High Performance Schools:
Affordable Green Design for K-12 Schools

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ABSTRACT

Schools in the United States spend $7.8 billion on energy each year—more than the cost of computers and textbooks combined, according to a 2003 report from the National Center for Education Statistics. The U.S. Department of Energy (DOE) estimates that these high utility bills could be reduced as much as 25% if schools adopt readily available high performance design principles and technologies. Accordingly, hundreds of K-12 schools across the country have made a commitment to improve the learning and teaching environment of schools while saving money and energy and protecting the environment.

DOE and its public- and private-sector partners have developed *Energy Design Guidelines for High Performance Schools*, customized for nine climate zones in U.S. states and territories. These design guidelines provide information for school decision makers and design professionals on the advantages of energy efficiency and renewable energy designs and technologies. With such features as natural daylighting, efficient electric lights, water conservation, and renewable energy, schools in all types of climates are proving that school buildings, and the students and teachers who occupy them, are indeed high performers.

This paper describes high performance schools from each of the nine climate zones associated with the *Energy Design Guidelines*. The nine case studies focus on the high performance design strategies implemented in each school, as well as the cost savings and benefits realized by students, faculty, the community, and the environment.

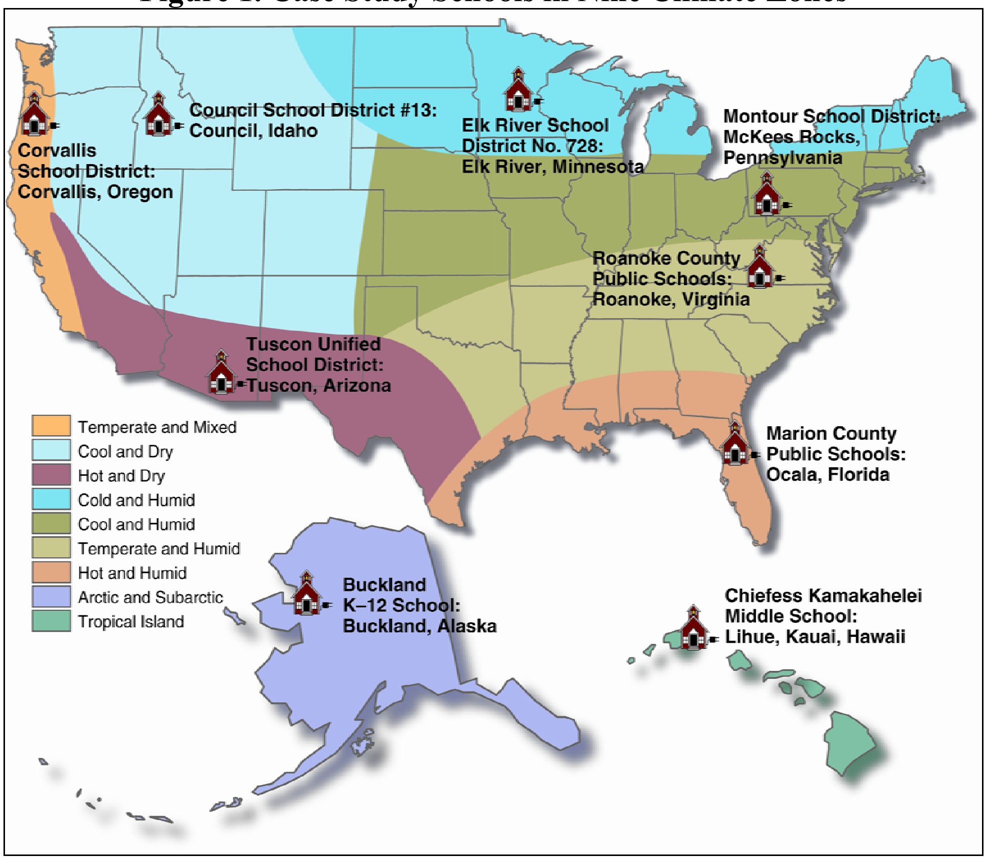
Introduction

Each year, U.S. schools spend $7.8 billion on energy costs; this is more than they spend on computers and textbooks combined (Smith et al. 2003). In 2002, DOE's EnergySmart Schools staff estimated that these high utility bills could be reduced as much as 25% if schools adopt readily available, high performance school design principles and technologies (Schoff 2004). These savings translate into direct benefits for school administrators, teachers, taxpayers, and most importantly, students. Today, hundreds of U.S. K-12 schools are making a commitment to improve the learning and teaching environment of schools, save money and energy, and protect the environment.

