because DOE instructed FSEC to stop work on the task.

Computer Analyses

During 1981, the Center began computational analyses on energy and buildings. Staff first conducted analyses using large-scale, sophisticated computer programs (such as BLAST) and microcomputer and electronic calculator-based programs (such as T-NODE, NEATWORK and TEANET). They developed improved algorithms and simplified load analysis programs by comparing experimental data with computer simulations.

In 1984, staff began efforts to advance FSEC capabilities in moisture research and analysis with the ability to understand moisture adsorption and desorption in building materials. Alp Kerestecioglu began the development of a computer model, called MADTARP, which resulted in two analytical models to account for moisture adsorption and desorption. By 1988, this model allowed for accurate quantification of cooling loads and humidity levels in buildings. The resulting computer simulations were key to the computer analyses during the late '80s and led to advanced computer modeling in the '90s.

Education

While the results of FSEC research could significantly improve the way buildings are designed, constructed and operated in hot, humid climates, knowledge of the results needed to be moved into the building professions. So, FSEC conducted major education programs throughout the 1980s. The programs targeted building professionals, homeowners and members of the general public who were interested in energy-efficient design.

In 1989, the buildings research division conducted more than a dozen workshops and held a home-design competition – the first such competition since 1981. Workshops on Energy-Efficient Florida Home Building, Air Quality in Homes and Visions for Developments reached nearly 500 professionals in the planning, development, design and construction fields.

Philip Fairey, State Representative Dick Batchelor and Chris Beck at Passive Design Awards (December 1980)

Bruce Anderson with David Block and Jim Roland at workshop (November 1983)

Philip Fairey at Low-Energy Workshop (March 1984)

Bobs Candies Factory

FSEC's research on heat pipes led to one of its most successful industrial partnerships and one of its most innovative technology applications. In large buildings that require sensitive moisture control, air conditioning is used to super-cool air to remove moisture. The air is then reheated for human comfort. The reheating consumes considerable energy. Heat pipes were shown to be an efficient method to accomplish the super-cooling and reheating processes without consuming energy.

By 1986, he had proved the concept in the laboratory but had yet to find a field demonstration. Bobs Candies, located in Albany, Georgia, was to be the site for this heat-pipe demonstration project.

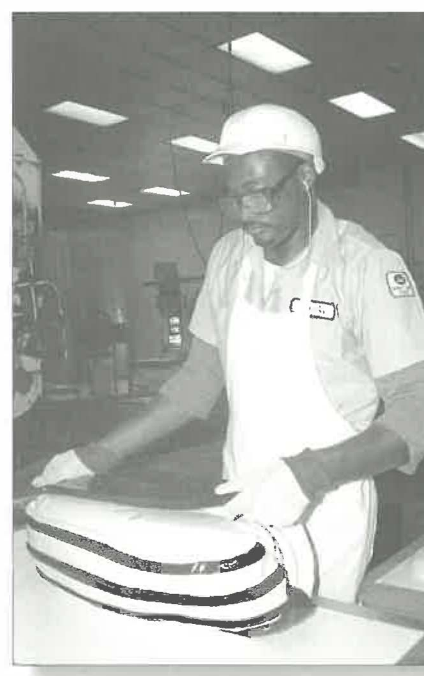
Don Bravaldo, Bobs Candies' head of production, was struggling with the problem of keeping energy costs down in the company's production and storage facilities. Air conditioners at the company's storage facilities must be precisely controlled to ensure that Christmas candies

Wally Boggs of Kennedy Space Center and Mukesh Khattar investigate heat pipes in air conditioning lab (October 1982)

Mukesh Khattar and heat pipes (March 1988)

FSEC began conducting research on NASA-supported heat-pipe technology in 1983. Originally developed to cool electronic equipment on satellites, the fluid-filled tubes move heat from one place to another without consuming energy. FSEC's Mukesh Khattar envisioned a terrestrial application for the technology as a replacement for electric-strip reheating in large air-conditioning systems.

maintain their quality. Bobs Candies makes 11,000 tons of candy a year, and most of it is stored for as long as eight months before shipment. Too much moisture or heat would ruin the delicate sweets, so relative humidity must be maintained between 38 and 42 percent, and temperatures cannot rise above 80°F. At one 45,000 square-foot warehouse, air conditioners over-cooled the air to remove



