Energy Efficient Retrofit Measures for Government Buildings
FEMP Workshop August 14, 2010

Annex 46 Subtask B Results

Building Envelope Technologies

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Annex 46

Holistic Assessment Tool-Kit on Energy Efficient Retrofit Measures for Government buildings (EnERGO)

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

Help develop **procedures** (such as project design and financing), **technologies**, and **evaluation guidelines** to help the government sector identify appropriate energy and water conservation measures, implement them, and maintain them.

Subtask A: method for energy analysis and technology assessment for government energy and facility managers. *[Energy assessment and analysis methodology/protocol and a tool "Energy Assessment Guide for Energy Managers and ESCO's"]*

Subtask B: identify energy efficiency technologies and offer guidance to facilitate design of government energy saving projects. *[Database of "Energy Saving Technologies and Measures for Government Building Retrofits" with examples of best practices]*

Subtask C: guidance to obtain the best possible results from an ESPC. *[Best Practice Guidelines for Innovative Energy Performance Contracts*]

Subtask D: puts the information from subtasks A, B and C in a toolkit form to make it easier for facility managers to access and apply it. *[IT-Toolkit "EnERGo"]*

Subtask B: Technology Fact Sheets and Case Studies

Case Studies

- Description of facility, site plan, architectural drawing
- Description of energy-saving technology, photograph
- Case study
  - Energy savings
  - Cost of implementation
  - Other pertinent information
- Design/implementation guidance
  - Lessons Learned
  - Best Practices
- Point of contact
- References

Technology Fact Sheets

- Technology description
- Photographs
- Qualitative description of energy savings
- Quantitative description of energy savings
  - Example barracks building
  - Example administrative building
  - "Industrial" building for certain technologies
- Annual simulations for 15 U.S. and 16 non-U.S. cities
  - Annual energy consumption/savings
  - Simple payback estimates
- Design/implementation guidance
- References

Case Studies Now Available - 1

Aerosol Duct Sealant

- NAVAIR in San Diego, CA
- Naval Station Newport, RI
- NAVAIR in Naval Base Kitsap in Bremerton, WA

Cool Roof

- A Retrofit for Energy Conservation Using Cool Metal Roof Technology in Paulding County, GA

Daylighting

- A Retrofit for Energy Conservation Using Daylighting Technology at Navy/ Marine Corps Buildings

Dedicated Outdoor Air System

- Application of Dedicated Outdoor Air System (DOAS) to Control Humidity in Military Barracks Facility at Fort Stewart, GA **(3 case studies)**

Demand-Controlled Ventilation

- A Retrofit for Energy Conservation Using Demand Controlled Ventilation in Birmingham, AL

Desiccant System

- A Retrofit for Energy Conservation Using Two-Wheel Desiccant System Technology in Maryland

Ground Source Heat Pumps

- A Retrofit Using Ground Source Heat Pumps at Fort Polk, LA

Case Studies Now Available - 2

Oil-Free Magnetic Bearing Chiller Compressor

- Fleet Industrial Supply Center in San Diego, CA
- Naval Air Station in Jacksonville, FL
- Naval Undersea Warfare Center in Newport, RI and the Fleet Industrial Supply Center in San Diego, CA

Radiant Heating

- Retrofit for Energy Conservation Using Infrared Radiant Heat at Third Squadron Bagotville, Quebec, Canada
- High-Efficiency Radiant Heating Panels in USAG Katterbach Hangar
- A Retrofit for Energy Conservation Using Tube Heater Technology
- High-Efficiency Radiant Heating Panels in Schweinfurt Conn Barracks
- High-Efficiency Radiant Heating Panels in Wiesbaden Army Airfield Hangar

Solar Wall

- Large Scale Application of SolarWall Solar Air Heating Systems to Preheat Ventilation Air at Fort Drum, NY

Thermal Destratification

- Thermal Destratification Technology at West Bethesda, MD

Case Studies Now Available - 3

Retrofit Buildings

- Retrofitting of an Administrative Building, Direction Régionale Des Affaires Culturelles (DRAC), Lyon, France
- Arquata Quarter, Turin, Italy
- Retrofitting of University Dormitories, City Vert-Bois, Montpellier, France
- Promoting Sustainability through High School Campus Redesign, Oak Ridge, TN, USA
- First Laboratory Building in Colorado To Obtain LEED Silver Certification, USA
- Municipal Youth Centre, Naples, Italy
- Retrofitting of Office Buildings in the Administrative Area of Gaujot, Strasbourg, France
- Passivhaus Retrofit - Provincial Environmental Protection Agency Building, Bozen, Italy

Water Conservation

- A Retrofit for Water Conservation Using a Membrane Bioreactor

Whole-Building Diagnostics

- A Retrofit for Energy Conservation Using Whole-Building Diagnosticians on Outside Air/Economizers at the FAA Denver Airport

International Energy Agency
Energy Conservation in Buildings and Community Systems Programme

A Retrofit for Energy Conservation Using Cool Metal Roof Technology in Paulding County, GA, USA

1 Photos

Figure 1. Lillian C. Poole Elementary School.

