Presented by:

ZERO-ENERGY SCHOOLS

HOW INNOVATIVE CONCRETE SYSTEMS ARE MAKING IT POSSIBLE

Richardsville Elementary School in Warren County, Kentucky, is the nation's first zero-energy school. Architect and photo credit: Sherman Carter Barnhart. MEP Engineer: CMTA, Inc. ICF System: Nudura.

LEARNING OBJECTIVES

Upon completion of this course the student will be able to:

1. Understand the principles and strategies behind zero-energy school design and construction.
2. Understand how innovative concrete systems such as ICFs are being used to achieve zero-energy schools.
3. Understand how a combination of energy-efficiency strategies, high-performance envelopes and solar power are used to meet zero-energy criteria.
4. Understand the contribution concrete makes to safe and productive schools by providing energy-efficient, quiet and resilient structures.

CONTINUING EDUCATION

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By: Lionel Lemay, PE, SE, LEED AP. Executive Vice President, Structures and Sustainability, National Ready Mixed Concrete Association; James Bogdan, LEED AP, QEP. Senior Director, Sustainability Initiatives, National Ready Mixed Concrete Association

INTRODUCTION

Richardsville Elementary School, completed in 2010, is the nation's first zero-energy school. The 77,000-square-foot building combines drastic reduction in energy consumption with on-site photovoltaic panels that produce more energy than required to run the building. The building is so energy efficient that it returns energy back to the grid.

"We are tremendously proud that since its opening in 2010, we have not paid a single utility bill on Richardsville Elementary School. The reason for this cost avoidance is that the building actually generates more electricity than it consumes. At the end of the school year, we usually get a check back from the utility company in excess of $30,000," says Jay Wilson, director of safety and energy management, Warren County, Kentucky, Public Schools.

"The easiest way to increase a school districts budget is to reduce energy consumption," says Kenny Stanfield, principal at Sherman Carter Barnhart and architect on Richardsville Elementary School, along with dozens of net-zero or near-net-zero schools in Kentucky. "And the most cost-effective way to save energy is not to need it," adds Stanfield.

Stanfield, along with CMTA, Inc., engineers lowered the energy use intensity (EUI) for Richardsville Elementary School to 18.2 kBtu/ft^2 compared with 73 kBtu/ft^2 required by the energy code, a 75 percent reduction. Because the energy use was so low and the building construction cost was below budget, the school district was able to absorb the cost of adding a 349 kW photovoltaic array to provide enough energy to power the school and sell a small amount back to the electric utility.

According to Stanfield, the trend towards zero-energy schools, also known as net-zero-energy or zero-net-energy, comes down to three factors:

1. State-of-the-art design strategies and technologies to reduce energy consumption.
2. An innovative building system such as insulating concrete forms (ICFs) that can provide high R-value, low air infiltration at a low cost.
3. Affordable on-site solar energy.

There are several reasons why schools are ideal zero-energy candidates:

1. Schools typically have low energy demand. They operate only nine months of the year, with well-defined and limited operating hours.
2. Occupancy levels are predictable and controlled and after-hours occupancy is limited.
3. Plug loads are low compared with other building types that might run a lot of appliances and computer equipment.
4. Schools are ideally suited for renewable energy, especially in the form of solar panels, since schools are often limited to two stories and have a relatively large roof area to volume ratio, meaning there is plenty of room to install solar panels. Most of the demand for energy comes during the day, when the sun is available to generate electricity.
5. Schools are owner occupied, which means there is an interest in minimizing operating costs, including utilities. School boards have bonding authority to fund long-term projects.
6. School can meet sustainability goals, since zero-energy buildings reduce annual carbon emissions both through energy efficiency and use of renewable energy.
7. A healthier, more comfortable indoor environment can help stimulate learning, help reduce student absences and lead to increased teacher retention, according to the Center for Green Schools.
8. Since many zero-energy schools are built using concrete construction with safe rooms and can generate their own power, zero-energy schools are disaster resilient; they can serve as a community shelter during and after a disaster.

Richardsville Elementary School is so energy efficient that it generates enough energy to sell back to the electric utility. Photo courtesy of CMTA, Inc.

