Student-influenced Learning Environments

What is Inside the Mind?

Image Credit: A4LE Conference Website

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Architect | Accredited Learning Environment Planner

Ron has led award-winning projects and his work has been recognized for its innovative planning and high levels of sustainability. He specializes in K12, Higher Ed, and Public Libraries, sharing his belief in life-long learning to help clients create memorable places.
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Architect | Senior Associate

Michele has a deep understanding that the built environment influences comfort, mood, focus and behavior of learners; which continues to be a key interest and component of her work. From Universal Design to Crime Prevention Through Environmental Design (CPTED), she helps to create safer more enjoyable spaces for everyone.
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Enhancing the Educational Experience

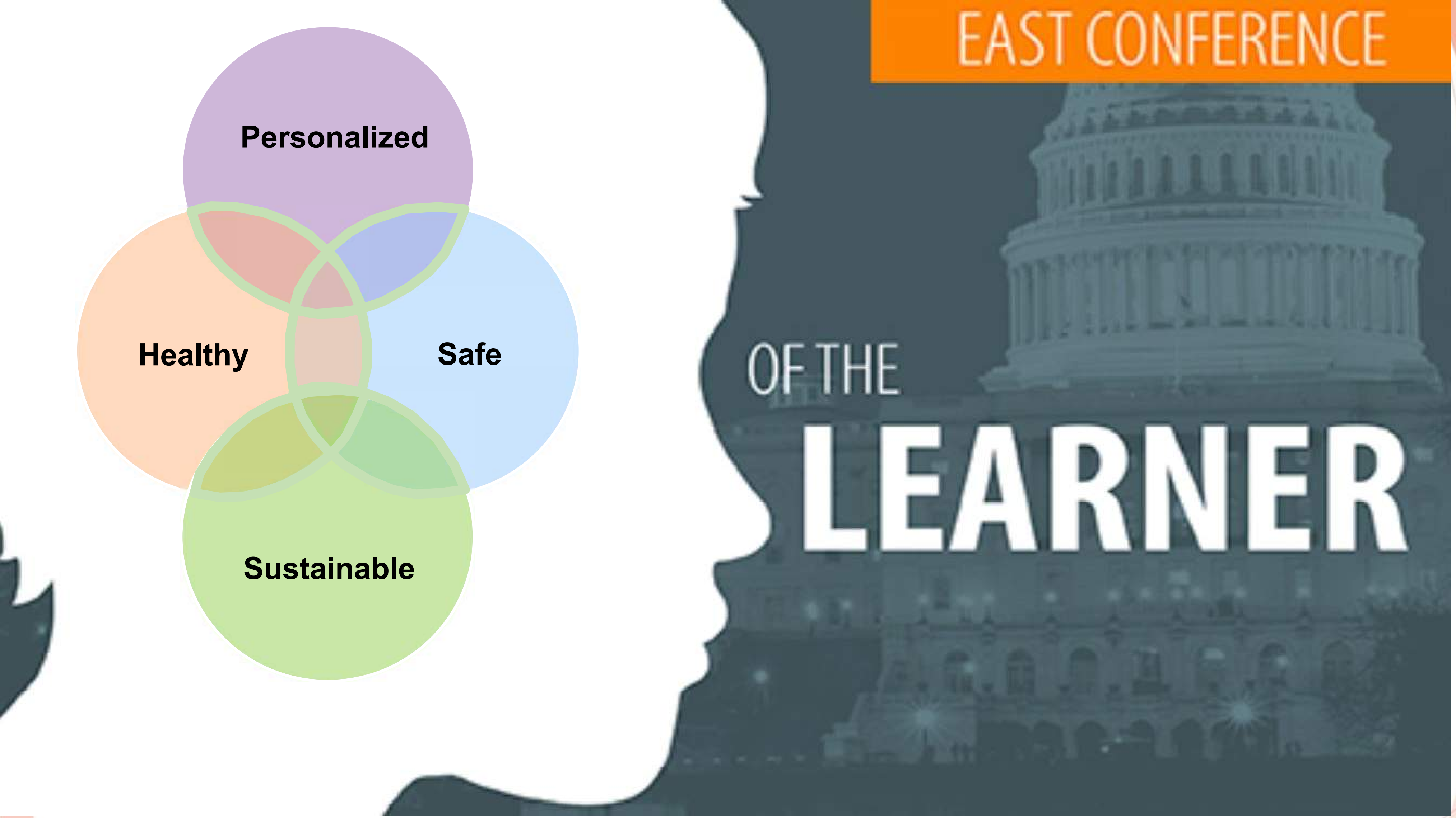

Image Credit: A4LE Conference Website

Student-influenced Learning Environment

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Enhancing the Educational Experience

1. Discuss strategies to create student-centered environments.
2. Discuss strategies to create safe spaces and experiences.
3. Discuss strategies to create healthy and mindful environments.
4. Discuss strategies to create sustainable learning environments.

(Educational Planning + Sustainability) x Community Connections = K12 Design

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Learning Objectives

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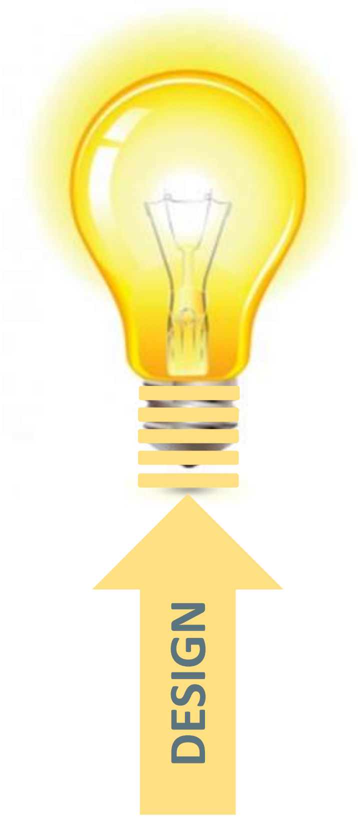
INCREASE STUDENT SUCCESS

Sustainable schools create an environment where teachers and faculty can cultivate a positive and progressive school culture. Teachers have more opportunities to devise unique learning opportunities and students benefit through increased participation and productivity and improved problem-solving and critical thinking skills.
Source: GreenSchoolsAlliance.org

Net zero buildings are the future. They provide a level of design, technology integration and measurement and monitoring beyond what the average building affords. Teachers can leverage these tools to drive experiential learning about passive design, on-site energy generation and storage, cutting-edge technology, community integration and the natural environment. They provide a learning lab far more effective than any textbook.
Source: GreenSchoolsAlliance.org



INCREASE STUDENT SUCCESS

Passive design strategies such as natural ventilation, improved insulation and airtightness, and the introduction of biophilic elements such as indoor plants that reduce volatile organic compounds and other air pollutants can improve the quality of indoor air and reduce the need for costly, energy-intensive HVAC equipment.
Source: GreenBiz 2016

U.S. Centers for Disease Control and Prevention states U.S. students miss about 14M school days per year due to respiratory issues related to poor IAQ. Improving IAQ alone can prevent more than 65% of asthma cases among K-5 students.
Source: GreenBiz 2016

With energy costs averaging about $300 per student per year, cash-strapped districts have found improving energy performance as the best way to lower operating and maintenance costs.
Source: GreenBiz 2016

Published Research

INCREASE STUDENT SUCCESS

Many design features critical to achieving net zero energy also lead to enhanced productivity. Daylighting not only reduces the need for energy-intensive lighting but also improves mood and alertness and provides students with a visual connection to nature.

Source: GreenBiz 2016

By taking a more innovative and integrated approach to designing and delivering thermal comfort, schools can improve individual occupant comfort in a variety of diverse climates using dramatically less energy. The USGBC's Center for Green Schools has published ample research on the connection between school buildings and student health and learning.

Source: GreenBiz 2016

Published Research

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STUDENTS	SCHOOLS	PLANET
98% of studies conducted by Stanford University revealed a positive impact as a result of environmental education.	Sustainable schools use 33% less energy and 32% less water than conventionally constructed schools.	Sustainable schools are designed to act as living laboratories to teach and embody eco-friendly initiatives that reduce our environmental impact.
Sustainable schools with natural light sources reported significant increases in test scores, and progression in reading and math.	**Sustainable Schools save, on average, $100,000 per year on operational costs. *($3M over 30-yr Bond Term)***	Sustainable school buildings are constructed with eco-friendly materials that decrease the reliance on fossil fuels, thus reducing carbon emissions.
Studies reported students were able to equally engage in environmental education regardless of where they fell on the intellectual spectrum.	**Reduced absenteeism, and improved student & teacher health: 38.5% reduction in asthma-related absences (#1 absentee reason in US)**	Green roofs last 30-50 years longer than typical roofs, reducing the amount of waste produced from more frequent replacement.
Studies reported increased student participation and engagement in class.	Sustainable schools receive direct and indirect savings from increased efficiency, higher teacher retention, and lower health costs, saving about $70 per square foot, 20 times higher than the initial "greening" costs.	Sustainable schools offer more opportunities for outdoor and hands-on learning, which inspire the next generation of environmental stewards.

Source: k-12_student_key_findings.pdf (naaee.org)

Source: greenschoolsalliance.org

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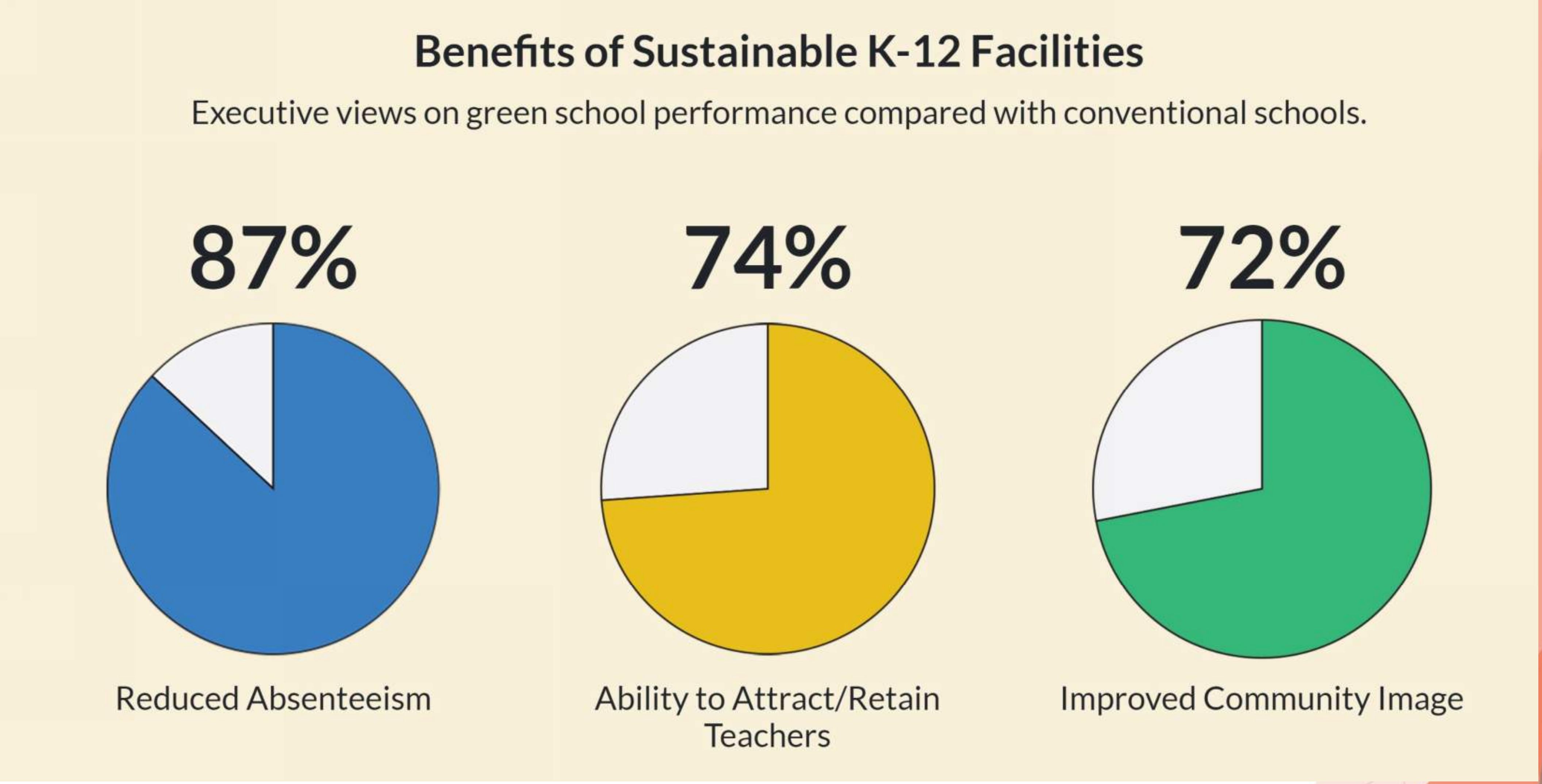