Public- and private-sector building industry partners are working to make school districts, architects, and engineers more aware of the benefits of energy-efficient designs and renewable energy technologies. These are outlined in the U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED™) rating system (USGBC 2004), American Society of Heating, Refrigerating, and Air-Conditioning Engineers' (ASHRAE) GreenGuide (Grumman 2003), and the Sustainable Building Industry Council's High Performance Schools Resource and Strategy Guide (SBIC 2004). The benefits of high performance design are also highlighted by the DOE-Environmental Protection Agency (EPA) ENERGY STAR® label for buildings (U.S. DOE 2004c). School districts all across the country are experiencing that energy efficiency and renewable energy make financial as well as academic sense.

The DOE National Renewable Energy Laboratory (NREL) and the Rebuild America/EnergySmart Schools program in DOE's Office of Weatherization and Intergovernmental Program have developed two climate-specific resources to help decision makers and designers bring the benefits of energy efficiency and renewable energy to school buildings. Published in 2002, the *Energy Design Guidelines for High Performance Schools* series is customized for seven climate zones in the continental United States (U.S. DOE 2002b-2002h). These design guidelines received the International Association of Business Communicator's Silver Quill Award for a Multi-page Publication in 2003. DOE published two more climate zone guidelines in 2004, one for tropical islands and one for arctic and subarctic climates (U.S. DOE 2004a, 2004b). A companion document, the *National Best Practices Manual for Building High Performance Schools* (U.S. DOE 2002a), contains more detailed information for architects and engineers for the first seven climate zones. Figure 1 shows where case study schools are located in each climate zone.

Figure 1. Case Study Schools in Nine Climate Zones



Source: National Renewable Energy Laboratory

Both resources illustrate the high performance design principles that can benefit schools today. And in fact, schools all around the country are improving the performance of their buildings (and their students) by adopting the cost-saving, high performance design principles outlined in the design guidelines. According to a 1999 study (and a 2003 follow-up report), students with the most natural light, or daylighting, in their classrooms progressed 20% faster on math tests and 26% faster on reading tests than students in the least daylit classrooms did, over a one-year period (Heschong Mahone Group 1999, 2003). By choosing high performance design features such as daylighting, efficient electric lighting, energy management systems, and renewable energy systems, schools in all types of climates are proving that school buildings—and the students and teachers who occupy them—are indeed high performers.

Implementing energy-efficient techniques and using renewable energy offer both financial and educational benefits to administrators, teachers, students, and community members. According to Daniel Sze, Rebuild America National Program Manager, schools in different climates have realized substantial savings in energy expenditures from implementing cost-effective, energy-efficient strategies in their buildings. These savings translate directly to additional funds for supplies, activities, and teachers and significant benefits to the environment (Sze 2004). The case studies that follow illustrate these benefits while describing high performance designs in schools in nine climate zones. Each case study highlights various high performance design aspects that the schools selected as appropriate for their climate zone and building needs. Results include improved learning environments, energy savings, monetary savings, and reduced environmental emissions.

Case Studies

Temperate and Mixed Climates: Corvallis School District 509J, Corvallis, Oregon

The Corvallis School District has eight elementary schools, two middle schools, and two high schools serving 6850 students. A new 125,000-square-foot middle school is scheduled to open in August 2004, and a new 230,000-square-foot high school in September 2006. The new schools will serve 552 students in the middle school and 1306 students in the high school. The school board, with the help of the district's Energy Education Coordinator, decided that energy efficiency would be a priority for the two new schools (Corvallis School District 2004). In 1999, the district partnered with an energy consultant, Energy Education, Inc., to identify and implement energy savings projects. By focusing on reducing energy use during off-peak hours and encouraging behavioral changes, such as turning off lights and computers when not in use, the district has saved $1.5 million from 1999 to 2004. A reimbursement from the local utility, Pacific Power, of $ 5,200 funded a lighting upgrade for the Corvallis High School cafeteria. A Consumer's Power rebate and Business Energy Tax Credit (BETC) of $24,000 funded the Crescent Valley High School gymnasium lighting retrofit (Mingo 2004). Other projects have included installing T-8 lighting; digitally controlled heating, ventilating, and air-conditioning (HVAC) equipment; and energy-efficient boilers. Teachers provided significant input on the design of the new schools, and both teachers and students have requested energy data for use in classrooms. The Oregon State Energy Office provided recommendations on community education and outreach to the administrative staff in the Corvallis School District (Wright 2004).