Figure 2. Bessie L. Baggett Elementary School [1].

2 Project Summary

This project was designed to quantify the net savings on cooling bills for Poole Elementary using a coating of paint on the roof containing highly reflective infrared (IR) pigments known as cool metal roof technology. A control school, Baggett Elementary, with a conventional coating, was used as a basis for comparison.

Two identical schools were built within the same county, one with the new roof technology, and the other having a traditional roof. Both feature Hunter Green Kyner 500-based paint, and the differences in the cooling bills were monitored during a 3 ½ year time frame [2]. Roofs generally retain solar energy, rather than reflecting it, causing a rise in temperature within the building. Thus, the cooling system must work harder to counteract this effect, resulting in higher energy costs. Coating the roof with a highly reflective pigment that has greater reflectance as well as higher emittance of solar energy lowers the roof temperature, and therefore, the heat conducted to the building. Such a coating on metal roofs is one of five types of cool roof technology [2].

3 Site

Lillian C. Poole Elementary and Bessie L. Baggett Elementary Schools
Paulding County, GA
Latitude: 33.9 N / Longitude: 84.8 W
Altitude: 318m (1043 ft).

The warmest month is July with an average maximum temperature of 32 °C (89.3 °F); the coldest month of the year is January with an average minimum temperature of -2 °C (28.5 °F).

Figure 3. Google Earth Map showing location of Paulding County, GA [3].

4 Building Description / Typology

4.1 Typology / Age

Each roof is manufactured by Architectural Metal Systems (AMS) of Eufaula, AL, and has an R-15 vinyl-faced blanket insulation over the purlins and 6 in. of R-19 batt insulation at the ceiling [4].

4.2 General Information

Year of construction:	2002-2003
Year of subject renovation:	Not applicable (technology installed as new construction)
Total floor area (m²):	90,000 sq ft
One school had IR-reflected coating painted on roof, other remained same for comparison Annual energy use of XX million MBTU (XX GJ) per year Occupied hours: XX hours per weekday; XX hours per weekend day Note: ORNL is obtaining updated savings estimates.	

4.3 Architectural Drawing:

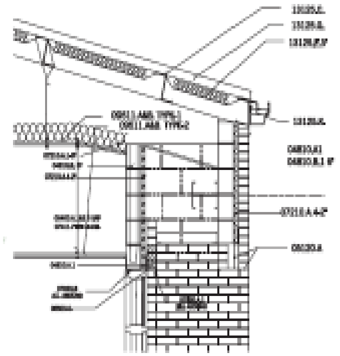

Figure 4. Diagram showing construction of cool roof materials.

5 Previous Heating, Ventilation, Cooling and Lighting Systems

This project did not involve changes to any of these existing systems.

6 Retrofit Energy Savings Features

6.1 Retrofit System Description

Most roof types accommodate a retrofit metal roof on top of the original structure without major modifications. Other types of cool roof technology, such as membranes and coatings, can be applied as a retrofit as long as the surface is dry and dust-free [2]. A retrofit was not performed in this particular case study, as the schools were new-construction.

6.2 Energy Saving Concept

Cool roof technology increases the solar reflectance and the thermal emittance of the roof material. A high solar reflectance means that the roof will reflect (rather than absorb) a higher fraction of incident solar radiation, and a high thermal emittance means that the roof will transfer heat to the relatively cold sky at a higher rate. Solar radiation primarily falls in the visible spectrum (46%) and the near-infrared spectrum (49%). A 'cool roof' is achieved by reflecting radiation in the visible spectrum (by using a light colored roof material) and by maximizing radiation heat transfer to the 'cold' sky in the infrared spectrum (by using a high emittance roof material).

6.3 Building Improvement

Lowering the temperature of the roofing materials prolongs their lifespan and delays the expense of installing a new roof. Both schools kept their existing (identical) HVAC systems.