Candy cane batch at Bobs Candies (March 1988) moisture; and then the too-cold air was warmed by resistance heaters. The process was costing the company $57,000 per year in electricity for this warehouse facility.

to a total of 81 percent. The warehouse's annual utility bill fell from more than $57,000 to less than $11,000 in 1988. [Reference 43]

Bobs Candies visit (Albany, GA): Don Bravaldo, Mukesh Khattar, Dave Block, Bob McCormick (January 1988)

In 1986, Don Bravaldo came across a newspaper article about NASA's heat pipes and Khattar's research. He contacted the Center, and following an initial meeting, Khattar predicted significant energy savings from heat pipes in the company's warehouse. NASA agreed to back Khattar's proposal. Georgia Power Company, the local utility, was also interested in monitoring the project. So, Bobs was a go.

In 1987, FSEC integrated a heat-pipe system into an existing air-conditioning system at the warehouse. The integrated system resulted in seasonal energy savings of more than 70 percent in 1987. In 1988, with some fine tuning of the overall system and controls, these savings increased

As a final note, Bobs discontinued its longtime operations in Albany because of financial woes on May 10, 2002. However, Bobs was back in production one month later after a team of state and local officials worked to save the family business.

FSEC applied the lessons learned from the Bobs Candies project to other applications. One was in the Salvador Dali Museum in St. Petersburg. This site was chosen from among 141 possible sites for the second heat-pipe demonstration project. Khattar left FSEC about this time for a position with EPRI in California so newly hired Don Shirey took on the Salvador Dali project. The Florida Energy Office, Florida Power Corporation and the museum's air-conditioning service contractor all sponsored this second, very successful heat-pipe demonstration project. [References 44 and 45]

FSEC also investigated heat pipes for use in grocery stores and for computer storage applications. By the end of the '80s, the heat-pipe work was replaced by studies on the potential for power electronics to control air-conditioning fans and compressor speeds and on variable-speed air-conditioning systems.

Bobs Candies warehouse visit (Albany, GA): Mukesh Khattar (January 1988)

Lighting fixtures for Rob Vieira and Ken Sheinkopf's Florida home building design book (April 1988)

Building Design Assistance Center

By the late '80s, FSEC's building research staff had gained an impressive body of knowledge on designs, applications and technologies to reduce energy use in buildings. To transfer that knowledge to the building industry, FSEC created the Building Design Assistance Center (BDAC). Supported by the Florida Energy Office and the U.S. Department of Energy, it served as a resource for architects and engineers designing energy-efficient commercial buildings. During 1988, the staff reviewed designs of schools, office buildings, libraries and museums from Pensacola to Miami. One firm summed up the BDAC's impact this way: "Our experience was terrific. It allowed us to construct a building that consumes only 50 percent of the energy required by a similar building.... Get the word out!"

HVAC and Duct Leaks

In 1989, work began in a new buildings research area – air supply duct leakage. The purpose of this work was to determine energy losses at air-conditioning units, air handlers and ducts in heating, ventilating and air-conditioning (HVAC) systems. The Florida Energy Office funded the joint effort that involved FSEC, Lakeland Electric and Water Municipal Utility and Natural Florida Retrofit, Inc., of Orlando. FSEC's Jim Cummings led this very important new (and continuing) effort.

In the initial investigation of 80 homes in the Lakeland region, results showed that most Florida homes have significant leaks in duct work, which triples air infiltration when air conditioners are operating. These duct leaks were shown to have dramatic energy impacts. After a duct leaks were repaired in seven homes, their air-conditioning energy use dropped by an average of 21 percent. The average repair cost was $110, and the annual energy savings were estimated to be $150 per year, giving a payback of about nine months. Analysis determined that, if all leaking duct systems in Florida homes were repaired, annual energy savings could exceed $250 million. [Reference 46]

Further analysis showed the impact of leaky ducts on electrical peak demand was even greater than on energy use. HVAC systems operate at maximum and draw in the most hostile outdoor air when the power utility is experiencing peak electrical demand. Consequently, duct leak repair is an outstanding opportunity to cost-effectively address utility company peak demand. FSEC's duct leakage program, which began in the late '80s, carried on major activities throughout the '90s.

Jim Cummings at Rangewood Villas (September 1987)

Energy-Efficient Industrialized Housing (EEIH)

FSEC initiated yet another major buildings program during the '80s. The energy-efficient industrialized residence test area as "Subratoville." The industrialized housing program continued to be a major FSEC activity into the '90s.