Source: Greening America's Schools

Published Research

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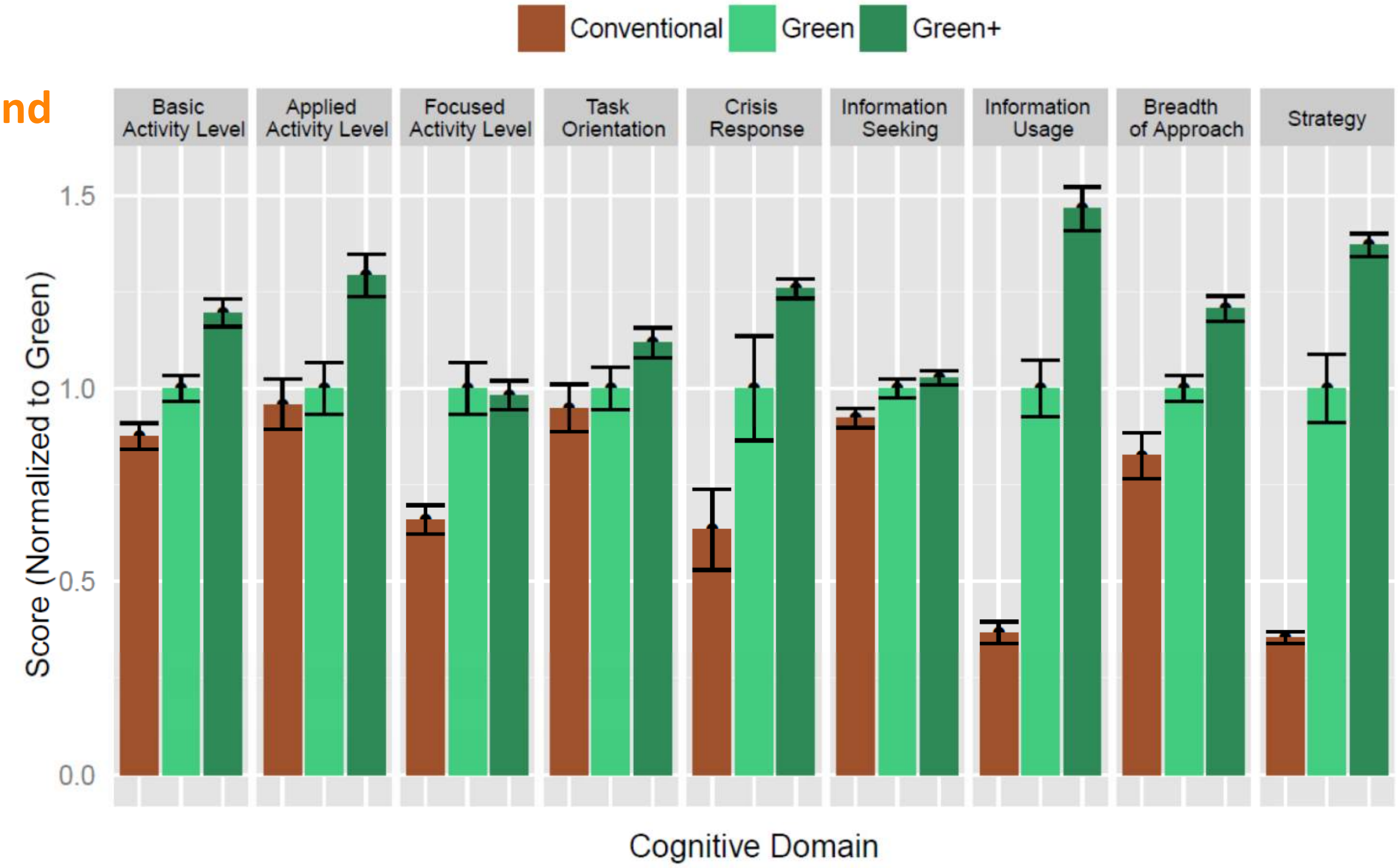
Cognitive Scores found to be:

61% higher in Green Buildings

101% higher in Enhanced Green Buildings

Source:
Harvard University, the TH Chan School of Public Health and the Global Environment

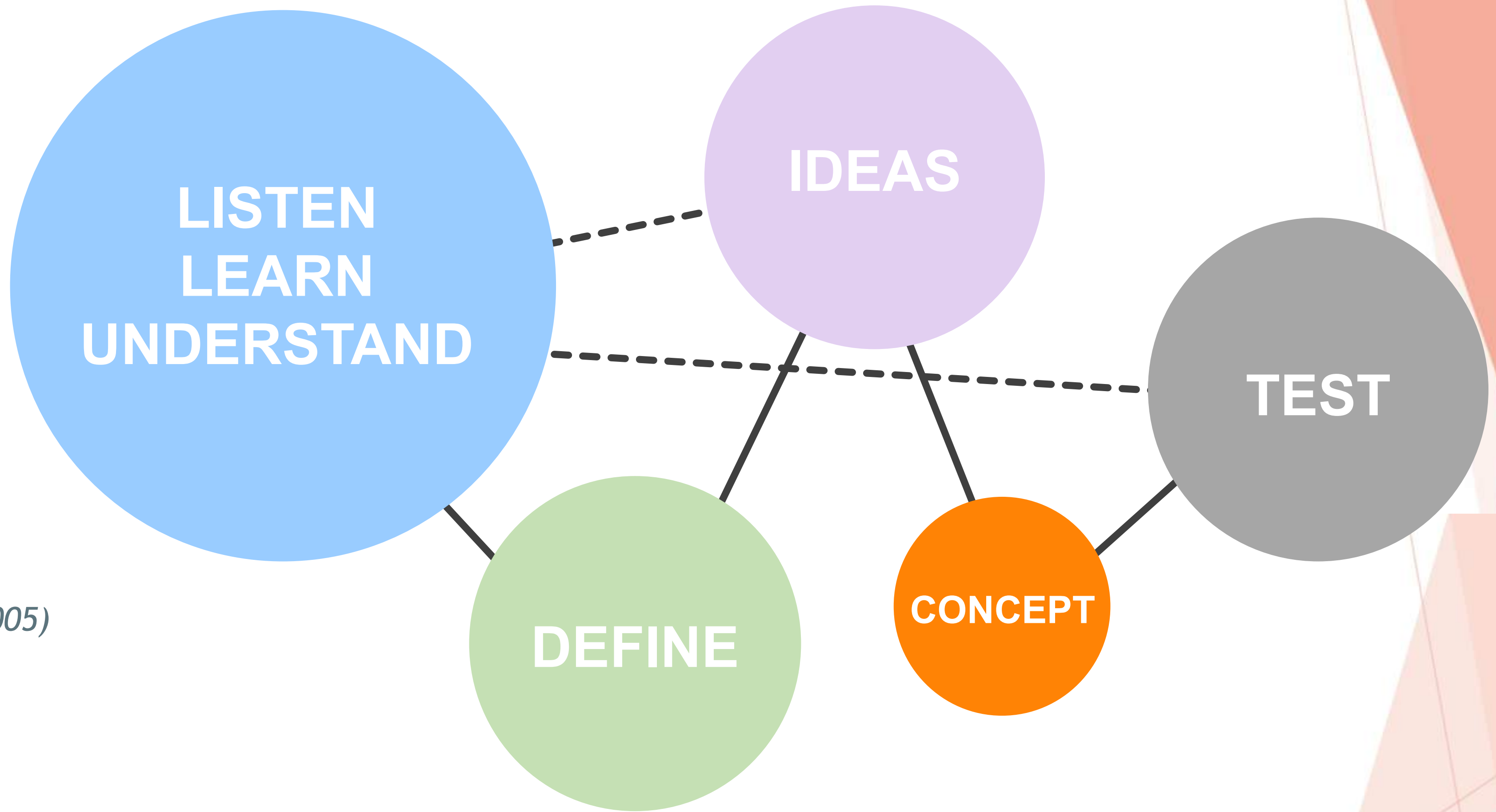


Published Research

Gates Middle School


Gates Middle School

Design Thinking Process



Source: dSchool
Stanford University (2005)
Dr Bernie Roth 1973

Source: IDEO (1991)
David Kelley 1978

Strategies to create Student-centered Environments:

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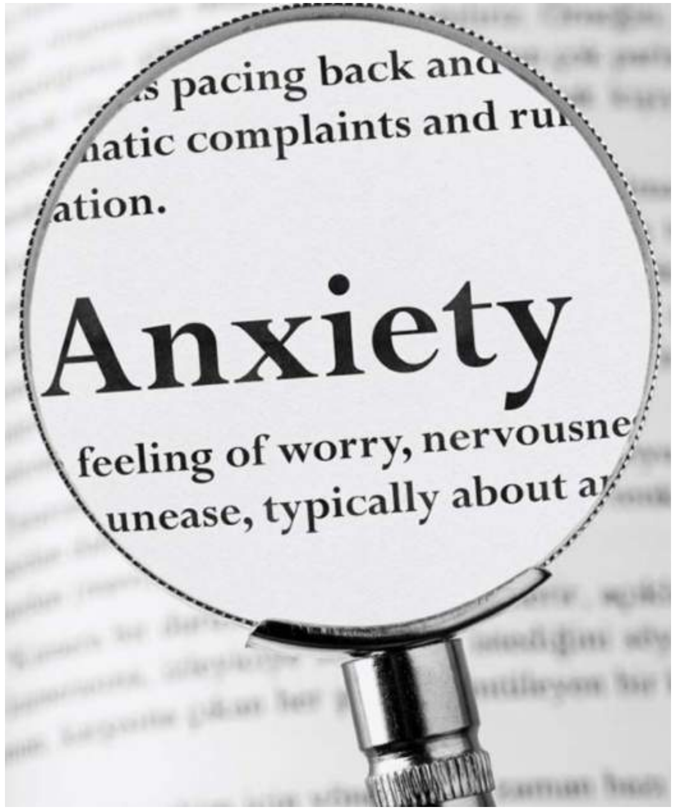
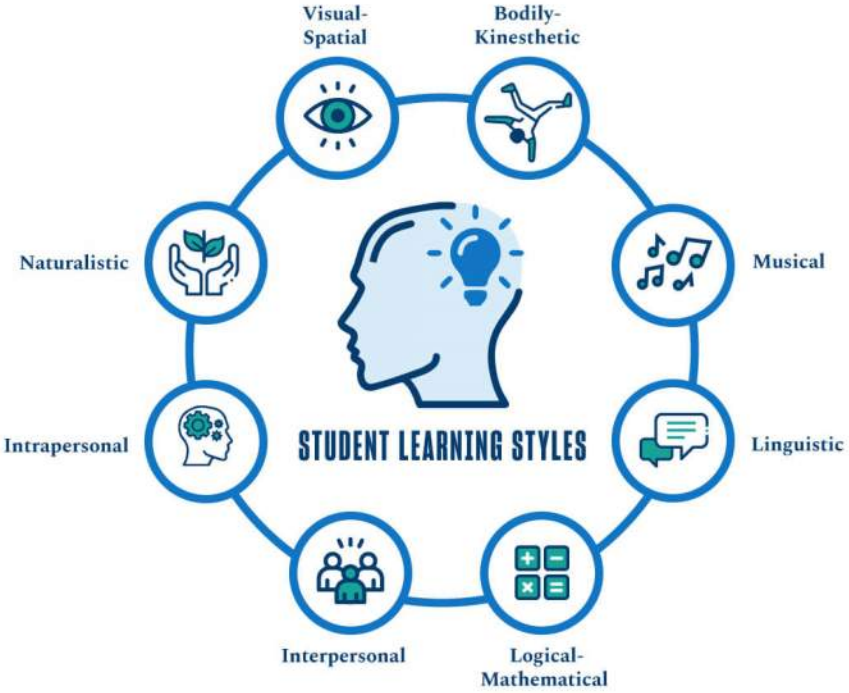
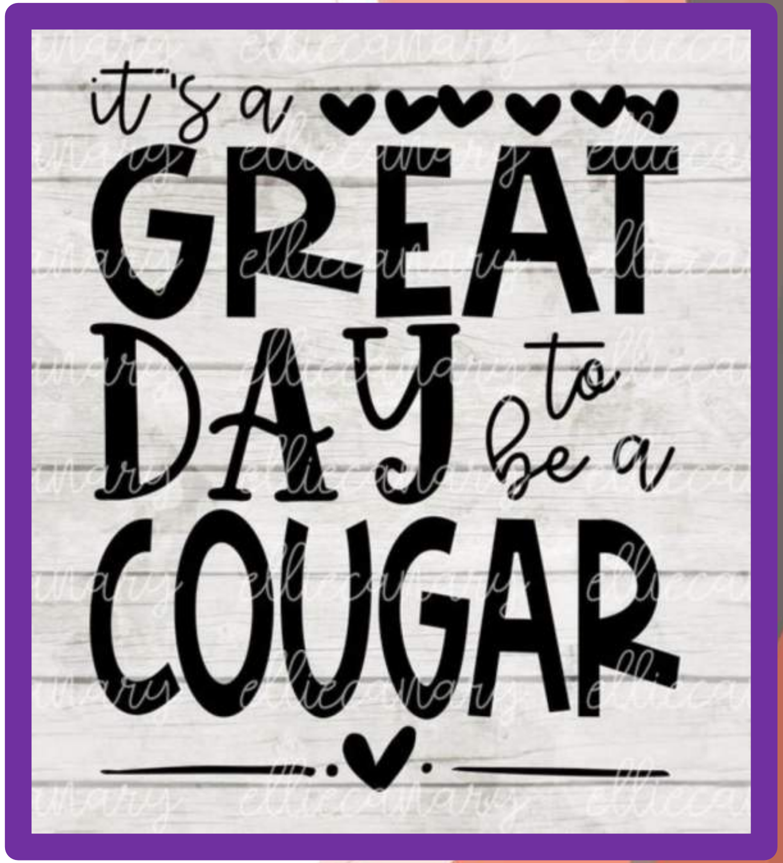
"A Day-in-Their-Life" at School







