



# Relocatable Classrooms: Less Energy, Better Air

## The Problem

In 2000, there were about 80,000 relocatable classrooms (RCs), also known as modular or portable classrooms, in California schools and a projected growth rate of 4,000 new RCs per year. Many of these classrooms have poor indoor air quality, are noisy, and consume more energy than they should—the typical HVAC unit has a seasonal energy-efficiency rating (SEER) of 10. In addition, industrial safety rules under California Code of Regulations Title 8 require that HVAC units for RCs provide continuous ventilation. Although the existing units offer that capability, teachers often turn off ventilation fans because the high noise levels disrupt classes.

## The Solution

Researchers at the Lawrence Berkeley National Laboratory (LBNL) developed specifications for an improved heat pump air-conditioning (IHPAC) system that provides a SEER performance of 13 and eliminates the noise and ventilation problems associated with the SEER 10 systems that are currently used in RCs. The Bard Manufacturing Co., a leading manufacturer of wall-mounted HVAC systems for RCs, built a prototype based on the IHPAC specifications. After researchers tested the prototype IHPAC at LBNL, 10 units were installed at two schools in California for a year of monitoring. The IHPAC, known as the Quiet Climate 2, is now available as a commercial product from Bard.

## Features and Benefits

Overall, the field tests revealed that the IHPAC units with SEER 13 ratings improve indoor air quality, save energy, operate more quietly, and provide similar or better thermal comfort than conventional HVAC units rated SEER 10.

**Ventilation.** The IHPAC features an automatic “smart controller” that triggers ventilation whenever it senses that the room is occupied. In addition, the controller was designed to “learn” the classroom’s occupancy schedule over a two-week period and from then on to ventilate the classroom before occupancy, based on the learned schedule. During the field tests, the IHPAC controls provided continuous ventilation when the rooms were occupied, which led to significantly lower levels of carbon dioxide, aldehyde, and other volatile organic compounds in the classrooms (**Figure 1** and **Figure 2**, next page). With the conventional units, ventilation was not continuous, because thermostats only turned on ventilation when

heating or cooling was required and because teachers turned off noisy units during class.

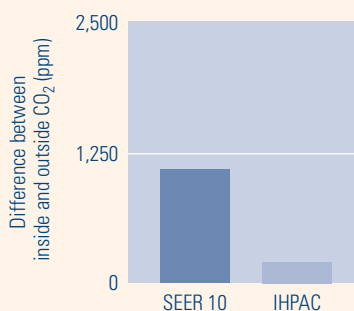
**Energy.** The specifications required that the IHPAC units have an efficiency rating of SEER 13. Contributing to increased efficiency were a two-stage operation—as opposed to a less-efficient single-stage unit—and reconfigured compressors, supply-air fan motor, condenser, and evaporator. A direct comparison of energy use between the new units and the old was difficult because teachers frequently turned off the old units when class was in session. If the units had been left

Figure 1: Increased ventilation with the improved HVAC unit

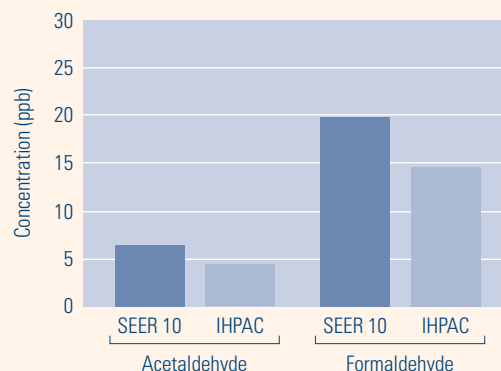
Field test results showed that the new HVAC system developed by Lawrence Berkeley

National Laboratory, the improved heat pump air-conditioning (IHPAC) system, increased classroom ventilation compared to the conventional HVAC unit with a SEER rating of 10. The first graph (A) shows that the improved HVAC unit reduced the difference in carbon dioxide levels between inside and outside the classroom compared to the conventional unit, which means the ventilation was better in the classroom with the improved HVAC unit. The second graph (B) shows a reduction in acetaldehyde and formaldehyde concentrations, two toxic chemicals found in buildings, in classrooms with the improved HVAC unit.