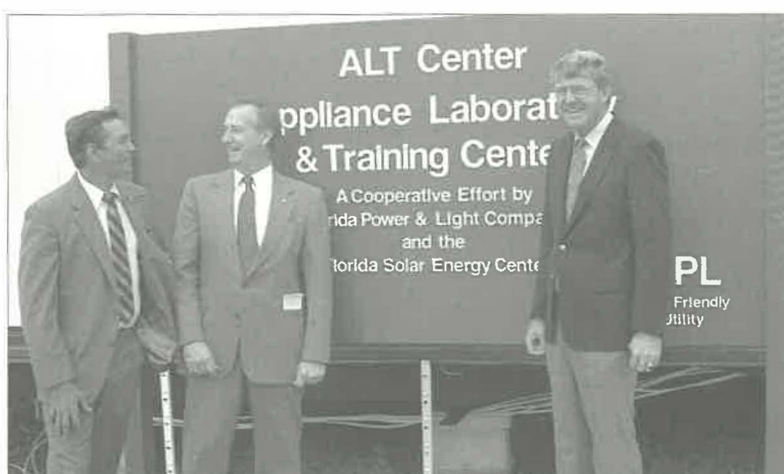
Industrialized Housing Test Houses (Subratoville) at FSEC (February 1990)

industrialized housing (EEIH) project began in 1989 as a DOE-funded cooperative program with the University of Oregon. The project goal was to enhance the quality of manufactured homes built in factory settings through use of energy-efficiency technologies. For this project, FSEC evaluated industrialized, automated technologies that would result in more energy-efficient houses. Under the direction of Subrato Chandra, FSEC constructed two side-by-side prototype industrialized houses at the Cape site in 1989. Tests compared their energy-efficiency improvements against a third unit constructed with conventional materials and techniques. [References 47 and 48] UCF's Department of Industrial Engineering partnered with FSEC in the project, and UCF's Bill Swart fondly referred to the

Appliance Laboratory and Training (ALT) Center

The Appliance Laboratory and Training (ALT) Center was the site of additional buildings-related activities that resulted in still more FSEC success stories. Funded under the direction of Bill Davis of Florida Power & Light Company (FPL), the ALT center consisted of three trailers located on land leased from the Canaveral Port Authority about a half-mile west of the Cape Canaveral site. Developed by Charlie Cromer, the ALT Center represented FPL's first major support for FSEC activities. Using the ALT Center, staff conducted research on technologies with the potential for shifting utility load. The program had the twin goals of determining ways to move electrical loads from on-peak times and testing innovative techniques to save consumers money and reduce energy use. The State, DOE, EPRI and other utilities provided additional equipment and project support. The ALT site eventually also became the location for FSEC's original Hydrogen Laboratory.

Initial ALT Center activities included studies and experiments on shifting electrical demand through residential hot water system and freezer operation profiles. Electricity consumption



ALT Center dedication: Charlie Cromer, Bill Davis (FPL) and David Block (May 1988) for water heating averages 3,000 kWh per year in a Florida home. Most of that consumption occurs in the early morning and early evening. Experiments tested the concept of charging the hot water storage tank during off-peak times so it could coast through the peak times. This would allow electrical loads to be more evenly spread throughout the day. The basic research analyzed how a number of hot water tank variables interact. The variables included hot water demand, draw rate, tank volume, insulation, temperature-setting of the tank and temperature of the surroundings. The analysis resulted in recommendations to FPL on peak-load reduction technologies. [Reference 49]

The residential freezer study looked at how much power freezers consume and at what times of day. This research defined a Florida-specific freezer power-load shape. The results showed that freezers would not be a load-saving appliance in Florida, as the majority of them are located in a hot, humid garage space.

At the ALT Center, researchers also investigated PV-powered residential swimming-pool pumps, residential ice storage air-conditioning, commercial cool storage air-conditioning, and residential hot water heat pumps. The main objective of all of these projects was to develop technologies to reduce electric load for the utility's seasonal peaks.

The ALT Center was moved to the auxiliary site when FSEC relocated to its new facilities. It is still the site of research projects for FPL.

Three trailers at ALT site (May 1988)

Bill Davis of FPL and Charlie Cromer (January 1988)

Armin Rudd (May 1987)