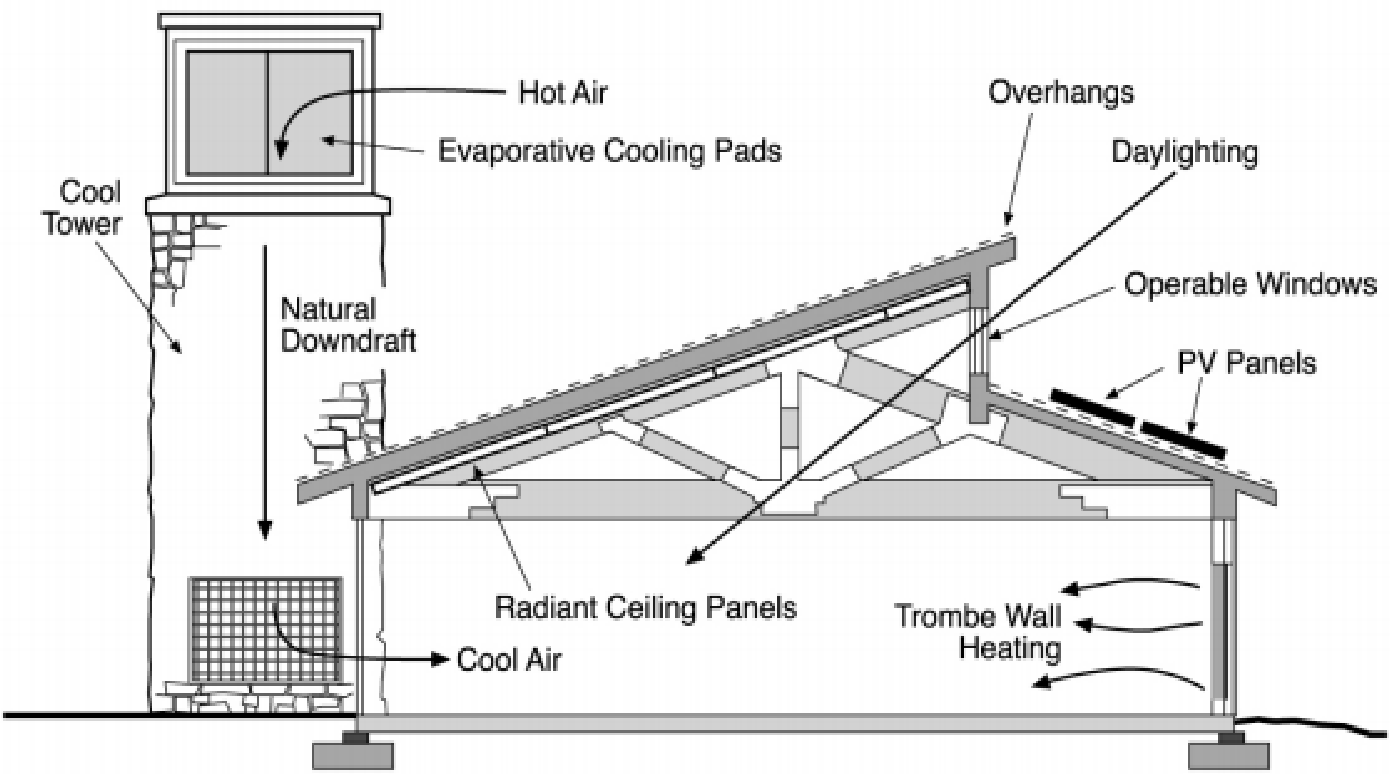
National Park Service
U.S. Department of the Interior

Zion National Park

Sustainable **Design Solutions**

Mitigating Effects of Natural Resource Use

NPS PHOTO



Source: NREL and NPS drawings.

Zion National Park, 2020

Table of Contents

Introduction

This guide contains background information on energy-efficient, *sustainable* architectural design, like Zion's Visitor Center, and an activity where students will design a building to mitigate the effects of inefficient energy use. This guide is specifically designed for eighth grade, but the activity can be modified for students at other levels.

Education Standards

Utah SEEd 8th Grade

Strand 8.4 Interactions with Natural Systems & Resources

Standard 8.4.3: Design a solution to monitor or mitigate the potential effects of the use of natural resources. Evaluate competing design solutions using a systematic process to determine how well each solution meets the criteria and constraints of the problem.

NGSS Middle School

MS-ESS3 **Earth and Human Activity**

MS-ESS3-3. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

MS-ETS1 Engineering Design

MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Theme

The Zion Visitor Center's sustainable, energy–efficient design presents a solution that mitigates the financial and environmental costs of inefficient natural resource use.

Focus

The activities focus on the aspects of energy-efficient architectural design and how to design a building that mitigates the effects of natural resource use.

Activities

Zion's Visitor Center Activity
Students will read brochure on Zion's Visitor Center and fill out a worksheet , highlighting its *sustainable* design solutions.

Sustainable Building Design:
Using Zion's Visitor Center as inspiration, students will design energy-efficient buildings to meet the criteria and constraints of the problem.

Background

According to the US Energy Information Administration, as of 2018, almost 63% of all of the United States' electricity was generated through the use of fossil fuels, like natural gas and coal.[1] Burning fossil fuels releases carbon dioxide, a greenhouse gas, into the Earth's atmosphere. In 2018, 81% of all greenhouse gas emissions came from carbon dioxide and 32% of that carbon dioxide came from the combustion of fossil fuels to generate electricity. [2] Greenhouse gases, like carbon dioxide, trap heat and contribute to the Earth's rising temperatures. These rising temperatures are the result of human-caused climate change and have already had negative impacts around the country and world. Glaciers and ice sheets are melting, resulting in rising seas and a loss of the earth's natural water storage system. Rising seas increase the damage from storm surges during storms like Hurricane Sandy. In addition, increased global temperatures exacerbate instances of drought, wildfires, floods, invasive species, and disease. [3]

Using historical climate change data, scientists create climate models to project potential future climate changes. Continued greenhouse gas emissions will cause further warming and long-lasting changes, increasing the likelihood of irreversible impacts.[4]

However, limiting climate change is not beyond our control. Substantial and sustained reductions in greenhouse gas emissions now, along with efforts to adapt to the change that is inevitable or already happening, can limit climate change impacts. [5]

There are many different ways to limit the effects of climate change. Individuals can use alternative transportation methods, plant a tree, buy local food, recycle, and take many other actions. [6]

Another solution includes building more energy-efficient *sustainable* buildings, like Zion's Visitor Center. These buildings reduce fossil fuel use as well as carbon dioxide emissions. By doing this, not only do we mitigate environmental damage, we also save money by using less energy.

Zion's Visitor Center: An Introduction to Sustainable Design

Duration

~15 minutes

Location

Inside

Key Vocabulary

Sustainable, Energy Efficient, Clerestory Windows, Low-E Coating, Fluorescent, Halogen, Incandescent, Insulation, Ventilation, Passive, Trombe wall, Photovoltaics

Objectives

Students will better understand how Zion's energy-efficient sustainable Visitor Center is an example of a designed solution that mitigates the effects of natural resource use. In addition, students will better understand the specific methods used to achieve this goal in architecture.