Source: Internet Images

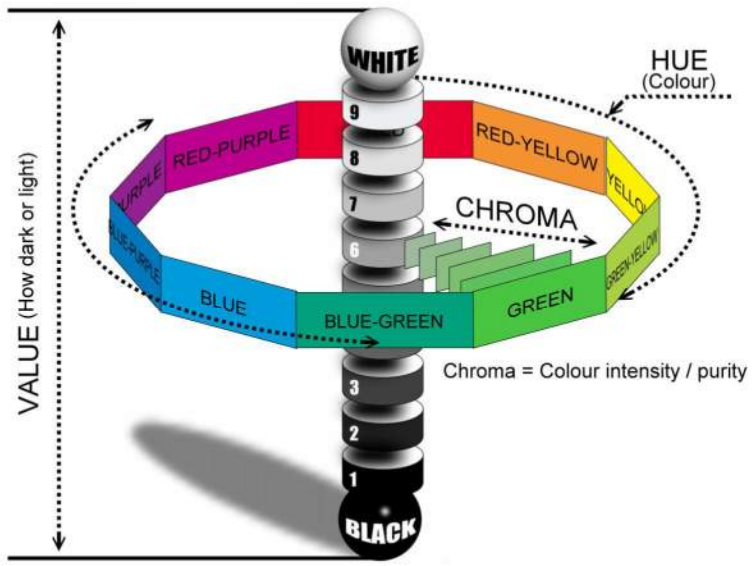
“Their Color Culture” at School

Symbolic Societal Cultural Emotional Maturational

Source: Relationship Between Color and Emotion
Naz Kaya, PhD, Helen Epps, PhD, University of Georgia (2004)

Munsell Color Theory & Albert H. Munsell Fundamentals of Color | Munsell Color System; Color Matching from Munsell Color Company

"Their Color Culture" at School



"…**Short term stress** increases in heart rate and stress hormone levels, can be beneficial to regulating physiological health *(Kandel et al., 2013).*
The physiological system needs to be tested regularly, but only enough for the body to remain resilient and adaptive. Physiological responses to environmental stressors can be buffered through design, allowing for the restoration of bodily resources before system damage occurs *(Steg, 2007)*….

Source: https://www.terrapinbrightgreen.com

Calming Comforting Happiness Hope Peaceful Relaxing

Source: Relationship Between Color and Emotion
Naz Kaya, PhD, Helen Epps, PhD, University of Georgia

Munsell Color Theory & Albert H. Munsell Fundamentals of Color | Munsell Color System; Color Matching from Munsell Color Company

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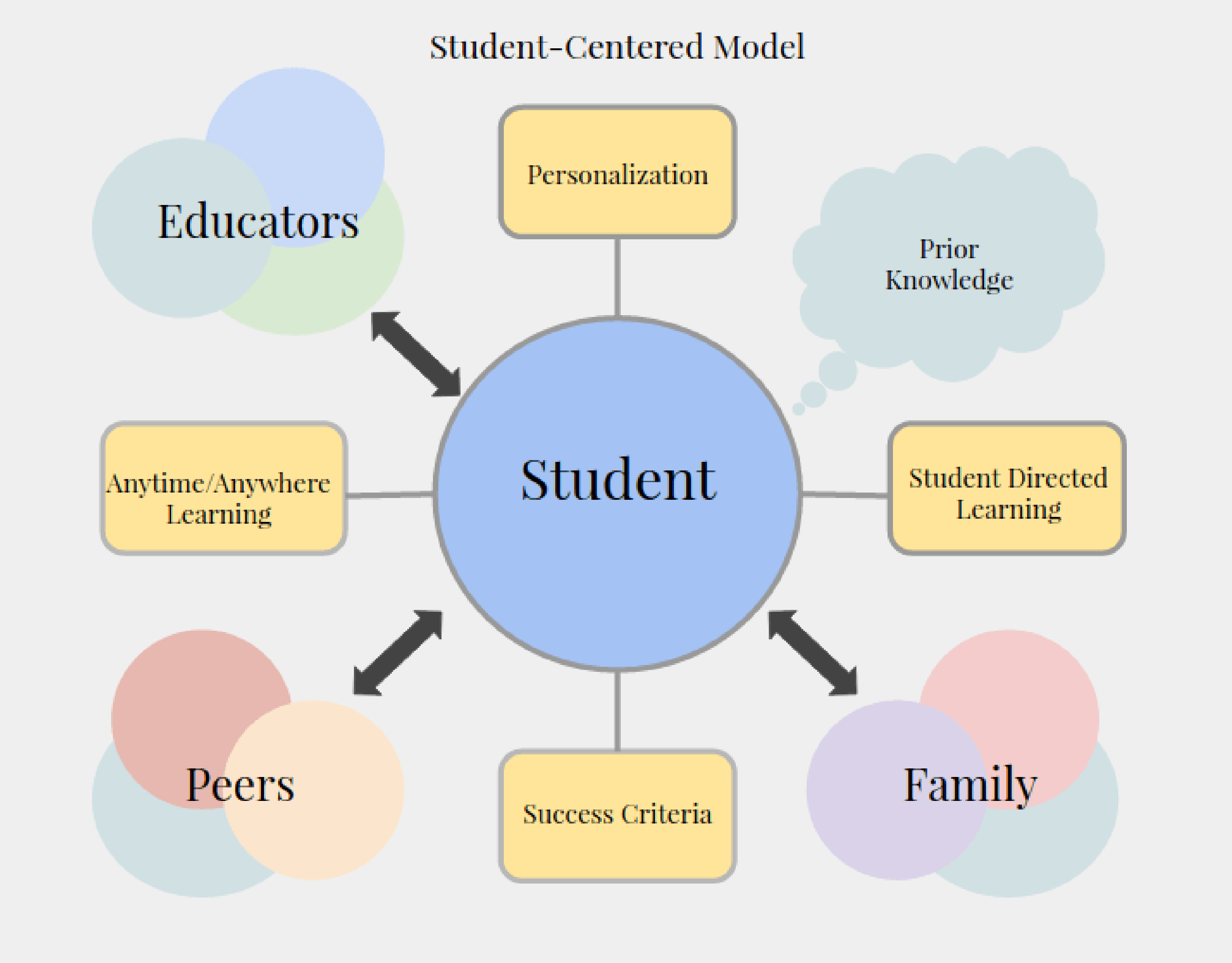
“Personalizing the Curriculum”

Students and Teachers Share the Focus.
Instead of listening to the teacher exclusively, students and teachers interact equally. Group work is encouraged, and students learn to collaborate and communicate with one another

“…Teaching walls become Student presentation walls…”



Source: Literacy and Language Center.com

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“Personalizing the Curriculum”

Choice Boards

Choice boards allow students to select activities they will complete to practice a skill or demonstrate understanding. In this approach to learning, students are given ownership and empowerment opportunities while teachers differentiate their instruction. Choice boards can be utilized not just for assessment purposes, but also to introduce new material, for supplemental practice, or as a combination of multiple parts of a lesson or unit.

Source: www.teachhub.com
Student-Centered Learning Strategies - TeachHUB

Jigsaw/Stations/Centers

Although an older concept, the Jigsaw method as evolved and been combined into a center/station approach. This strategy involves students utilizing cooperative learning as they seek to put the “puzzle” together. Each student takes responsibility for an individual component of knowledge, then takes knowledge learned and gained and applies it to the larger body of work (puzzle). This concept is used for students to demonstrate learning.

Source: www.teachhub.com
Student-Centered Learning Strategies - TeachHUB

“Personalizing the Curriculum”

Inquiry-Based Learning

In this learning strategy, student questions, ideas, and analysis are highlighted and fostered, focusing on the student perspective regarding a particular open question or problem. This strategy is particularly useful for initial student engagement, leading students to move beyond basic knowledge to a deeper understanding of critical thinking, evidence-based reasoning, and creative problem solving. Components of a lesson can include case studies, group projects, and research projects, to hone skills highly valuable in the world in which we now live.

Source: www.teachhub.com
Student-Centered Learning Strategies - TeachHUB

Project-Based & Problem-Based Learning (PBL)

In project-based learning, students work on longer tasks that culminate in the creation of an original presentation or product. This strategy relies on student collaboration, communication, and creativity, with the teacher serving as a facilitator for student work and progress.

Problem-based learning includes shorter projects that examine a “real-life” problem, and through definition, research, and causes of the problem, students collaboratively evaluate solutions to the chosen problem, solve the problem, or report potential solutions and/or findings.

Source: www.teachhub.com
Student-Centered Learning Strategies - TeachHUB

“Personalizing the Curriculum”

Flipped Classrooms

A strategy to maximize instructional time within the classroom utilizes technology. New or introductory content is delivered to students outside of the classroom, with teachers incorporating many of the strategies already discussed such as choice boards or jigsawing to allow student choice in their learning. Learning material can include readings, videos, pre-recorded presentations or direct instruction. Classroom time is used by the teacher to facilitate learning and help students gain practice applying knowledge learned outside of the classroom.

Instead of the typical “exit ticket” where students hand in a completed work showing mastery or further questions about understanding, students use “entrance tickets,” where they enter the classroom with a completed assignment, written response, quiz, or blog post serving as their “ticket.” Ultimately, the flipped classroom model can incorporate multiple student-centered learning strategies, making it very popular in schools today.

Reality: *“…This model is way too much work for the teacher…”*
Response: *“…This is THE reason for team teaching…”*

Source: www.teachhub.com
Student-Centered Learning Strategies - TeachHUB

“Personalizing the Curriculum”

Technology Today (anytime / anywhere learning)

Zoom & Teams, we all know about by now.
eSpark, standards-based games, engaging videos, and digital activities, students work independently to succeed at their own level and at their own pace.
Prodigy, teachers can align the in-game questions to match their Math instruction.
Epic, used by 94% of US schools, teachers can assign books or create collections of books for students to read. Some of these texts also have short comprehension quizzes at the end.

iXL, covers four core subjects and is Common Core and State Standards-aligned. the Real-Time Diagnostic, evaluates students’ grade-level proficiency in math and language arts at a deeper level. Teachers gain data to help them make informed decisions about each student’s learning. In addition, iXL uses the insight from student work combined with the diagnostic to generate a personalized guide for each learner.

And other available tools are digital resources used to personalize learning.

Source: www.teachhub.com
Student-Centered Learning Strategies - TeachHUB

Strategies to create Student-centered Environments:

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Purposeful Student Movement

Student Resources and Support

Multi-use Flexible Adaptable Space

Student Centered Learning (Curriculum)

Equality Gender Neutral Diversity Equity

Student Comfort & Safety

DESIGN

INCREASE STUDENT SUCCESS

Strategies to create Student-centered Environments:

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Safety and learning go hand-in-hand

School Safety is *NOT* achieved with a single program or piece of security equipment:

a) Arrive at school feeling safe, welcomed, and respected;

b) Enjoy a trusting relationship with at least one adult in the building;

c) Understand and respect clear academic and behavioral expectations; and

d) Know they have access to needed mental health supports.

Source: https://www.nasponline.org: Rethinking School Safety Key Message

National Association of School Psychologists

Genuine Security Encompasses Both Physical & Psychological Safety

a) Our schools must not resemble fortresses;

b) Excessive building security (e.g., metal detectors, etc..) can actually decrease a sense of safety and does not guarantee protection;

c) We cannot barricade against all possible harm; trying to do so is counterproductive to maintaining a healthy learning environment and is an ineffective use of resources;

d) To truly improve school safety, reasonable physical security must be combined with reasonable psychological safety efforts that promote a positive school climate.

Source: https://www.nasponline.org: Rethinking School Safety Key Message

NASP
National Association of School Psychologists

Strategies to create Safe Environments:

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Safety Works When it Welcomes

- Creating a warm and welcoming environment
- Fostering a sense of physical and social order
- Creating a sense of ownership by students
- Minimizing opportunities for out-of-sight activities
- Sending positive messages to students
- Maximizing the presence of authority figures
- Managing access to all school areas

Source: https://www.cptedtraining.net

Strategies to create Safe Environments:

Natural surveillance

Physical features that improve visibility. Such as strategic use of glass so students and staff can see and be seen.