7 Resulting Energy Savings

The annual energy savings at Poole Elementary were nearly $15,000 in the 2006-2007 school year alone. Considering that the projected lifetime of the coating is 35 years, a total savings of $525,000 is achievable, not including the likely increase in fuel prices [2].

8 User Evaluation

Significant cost savings on utility bills were demonstrated. This savings to the taxpayer could be used to fund other educational programs or facilities.

9 Renovation Costs

For this case study, there was no difference in the initial cost between the roofs at Poole Elementary and Baggett Elementary Schools. However, if a building were retrofitted with a metal roof, there is no difference in cost associated with a cool roofing material chosen [2].

10 Experiences / Lessons Learned

10.1 Energy Use

Poole Elementary saved about 13% of their annual energy consumption, but cool roof technology has the potential to lower cooling costs by as much as 40% [2].

10.2 Environmental Impact

For buildings with no cooling, this technology has an impact on thermal comfort and productivity only. Reduction in energy consumption in buildings with air conditioning results in greenhouse gas reduction as well.

10.3 Economics

The cost of a cool metal roof can be the same as a traditional roof, depending on the type of material chosen. The money saved on energy costs, especially over a long period of time, can be significant. Additionally, keeping roofing materials cooler also prolongs their life expectancy, thus delaying the expense of installing a new roof.

10.4 Practical Experiences of Interest to a Broader Audience

This technology is most applicable in warmer climates, and could lead to a reduction in the urban heat island effect by reducing ambient air temperatures and inhibiting smog formation. Air pollution would also be decreased by reducing amount of fossil fuels burned to cool the buildings. Also, the roof material is made from recycled materials, which can be recycled again. For all of these reasons, cool metal roofs help qualify for Leadership in Energy and Environmental Design (LEED)® certification [4].

ORNL's Building Technology Center completed a 3-year study to evaluate the energy efficiency and service life of metal roofing systems. The results are available at www.coolmetalroofing.org. Overall, the study showed that metal panels maintain high levels of reflectance even after continued exposure to the elements over many years. The panels maintained high levels of emittance which, in some cases, increased slightly. Also, both painted and unpainted metal panels maintain their energy efficiency better over time than any of the other roofing systems studied. Lawrence Berkeley National Laboratory and the National Renewable Energy Lab [4] have also done other studies on cool roof technology.

10.5 Resulting Design Guidance

There are five categories of cool roof material available. If intended for a flat-roofed industrial building, then metal roofs, coatings, and membranes are the best option. If intended for a sloped residential roof, then reflective tiles and asphalt shingles are better since aesthetics are often an issue. Cool roof technology is typically installed during new construction or re-roofing projects [2].

11 General Data

11.1 Address of Project

Lillian C. Poole Elementary	Bessie L. Baggett Elementary
1002 Wayside Ln.	948 Williams Lake Rd.
Dallas, GA 30132	Powder Springs, GA 30127

11.2 Existing or New Case Study

Existing

11.3 Date of Report

November 2007

12 Acknowledgements

Project Sponsor: Cool Metal Roofing Coalition
Designer: AMS and Roy Denney and Steve McCune of Southern A&E in Austell, GA
General Contractor: AMS, Roy Denney and Steve McCune of Southern A&E, Austell, GA
Case Study Authors: Cool Metal Roofing Coalition

13 References

1. Photos: Robert Scichili Associates, Inc. and Green Metal Consulting, Inc.
2. *Cool Roofs: Putting a Lid on Energy Use.* U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy Building Technologies Program, International Energy Agency's Energy Conservation in Buildings and Community Systems Programme, and the U.S.A. Corps of Engineers.
3. http://maps.google.com/maps?hl=en&tab=nl
4. *Case Study: Metal Roofing Goes to School for Big Energy Savings*, Cool Metal Roofing Coalition, Pittsburgh, PA.

14 Point of Contact

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A Retrofit for Energy Conservation Using Ground Source Heat Pumps at Fort Polk, LA

1 Photo

Figure 1. Fort Polk, LA Family Housing [1].

2 Project Summary

In January 1994, the Army awarded a 20-year shared energy savings contracts to Co-Energy Group (CEG), a Santa Monica, CA based performance contracting energy service contractor (PC/ESCO). In 1996, the world's largest installation of geothermal heat pumps was completed, replacing 3,243 air-source heat pumps and 760 central air conditioning/ natural gas forced air furnace systems for 4,003 housing units [2]. Other conservation measures were taken, such as installing compact fluorescent light bulbs (CFLs), low-flow showerheads, desuperheaters (for water-heating), and attic insulation where needed. This increase in efficiency and reduction in energy cost was necessary to meet the mandated reduction in Federal building energy use [1].