Method

Divide students into pairs and distribute a copy of *Zion National Park Visitor Center: A Sustainable Building for the Future* to each group. Give every student a worksheet. Student should read through the brochure and answer the questions on the worksheet in their groups.

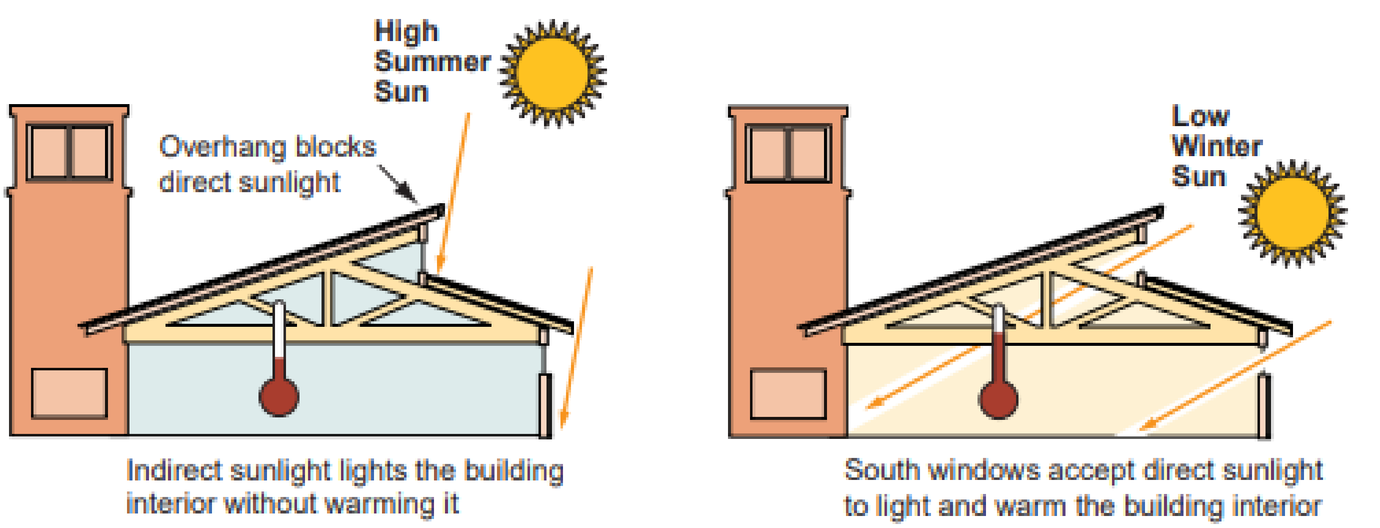
Materials

- Copies of *Zion National Park Visitor Center: A Sustainable Building for the Future* (one per two students)
- Copies of *Zion Visitor Center Vocabulary Sheets* and *Worksheets* (one per student)

Background

The Visitor Center, designed by Park Service staff and the National Renewable Energy Lab, opened in 2000.[7] The design goal for the building was to create a sustainable building that incorporated the area's natural features and energy-efficient building concepts into an attractive design that saved energy, minimized operating expenses, and protected the environment.[8]

The building's design achieves these goals through multiple design solutions, like: cooling towers, Trombe walls, daylighting, solar panels, clerestory windows, extra insulation, and natural ventilation. (More specifics about these features can be found in *Zion National Park Visitor Center: A Sustainable Building for the Future*.) All features strive for energy-efficiency by utilizing passive cooling, heating, and lighting strategies and minimizing energy waste wherever possible. For example, solar panels provide 30% of the buildings' power and 80% of the structure is lit through natural daylight.[9]



National Renewable Energy Laboratory Graphics

Background (Continued)

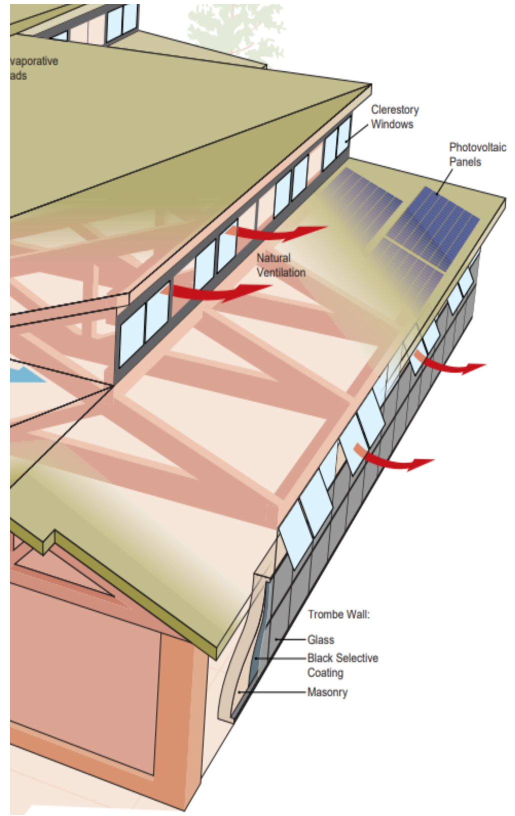
The Zion Visitor Center's design received several awards: Green Building Challenge (2000), American Institute of Architects' Top Ten Green Projects, and American Society of Landscapes Architects Design Honor Award (2001).[10]

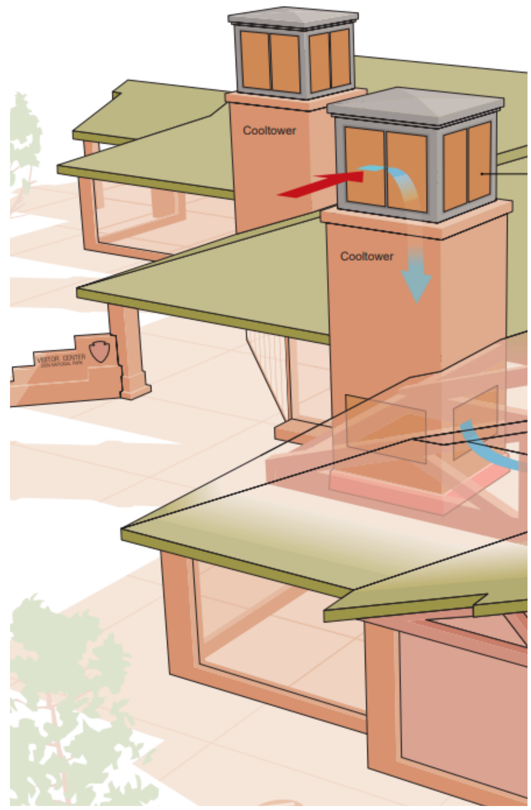
In addition, The Visitor Center has reaped other benefits, financial as well as environmental. The design saves an average of $14,000 per year due to a 74.4% reduction in overall energy use. The reductions break down is as follows:

· 64.4% Heating
· 95.6% Cooling
· 73.6% Lighting
· 43% Plug Loads
· 91.7% Fans

In the fight against climate change, the new Visitor Center design also has reduced carbon dioxide emissions annually by 310,000 pounds! (All 2006 figures)[11]

The Zion Visitor Center serves as inspiration for architectural design solutions that mitigate the effects of inefficient energy use and climate change.