Access management

Signage, well-marked entrances and exits, and landscaping to improve, direct, or limit access to certain areas.

Territoriality

A welcoming environment. Displaying motivational signs, student art, murals, and meaningful colors to create warmth and pride.

Physical maintenance

Repair and general upkeep of space to maintain safety and comfort.

Order maintenance

Reducing negative behavior. Adult presence while students are on the move and the knowledge that adults are always present.

Source: https://www.cptedtraining.net

Strategies to create Safe Environments:

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Strategies to create Safe Environments:

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Needham-Hillside Elementary School

Strategies to create Safe Environments:

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Making Schools Safer Through the Use of Murals and Artwork

One of the powerful components of Crime Prevention Through Environmental Design involves the creation of what is known as positive territoriality. Positive territoriality is designed to create a greater sense of ownership and connectivity between legitimate users of a place and the physical place. Murals and artwork are two of the more common ways schools can improve positive territoriality to improve school climate and culture. Murals, student artwork and other approaches designed to create positive territoriality also can help to tone down the use of physical security measures such as access control, visitor screening processes, security cameras as well as the assignment of security and police officers to schools.

Source: https://www.cptedtraining.net

Making Schools Safer Through Positive Connections

While often thought of as beneficial in other ways, positive connections between staff and students have been demonstrated to improve school safety. *Source: Safe Havens International*

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West Parish Elementary School

Strategies to create Safe Environments:

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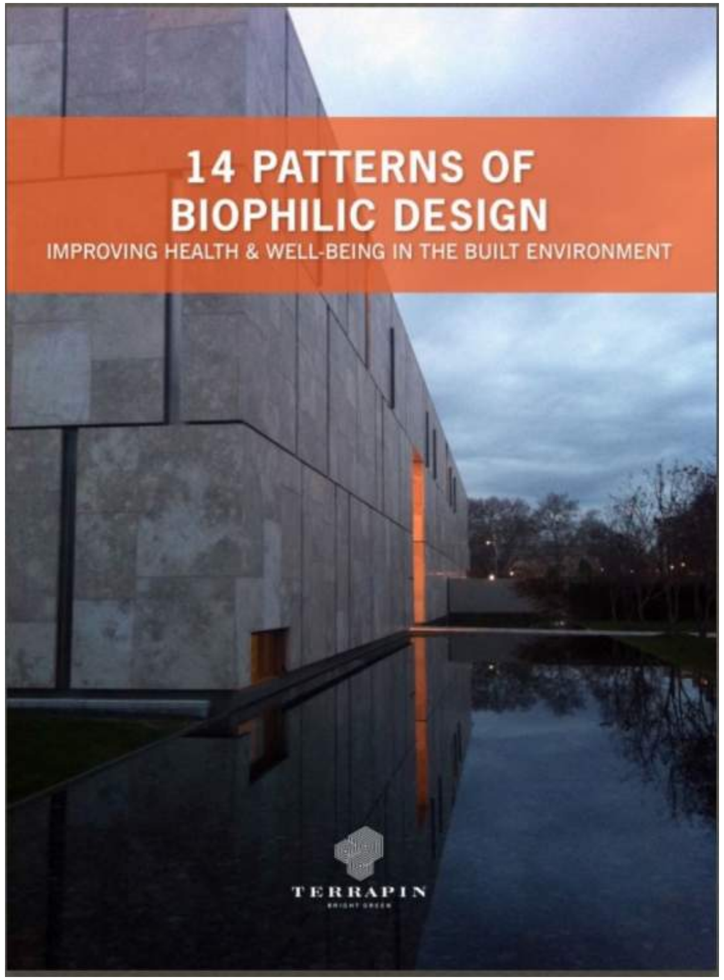
Feeling Connected and Safe

Biophilic design can reduce stress, improve cognitive function and creativity, improve our well-being and expedite healing….design that reconnects us with nature – *biophilic design* – is essential for providing people opportunities to live and work in healthy places and spaces with less stress and greater overall health and well-being.

Nature in the Space Patterns

Refers to incorporating real physical elements of nature into interior spaces. Such as, windows with a tree-filled view, indoor water fixtures, and daylighting to mimic circadian rhythms and natural conditions.



Source: https://www.terrapinbrightgreen.com

Natural Analogues Patterns

Refers to incorporating literal and implied representations of nature into a physical space. Using textile patterns, furniture, or surfaces that simulate elements of the natural environment.

Nature of the Space Patterns

Refers to how we relate to the design of a physical space and how the various elements of that space relate to one another. Such as, sight lines, the relative size of furniture and other fixtures, and the overall natural flow of the space.

Source: https://www.terrapinbrightgreen.com

14 Patterns of Biophilic Design

Nature in the Space Patterns

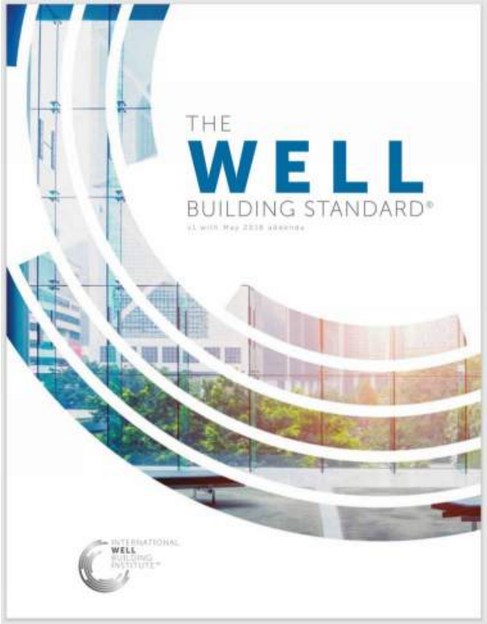
1. Visual Connection with Nature
2. Non-Visual Connection with Nature
3. Non-Rhythmic Sensory Stimuli
4. Thermal & Airflow Variability
5. Presence of Water
6. Dynamic & Diffuse Light
7. Connection with Natural Systems

Natural Analogues Patterns

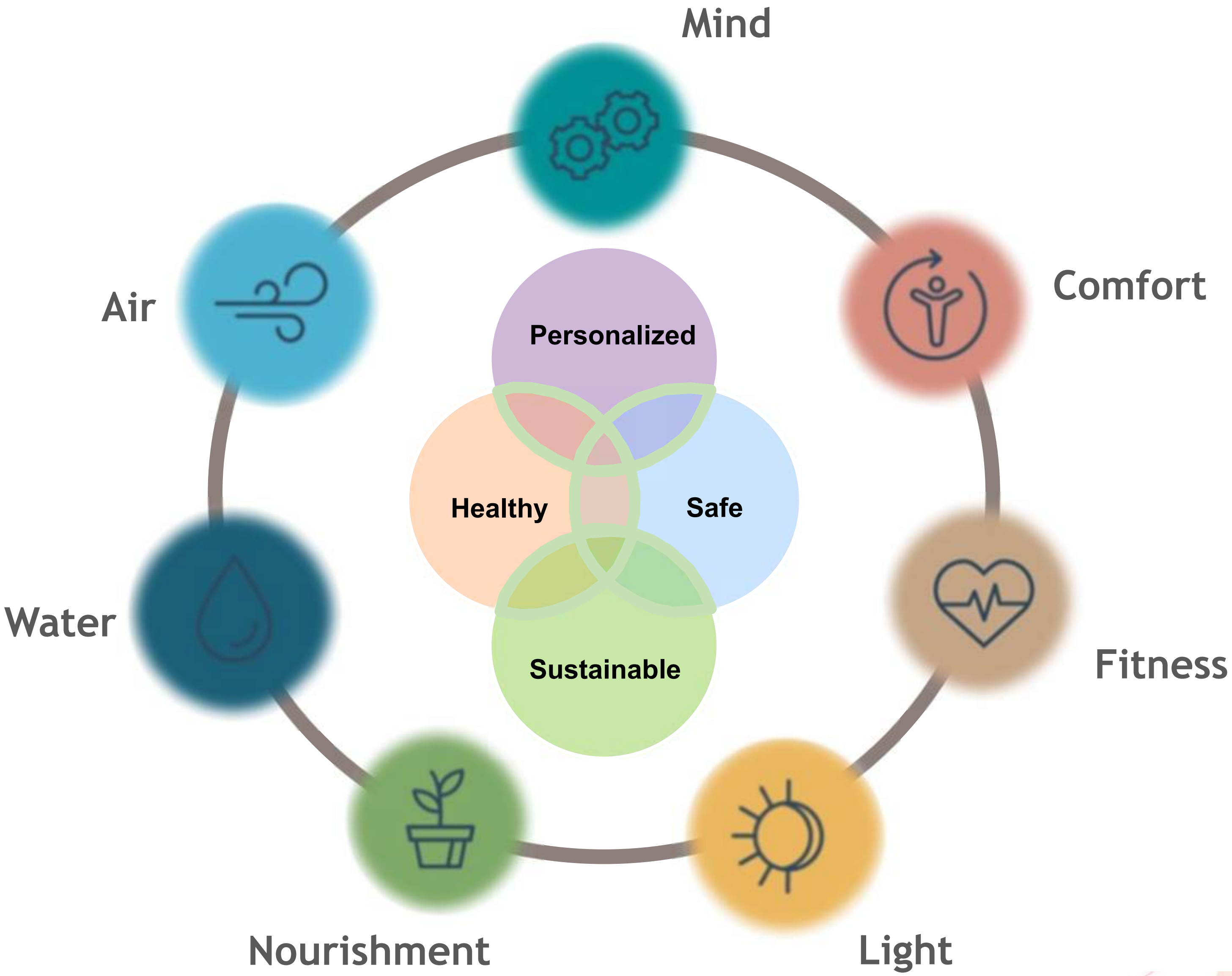
8. Biomorphic Forms & Patterns
9. Material Connection with Nature
10. Complexity & Order

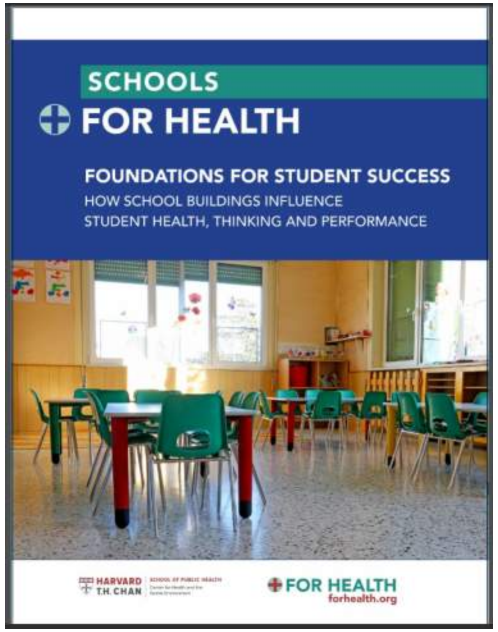
Nature of the Space Patterns

11. Prospect
12. Refuge
13. Mystery
14. Risk/Peril



Resource: WELL Graphic (modified)





Resource: Harvard University, the TH Chan School of Public Health and the Global Environment

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Strategies to create Healthy & Mindful Environments:

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10 Mental Health Tips For Online Learning

1. Learn how to meditate
Meditation is at the heart of many relaxation rituals.

2. Make an effort to be conscious
In recent years, mindfulness, or a state of active focus on the present, has risen to prominence as a critical component of mental wellbeing.

3. Eat well and exercise regularly
Healthy living's foundational elements have a huge effect on physical and mental health.

4. Take a break

5. Get out there and mingle
It can be challenging to remember to set aside time to spend responsibly with mates with too much to do.

6. Set achievable goals
Don't worry if you can't do it all at once. Making your goals daunting yet realistic is the best way to ensure you achieve them.

Source: .www.youmustgethealthy.com

7. Create time for pleasure
Make time for your favorite pastime. Some "me time" is an important aspect of anyone's life.

8. Spend time with the outdoors
Go outside for some of the things on this list, if you're willing. According to Business Insider, taking a walk in the woods or doing yoga in the sun will help you calm your nerves, and boosts your creativity.

9. Be easy with yourself
It's pretty normal to forgive loved ones for failing to complete a job or forgetting to keep an appointment. Studies have shown that self-compassion is also a critical component of mental well-being in online learning.