3 Site

The project was located at the U.S. Army's Fort Polk military base, in west-central Louisiana just outside of Leesville. The Ground Source Heat Pumps (GSHP)s served family housing units at Fort Polk.

4 Building Description / Typology

4.1 Typology / Age

The housing units were apartments, townhouses, and duplexes built between 1972 and 1988. Unit floor space ranged from 900 to 1,400 sq ft [2].

4.2 General Information

Year of construction:	1972 - 1988
Year of subject renovation:	1995 - 1996
Number of buildings:	4003 apartments

4.3 Architectural Drawing:

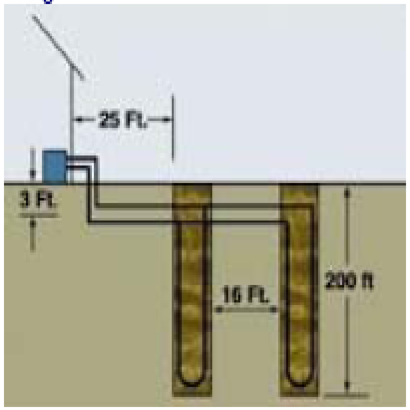

Figure 2. Each heat pump is linked to two U-shaped ground heat exchangers that are in 4-1/8-inch vertical bores.

5 Previous Heating, Ventilation, Cooling and Lighting Systems

The HVAC systems that were replaced consisted of a hodge-podge of minimum-efficiency central system and packaged heat pump units that presented a large logistical maintenance problem. It is assumed that the lighting replaced by CFLs was traditional incandescent lighting.

The Army had outsourced housing maintenance to the lowest-bidding contractors to deal with the increasing number of service requests to the HVAC equipment. These maintenance requests were acute and worsening, averaging 90 calls per day. The number of different types of units made it difficult for the maintenance contractors to keep parts stocked and technicians trained for all of them.

6 Retrofit Energy Savings Features

6.1 Retrofit System Description

The solution was to replace the inefficient heating and cooling systems (with energy efficiency ratings (EER) of between 7 and 8) with GSHPs that have an EER of 15.4 [2]. This is in addition to the other energy-efficiency measures such as replacing all light bulbs with CFLs, installing low-flow showerheads, and desuperheaters. About 75% of the GSHPs used desuperheaters, which recover waste heat and transfer it to the water heater. They were not used in the other homes because the heat pumps and water heaters were too far apart to make their use practical.

The GSHP configuration is a closed-loop, vertical-borehole ground heat exchanger system. Each heat pump has its own ground heat exchanger of the vertical U-tube type of polyethylene pipe. Over 8,000 borehole heat exchangers were drilled. Each borehole has a 4-in. diameter and a 100 to 450 ft depth. The heat exchanger, heat pump, and other system components were designed for easy installation, compact size, maximum efficiency, long life, low maintenance cost, and adequate capacity to provide a more comfortable environment for residents [1]. A TRNSYS model was used to size the GSHPs.

6.2 Energy Saving Concept

GSHPs most often exchange heat with the ground by means of a ground heat exchanger. The heat exchanger consists mainly of long pipes, either drilled vertically into the ground or buried in trenches, that use the tempering effect of the earth to heat cold water or cool warm water. When the system operates, a pump circulates the water through the heat exchanger and the heat pump, and the heat pump moves energy between the conditioned space and the water. Because it relies on the earth (instead of outdoor air) as the heating or cooling source, it is substantially cheaper to run than a conventional heating and air conditioning system [3].

GSHPs are more efficient than conventional heating and cooling systems because, with ground source units, air needs to be moved on only one side of the unit. On the other side, it moves water, and it takes less electricity to move 2.5 gpm/ton of water (or anti freeze, in northern climates) than it would take to move the 900 CFM/ton of air required in air source heat pumps across the outdoor unit. Unlike air source heat pumps, ground source systems do not need to defrost. Because there is no outdoor unit, there are no defrost controls to maintain and no performance deterioration from corrosion, vandalism, or clogging with debris.

Air source units must engage backup electric-resistance heat at low outdoor air temperatures in all locations, but GSHPs require backup only in extreme heating-dominated climates. Also, since ground temperatures remain relatively constant, GSHPs do not have to contend with the capacity-limiting and efficiency-reducing operating conditions caused by extreme outdoor temperatures.