National Renewable Energy Laboratory Graphics

Sustainable Building Design

Duration

~45 minutes

Location

Inside

Key Vocabulary

Sustainable Building, Renewable Energy, Water Efficiency, Waste Reduction, Toxin Reduction, Solar Power, Wind Power, Hydropower

Objectives

Students will design their own energy efficient building that will mitigate the effects of inefficient use of energy and natural resources in general.

Method

Using what they learned from Zion's Visitor Center, the students will use the *Sustainable Building Design Worksheet* to guide them in their building design. Finally, they will draw their building, including at least seven fully

Materials

- Copies of *Sustainable Design Worksheet* (one per student)
- Pencils (one per student)
- An assortment of rulers, colored pencils, and markers
- Large white construction paper or butcher paper

Background

Please refer to the Zion's Visitor Center Activity for background information on Zion's Visitor Center and the numerous design solutions it includes for achieving a more energy-efficient building.

When designing a sustainable building, design teams should consider several different elements: energy-efficiency and renewable energy, water efficiency, environmentally preferable building materials, waste reduction, and toxin reduction.[12]

For energy-efficiency, you should consider passive ways to get desired services like: heating, cooling, lighting, etc. For example, orientating rectangular buildings with the long axis faces east/west increases shade in the summer and warmth in the winter.

NPS PHOTO

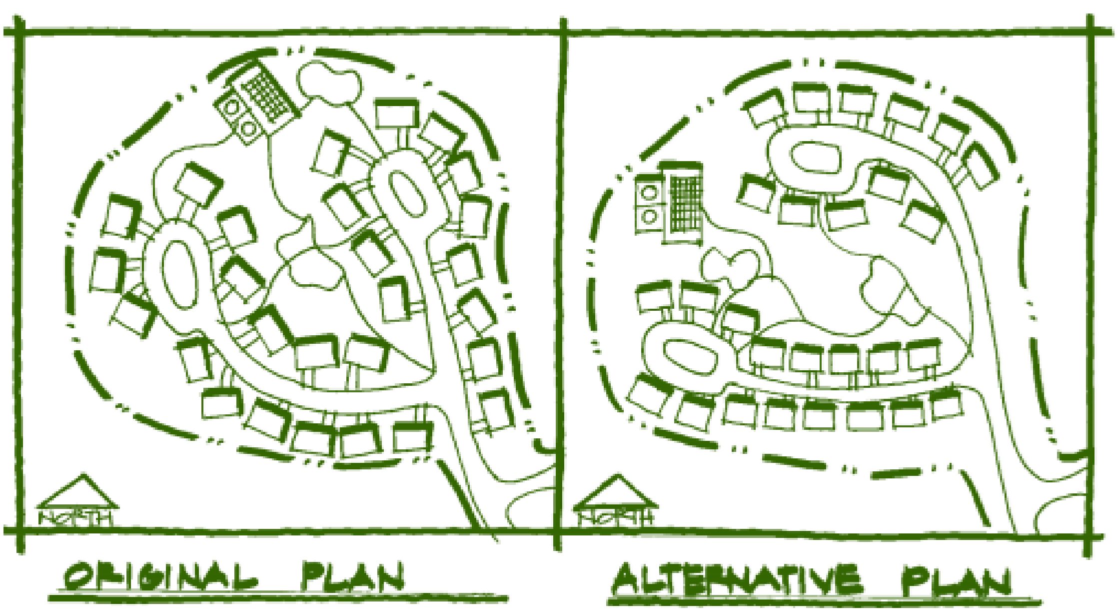
Background (Continued)

Furthermore, by placing windows in the optimal places, you can use natural drafts for cooling airflow. Installing passive or very low energy elements, like Trombe walls or cooling towers, all maximize environmental factors (sun, shade, outside air) to preform services for which we often use electricity. When passive techniques need support, you should look for the most energy-efficient solutions, like fluorescent light bulbs or energy-efficient air conditioners and heaters. Finally, for energy, you should try to integrate renewable energy--like solar or wind power--into the building's power networks, so that the energy used comes from a sustainable source. [13]

For water efficiency inside, you can install low flow toilets, faucets, showerheads, and water efficient appliances. Outside, planting native, drought tolerant or low water plants will minimize the amount of water wasted through watering and irrigation. Setting your irrigation system to water either at night or early morning will minimize the amount of water lost through evaporation. Also, the use of reclaimed water for irrigation minimizes the waste of drinkable water. [14]

Environmentally preferable material, waste reduction, and toxin reduction are related goals. You should buy and use building materials produced in sustainable, toxin-free (or toxin-reduced) ways and ideally, made from recycled products. For example, you can buy plastic lumber made from recycled bottles and bags, which can be used for outdoor benches, decks, and picnic tables. Buy paint, insulation, carpet, etc. that are low in toxins. This is not only better for the environment, but safer for you. Finally, ensure you have accurate measurements and create detailed constructions plans so that you do not buy large amounts of excess materials that will not be used. If you have excess materials, you can donate, reuse, or recycle them in order to minimize waste.[15]

By thinking out all these elements in the design process, you not only reduce some building costs, future energy bills, and waste, your building will reduce the use of natural resources, specifically reducing greenhouse gas emissions and therefore, saving our planet.



This site plan illustrates two variations of the same military housing project. The alternative plan has excellent orientation on all buildings, the original plan doesn't.

Source: ENSAR Group

Department of Energy Graphic

Suggested Procedure:

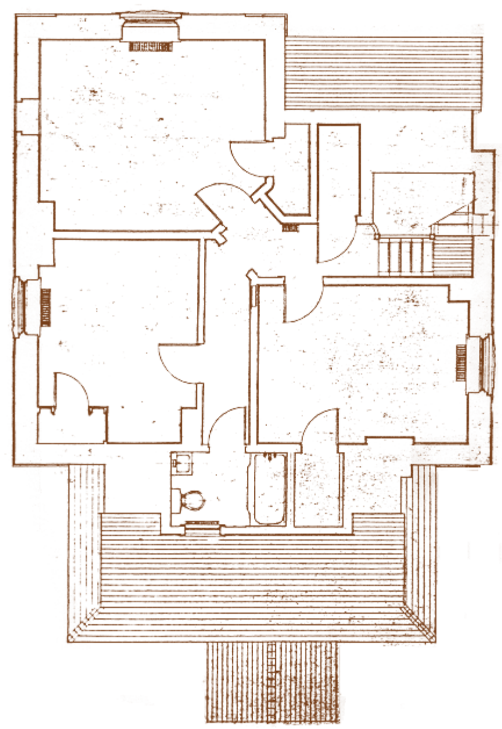
1. Present climate change as problem to be solved. (Students should already have a background in how burning fossil fuels releases greenhouse gases, which increases global temperature.) Go through the some negative effects of climate change: melting glaciers, rising sea levels, more intense and dangerous storms, flooding, drought, wildfires, and/or species pushed to brink of extinction. Alternatively, present a current news item as the result of climate change (we're almost out of hurricane names already for 2020 or that the entire west coast is on fire).

2. Present solutions: Even though future seems bleak, we can still stop this! We must take action to reduce greenhouse gas emissions through many means. Explain this lesson will focus on sustainable design as one was to mitigate climate change. You too can stop climate change! (If preferred, make a financial argument for why energy-efficient sustainable building save a lot of money.)