ZERO-ENERGY STRATEGIES

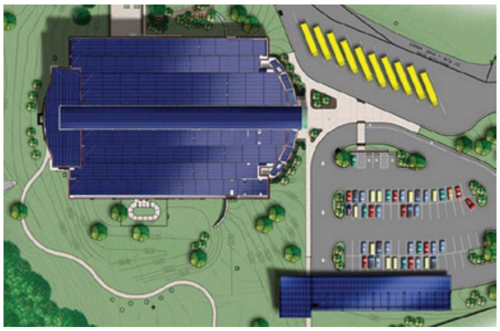
"The key to achieving zero-energy is *drastic* energy reduction and cost shifting to areas that pay dividends. It starts with efficient floor plans that are fully optimized (high net to gross ratio) and less expensive to construct," says Ben Robertson, engineer with CMTA, Inc. "Sure, any building can be zero-energy, but doing it without spending more money is where true success is achieved," adds Robertson.

Although installing on-site renewable energy infrastructure such as solar arrays is coming down in price, it still requires an up-front investment. Making the building as energy efficient as possible helps to reduce the size of the renewable power infrastructure needed, thus keeping initial costs down. In addition, using cost-effective construction methods and materials allows room in the budget for the initial investment in power-generating equipment. The following are the key strategies to achieving these goals:

Passive Solar Strategies

Building orientation, daylighting, building volume and thermal mass are all building properties that can be optimized by designers to help reduce energy consumption without increasing cost or compromising function and aesthetics. Passive solar strategies include:

- **East/West building orientation:** If possible, line up the building's main circulation axis in an east/west orientation with academic spaces along the north and south walls of the building to control natural light.
- **Daylighting:** Use daylighting for classrooms with a combination of exterior solar shades to block sun during high sun orientation or light shelves to reflect light deep into interior spaces during low sunlight conditions. Use clerestories or windows mounted at higher elevation, with ceilings sloped to the interior to allow light to penetrate further. Use aerogel



East/west orientations, daylighting and compact volume helped reduce energy consumption of Richardsville Elementary School. Photos courtesy of Sherman Carter Barnhart and CMTA, Inc.

insulated glazing or low-e coatings to reduce solar heat gain.

- **Compact building volume:** Use rectangular, multistory designs (at least two stories) to reduce the exterior wall-to-floor area, window-to-floor area and roof-to-floor area ratios.
- **Thermal mass:** Use building systems that have high thermal mass, such as concrete for the walls and floors of the structure.

High-Performance Envelope and Structure

Sherman Carter Barnhart, along with other architects highlighted in the case studies below have come to the realization that ICFs incorporate all the properties needed for zero-energy school construction. ICFs are used for the following reasons:

- They act as load-bearing walls with super-insulation, thermal mass and air barrier all in one. ICFs create one of the tightest envelopes available. You can achieve low air-infiltration rates with other systems, but it is significantly more complex.
- They reduce sound transmission from outside and between classrooms, and for gymnasiums, music rooms and theaters.
- They keep students and teachers safe from Mother Nature's wrath. Concrete systems are resistant to fire, tornados, hurricanes, floods and earthquakes.

Energy-Efficient HVAC Systems and Technology

The use of energy-efficient mechanical systems and active control technology is critical to keeping energy use intensity (EUI) as low as possible. Strategies include:

- Use efficient geothermal HVAC systems with variable-speed heat pumps. Use one heat pump for two classrooms.

INSULATING CONCRETE FORMS

Insulating concrete forms (ICFs) combine two well-established building products: reinforced concrete for strength and durability, and expanded polystyrene (EPS) insulation for energy efficiency. ICF walls are made up of two layers of rigid insulation held together with plastic ties to form ICF units with a cavity in the center. The ICF units are stacked in the shape of the wall, reinforcing steel is added into the cavity and then concrete is placed into the form. The result is a reinforced concrete wall with a layer of insulation on each side. What makes ICFs different from traditional concrete construction is that the forms remain in place after the concrete is cured to provide thermal insulation. The combination of reinforced concrete and insulation provides an ideal load bearing wall, thermal envelope, air barrier, fire barrier and sound barrier.