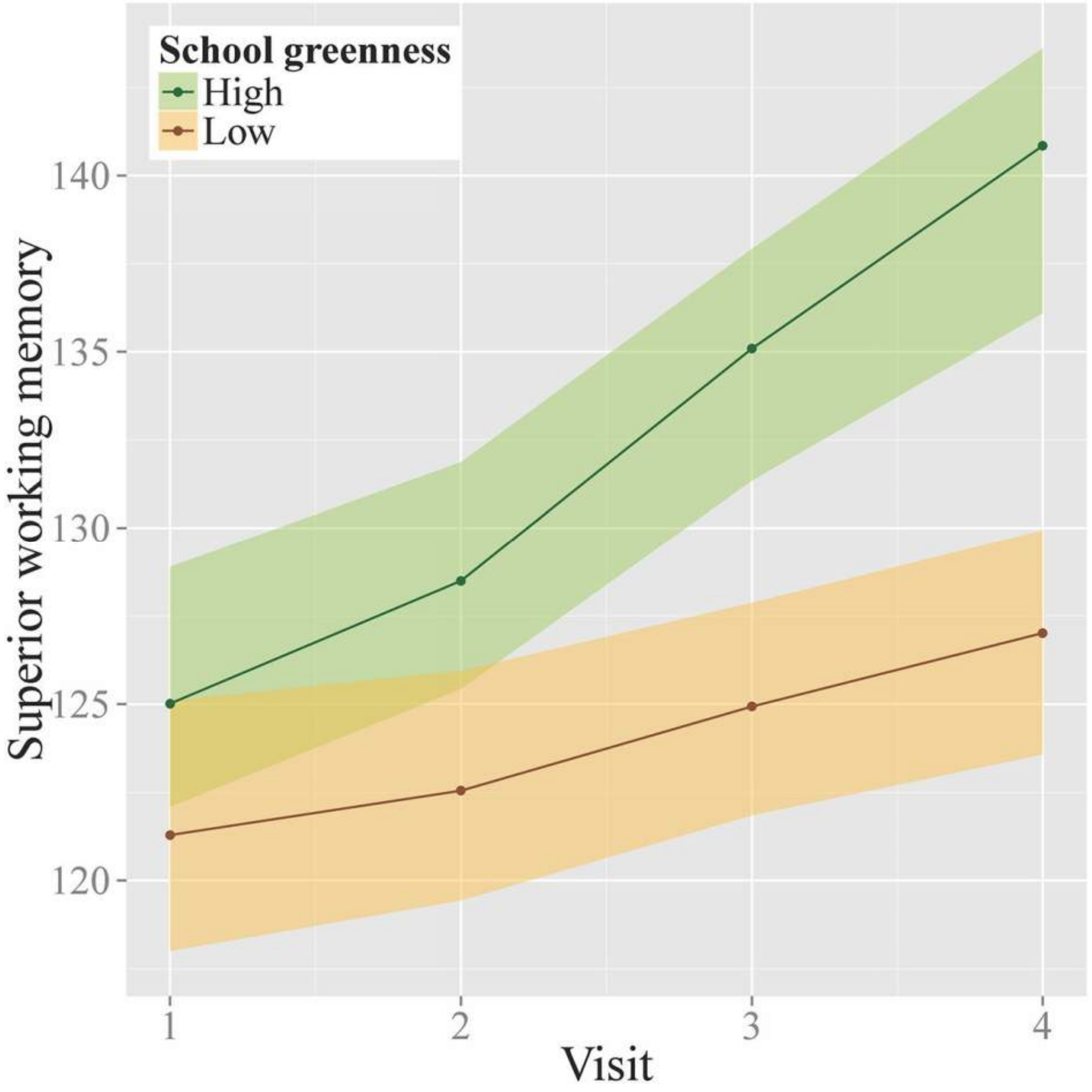
10. Have a study space
Creating a study space will help you manage your time and schedule better. In the study space, you should keep all the materials you need, make the learning environment comfortable, but not overly comfortable.

Biophilic Learning Environments Boost Student Achievement

Over 12 months, average working memory increased by 22.8%, superior working memory by 15.2%, and inattentiveness decreased by 18.9%

Source: ©2015 by National Academy of Sciences

PNAS



Personal Comfort

A recent study examining Regents exam test scores in 75,000 high school students in New York City, Park (2016) found that for every increase of 1°F, test scores fell by 0.2%; for the average student, the likelihood of failing an exam taken on a 90°F day versus a 75°F day would be 12.3% higher.

Young children have higher metabolic rates, higher core body temperature, less developed thermoregulation capabilities, and a wider range of thermal responses. Children are more vulnerable to the effects of heat stress and appear more uncomfortable at higher temperatures than those of adults. They have also been found to prefer cooler environments (Nam et al., 2015; Vanos et al., 2016; Zomorodian et al., 2016).

An accumulating body of evidence suggests that learning and memory can be impaired when the sleep–wake cycle is disrupted (Collwell, 2015; Keis et al., 2014; Wright Jr. et al., 2006). Thus it is important to consider how circadian-stimulating electrical lighting can be combined with daylighting strategies to optimize the well-being of children in school.

Resource: Harvard University, the TH Chan School of Public Health and the Global Environment; Foundations for Student Success

INCREASE
STUDENT
SUCCESS

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Strategies to create Healthy & Mindful Environments:

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LIVING BUILDING CHALLENGE

nbi new buildings institute

GREEN GLOBE CERTIFIED

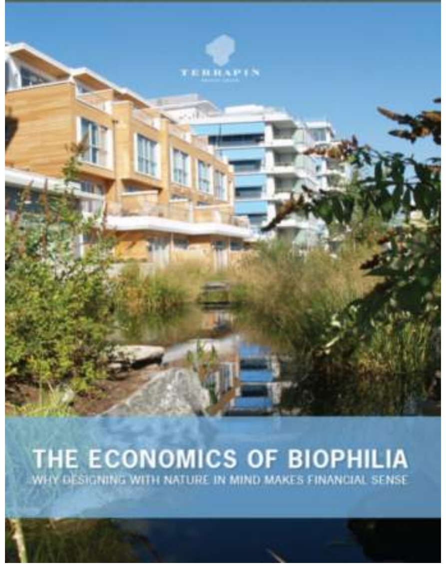
PHIUS Passive House Institute US

LEED for the environment

WELL for the people

CHPS

https://www.ashrae.org/technical-resources/aedgs/zero-energy-aedg-free-download


TERRAPIN
THE ECONOMICS OF BIOPHILIA
WHY DESIGNING WITH NATURE IN MIND MAKES FINANCIAL SENSE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Plug Load Best Practices Guide
Managing Your Office Equipment Plug Load
Guide to Energy Savings
Plug loads can be managed through low- and no-cost measures that are relatively straightforward to implement.
This Guide shows how simple changes can cut costs and save energy in offices.
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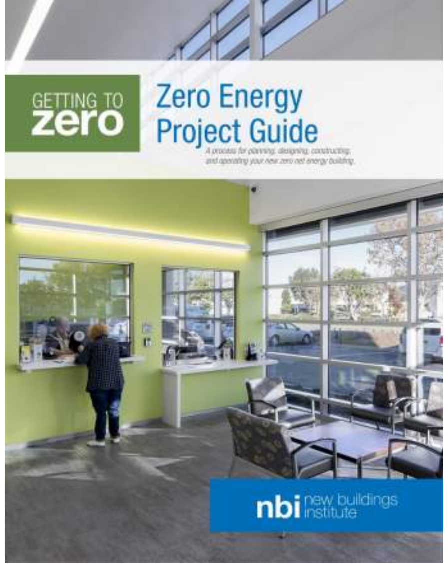
New Construction
A prescriptive guide to achieve significant, predictable energy savings in new commercial buildings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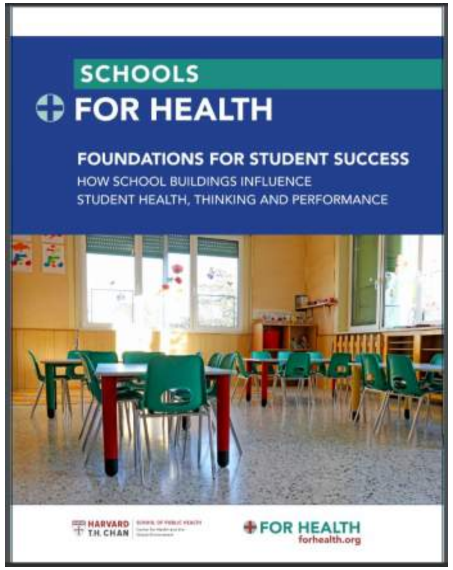
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FOUNDATIONS FOR STUDENT SUCCESS
HOW SCHOOL BUILDINGS INFLUENCE STUDENT HEALTH, THINKING AND PERFORMANCE
HARVARD T.H. CHAN
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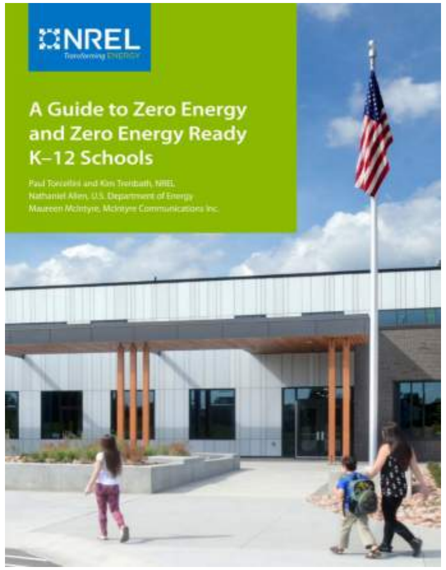
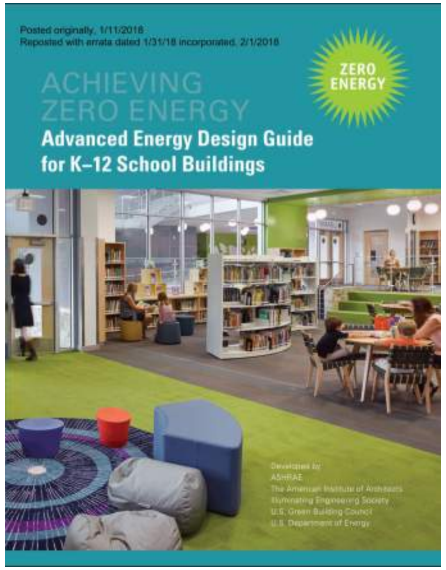
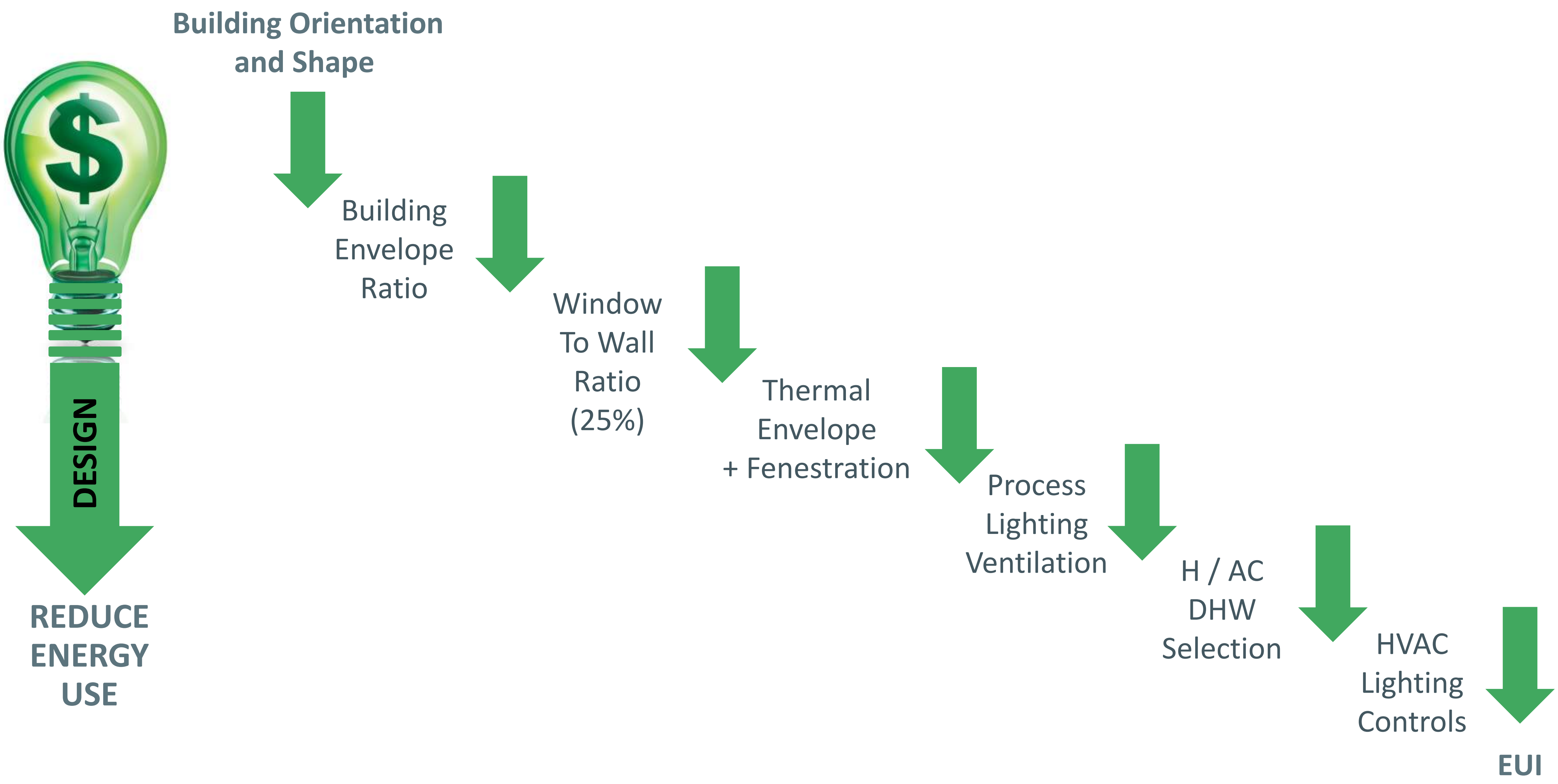