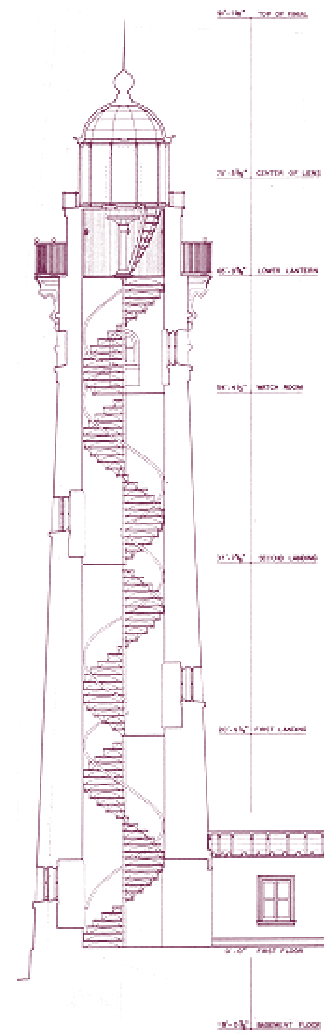
3. Review what they remember from the *Zion Visitor Center Worksheet*. What methods of energy-efficient/sustainable design did the Visitor Center use? Students can use the worksheet as a guideline.

4. Show the how sustainable design elements fall into three general categories: energy-efficiency (which includes renewable energy), water efficiency, and environmentally preferable building materials (which includes waste reduction and toxin reduction). Write up on white board and sort the Visitor Center elements into categories. Next, students can brainstorm other elements of design.

5. Split students into groups of 2-4. Handout copies of the *Sustainable Design Worksheet* and a large piece of white construction paper. The worksheet will guide them through design elements for their building, using the Zion Visitor Center as inspiration.



NPS/Historic Documentation Programs



NPS/Historic Documentation Programs

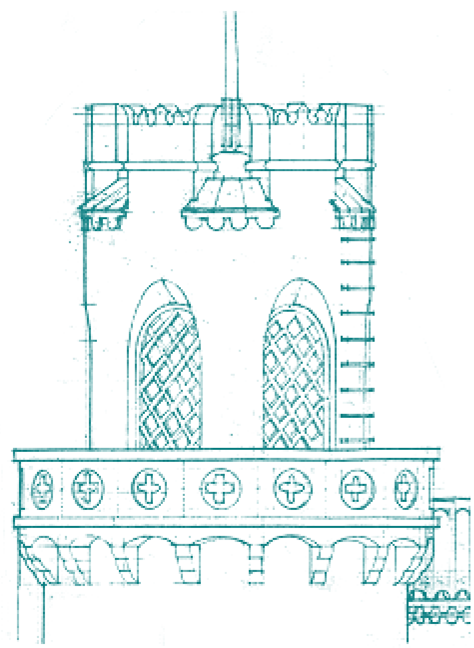
6. Students should fill out the worksheet together to create the outline for their sustainable building design. (This part could be extended significantly to include extensive research into sustainable design, if desired.)

7. Once completed, students should gather drawing materials (pencils, markers, rulers, etc.) They should neatly draw the design for their sustainable building, labeling energy and water efficient elements. Drawings should include the following elements:
    - The cardinal directions (North South East West)
    - At least one element of water-efficient landscaping
    - At least one source of renewable energy
    - At least one source of passive lighting
    - At least one source of passive heating
    - At least one source of passive cooling
    - At least one source of natural ventilation
    - At least one thing built out of recycled or reused products

8. If time allows, student could share designs with class, explaining how they included the various required sustainable design elements.

9. Possible extensions:
    - Formal presentations
    - Build models of buildings
    - Build one energy efficient element, like a solar panel, mini Trombe wall, etc.

NPS/Historic Documentation Programs



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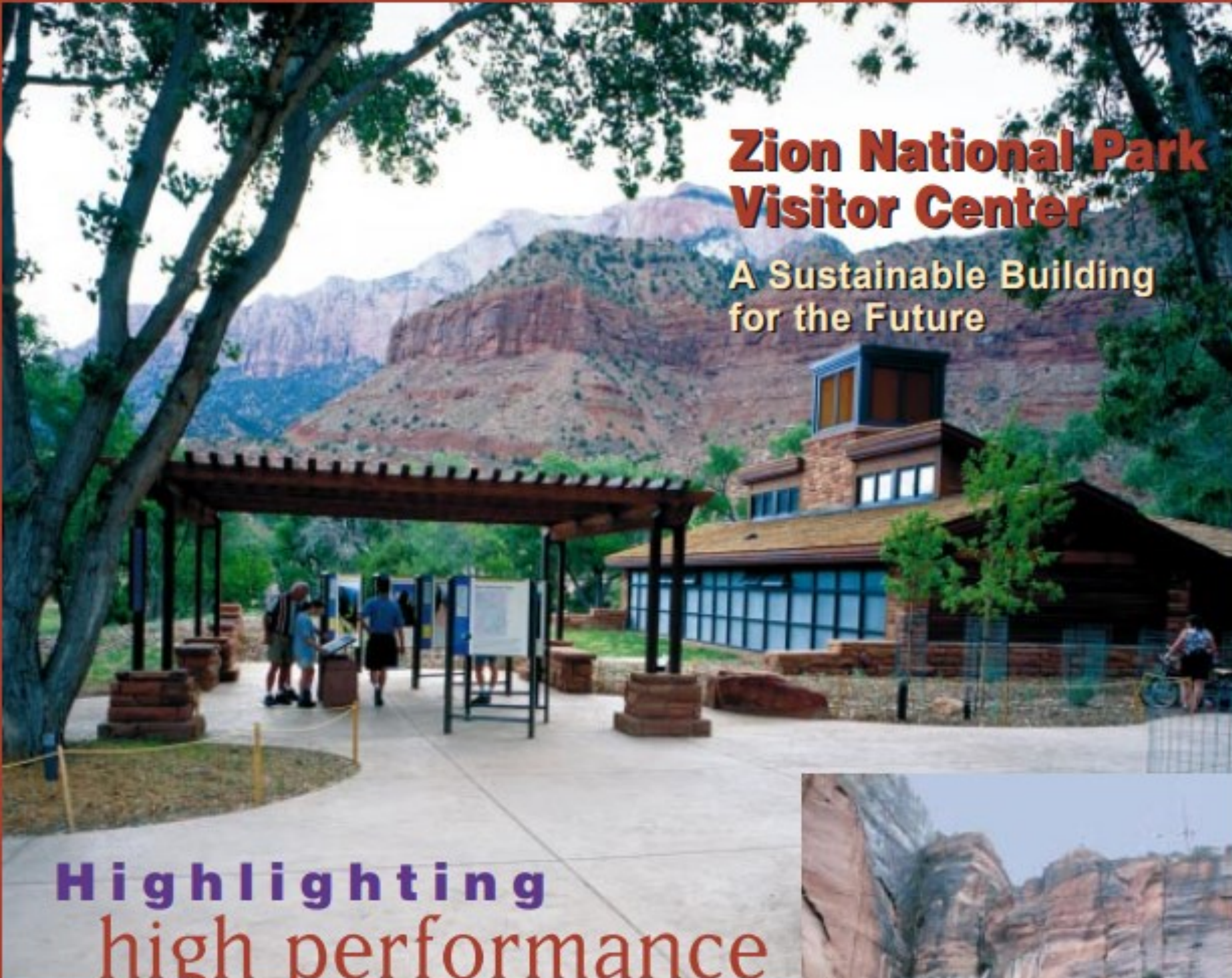


Zion National Park Visitor Center

A Sustainable Building for the Future

Highlighting high performance

Since the time of the Ancestral Puebloans, visitors to the Zion National Park area have been awed by natural sandstone canyons, mesas, and rock sculptures. Carved by the Virgin River, the narrow canyon provided shade, cool breezes, and natural cooling in the summer and warm rock surfaces in the winter. In 1919, the park was established to preserve the natural beauty of the area for generations to come.