Ease of Construction

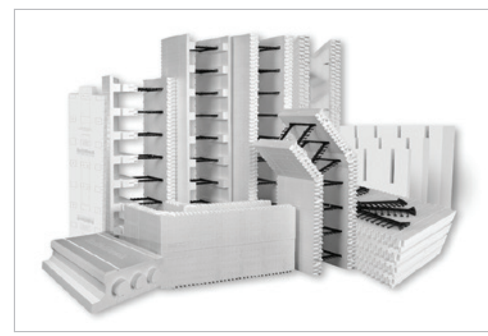
The efficient construction process is what sets ICF building systems apart from other building systems such as wood frame, steel frame and masonry construction. ICF construction can help contain construction costs and reduce construction time because of the inherent efficiencies of the installed assembly that serves nine functions:

1. Concrete form (that stays in place)
2. Thermal barrier
3. Air barrier
4. Moisture barrier
5. Fire barrier
6. Sound barrier
7. Substrate for running utilities
8. Substrate for attaching finish materials
9. Reinforced concrete structure

Richardsville Elementary School used the Nudura ICF system. Photo courtesy of Sherman Carter Barnhart.

In other forms of construction, these functions are installed by several different trades, usually at significantly added cost. General contractors can realize a number of on-site efficiencies, including fewer trades, reduced crew size and accelerated construction schedules. Because construction schedules are usually much shorter with ICF construction, the general contractor is able to finish on time and within budget. The building owner is able to put the building into service sooner, cutting short financing costs.

There are many different ICF manufacturers with similar ICF systems. The blocks range in size from 48 to 96 inches long and 12 to 24 inches high depending on the manufacturer. The most common configuration of an ICF unit is made up of two layers of 2 3/8- to-2 3/4-inch-thick EPS insulation spaced 4, 6, 8, 10 or 12 inches apart depending on design requirements. The most common spacing is 6 inches or 8 inches for most low- to mid-rise buildings. But for taller buildings, taller walls or exceptionally large loadings, thicker walls are necessary. For simplicity, ICFs are generally called out by the width of its cavity, hence an ICF with a 6-inch cavity is called a 6-inch ICF and so forth.



ICF wall and floor components. Image courtesy of BuildBlock.

ICF manufacturers have a variety of ICF blocks to accommodate any design condition and have outstanding technical support, including design manuals, design details, engineering support and all the test reports needed for school construction, such as fire, energy and noise. They have special components including straight blocks, corner blocks, brick ledges, angled blocks, curved blocks and half-height units, minimizing the need for field modifications that further reduce construction time.

Another benefit of ICFs is that construction projects can continue through the coldest and hottest weather because of the insulating quality of the ICF forms. This means that concrete will continue to gain strength within the protective formwork despite freezing conditions, and not overheat during extreme summer conditions. In addition, all ICF systems have furring strips integrated into the plastic ties that permit easy attachment of any interior or exterior finish.

There are also ICF concrete floor and roof systems. The concept is similar in that the ICF floor or roof is made with rigid insulation to function as a one-sided form at the bottom surface. The forms are installed to span between concrete walls, reinforcing steel is installed and then concrete is placed onto the forms. The result is a reinforced concrete floor or roof with rigid insulation on the bottom. Other types of floor systems often used in combination with ICF walls include precast hollow-core plank and composite concrete floors over steel joists.

- Use occupancy sensors for lighting and other occupancy-dependent systems.
- Control outside air ventilation with dedicated outside air systems, heat recovery wheels and demand control ventilation based on occupancy.
- Use automated dimming to reduce artificial-lighting requirements—although if using LED lighting, automated dimming can be eliminated since LED lighting is extremely energy efficient.
- Use ENERGY STAR convection ovens as a healthier option to traditional fryers and skillets, as they eliminate the need for energy-intensive type I ventilation hoods.
- Use ENERGY STAR laptops on carts that permit computers to be transported to classrooms instead of having dedicated computer labs with energy-intensive desktops.
- Use dark sky approach to exterior lighting. Use security lighting with motion sensors to alert local police if there is activity on school property after dark.

On-site Power Generation

Most schools, including Richardsville Elementary, use photovoltaic panels as the main source of on-site power generation. Solar panels are becoming more common at schools across the United States. According to the Solar Energy Industries Association report *Brighter Future: A Study on Solar in U.S. Schools*, there are approximately 5,500 K-12 schools with solar photovoltaic installations in the country. A precipitous decline in the cost of solar panels has made installations financially viable. According to National Renewable Energy Laboratory, the cost of commercial solar installations has fallen to $2.80 per watt in 2017, compared with $7.24 per watt in 2010, a 60 percent decline in just seven years. This explains why 61 percent of the solar capacity in K-12 schools has been installed in the last five years.