Because the schools have had significant energy and monetary savings, the community has been supportive of energy efficiency and renewable energy projects in the two new schools. In the *2004 Report to the Superintendent* (Corvallis School District 2004), the school district called for energy efficiency and renewable energy measures to be pursued for the two new schools. Both schools are applying for LEED Silver ratings. Energy efficiency and renewable energy will be incorporated directly into the buildings and curriculum. Estimates indicate that the new high school will use 35% less energy than a conventional school built to code, and the middle school, 30% less energy. The district is also planning to install a small, grid-connected photovoltaic system in one of the elementary schools for educational purposes (Mingo 2004).

Hot and Dry Climates: Tucson Unified School District, Tucson, Arizona

The Tucson Unified School District's (TUSD) primary goal for school building construction and maintenance is to improve the learning and teaching environment by improving building and systems performance and energy savings. Because of Tucson's hot, dry climate, energy use—particularly for cooling loads—is a significant portion of the total school budget. The TUSD has 107 schools and 8 million square feet of interior space supporting approximately 60,000 students. According to district staff, the potential savings resulting from energy efficiency and water efficiency projects (identified in professional energy audits) is more than $1 million annually. These projects featured lighting retrofits, use of reclaimed water for irrigation, and energy management systems. The TUSD established a Resources Efficiency Awareness Program (REAP) in 1991, a point system for schools with monetary awards. The district wrote, "Everyone in TUSD can manage energy, water, and waste more wisely to improve both student and school facility performance. We all benefit by practicing better environmental and economic stewardship" (TUSD 2004).

The TUSD is also actively promoting renewable energy through the Tucson Solar School Project. This area has excellent solar resources, and TUSD will be installing solar electric (photovoltaic) systems in six schools in 2004 and 2005. Project partners include Tucson Electric Power Company (TEP), the Greater Tucson Coalition for Solar Energy, and state and national solar energy programs. In 2002, TUSD, in partnership with TEP, installed two 8-kilowatt (kW) photovoltaic systems purchased through TEP's SunShare program. Six additional TUSD schools will be selected for 1-2 kW photovoltaic system installations, and the technology will be integrated into the math and science curriculum. Participating schools will also receive targeted energy efficiency retrofits such as lighting upgrades, vending machine controls, and energy management control systems. By reducing energy costs and providing new learning opportunities for students, energy efficiency and renewable energy are helping the Tucson program address both financial and academic needs (TUSD 2004).

Hot and Humid Climates: Marion County Public Schools, Ocala, Florida

In 1999, utility bills for energy in the Marion County Public Schools district accounted for more than $4 million of the district's operating budget (Rebuild America 2003). Recognizing an important opportunity to save money, the district started an energy management program that included projects such as programmable thermostats, timers for hot water heaters and lighting retrofits. Four years later, in 2003, the district passed the $1 million savings milestone and reduced its energy consumption by 8½% (Marion County Public Schools 2004). Marion County's energy management program aims to achieve energy savings by eliminating wasted energy while enhancing the quality of the educational environment. Marion County Public Schools staff believe that energy management policies such as an energy accountability program and school energy management plans have a significant impact on the quality of the learning environment, particularly in terms of lighting and indoor air quality. Indoor air quality is a particular challenge for many schools in hot, humid climates; Marion County plans to improve its schools' indoor air quality through high-efficiency HVAC systems.