In creating the Zion National Park Visitor Center, the National Park Service, working with the U.S. Department of Energy's National Renewable Energy Laboratory, has stayed true to the tenets of protecting Zion's natural beauty—by creating a sustainable building that incorporates the area's natural features and energy-efficient building concepts into an attractive design, saving energy and operating expenses while protecting the environment. The visitor center, like Zion National Park, serves as an example of how the nation can protect its most precious resource—the earth.

Low-energy design and renewable energy at Zion Visitor Center

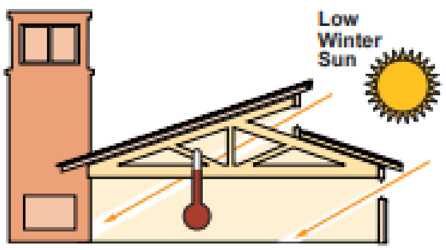
Lighting

The primary source of light in the Visitor Center is daylight. The building's energy management computer adjusts electric light as needed. No incandescent or halogen lights are used—T-8 fluorescent lamps and compact-fluorescent lamps are much more energy efficient. The exit signs provide a gentle glow with solid-state LED technology that also consumes very little energy.

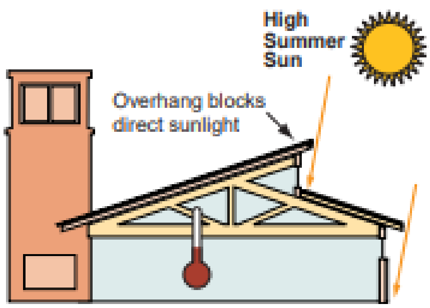
Windows

Clerestory windows are part of the lighting system as well as a part of the heating and cooling systems. Computer simulations helped size the windows to collect the right amount of light. The sun enters in the winter, helping to keep the space heated (passive solar heating), and overhangs shade the glass from the high summer sun. A low-e coating on the glass reduces heat loss from the building while allowing light and heat to enter.

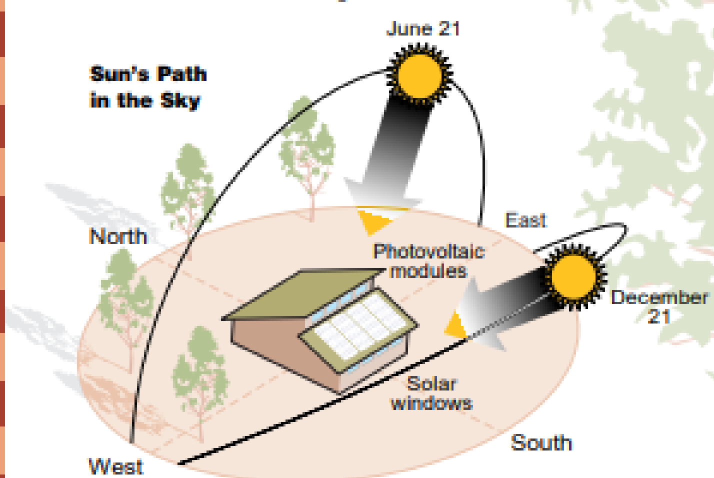
The Visitor Center was designed to block the west windows from the summer sun. These windows are made from glass that diverts the sun's heat. A tree canopy also minimizes heat gain on summer afternoons.