That said, there is still a capital cost of solar panel installation that must be accounted for to meet strict budget limitations of most school boards. The following are key strategies:

- Minimize the EUI of the building using all the strategies previously mentioned. According to the New Building Institute, the target EUI for zero-energy schools is 20-24 kBtu/ft^2 or lower if possible.
- During construction, utilize design strategies and building systems that are efficient and cost- effective to help offset the initial cost of solar panel installation.

QUIZ

1. The main components of ICFs are:
   a. Steel and plastic
   b. Insulation and concrete
   c. Plastic and aluminum
   d. Wood and masonry

2. ICF walls are most frequently used as ________ walls to support vertical and horizontal loading
   a. Frame
   b. Bearing
   c. Partition
   d. Clerestory

3. One of the reasons ICFs are cost competitive is that they serve nine functions, including:
   a. Exterior finish and roofing
   b. Photo voltaic panels and sunscreen
   c. Thermal barrier, air barrier and moisture barrier
   d. Columns and beams

4. To attach interior and exterior finish to an ICF wall one must first install wood furring strips.
   a. True
   b. False

5. Even though ICF construction costs about the same as wood, steel or masonry, they are often used in school construction because of reduced:
   a. Winter months
   b. Wall lengths
   c. Transportation distances
   d. Construction time

6. Floor systems often combined with ICF walls in school construction include:
   a. Precast hollow-core plank
   b. ICF floor systems
   c. Composite concrete floors over steel joists
   d. All of the above

7. Which three attributes of ICFs contribute to energy efficiency?
   a. High insulation value, thermal mass and low air infiltration
   b. High insulation value, thermal bridging and low air infiltration
   c. Thermal mass, thermal bridging and high air circulation
   d. Thermal mass, thermal bridging and convection

8. A zero-energy school should set a target energy use intensity (EUI) of ______ or less:
   a. 20–24 kBtu/ft^2
   b. 120–130 kBtu/ft^2
   c. 73 kBtu/ft^2
   d. 40–44 kBtu/ft^2

9. The concrete core of an ICF wall system offers:
   a. Noise and vibration control
   b. Fire resistance
   c. Thermal mass
   d. All of the above

10. Once concrete is placed into ICF forms and concrete hardens, the forms are removed for re-use.
    a. True
    b. False

SPONSOR INFORMATION

BUILD WITH STRENGTH

Build with Strength, a coalition of the National Ready Mixed Concrete Association, educates the building and design communities and policymakers on the benefits of ready-mixed concrete, and encourages its use as the building material of choice. No other material can replicate concrete's advantages in terms of strength, durability, safety and ease of use.

This article continues on http://go.hw.net/AR052018-1.
Go online to read the rest of the article and complete the corresponding quiz for credit.

Low-Impact Development Strategies

Conserving water is another way to reduce environmental impact and construction cost. Low-impact development strategies help meet zero-energy goals:

- Utilizing native plantings and rain gardens helps reduce irrigation demands.
- Using permeable pavements reduces stormwater runoff, filters stormwater and reduces the need for expensive stormwater infrastructure.
- Permeable pavements and rain gardens can eliminate the need for detention basins, leaving more space for athletic fields and outdoor education opportunities for students.

Energize the Curriculum

Finally, make sure you engage the students and teachers by providing learning opportunities about energy efficiency and how the zero-energy building is helping to reduce environmental impacts. Richardsville Elementary School used the following displays and interactive stations to help students visualize their contributions to reducing environmental impacts:

- **Geothermal energy:** Provide detail on how geothermal energy works, and expose piping with a temperature gauge so students can monitor the system's performance.
- **Solar energy:** Provide detail on how solar energy is captured and converted to electricity for use in the building. Provide a gauge to show how much energy is being produced. Provide a laptop computer battery-charging station where students can see the energy being received from the solar panels.
- **Water conservation:** Provide a station on water conservation that enables students to monitor the amount of rainwater collected and used in the rain garden.