The county's energy management committee, composed of facility managers, teachers and administrative staff, believes that developing, promoting and following good energy management policy not only enhances the classroom teaching and learning environment but also affects the bottom line. Accordingly, Marion County is working with a local energy services company (ESCO) to provide several schools in the district with energy management services. Projects include high-efficiency HVAC and lighting retrofits at junior high and high schools. Based on savings resulting from past energy efficiency programs, Rob Van Der Like, the school district's energy manager, was able to convince district financial officers to fund an investment-grade audit to identify energy savings opportunities to coincide with system maintenance and replacements (Van Der Like 2004b). The new budget includes funds for hardware upgrades such as lighting, variable-speed drives for HVAC systems, high-efficiency water fixtures, and energy management system controls. Now, both the district and the ESCO know that money will be available to fund energy efficiency projects. Because of their overwhelmingly positive experience with energy efficiency retrofits, Marion County officials are working with local architectural and engineering (A/E) firms to create a sustainable design template for new elementary schools in the district.

Addressing energy use at schools can also have unexpected financial benefits. When Van Der Like noticed a district junior high school's usage regularly exceeded that of comparably sized facilities, he and the utility worked together for more than a year before finally determining the cause. The problem was traced to a faulty meter that incorrectly recorded energy use in the utility's favor. Though not obligated to pay more than one year's damage, the utility agreed to refund the overcharge for the life of the meter (6 years), and the district received a $294,000 check (Van Der Like 2004a).

Temperate and Humid Climates: Roanoke County Public Schools, Roanoke, Virginia

Although Roanoke County Public Schools is a small district (1480 students), it has been able to add a new high school and elementary school and renovate six other buildings. The district has also found that small savings add up quickly. Like the Corvallis School District, Roanoke has worked with both Energy Education, Inc., and DOE's Rebuild America Program to identify and implement energy efficiency measures. To determine project priorities, Roanoke's energy manager used data loggers in classrooms to record temperature, humidity, and light intensity. The data helped pinpoint high-energy-use areas—such as classrooms, hallways, and offices—at individual facilities. After reviewing the data and recommendations from public- and private-sector partners, Roanoke installed T-8 lighting, an energy management system (EMS), and a monitor/controller unit for boilers. Energy efficiency projects in this district have reduced utility bills by 24%, for $2.9 million in savings, since August 1998 (Kelly 2003).

In 2003, both Oak Grove Elementary and the Central Administration Building in the district received the ENERGY STAR label for buildings. Oak Grove Elementary, originally built in 1959, is a 46,444-square-foot building housing 500 students. With its new EMS and lighting, the school runs very efficiently. Because the air conditioning load is high, the district's energy manager, Butch Kelly, states, "In addition to the automated controls system, the custodial staff takes great pleasure in keeping the air conditioning off when working in the summer. They are able to work by using cross ventilation" (Kelly 2003). Teachers are also supportive of energy efficiency. The teachers use data and concepts from the energy efficiency projects in their classrooms to help achieve state learning standards. Thus, energy efficiency projects enrich the district's curriculum as well as its financial situation.

Cool and Humid Climates: Montour School District, McKees Rocks, Pennsylvania

In 1997, the Montour School District in McKees Rocks faced the same budget challenge experienced in many school districts across the country: the budget could not cover the rising cost of energy. For Montour to stay within budget, it needed to reduce annual energy expenses by nearly 16% (Venture Lighting 2003). In 1998, the district, which serves 35,000 students, initiated a 10-year energy savings performance contract (ESPC) with a utility service company that then made improvements in four of the district's five schools. The project is guaranteed to deliver more than $1 million in savings by the end of the contract (Innovative Design 2003).

The ESPC allowed Montour schools to improve the schools' lighting levels and reduce their maintenance costs. Other improvements included an EMS in each school and new, energy-efficient motors. During the second year of the ESPC, lighting controls were installed in school gymnasiums, along with metal halide luminaries with pulse-start metal halide lamps and ballasts; these reduced both demand and energy consumption. Improvements were also made to computer labs, such as dimming controls and electronic dimming ballasts. These not only save energy, they also reduce glare and eyestrain (Miedel and Zbihley 2000).

Cold and Humid Climates: Elk River School District No. 728, Elk River, Minnesota

Elk River School District No. 728 has 11,000 students in 17 buildings. Rogers High School, the first high performance high school in Minnesota, was completed in 2003. With a projected 850 students for the 2004-2005 school year and 257,000 square-feet, this high school uses 25% less energy than the state standard for such schools, which translates into annual savings (in avoided costs) of approximately $175,000. Overall, the entire project cost for Rogers High School was $32 million. In the late 1990s, the district found that additional classrooms were needed and that current buildings were becoming increasingly expensive to maintain because of mold and other indoor air quality issues in this variable climate. Working with a local design firm with experience in high performance buildings, the Elk River's director of business and operations began a series of activities needed to construct high performance schools throughout the district (Bratlie 2004).