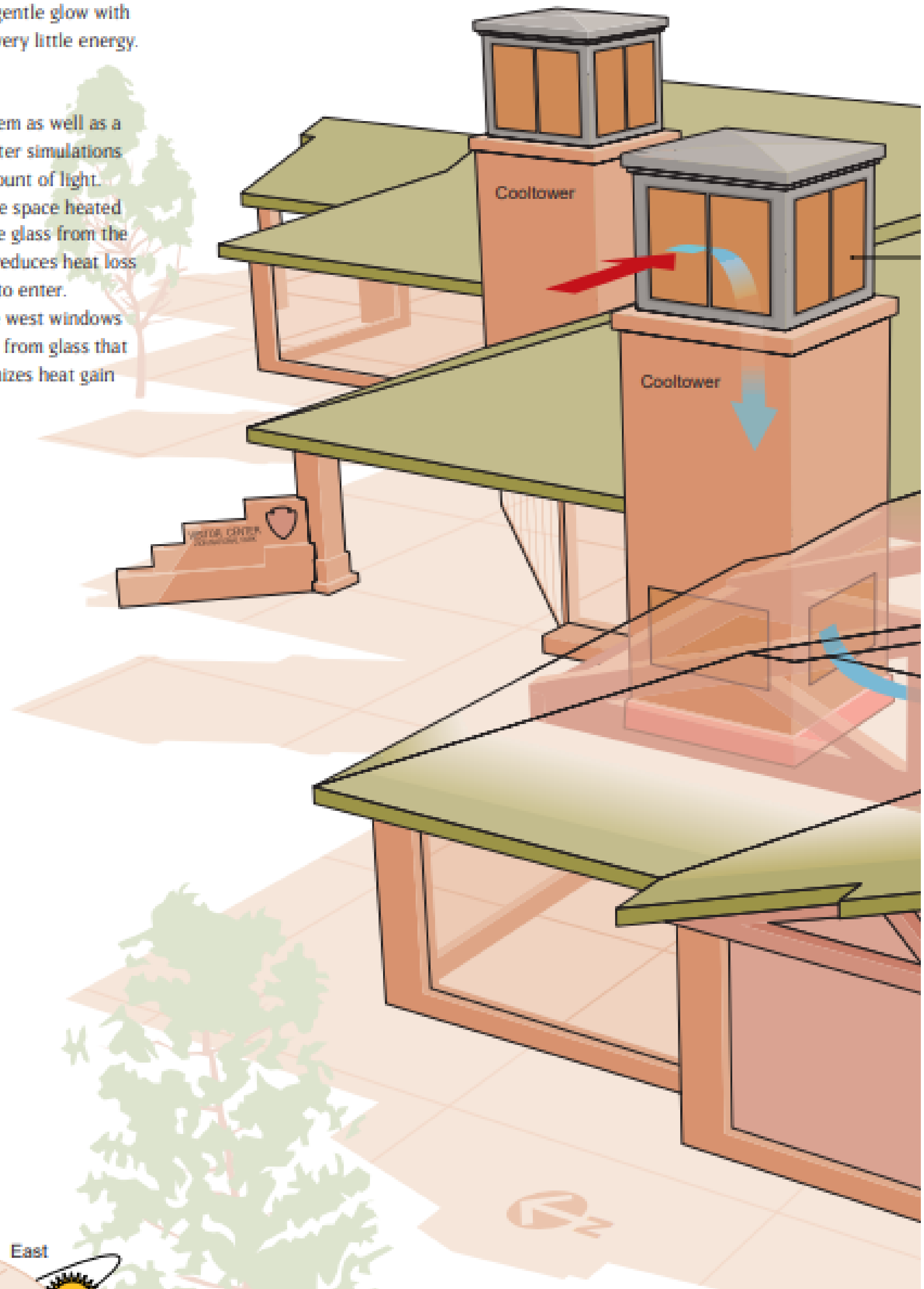


South windows accept direct sunlight to light and warm the building interior



Indirect sunlight lights the building interior without warming it





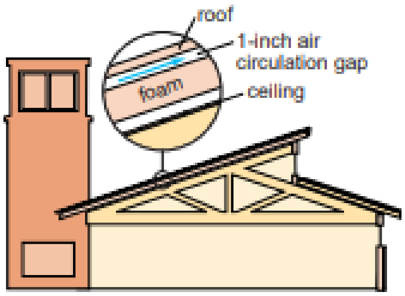
Energy-Efficient Landscaping

Landscaping, including shade structures and existing trees, creates an extension of the Visitor Center. These outdoor "rooms" for permanent displays allow for a smaller building design as well as lower capital and operation costs. Irrigation ditches provide most of the water needed for landscaping, saving pumping energy and water treatment.

Insulation

The building is well insulated, designed to use 70% less energy than a typical building without costing more to build. The roof is made of structural-insulated panels. These panels sandwich a layer of rigid foam insulation between sheets of oriented strand board. The panels are tighter than standard frame construction insulation systems, keeping heat out of the building in summer and in the building in winter.

The building also has foam insulation in wall cavities and insulated windows.



Natural Ventilation

The high clerestory windows help cool the Visitor Center by allowing hot air to escape while low windows near the doors allow cool air in. The building's energy management computer controls operation of the clerestory windows.

Passive Down-Draft Cooltowers

When natural ventilation is not adequate, cooltowers help bring the indoor temperature down. Water sprayed on pads at the top of the towers evaporates, cooling the air. The cool, dense air "falls" through the tower and exits through the large openings at the bottom of the towers. The building's energy management computer controls the size of the openings at the bottom of the tower and can direct the cool air into the building, onto the patio, or both.

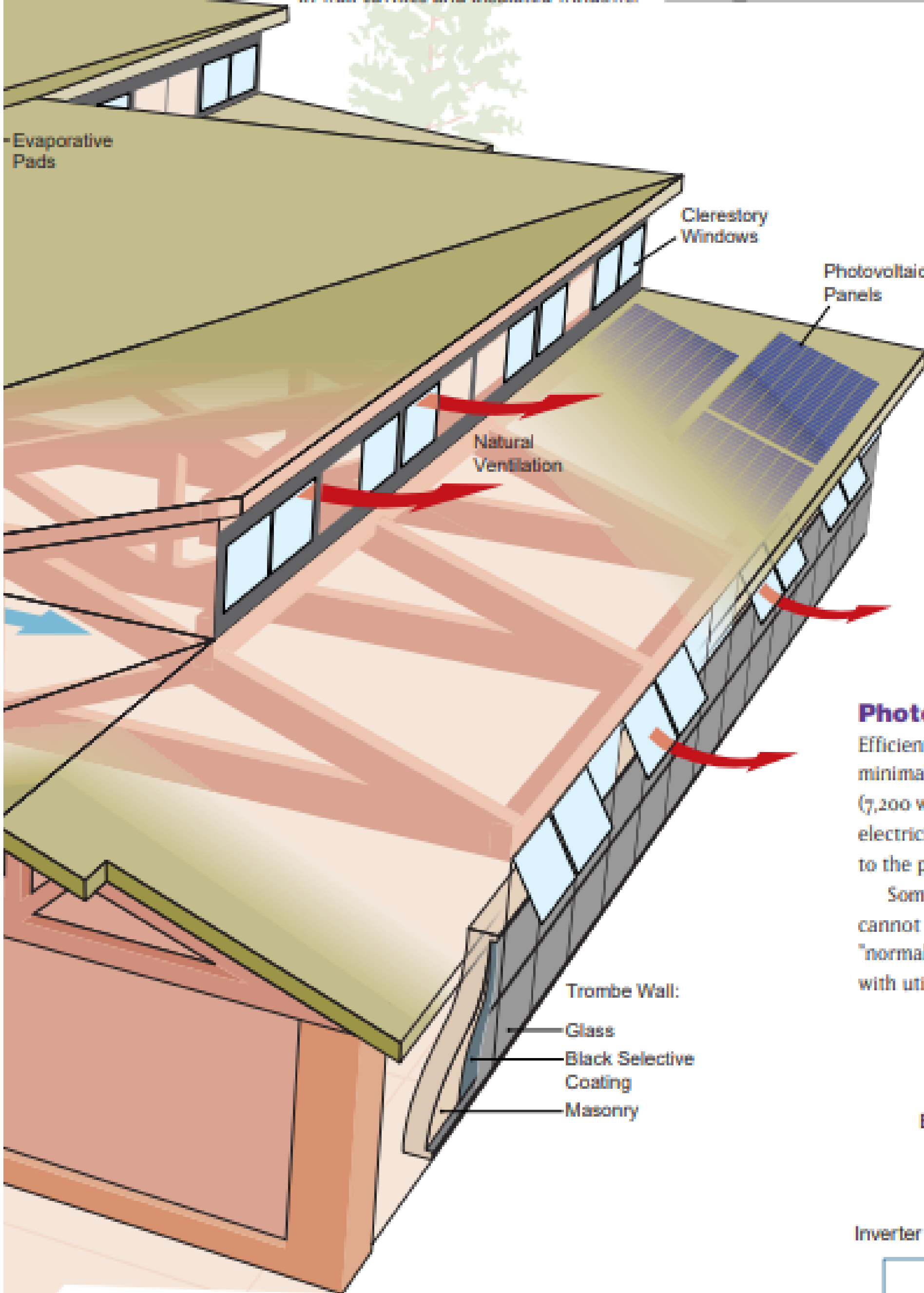
Heating

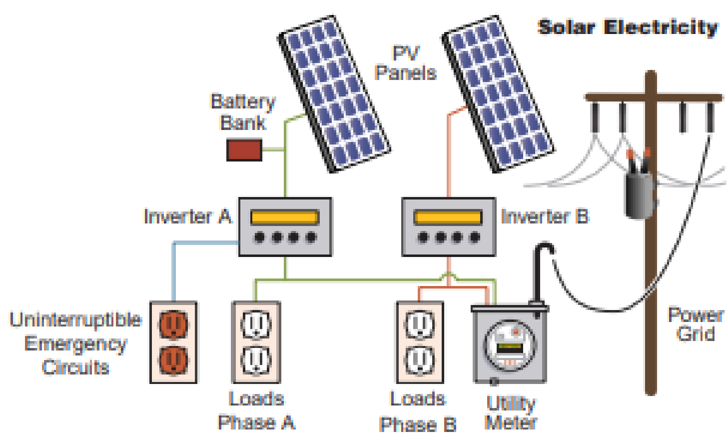
The Trombe wall provides most of the heating for the building. Heat from the sun is trapped between a pane of glass and a black selective coating. A masonry wall stores the heat for release into the building later in the day. Surface temperature of the inside of the Trombe wall can often reach 100°F (38°C). This warm surface provides radiant comfort to the visitors. When the sun is not shining, radiant ceiling panels provide heat.