BEYOND ZERO-ENERGY SCHOOLS

Schools are not the only building type going zero energy. Nor are schools the only building type using ICF construction. There are examples of high-performance ICF buildings all over the U.S. and Canada, including single-family residential, multifamily residential, hotels, dormitories, assisted living facilities, offices, health-care facilities, manufacturing and warehouse buildings. Theaters are also trending towards ICF construction for superior sound attenuation. To learn more about ICFs for multifamily residential, including apartments, condos, hotels, dormitories and assisted living facilities, visit http://go.hw.net/AR217Course1. To learn more about ICFs for commercial applications, go to http://go.hw.net/AR042017-2.

CONCLUSION

Zero-energy schools are becoming more popular. High-performance envelopes using ICFs, along with the lower cost of renewable energy, is making it possible. ICF systems result in construction that is faster, easier and less labor intensive than other construction methods, making it possible to offset the cost of solar panels. ICF systems combine reinforced concrete with fire, sound, thermal, air and moisture barriers in one step that reduces the number of trades required on-site. Construction can continue all year long, since the forms provide an ideal curing condition for concrete during the hottest and coldest weather.

All this leads to a construction system that is ideal to meet the demands of the zero-energy buildings. ICFs are a modern building system that is easy to use and cost competitive. To find out more about ICF construction and concrete construction in general, visit www.BuildwithStrength.com and www.icf-ma.org. ■

ALAMOSA ELEMENTARY SCHOOLS, ALAMOSA, COLORADO

Design, construction and photo credit: Neenan Archistruction. ICF system: Fox Blocks.

Completed in 2010, Alamosa Elementary School is a design-build project located in one of the most economically challenged areas of southern Colorado. Two connected school buildings (grades K-2 and 3–5), with a combined area of 145,000 square feet, had the shells of both buildings constructed with 51,400 square feet of ICFs, including 75 percent of the exterior walls, in just 90 days. A LEED Gold certification was awarded for integrating various sustainable design aspects, including under-slab hydronic heating and ICFs. Combined, these systems reduce energy loads by 72 percent compared with metal framing, thereby allocating money to classroom needs instead of utility bills. Also, energy modeling found that the building could be designed without air conditioning—and still be comfortable. Solar thermal and solar panels provide hot water and heat when needed. Just as important, nearly every space in the building has daylight and views to the outdoors.

DEARING ELEMENTARY SCHOOL, ROUND ROCK, TEXAS

Photo credit: Luis Ayala. Architect: Stantec. MEP: CMTA, Inc. ICF system: Nudura.

Dearing Elementary School was one of the first zero-energy-ready schools built in central Texas. The two-story, 93,376-square-foot school is a compact design that fits on a 7-acre site to save on energy costs. The planning process redefined the district's vision on energy efficiency and led to a transformational facility design where this school acted as a catalyst for future zero-energy strategies for the district. Design features included geothermal for electricity and heating, a sophisticated building energy management system, 100 percent LED lighting, advanced HVAC systems and 100 percent daylight in each room. The design also incorporated ICFs for exterior walls. The combined strategies resulted in an EUI of 17 kBtu/ft^2, which is 76 percent lower than the average school in its climate zone. Polished concrete floors were used to reduce maintenance costs and increase the floor's life cycle. Additionally, located in "Tornado Alley," it was important for the school to withstand extreme weather events, including 200-mile-per-hour winds and debris traveling at more than 100 miles per hour. *Engineering News-Record (ENR) Texas & Louisiana* awarded this project with a Best Green Project for 2015.

SOUTH WARREN MIDDLE AND HIGH SCHOOL, BOWLING GREEN, KENTUCKY

Architect and photo credit: Sherman Carter Barnhart. ICF system: Nudura.

At the time of construction, South Warren was the largest K-12 school building in the state of Kentucky. Comprising 332,000 square feet, the building sits on an 85-acre site. Goals of the project included energy efficiency, speed of construction, student safety and "green" design principles. The design team identified targets for potential energy reduction, such as a super-insulated roof system, optimized geothermal HVAC system and daylight harvesting. But in terms of a critical path for these decisions, which also included safety, the building envelope was determined to be the most important.