Opening at the same time as Rogers High School was the new Westwood Elementary School with 74,000 square-feet. This elementary has 475 students, cost $11.5 million to build and is expected to save $65,000 to $75,000 per year in energy cost savings over code-built buildings. Westwood Elementary is expected to receive a LEED Silver certification — the first elementary school in Minnesota to receive this distinction. Using passive heating and cooling specifically designed for this climate, as well as daylighting techniques, the elementary school uses 50% less energy than state standards. According to district personnel, there have been days in winter when it costs nothing to heat the school. According to Ron Bratlie, the Director of Special Projects, “The building maintained its desired temperature even with a constant flow of fresh air coming in” (Bratlie 2004). As is the case with many high performance schools, the smaller HVAC equipment needed to heat and cool the structure is responsible for significant cost reductions (Bratlie 2004).

Elk River School District is committed to creating a better learning environment for its students and teachers, and it is considered to be a leader in the state in high performance school construction. Members of the district staff regularly give presentations to other districts on the high performance design and construction process. Elk River schools have also been featured in Connexus Energy’s magazine and in a 2003 study by the Environmental Law Institute in Washington, D.C.

Cool and Dry Climates: Council School District #13, Council, Idaho

Council School District #13 in Council, Idaho, demonstrates how high performance features can have large impacts even in small schools. The district has 320 students and maintains 80,000 square feet of interior space at a K-8 school and one high school. After receiving help from the Energy Division of the Idaho Department of Water Resources and the Rebuild America Program, the district identified a 47-year-old boiler and radiant electric heat in the gymnasium of one of the schools as obvious targets for energy savings. Instead of merely replacing the boiler with a new, high-efficiency model, the school district decided to apply for a U.S. Forestry Service grant under the *Fuels for Schools* program; this resulted in a $386,000 award to use for an advanced biomass system based on renewable energy technology (Dalgleish 2004).

The district then entered into a performance contract with Siemens Building Technologies to design a new biomass energy system fueled by wood chips (Dalgleish 2004). Since the water in the system would be heated to only 85°F instead of 180°F, the school will use 50 tons of fuel per year rather than 300 tons. Water in the system can be replaced with naturally occurring cold ground water for cooling the building in warmer weather. Additional savings can be gained by using the 85°F water to preheat water heaters. The district has implemented other energy efficiency measures, including new T-8 lamps, new ballasts, light reduction in areas tested for light intensity, and digital controls. The proposed biomass project will require an additional $2.6 million from voters and a bond. Although the bond had not yet passed when this paper was prepared, Superintendent Murray Dalgleish was confident that the community would support it in October 2004, and groundbreaking is planned for spring 2005.

Council School District #13 estimates that these improvements will save more than $800,000 in energy costs over the next 15 years. The district, which plans to make energy efficiency upgrades and the biomass plant part of the curriculum, will also be a showcase and demonstration for other small schools in the state (Dalgleish 2004).

Arctic and Subarctic Climates: Buckland K-12 School, Buckland, Alaska

Within the two climate zones specified in the guidelines for the state of Alaska, schools can generally be divided into two types: urban and "bush," or village, schools. Most urban schools are in Anchorage, Fairbanks, Juneau, and their immediate surrounding areas (Rebuild America 2004). These schools have challenges similar to those of schools in the lower 48 states. However, due to Alaska's colder winters and higher fuel costs, a strong emphasis is placed on effective use of daylighting and other lighting during the long, dark winters, as well as high-value insulation needed. In remote communities, schools also frequently host a variety of activities, including education for K-12 children and adults, community meetings, and social gatherings.

