Science Fair Kits

Eco-Structure Building Kit

GP00021

Guide for Educators

Worldwide, there is a housing and homelessness crisis. 100 million are homeless (United Nations, 2005 survey). 1.6 billion live in substandard housing (Habitat for Humanity, 2015). 22.5 million are refugees (United Nations, 2016). 550,000 are homeless in the US each night (HUD, 2017). 6-10 million in the United States face severe housing cost burden or are 'doubled-up,' living with family or friends (National Alliance to End Homelessness, 2016).

The challenge to engineers is clear: design safe, affordable housing that is good for the health and well-being of people and the planet. This kit allows budding engineers to try their hand at this daunting task using simple materials. The kit is intended for classroom or school-wide STEM challenge competitions but can be adapted for home use. Enough materials are provided to allow student teams to build a prototype as well as a final version.

Guide includes a Bill of Materials Worksheet, a Judging Rubric, and a Test Result Calculation Sheet.

NGSS Standards

Energy: Conservation of Energy and Energy Transfer, 4-PS3-2 & 4-PS3-4.

Contents of Kit

10 sheets 1/8" x 14" x 14" corrugated cardboard, 10 sheets 8.5" x 11" medium weight chipboard, 10 sheets 1/8" x 12" x 12" foam pads, 8 sheets 12" x 12" Cello sheets, 1 roll 3/4" x 60 yds masking tape, 1 plastic thermometer, 1 CdS photocell, 2 alligator clip to 4 mm banana connector leads, 1 plastic serrated safety-knife for cardboard.

Required Equipment (not included)

Scissors

Optional Equipment (not included)

Digital multimeter, Eisco Scientific model PH1121B (www.eiscolabs.com/products/ph1121b)

Portable room fan

250 Watt (or higher) heat bulb and lamp

Small flashlight (to read thermometer)

Pedagogical Guide

The guide is written for use in a classroom or school-wide STEM competition. Content can be adapted for home use.

Teams of 4-5 students design and build scale structures from simple materials. Sufficient materials are provided to build both a prototype structure as well as a final structure. The prototype structure may be built at home, but the final structure is to be built on-site on the competition day.

Only supplied materials may be used for structural elements (including windows and insulation). Students may supply their own aesthetic components (paint, vegetation, and brick people/furniture).

Structures must incorporate the principles of **healthy**, **clean**, and **safe** building design.

Students use a design journal to chronicle the evolution of their design. When they've settled on a design, they make hand-drawn blueprints which will allow them to efficiently build the structure on competition day.

Students also complete a Bill of Materials worksheet (sample included in this guide) and make a poster presentation about their structure and design elements to bring on competition day.

Structures can be tested for energy efficiency, use of natural light, and structural integrity.

Students present their structures and design choices to a judging panel (sample rubric included in this guide).

Design Considerations

Healthy Structures

Healthy structures promote occupant well-being.

They include strategies to mitigate indoor (radon, mold, dust), and outdoor pollutants (pollen, vehicle exhaust, odor from dumpsters, etc.).

Designs must also include strategies which improve or alleviates vitamin D deficiency, Seasonal Affective Disorder, stress induced illness, sick building syndrome.

Clean Structures

Clean structures reduce environmental impact.

They include strategies to reduce energy usage, conserve building materials, maximize use of natural lighting, incorporate natural vegetation.

Designs must also consider day/night cycles (day/night external temperature variation, and day/night heat generation from occupants), winter/summer cycles (solar inclination, annual temp. variation), characteristics of local climate: (cloud cover, snow, altitude, humidity).

Safe Structures

Safe structures eliminate human hazards.

Clean structures consider safety factors like: access to exits and fire escapes, snow bearing capacity, earthquake resilience, adequate ventilation, and wind resilience.

Designs must also use known safety techniques, and where possible, innovate with new safety techniques (exit slides, for example).

Construction Ideas

- Retractable roof, walls
- Bicolored roof (black for winter, white for summer)
- Extra large eaves
- Double insulation on equator-side
- Geodesic structure
- Double- & Triple-pane windows
- Roof vents - End vents
- No attic - extra attic
- Asymmetric roof
- Subterranean floors
- Double walls
- Double roof
- Roof shade
- Hanging plants on equator-side
- Convection venting
- Emergency exit slides
- Tilted building (to reduce summer profile)

Sample Structures

Structure 1:

Structure 2:

Structure Tests

The students structures are run through 5 tests: 2 energy efficiency tests, 1 natural lighting test, and 2 structural integrity tests. Test results are written up on the included worksheet.

Energy Efficiency Tests

Thermometers are built into one of the occupied floors of structure so it can be read externally (visual access through window). Structures are heated with high-wattage incandescent or infrared lights (not included but available at local hardware stores or online.)