Subsequently, this was the first educational project anywhere to utilize ICF construction for the entire structural wall system of the building, both exterior and interior bearing walls. Construction spanned the winter without delay. ICFs allow the concrete to be protected and insulated when placed, permitting continuity of the construction schedule. The gymnasium has 40-foot-tall ICF walls, two "cafetoriums" with 35-foot-tall walls and a performing art center with a compound curve. The 8-inch and 12-inch ICF wall system provides students a safer building even during the severe tornadic activity that is common during Kentucky's spring and summer seasons. The inherent core strength of the concrete in the ICF wall system, coupled with the hollow-core concrete plank floor system, created a building structure capable of resisting 250-mph winds. By combining all sustainable elements, South Warren is zero-energy ready, operating at only 24.3 kBtu/ft^2 EUI, which equates to a 70 percent reduction in energy use compared with the average school in Climate Zone 4. Additionally, it was calculated that the ICF construction costs less per square foot than traditional masonry and steel framing.

ST. ANNE'S BELFIELD SCHOOL, CHARLOTTESVILLE, VIRGINIA

Architect and photo credit: Bowie Gridley. ICF system: Amvic.

St. Anne's Belfield is a four-story, 105,000-square-foot school. Educating students in preschool through 8th grade, it is also known as the Learning Village. It was a multi-building project with significant attention given to the use of sustainable technologies. The facility integrated several green elements, including a geothermal HVAC system, which has more than 100 wells that efficiently heat and cool the building. Large, energy-efficient windows bring natural light into the building and reduces its dependence on artificial lighting. The school also has an underground cistern that has a capacity to store 75,000 gallons of rainwater and runoff for irrigation. Construction on the new school began in 2009 and was completed in mid-2010. The school features ICF walls that make the building very energy efficient. ICF installation only took seven months of the entire construction schedule. When constructed, it was the first school in Virginia to be built with ICFs. The school secured LEED Gold certification and, due to the ICF system and other technologies, earned every available point in the optimizing energy performance credit.

GLASGOW HIGH SCHOOL, GLASGOW, KENTUCKY

Architect and photo credit: Sherman Carter Barnhart. ICF System: Fox Blocks.

The Glasgow High School is a 180,000-square-foot building with many sustainable elements. From the time the footers were poured in April 2011 until the school opened in August 2012, the project was constructed on schedule despite the seemingly constant rain. The project team met the challenge: achieving a timeless aesthetic with balancing modern energy efficiency. Technologies such as rigid roof insulation, a white TPO single-ply roof system to reduce solar heat gain, and solar tubes were installed in corridors and interior classrooms. Bringing daylighting into these spaces was a major design consideration and was balanced with sensors that adjust the artificial lighting based on both the amount of natural daylight and occupancy needs. Building with 31,000 square feet of 8-inch and 12-inch ICFs was also a key factor in meeting energy and design goals, especially since windows were large and plentiful, including a 52-foot-radius wall with numerous arched openings and windows 30 feet high. All combined, the building earned LEED certification, with a level of craftsmanship that pleased the owner. Total construction lasted 420 days, with 70 days start to finish devoted to ICF installation and concrete placing. Installation was shared between two different installers due to the project schedule, indicating the ease of installation and workflow of ICF systems.

DISCOVERY ELEMENTARY SCHOOL, ARLINGTON, VIRGINIA

Photo credit: Alan Karchmer. Architect: VMDO Architects. MEP: CMTA, Inc. ICF system: Fox Blocks.

Discovery Elementary School, which opened in 2015, was the first elementary school building to be built in the local public school system in over a decade. The design utilized every nook and cranny of the school to integrate design, sustainability and learning, and served as a catalyst for future zero-energy design requirements in the district. Upon opening, the school was the first zero-energy school in the mid-Atlantic. With a floor plan of 97,588 square feet, the two-story elementary school was built using 3,000 linear feet of ICF bearing wall.

To meet energy goals, sustainable building elements included 1,706 roof-mounted solar panels, a geothermal well field, solar pre-heat of domestic water, 100 percent LED lighting and ICF exterior walls. Actual EUI is approximately 16 kBtu/ft^2, which is 76 percent lower than the national school average for Climate Zone 4. With the photovoltaic array, the school is "net positive energy"—producing more power than it uses. An energy dashboard is on display for teacher curriculum and student projects. The school was named a U.S. Department of Education Green Ribbon School and is a recipient of various design accolades, including the AIA COTE Award and A4LE National Award. The project was completed under budget, and the building annually saves more than $100,000 per year in utility costs, which shifts funds to academic needs.