NREL
A Guide to Zero Energy and Zero Energy Ready K–12 Schools


ne ep
Zero Energy Schools Toolkit
May 2020


Posted originally, 1/11/2018
Reposted with errata dated 1/31/18 incorporated, 2/1/2018
ZERO ENERGY
ACHIEVING ZERO ENERGY
Advanced Energy Design Guide for K–12 School Buildings

Strategies to create Sustainable Environments:

DORE + WHITTIER ARCHITECTS



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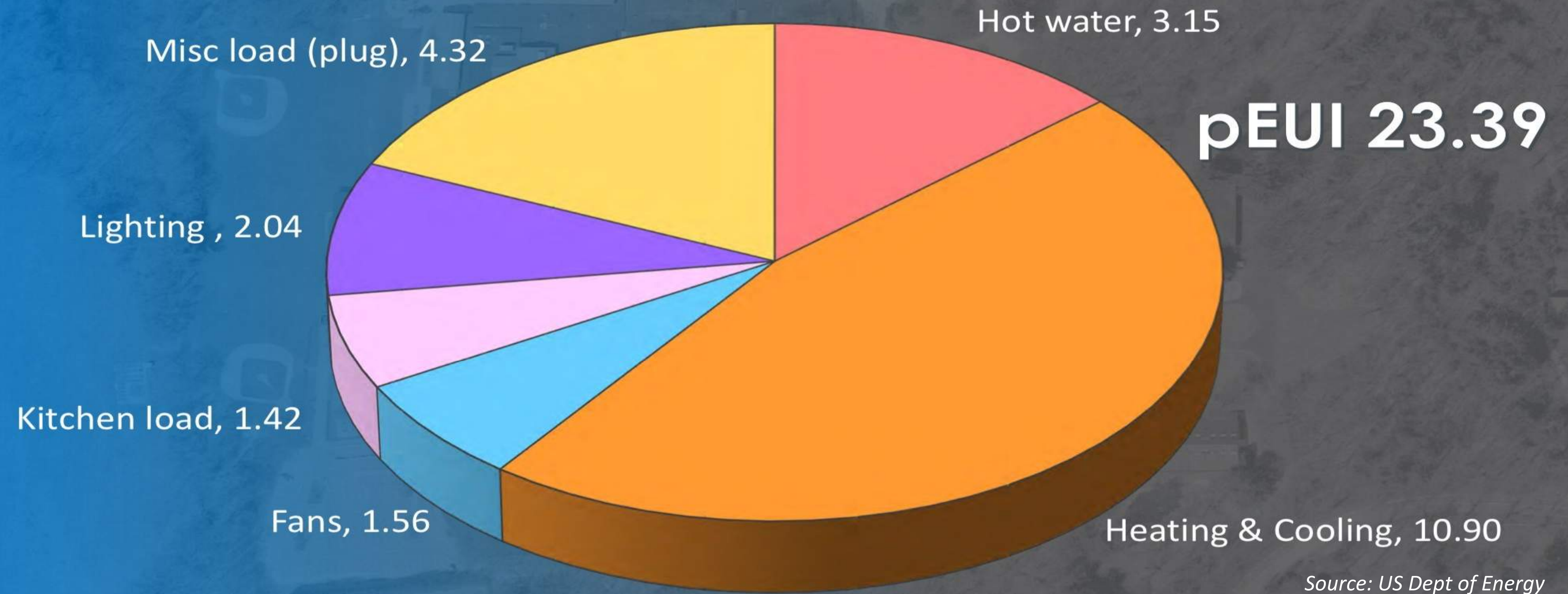
Energy Use Intensity Distribution (kBtu/SF/Yr) *US DOE Example*



pEUI 23.39

Source: US Dept of Energy

Energy Use Intensity (EUI)

MA, RI, CT, and Southern NH

Climate Zone 5A

EUI Target = 19.1 to 19.2

VT, most of NH and ME

Climate Zone 6A

EUI Target = 20.6 to 21.1

Northern ME

Climate Zone 7

EUI Target = 21.5 to 22.3

Table 3-1 Target EUI

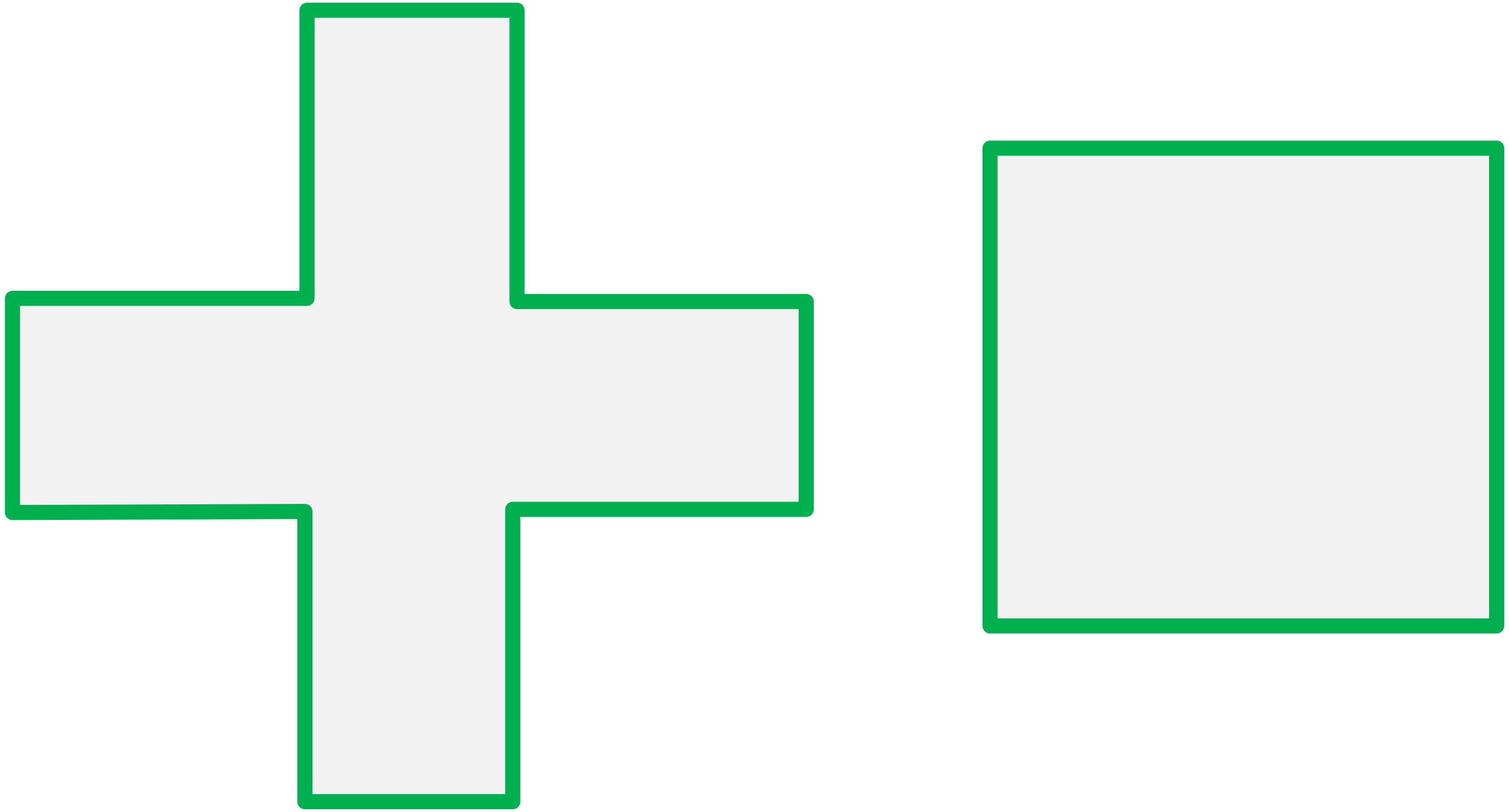
Climate Zone	Site Energy		Source Energy	
	Primary School EUI, $kBtu/ft^2 \cdot yr$	Secondary School EUI, $kBtu/ft^2 \cdot yr$	Primary School EUI, $kBtu/ft^2 \cdot yr$	Secondary School EUI, $kBtu/ft^2 \cdot yr$
0A	22.5	22.9	69.1	70.5
0B	23.1	23.2	71.4	71.6
1A	21.3	21.1	65.5	65.0
1B	21.7	21.6	66.6	66.6
2A	20.9	21.3	63.8	65.1
2B	19.6	19.9	59.7	60.8
3A	18.8	19.1	56.7	57.7
3B	19.0	19.4	57.3	58.8
3C	17.5	17.6	52.6	52.8
4A	18.8	18.9	56.3	56.7
4B	18.4	18.5	55.1	55.5
4C	17.5	17.6	51.9	52.3
5A	19.2	19.1	57.1	56.9
5B	18.7	19.0	55.6	56.6
5C	17.4	17.6	49.7	52.3
6A	21.1	20.6	62.8	61.2
6B	19.5	19.5	57.9	57.9
7	22.3	21.5	66.2	63.7
8	25.2	23.8	71.1	70.7

Source: New Buildings Institute (NBI)

Value Analysis

Shape & Solar Orientation

Some of the most basic and initial organizational decisions during the educational planning have the greatest impact of the resulting energy performance and the initial, operational, and maintenance costs.

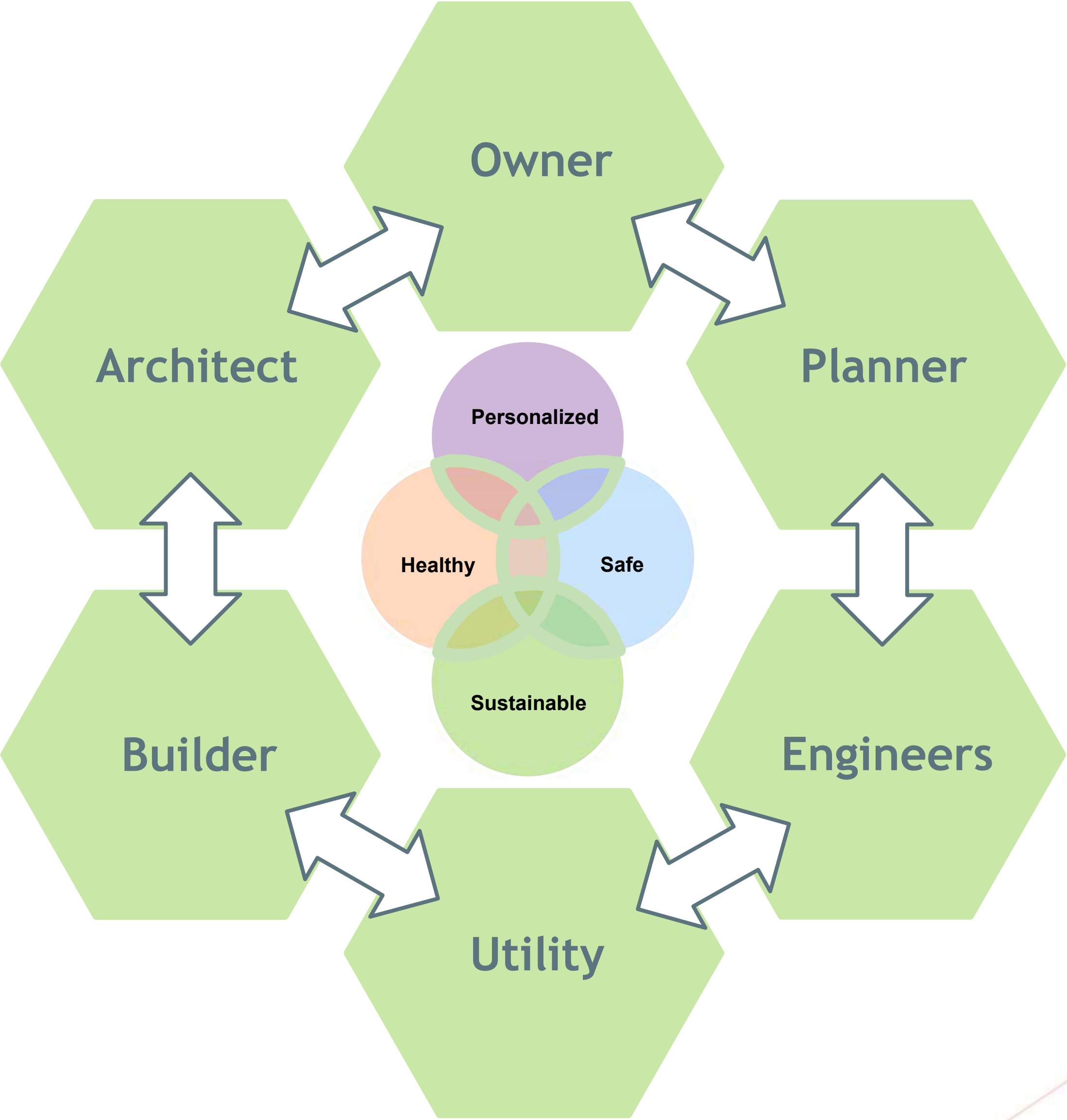


Value Analysis

Balancing Decisions & Shifting Costs

As some energy efficient strategies create a rise in cost over a traditional design, other strategies result in lower costs due to heating, cooling, ventilation, etc… being reduced in capacity.