GSHPs also generally require less maintenance, as the heat pump is a packaged water-to-air unit that is factory charged with refrigerant, avoiding the problems associated with field-charged split systems. Also, the underground piping is high-density polyethylene, which is usually guaranteed for 50 years. ASHRAE gives the median service life of a water source heat pump as 4 years longer than that of an air source pump. Such longevity factors tend to lower the charges for maintenance contracts for the equipment by as much as 25% [3].

7 Resulting Energy Savings

ORNL's evaluation of energy savings was based on pre- and post-retrofit monitoring of energy flows, with data taken at 15-minute intervals from August 1994 through February 1997. The retrofit construction period extended from March 1995 through August 1996 [1]. The overall project reduced the annual family housing electrical consumption by 33% (26 million kWh), summer peak electrical demand by 43% (7.5 MW), eliminated natural gas consumption for space and water heating, and improved load factor from 52 to 62%. This efficiency improvement also reduces CO_2 emissions by 22,400 tons annually. A TRNSYS simulation model showed that 66% of the savings could be attributed to the new heat pumps, 29% to the lighting retrofit, and 5% to installation of the low-flow showerheads [3]. In accordance with CEG's agreement, the Department of Defense's 22.5% share of the energy savings equates to $345,000/year during the 20-year contract and over $2 million annually afterwards, as long as the GSHPs last [1].

8 User Evaluation

While no housing occupant was interviewed in this report, it was documented that maintenance requests were reduced to virtually none on installation of the GSHPs.

9 Renovation Costs

CEG bore all the up-front costs of the project and assumed responsibility for maintenance in exchange for a 77.5% share of the energy savings and a fixed price for maintenance equal to 77.5% of the Army's projected cost for maintenance without the energy retrofit [1]. The company spent $19 million on GSHPs, which averages to a cost of about $4,700 per housing unit. This arrangement allowed them to recover their capital investment, cover the cost of financing the investment, system operation and maintenance expenses, and earn a profit [2].

10 Experiences / Lessons Learned

The engineers and project managers supervising this massive undertaking had three main tasks before installing the system: to develop models of energy consumption and perform design calculations to size heat pumps and ground heat exchangers for the 4,003 apartments; to engineer the other retrofits for each apartment; and to estimate the overall energy savings [1].

At the time of the RFP, the only company that bid was CEG, as GSHPs were not a well-known or -utilized technology. Once they received the bid and began development of the project, CEG found it more feasible to redesign some smaller existing units to meet project specifications. Previously, none of the 1.5 to 2-ton GSHPs on the market was efficient enough with a low enough installation cost to make the project cost-effective.

During the installation, about 680 miles of 1-in plastic tubing were used. When burying the tubing, the contractors had to be careful to avoid other buried pipes, such as sewer lines and water supply pipes. Where the tubing comes out of the ground, cement was used to seal the borehole and prevent surface water runoff and its contaminants from flowing down into the water table [3].

Part of the motivation for the project was that the Clinton Administration had passed Executive Order 12902 as part of The Energy Policy Act of 1992 mandating that the government become more energy-efficient. This directive was to reduce the energy consumption of Federal agencies by 30% by 2005, as compared to a 1985 baseline. The deficit-reduction policies of Congress suggested that any increase in energy use would have to be funded from the training or salary budget, because the $13 million annual energy budget was not going to be increased [1].

The Fort Polk project received Vice President Al Gore's "Hammer Award" in 1997 for "hammering away at building a better government"-one that works better and costs less [1].

11 General Data

Address of Project:	7784 Colorado Ave #840 Fort Polk, LA 71459
Existing or New Case Study:	Existing
Date of Report:	March 1988

12 Acknowledgements

Designer and General Contractor:	Co-Energy Group, Santa Monica, CA
Case Study Authors:	Patrick Hughes and John Shonder, of DOE's ORNL, led the DOE evaluation of the project.

13 References

P.J. Hughes and J.A. Shonder. Oak Ridge National Laboratory (1998). The Evaluation of a 4000-Home Geothermal Heat Pump Retrofit at Fort Polk, LA: Final Report.

Holihan, P. Energy Information Administration/ Renewable Energy 1998: Issues and Trends. Analysis of Geothermal Heat Pump Manufacturers Survey Data, http://www.homeenergy.org/archive/hem.dis.anl.gov/eehem/99/990913.html

14 Contact

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For more information on FEMP Resources:

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Also looking for additional *documented* case studies of energy and water saving projects that can be put on the FEMP Website