The goal of this test is to simulate solar heating. Structures should make efficient use of solar radiation in the winter and minimize heating from solar radiation in the summer. A smaller temperature change is earns more points for the Summer Test, a larger temperature change earns more points for the Winter Test (see Test Result Calculation Sheet on page 9).

Summer Test - light at noon-inclination of summer sun.

Winter Test - light at noon-inclination of winter sun.

Temperatures are recorded initially and after 10 min of heating for each angle. Students calculate temperature difference for each test.

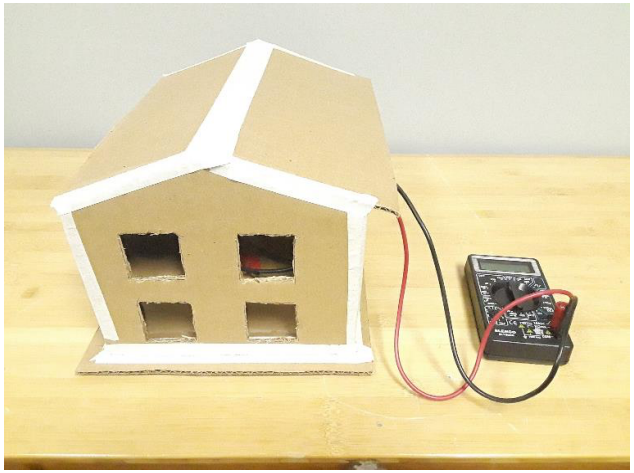
Ambient Lighting Test

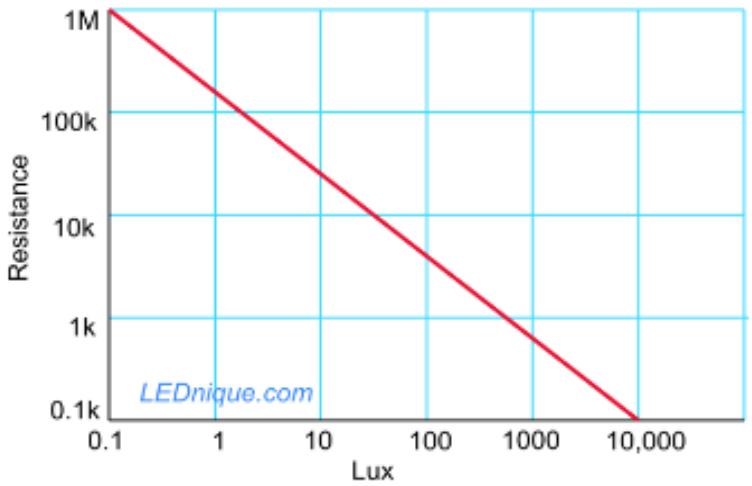
Students build a CdS photocells into one of the floors of structure with wire leads accessible from the outside.

The goal of this test is to provide a simple comparison of the amount of natural lighting in the structure. Natural lighting helps reduce Seasonal Affective Disorder and can reduce stress in the workplace.

Ambient Lighting Test: Digital multimeter (not included) used to measure the resistance of the photocells to quantify natural lighting.

Resistance is then converted to lux by students using CdS photocell chart on the next page.





Structural Integrity Tests

These tests ensure that care was taken to make the structure strong, both to lateral and vertical forces.

Wind Test: Structures placed next to a portable room fan to test for quality of construction and structural integrity. Structure rated from 1-4 for resistance to wind.

Snow Test: Folded towel or heavy blanket placed on structure to simulate snow. Additional weights can be added to towel. Structure rated from 1-4 for buckling and bowing strength.

Manufactured by :

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www.eiscolabs.com

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Bill of Materials Worksheet

Scale: 1 cm = 1.5 ft
Examples:

4 cm (height of brick minifigure) = 6 ft
30 cm (size of supplied corrugated cardboard) = 45 ft
1 cm^2 = 2.25 ft^2
$123\ cm^2 = (123\ cm^2 \times 2.25\ ft^2/cm^2) = 276.75\ ft^2$
Cost of 3456 ft^2 of Insulated Walls: $3456\ ft^2 \times \$15/ft^2 = \$51{,}840$

Insulated Walls
Corrugated Cardboard, 1/8" thick - $\$15/ft^2$

Total scale area: _____ cm^2 Total area:_____ ft^2 Total cost: $_____

Interior Walls, Doors, and Garage Doors
Chipboard Pads, 0.022" thick - $\$5/ft^2$