Photovoltaics

Efficient design of the building eliminated large electric loads—minimal lights and no air-conditioning. Photovoltaic panels (7,200 watts) on the south roof provide the majority of the electricity needed by the building. Excess power is sold back to the power company for use elsewhere.

Some of the energy is stored in batteries. When the utility cannot provide power, the batteries provide power for "normal" daytime use. Using photovoltaics in combination with utility power results in a highly reliable power source.





Energy Management Computer

A computer ensures that all the energy-efficient features work together, collects weather data, and makes energy decisions about the building. It controls the cooltowers, radiant ceiling panels, lighting, and windows.

Buildings for the 21st Century

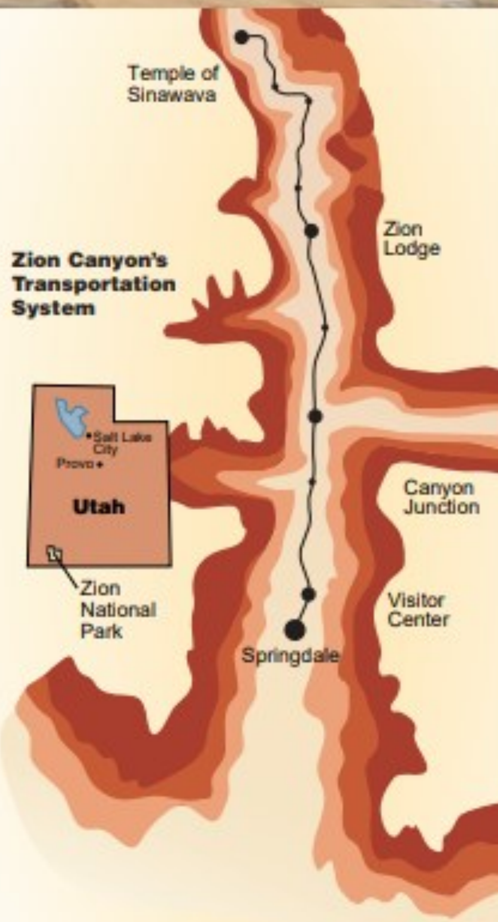
Buildings that are more energy efficient, comfortable, and affordable ...that's the goal of DOE's Office of Building Technology, State and Community Programs (BTS). To accelerate the development and wide application of energy efficiency measures, BTS:

- Conducts R&D on technologies and concepts for energy efficiency, working closely with the building industry and with manufacturers of materials, equipment, and appliances
- Promotes energy/money saving opportunities to both builders and buyers of homes and commercial buildings
- Works with state and local regulatory groups to improve building codes, appliance standards, and guidelines for efficient energy use
- Provides support and grants to states and communities for deployment of energy-efficient technologies and practices.

OFFICE OF BUILDING TECHNOLOGY, STATE AND COMMUNITY PROGRAMS

OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY

Zion National Park's new transportation system relieves congestion and protects the park.



Transportation: The Key to Protecting the Park

The first automobile road was built into the park in 1917, allowing 1,000 people a year to visit Zion. Today, more than 2.5 million visitors see the park annually. Because Zion exists in a narrow canyon, automobile traffic causes air and noise pollution as well as congestion that is detrimental to the park's resources and visitor experience.

As part of redesigning the visitors' experience, transportation of the park's visitors was an integral part of the plan. Clean-running propane buses were designed to shuttle visitors to nine stops in Zion Canyon and six stops in the town of Springdale, Utah. Visitors are asked to leave their vehicles at parking facilities outside the park. The buses dramatically reduce automobile traffic in the park, protecting the park and providing a pleasant experience for visitors.

Contacts

U.S. Department of Energy

Energy Efficiency and Renewable Energy Clearinghouse (EREC)
1-800-DOE-3732
www.eren.doe.gov

Office of Building Technology, State and Community Programs
www.eren.doe.gov/buildings/highperformance

Green Energy Parks Program
www.eren.doe.gov/femp/techassist/greenparks.html

National Renewable Energy Laboratory

Center for Buildings and Thermal Systems
www.nrel.gov/buildings/highperformance

U.S. National Park Service

Zion National Park
www.nps.gov/zion

Produced for the U.S. Department of Energy by the National Renewable Energy Laboratory, a DOE national laboratory

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Zion Visitor Center Vocabulary Sheet

Sustainable	**Adjective.** A way of harvesting or using a resource so that the resource is not used up or permanently damaged.
Energy-Efficient	**Adjective.** Using less energy to perform the same task – that is, eliminating energy waste.
Clerestory Windows	**Noun.** A high section of wall that contains windows above eye level. Their purpose is to let in light, fresh air, or both.
Low-E Coating	**Noun**. This window coating minimizes the amount of ultraviolet and infrared light (the light can give you a sunburn) that can pass through glass. It still lets visible light through, so it is not dark inside.
Incandescent Light	**Noun.** This light uses an electric current to heat up a wire filament until it glows . It is one of the least energy-efficient ways to make light.
Halogen Light	**Noun.** This light also uses an electric current to heat up a wire filament, but in addition, it also light sup a mixture of different gases, including a halogen**. It is** more efficient than incandescent lights, but less than fluorescent lights.
Fluorescent Light	Noun. This light uses an electric current to "light up" a mercury vapor gas. It is four to six times more energy-efficient than an incandescent light.
Insulation	**Noun.** Any material that does not transfer heat easily. When placed in the walls, ceiling, or floors of a structure, it will reduce the rate of heat flowing between inside and outside.
Ventilation	**Noun.** Simply, the circulation of air. In construction, this is when 'clean' air (normally outdoor air) is brought into a building and stale air is removed.
Passive	Adjective. In construction, this refers to ways of capturing natural sources of light, heat, air-conditioning, etc. that do not need human generated energy. For example , using sunlight for light and heat, instead of turning on a heater or light bulb, would be considered passive.
Trombe wall	**Noun.** An equator-facing wall that is painted a dark color in order to absorb heat from sunlight and covered with a glass on the outside. This provides passive heat for a building.
Photovoltaics	**Adjective.** In simple terms, this is a fancy words for the way solar panels turn sunlight into electricity.

Zion Visitor Center Worksheet

Instructions:

1. Pair up with another student and read through the Zion Visitor Center Vocabulary Sheet.
2. Read through the *Zion National Park Visitor Center: A Sustainable Building for the Future* brochure, highlighting the vocabulary words as you go.
3. Answer the following questions with your partner.

Questions:

1) How does the Visitor Center get its light? It which specific ways is it energy-efficient?

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____

____

2) How do the clerestory windows help keep the building cool in the summer and warm in the winter?

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______

3) How does the landscaping help the area be more energy efficient?

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______

4) Why is insulation an important part of saving energy? How is good insulation achieved in the Visitor Center?