### A. Indoor carbon dioxide levels reduced



### B. Indoor toxic chemicals levels reduced



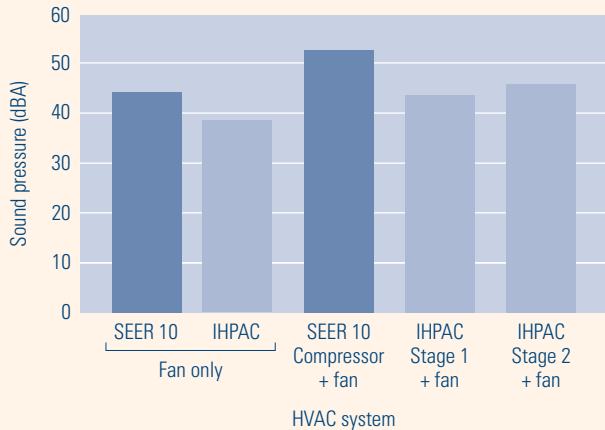
Notes: CO<sub>2</sub> = carbon dioxide; ppm = parts per million; ppb = parts per billion.

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Figure 2: Less noise created by the improved HVAC units

The improved HVAC designed by Lawrence Berkeley National Laboratory, dubbed the improved heat pump air-conditioning (IHPAC) system, creates less noise than the conventional HVAC unit with a seasonal energy-efficiency rating (SEER) of 10. The figure shows that the IHPAC system reduced fan-only sound pressure by 6 decibels and compressor and fan sound pressure by 6 to 8 decibels compared to the conventional unit. Note that the improved HVAC unit has two compressor stages as part of its energy-efficient design.



Note: dBA = decibels audible.

on, researchers estimate that the old equipment would have consumed 30 to 40 percent more energy per year than the new equipment.

**Noise.** The IHPAC units were reengineered to minimize noise and vibration and operated considerably more quietly than the conventional units, which reached 56 decibels audible (dBA) with the compressor and fan on. The average noise levels for the IHPAC units were below 45 dBA with the Stage 1 compressor and fan on and higher than the 45 dBA maximum level with the compressor in Stage 2 and fan on, which was louder than expected. After the study, the researchers found that the acoustics could have been improved by making the RC walls sturdier.

## Applications

Although the study primarily focused on RC applications, these wall-mounted packaged units are designed to fit on any modular or portable buildings for both new construction and

retrofit applications. As long as the units are sized properly, they can be used in most U.S. climates. With the installation of an optional heat pump dehumidifier, they can operate effectively even in humid climates.

## California Codes and Standards

The IHPAC meets the Title 8 requirement for continuous ventilation during business hours in California classrooms with installed mechanical HVAC equipment.

## What's Next

The LBNL researchers plan to further improve the energy efficiency of the IHPAC systems, focusing on the performance of the filtration system—an energy-intensive technology. They would also like to study the effects of poor ventilation on teacher and student performance and attendance, although no funding for this study is presently available.

## Collaborators

This project was a collaborative effort between LBNL, Bard Manufacturing Co., and Geary Pacific Supply Corp., the West Coast distributor of Bard HVAC equipment.

## For More Information

Reports documenting this project and providing more details may be found at the LBNL “Improving Ventilation and Saving Energy” web site at <http://eetd.lbl.gov/ied/ivse>.

To view Technical Briefs on other topics, visit [www.esource.com/public/products/cec\\_form.asp](http://www.esource.com/public/products/cec_form.asp).

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## About PIER

This project was conducted by the California Energy Commission's Public Interest Energy Research (PIER) Program. PIER supports public-interest energy research and development that helps improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

**Arnold Schwarzenegger, Governor**

**For more information see** [www.energy.ca.gov/pier](http://www.energy.ca.gov/pier)

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