Total scale area: _____ cm^2 Total area:_____ ft^2 Total cost: $_____

Windows and Skylights
Clear Cello Sheets, 0.001" thick - $\$10/ft^2$

Total scale area: _____ cm^2 Total area:_____ ft^2 Total cost: $_____

Ceiling Insulation
Foam, 1/8" thick - $\$2/ft^2$

Total scale area: _____ cm^2 Total area:_____ ft^2 Total cost: $_____

Structural Elements
Masking Tape - $0.50/ft

Total scale length: _____ cm Total length:_____ ft Total cost: $_____

Total cost of building:_____

$$\textbf{Score} = \frac{\$354{,}000 - \text{Total Cost}}{\$354{,}000} \times 10 = \_\_\_\_\_$$

Calibrated so that using ½ of provided materials costs $354,000

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Judging Rubric

Team #_____ Grade Level _____ Judge #_____ Scores: Bill of Materials _____ Test Results_____ Judging Rubric _____ Total Score_____

	4	3	2	1	Score (1-4):
Design	Creative and thoughtful use of components. Project meets all parts of challenge. Design exhibits obvious care and effort.	Somewhat creative use of components. Project meets all parts of challenge. Design exhibits obvious care and effort.	Minimally creative use of components. Project meets most of challenge. Design exhibits moderate care and effort.	Minimally creative use of components. Meets only few parts of challenge. Design exhibits little care or thought.	
Narrative (Journal and Photojournal)	Well-written with no grammatical or spelling errors. All team members contributed. Many outside resources used and listed with commentary. Clear evidence of off-line prototyping.	Well-written with no grammatical or spelling errors. All team members contributed. Few outside resources used, listed, or little to no commentary given.	Narrative is lacking in detail. Few to no outside resources used. Not clear that all team members contributed. Narrative contains grammatical and/or spelling errors.	Narrative contains many grammatical and/or spelling errors. No outside resources used. No evidence that all members contributed.	
Blueprint	Drawing for each part given with dimensions and scale shown clearly. Material specified, scale given, area calculated, and price of part listed. No calculation, grammatical or spelling errors.	Drawing for some parts given with dimensions and scale shown. Material specified, area calculated, and price of part listed. Very few errors.	Drawings not complete, not to scale, and some parts missing. Details missing such as material, scale, area, and/or price. Some errors.	No drawings or hastily drawn not to scales and with no details given. Many errors.	
Teamwork	Team works well together. Ideas of all members listened to and respected. All members participated in all aspects of competition.	Team works well together. All team members contributing to structure, though some are less engaged than others.	Some team members distracted and not focused on building the structure. Blueprint and narrative show lack of teamwork.	Some team members not working on structure. Obvious that not all team members participated in design and preparation for competition.	
Creativity	Teams were creative with overall design and able to meet project requirements within time limits.	Team exhibited creativity in meeting project requirements. Additional elements could have been added with better planning.	Team exhibited moderate creativity in meeting project requirements. Structure completed in time but lacking complexity.	Design lacks creativity. Structure not completed within time limits.	
Presentation	Presentation was engaging, well organized and covered all topics. All team members participated.	Presentation well organized and covered all topics. All team members participated.	Presentation lacks organization. Presentation dominated by a few team members.	Presentation unorganized and lacking focus. One team member dominated presentation.	
				Total	

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Test Result Calculation Sheet

Team #_____ Grade Level _____ Total Test Score_____

Summer Test

Initial Temperature	
Final Temperature	
Temperature Difference	

Summer Score = 10 – Temperature Difference = _____

Winter Test

Initial Temperature	
Final Temperature	
Temperature Difference	

Winter Score = Temperature Difference = _____

Ambient Light Test

Measured Resistance [Ω]	
Illuminance [lux]	

Ambient Light Score
= Illuminance/100 = _____

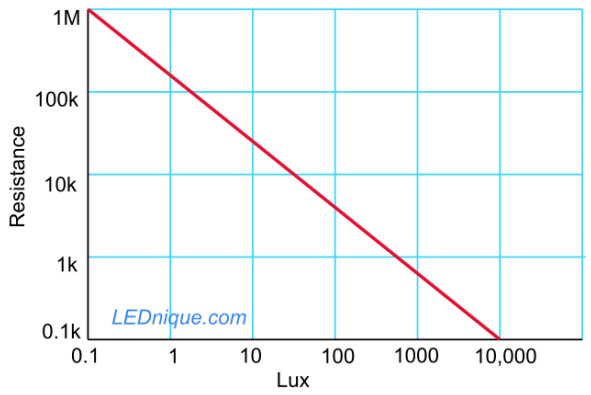

Figure 3. Graph of resistance versus light level.

Wind/Snow Tests

	10	7	4	1	Score
Wind	No visible reaction. Sheds wind easily.	Some flapping, bowing, leaning or bending.	Major flapping, bowing, leaning, or bending.	Structure fails.	
Snow	No visible bowing or twisting.	Small amount of bowing and/or twisting.	Large amount of bowing and/or twisting.	Structure fails.	

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