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______

5) How do the cooling towers help cool with Visitor Center in passive manner?

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______

6) How does the Trombe tower work?

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____

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Sustainable Design Worksheet

Please use your answers to the following questions to design your own sustainable building. Feel free to use the answers from your *Zion Visitor Center Worksheet* for inspiration.

1) What is the weather and climate like where you're building? Will heating or cooling be more important or equally important?

____

____

____

2) How will you orient your building in order increase passive cooling in the summer and warming in the winter?

____

____

3) Will your building use cooling towers, Trombe walls or some other forms of energy efficient technology? If so, which and how will they work?

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4) How will you insulate the building?

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7) How will your design incorporate solar, wind, or hydro power?

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8) How will the landscaping outside your building save water and support your energy efficiency goals?

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9)How will you incorporate recycled or reused products into your design?

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____

____

10) How will you reduce toxins while building?

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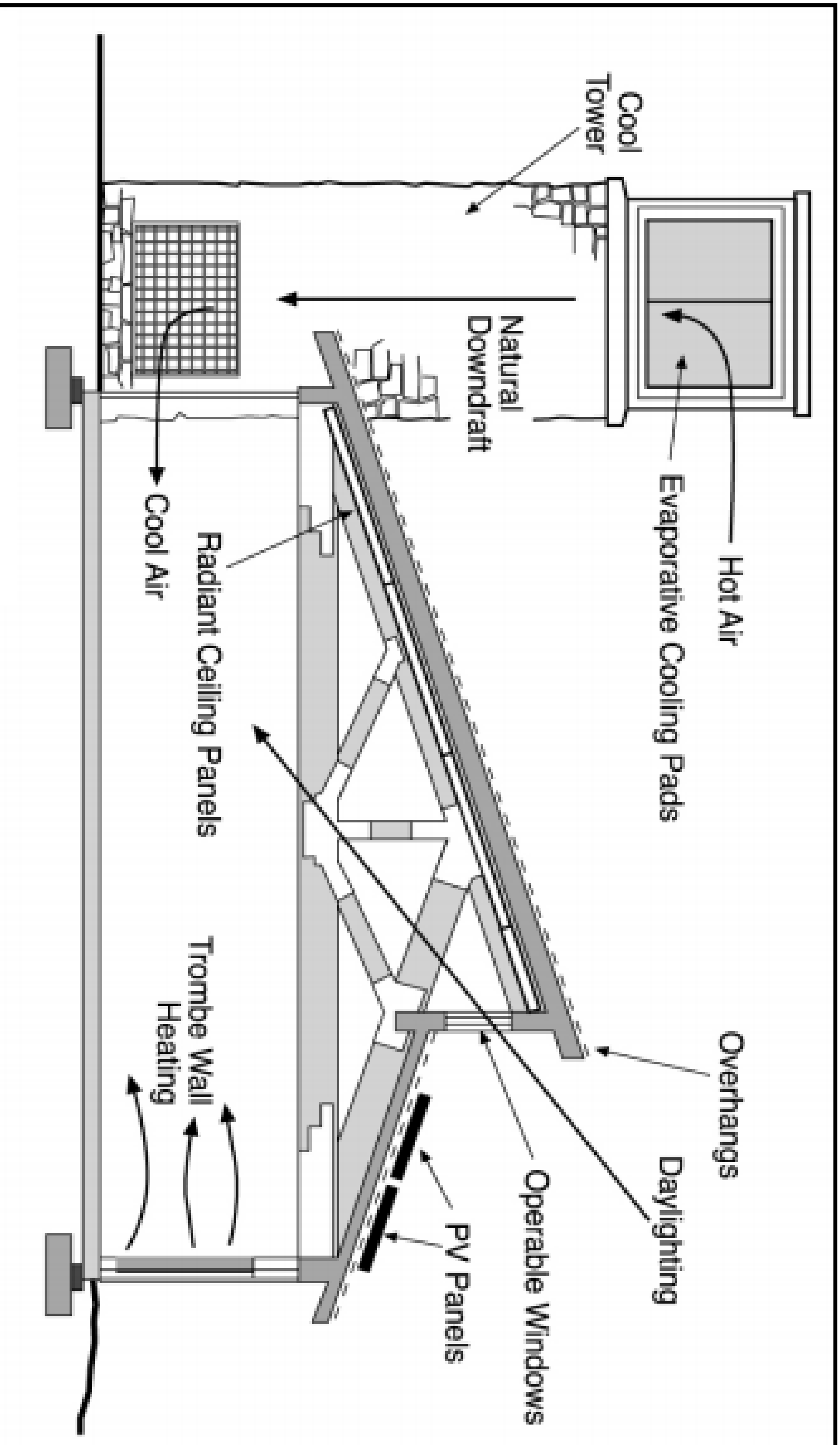
____

Now, it’s time to draw your plans! On a large piece of paper, please neatly draw the design for your sustainable building, labeling energy and water efficient elements.



Source: NREL and NPS drawings.


NPS PHOTO

Resources & References

The following are government websites used as sources for the background information sections of the lesson plan.

These web pages are also good resources for addition information:

[1] Data about U.S. electricity generation by energy source taken from: https://www.eia.gov/tools/faqs/faq.php?id=427&t=3

[2] Data about greenhouse gases taken from: https://www.epa.gov/ghgemissions/overview-greenhouse-gases

[3] Paraphrased from *Climate Change in National Parks* brochure.

[4-5]Taken directly from *Climate Change in National Parks* brochure.

[6] Actions to mitigate climate change paraphrased from: https://www.nps.gov/subjects/climatechange/athome.htm

[7] Information about sustainable architecture at Zion taken directly from: https://www.nps.gov/zion/learn/management/sustainable-architecture.htm

[8] Information about the sustainable elements of the Zion Visitor Center paraphrased from: https://www.nps.gov/zion/learn/nature/upload/DOE%20Brochure.pdf

[9] Data about the Zion Visitor Center's energy efficiency taken from: https://www.nps.gov/zion/learn/nature/zion-canyon-visitor-center.htm

[10] Information about the awards that the Zion Visitor Center earned taken from: https://www.nps.gov/zion/learn/management/sustainable-architecture.htm

[11] Data about the Visitor Center's reduction in energy consumption taken from: https://www.nps.gov/zion/learn/nature/zion-canyon-visitor-center.htm

[12] The elements of sustainable building design paraphrased from: https://archive.epa.gov/greenbuilding/web/html/components.html

[13] Information about specific sustainable building design elements taken from: https://www.nrel.gov/docs/fy01osti/29267.pdf

[14] Information about water efficient design taken from both https://www.epa.gov/watersense and https://www.nrel.gov/docs/fy01osti/29267.pdf

[15] Information about recycling and reducing waste/toxins while building from https://nepis.epa.gov/Exe/ZyPDF.cgi/P10009PI.PDF?Dockey=P10009PI.PDF and https://www.epa.gov/greenerproducts/identify-greener-products-and-services

For additional resources, please check out:

- This website has information about energy efficient appliances: https://www.epa.gov/greenerproducts/identify-greener-products-and-services
- This paper goes into even more detail on the sustainable design of Zion's Visitor Center: nrel.gov/docs/fy02osti/32157.pdf