Buckland K-12 School is in the Northwest Arctic Borough, which has a total population of only 7,300; approximately 450 people live in Buckland (U.S. Census Bureau 2001). This climate zone is characterized by long, cold winters and cool summers. Transportation is chiefly by plane, small boat, barge, and snow machine; there are no roads outside the village. Electricity is supplied by diesel generators; fuel, which arrives in barges throughout summer, is very expensive primarily because of transportation costs. Therefore, the design emphasis is on reducing energy consumption for heating and lighting to reduce fuel costs where possible. The combined renovation/new construction Buckland K-12 School project was completed in 2001 and included 11,000 square feet of renovated secondary classrooms and 30,000 square feet of new elementary, library, and administrative offices (DesignShare 2001). The school serves 270 K-12 students and cost a total of $12.5 million, or about $300 per square foot, which is competitive with construction costs for permanent facilities in remote locations. The aerodynamic form of the new structure has minimized snow drifting and reduced total surface area, thus reducing total building heat loss. Overall, the annual utility bills are about 30% less than that for most remote facilities of this type and size (Rebuild America 2004).

Rather than building a completely new school, the Buckland community, in partnership with the A/E team, was able to rejuvenate, reprogram, and reuse the existing secondary school structure. In Alaska, many facilities built in the 1970s have had to be torn down, leading to waste and considerable expense for new materials. In this instance, the existing Buckland facility became a significant resource, and the resulting cost savings helped finance high performance features such as better insulation (reducing fuel costs) and daylighting. Daylighting and large, open, interior spaces help to mitigate the effects of the long, dark winters.

According to the A/E team, community members, district staff, teachers, students, community leaders and others provided input during many of the phases of the project: educational specification development, schematic design, and a value engineering effort after the project's budget was cut by 20%. As a result, the community has developed a sense of ownership of their facility. In addition, the community frequently uses the library/computer room, teleconference room, Inupiat (Inupiaq) Cultural Center and community kitchen, cafeteria/gym/multi- use space, and vocational education spaces throughout the year.

Tropical Island Climates: Chiefess Kamakahelei Middle School, Lihue, Kauai, Hawaii

In October 1997, Kauai school representatives, teachers, and students joined with architects, staff, and personnel from DOE to create a school that meets students' needs and demonstrates resource and energy efficiency. As a result, the Chiefess Kamakahelei Middle School is one of DOE's 21st Century Schools, emphasizing energy efficiency, flexibility, safety, and a sense of community ownership. A team of administration, faculty, students, parents, and others in the community shared in making planning decisions to provide a self-sufficient and secure learning environment for the 1064 students (U.S. DOE 2004a).

High performance design was an important project requirement, and the school (which opened in June 2000) reflects that commitment. The 134,000-square-foot building is oriented on its east-west axis to maximize exposure to daylight and capture the northeast trade winds. To take advantage of the trade winds, all buildings at the school—except the library and music buildings—are naturally ventilated. Variable-air-volume systems are used with variable-speed drives to ventilate the library and music buildings. A heat recovery unit supplements the hot water system by converting the heat of the refrigerant to further reduce energy use. The building also has a high performance shell, with tinted, low-e windows and R-19 roof insulation.

Daylighting strategies were used to design most of the rooms, in combination with an efficient electric lighting system. The lighting design employs T-8 fluorescent lamps and electronic ballasts, in sharp contrast to the older T-12 fluorescent lamps with magnetic ballasts (U.S. DOE 2004a).

Conclusions

The schools in the nine climate zones described in these case studies all receive financial and educational benefits from the high performance design of their buildings. And more schools throughout the country are realizing the benefits of high performance design. As shown in the *Energy Design Guidelines for High Performance* Schools (U.S. DOE 2002b-2002h, 2004a, 2004b), the *National Best Practices Manual for Building High Performance Schools* (U.S. DOE 2002a), and similar documents, energy efficiency and renewable energy technologies implemented in retrofits or new construction can provide energy savings, as well as a better learning environment. Moreover, though environmental impacts are important, these projects are often more attractive than conventional design practices from a financial perspective, since these buildings use less energy than their conventional counterparts. The schools in the case studies show that these cost savings free up resources to fund other important needs of both students and teachers.

These energy efficiency and renewable energy technologies can also be the subjects of study in math and science curriculums, providing opportunities to engage in hands-on learning. Photovoltaic arrays hooked to displays showing energy produced and views exposing HVAC equipment have become valuable teaching aids for instructors. School districts are learning that energy efficiency and renewable energy technologies not only affect the bottom line, they are also useful vehicles for increasing math and science scores and teaching today's students about tomorrow's energy future.

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