"…a mechanical & window bid miracle…"



INSIDE THE MIND OF THE LEARNER
EAST CONFERENCE

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ASSOCIATION FOR LEARNING ENVIRONMENTS
Enhancing the Educational Experience
CELEBRATING 100 YEARS 1921-2021

Concept Sketch: Hanlon Elementary School
Targeting Zero-Net-Energy & LEED Certification

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ENERGY USAGE : Modeling

Min Exterior Wall Ratio (Shape)

25% Window-to-Wall Ratio

Strategic Window Placement in 100% Core Learning Spaces

Fixed Fiberglass Windows

R34 Walls, R60 Roof, R20 slab,
Mech Basement R20,
R7.14 (0,14 U-v) 3-P Windows,
R2.9 (0.34 U-v) HP CW / SF,
R2.78 (0.36 U-v) Doors,
R2.5 (0.4 U-v) Skylights.

Keeping it Simple to Build

Four-pipe water-to-water ground source (geothermal) hybrid (DHW) heating and cooling

Separate Heating/Cooling from Ventilation

Thermal Zoning

Heat Recovery

CO_2 Sensors/Demand Control Ventilation / Scheduling

All LED Lighting

Keeping it Simple to Operate

Occupancy Sensors (OFF)

Solar Hot Water Collectors

Low-Temp Heating

Energy-Efficient HVAC

All electric with LP Generator

Whole Building Metering

All Electric (DWH + Kitchens)

Annual Commissioning

ENERGY USAGE : Modeling

Food Service Energy Reductions:

Menu Design / Food Offerings

Heat Recovery

Community Use Scheduling:

Predicted Annual Hours per Zone

Predicted Annual Occupants per Zone

Predicted Ventilation Needs Off-hours

Keeping it Simple to Build

IT and AV Equipment Sizing

Right-size POE switches & capacity

Heat Recovery

Right-size Cooling Needs

Predicted Annual Use Hours

Ghosting Control with Occupancy Sensors and Time Clocks

Right-size Server Equipment

Keeping it Simple to Operate

Renewable Energy Systems

Roof, Parking Canopy, Ground Mounted, Wall Mounted Solar

Electrical Transformer Type & Size

On-site Charging & Energy Use

Annual Exterior Site Use Hours

Owning vs RECs vs PPAs

Net Cost versus Net Energy

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Value Analysis

Energy Usage

Existing Schools: 67,601 sqft (no AC or Code-reqd. Ventilation)

Example of 3-year Utility Cost Average:

276,390.5 kWh 2017-2028 average thru 2019-2020 average annual use
276,390.5 kWh x 3.412 kBtu/kWh = 943,044 kBtu

47,238.89 Therms 2017-2018 average thru 2019-2020 average annual use
47,238.89 Therms x 100 kBtu/Therm = 4,723,889 kBtu

943,044 kBtu + 4,723,889 kBtu = 5,666,971 kBtu annual use
5,666,971 kBtu / 67,601 sqft = EUI = **83.8 kBtu/sqft/year**

Based on 2018-2020 average Energy Bills + (Estimating for AC and Ventilation)
$58,042.00 electricity + $14,196 (estimate for AC = approx. 1 kWh/sqft x $0.21)
$59,521.00 natural gas + $23,808 (estimate for ventilation = approx. 40%)

$155,567.00 per year / 67,601 sqft **= $2.30/sqft /year**

Value Analysis

Energy Usage

New Hanlon School: 112,800 sqft

Example:

EUI Target of 20 kBtu/sqft/year (Without Solar Energy Reduction)
20 kBtu/sqft/year ÷ 3.412 kBtu/kW x $0.21/kWh = $1.23/sqft/year
$1.23/sqft/year x 112,800 sqft x 20 years = **$2,774,880**

Comparing Existing School Cost: 67,601 sqft
Based on 3-yr Ave Energy Bills + AC and Ventilation Estimate
$2.30/sqft/year x 67,601 sqft x 20 years = **$3,111,340**

20-year Savings: $336,460
30-year Savings: $504,690

Value Analysis

Energy Usage

All Electric vs Fossil Fuels: Carbon Neutral and Size Renewable Energy

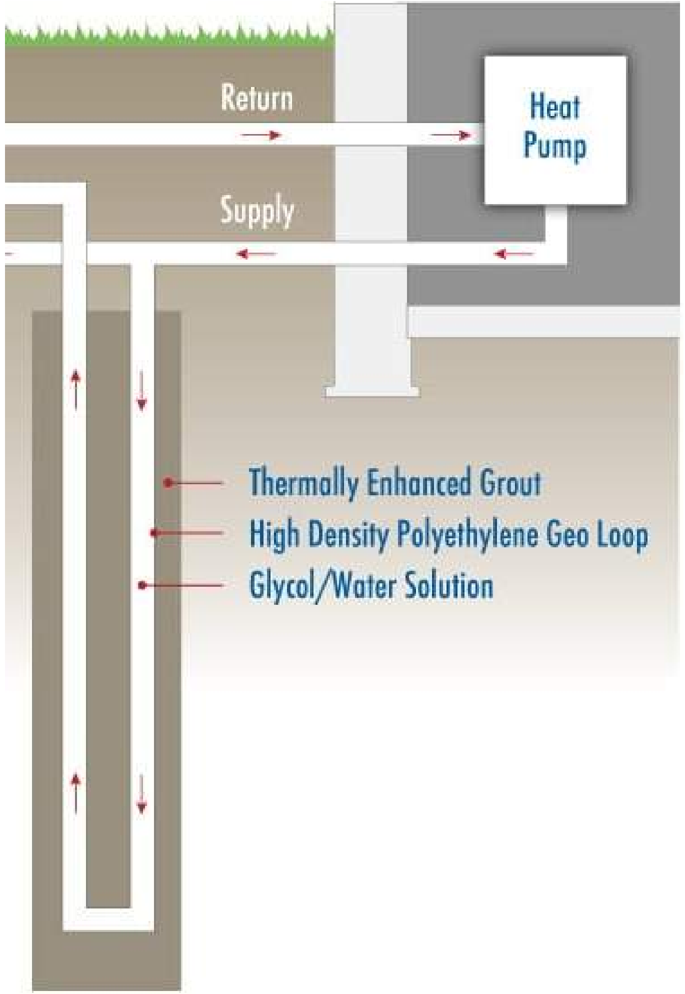
Example: Provide 9 MMBtu of heat annually for DHW

- Option #1: Buy 3 MMBtu of electricity x 3.0 (COP heat pump) = 9 MMBtu
- Option #2: Buy 10 MMBtu of natural gas x 0.9 (boiler efficiency) = 9 MMBtu
- Option #3: Buy 12 MMBtu of fuel oil x 0.75 (boiler efficiency) = 9 MMBtu

"Site" Net-zero Calculation:

- Option #1: Delivered energy = 3 MMBtu or electricity
  Required additional PV energy for NZE = 3 MMBtu
- Option #2: Delivered energy = 10 MMBtu of natural gas
  Required additional PV energy for NZE = 10 MMBtu

PV array size: Option #2 results in increased area and cost of PV system compared with Option #1 (additional 7 MMBtu annual solar production) for NBI verification of site net-zero.



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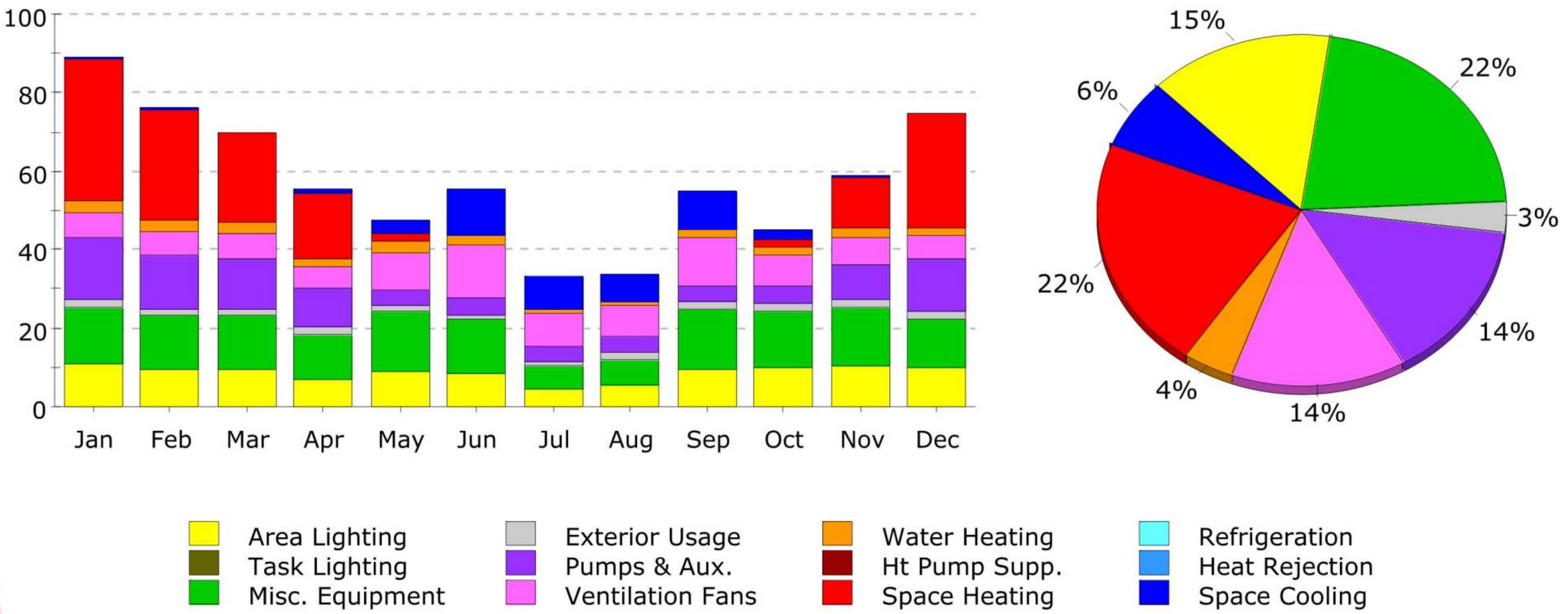
Schematic Design Example: All Electric Modeling Results



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Renewable Energy: Photovoltaic (PV) System Size

Value Analysis

Renewable Energy

Assume:

- Building Area = 112,800 SF
- EUI = 20 kBTU/SF/yr
- 15 W/sf (assumes microinverters on low slope roof for average high quality PV panel)
- 1,192 kWh annually per rated kW

  (NREL PVWatt Calculator Tool, subject to site solar potential evaluation)
- Ground coverage ratio: 0.9 (low slope roof angle)

kWh Consumption:	20,000 BTU/sf/yr x 112,800 sf ÷ 3412 BTU/kWh = 661,196 kWh/yr
System rating:	661,196 kWh/yr ÷ 1,192 kWh/kW/yr = 555 kW.
Size of Array:	(555 kW x 1,000) ÷ 15 W/sf ÷ (0.9 coverage ratio) = **41,111 sqft of PV area**

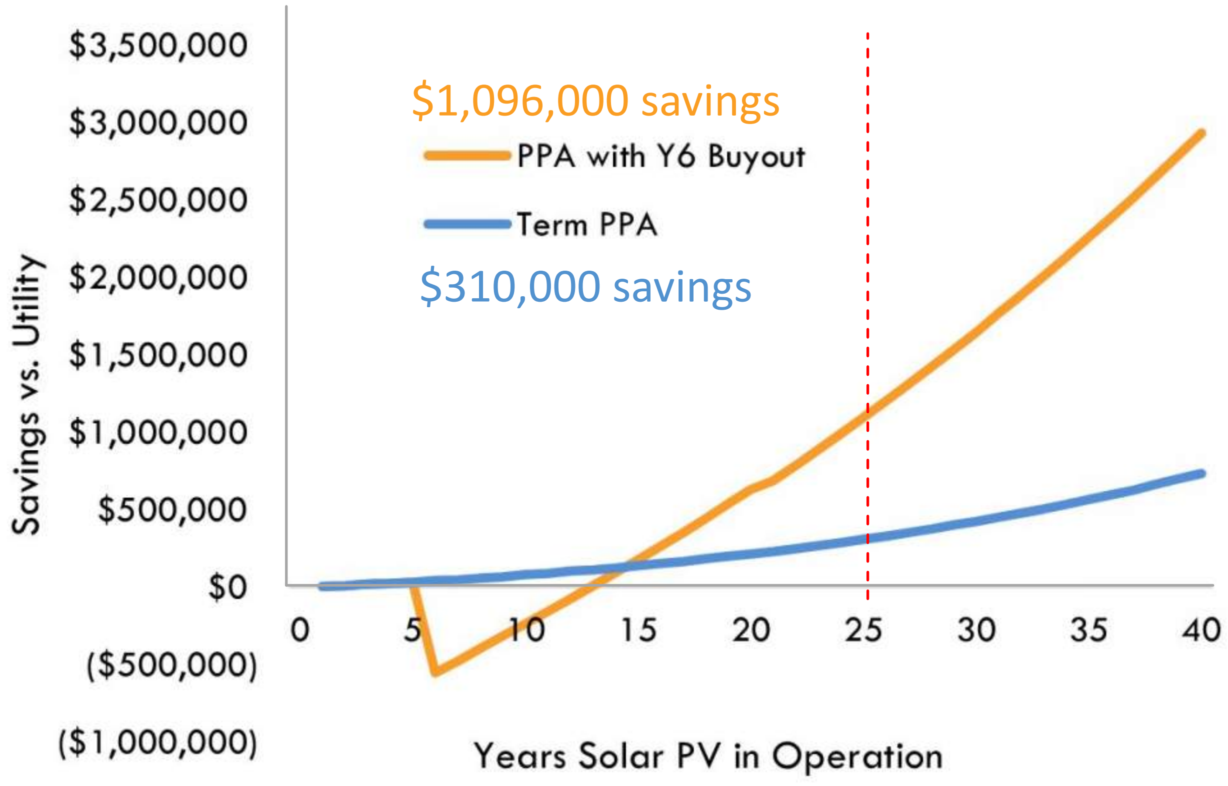
Example: Buy or Power Purchase Agreement

Value Analysis

Renewable Energy

<u>Example:</u>
1450 panels = 638kW
689,020 annual kWh
364.5 tons carbon offset

Cost of Ownership
$1,102,447 up-front
or
$661,468 buy-out in 6 yrs
or
25-year no cost PPA term



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Value Analysis

Renewable Energy

New School: 112,800 sqft

EUI Target of 20 (With Solar Energy Reduction)
20 kBtu ÷ 3.412 kBtu/kW x 112,800 sqft = 661,196 kWh per year

Solar Assumption (20% less area for net-metering):
41,111 sqft PV area x 15 W/sf x (0.9 coverage ratio) = 555,000W
1,344 kWh/kW x 555 kW system = 554,320 kWh

661,196 kWh per year – 544,320 kWh solar = 116,876 kWh/yr
116,876 kWh x $0.21/kWh = $24,544 per year x 20 years = **$490,880**

Comparing Existing School Cost: 67,601 sqft
Based on 3-yr Ave Energy Bills + AC and Ventilation Estimate
$2.30/sqft/year x 67,601 sqft x 20 years = **$3,111,340**

20-year Savings: $2,620,460
30-year Savings: $3,930,690


UMASS Amhearst

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ZNE Schools & PV System Considerations: System Performance

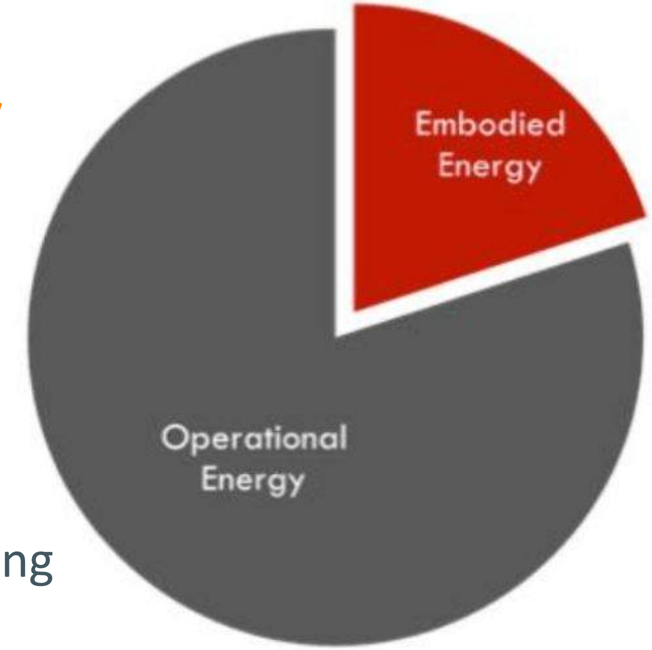
Value Analysis

Things to Consider and Explore with Zero-Net Energy Schools and Solar Arrays:

- **Schedule:** Consider when the system draws from the grid
  - Avoid peak hours; which is the worst time for fossil fuels power plants (GHG)
  - Avoid peak hours; which can impact utility rates due to unanticipated loads
- **Flexibility:** Explore ways to shed and/or shift loads during peak hours
- **Back-up:** Consider fossil-fuel fired generators, which have higher carbon emissions.
  - Explore battery storage to avoid fuel-fired generators
- **Emissions:** Consider vehicles (transportation) and other School-related carbon.
- **Unintended Consequences:** High Performance Schools require more embodied carbon; ie: thicker walls and energy-saving material / system measures.
- **Community Benefit:** Explore Town-wide arrays rather than 1 isolated building.

Addressing Embodied Carbon

Carbon Neutrality



Typical Building

High Performance Building

Source: Institute for Market Transformation (www.imt.org)

Consider for Embodied Carbon: On average 1 kWh of electricity produces 1 pound of carbon in the US. A Solar Array of 638kW produces 689,020 kWh; which saves 344.5 tons of carbon emissions each year; using this rule of thumb. Our previous example is source specific and saved 364.5 tons.

Carbon Neutrality

Embodied Carbon Challenge

Embodied carbon includes all the carbon emissions involved in the processing, transport, utilization, and end-of-life disposition of building materials. According to Architecture 2030, almost half of the carbon impact from new construction by 2020 will come from embodied carbon.
Source: ZeroEnergyProject.org

Nearly 11% of all carbon emissions worldwide come from embodied carbon in buildings.
Source: New Buildings Institute

AIA 2030 Challenge School Buildings seek, on average, 84.6 lbs per sqft of embodied carbon. (30% reduction)
Source: www.buildinggreen.com:
"Structural Engineers Study Embodied Carbon of 600 Buildings" (Thornton Thomasetti)

Embodied Carbon Challenge

Carbon Neutrality

Buildings generate nearly 40% of annual global greenhouse gas emissions, and the world's building stock is expected to double by 2060. That's equivalent to building a new New York City every month!

In order to shrink the carbon footprint of buildings, embodied carbon in new buildings must be reduced. Embodied carbon, or the carbon emitted from the manufacturing of building materials and construction, will account for nearly 50% of carbon emissions from new construction over the next 3 decades. In any given building, concrete can contribute a minimum of 50% of the embodied carbon footprint.

Source: www.CarbonCure.com

Carbon Neutrality

Embodied Carbon in Materials

High Impact Materials for Carbon Reduction:

- Concrete
- Steel / Aluminum
- Wood (old growth)
- Insulation
- Carpet
- Gypsum Board

Low Carbon / Carbon Sequestering Materials:

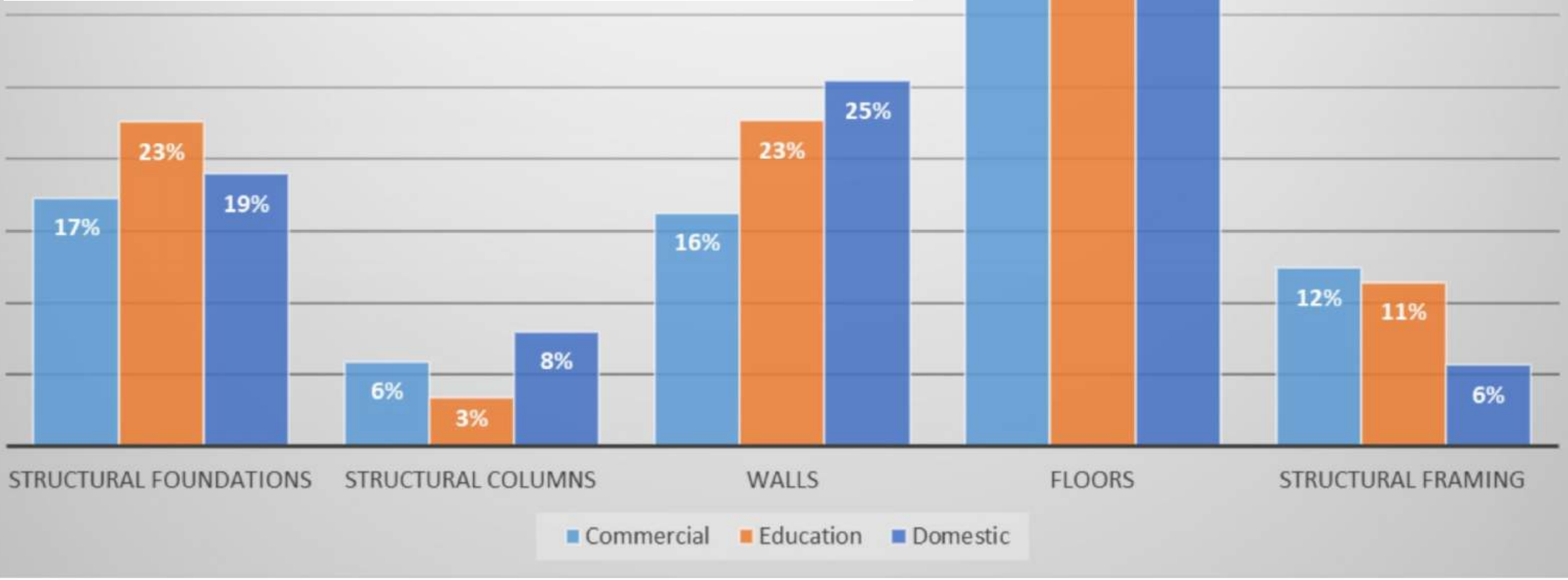
- Bamboo
- Hempcrete
- Sheep's Wool
- Straw Bale
- Wood (engineered, fast-growth)

Source:
Carbon-Smart Materials Palette, Architecture 2030, Embodied Carbon Network

Where is the Embodied Carbon?

Typical Building = 590 kg/m2
Typical LEED Building = 510kg/m2
AIA 2030 Challenge seeks 30% reduction = 413 kg/m2
….or 84.6 lbs/sqft ….or 0.042 tons/sqft

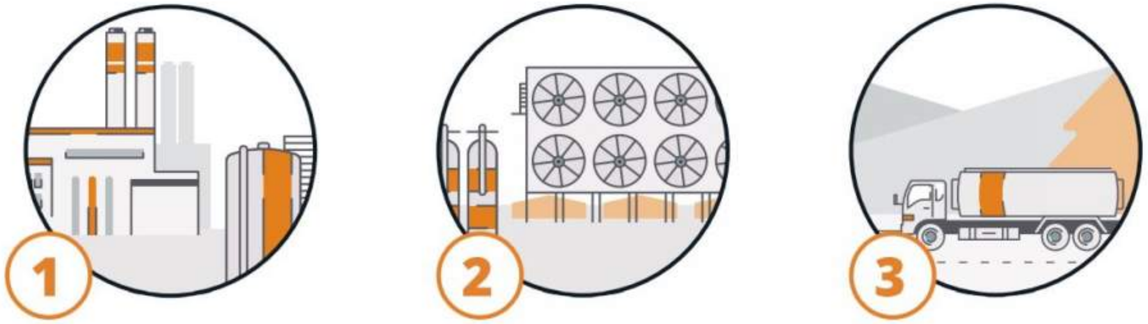
Note: 1kg/m2 = 0.2048 lbs/sqft



Source: www.buildinggreen.com: "Structural Engineers Study Embodied Carbon of 600 Buildings" (Thornton Thomasetti)

Reducing Concrete’s Carbon Footprint

Carbon Neutrality



1. CarbonCure’s technology is retrofitted to an existing concrete plant.
2. Carbon dioxide (CO_2) gas is primarily sourced as a by-product from industrial processes.
3. The purified CO_2 gas is delivered in pressurized vessels by commercial gas suppliers.

4. CarbonCure’s proprietary delivery system precisely injects the CO_2 into the concrete mix.
5. Batching is controlled by a simple interface that’s integrated with the batch computer.
6. Once injected, CO_2 reacts with cement to form a nano-sized mineral that becomes permanently embedded in concrete.

Source: www.CarbonCure.com

Reducing Concrete's Carbon Footprint

Carbon Neutrality

CarbonCure for Precast

CarbonCure for Masonry

Source: www.CarbonCure.com

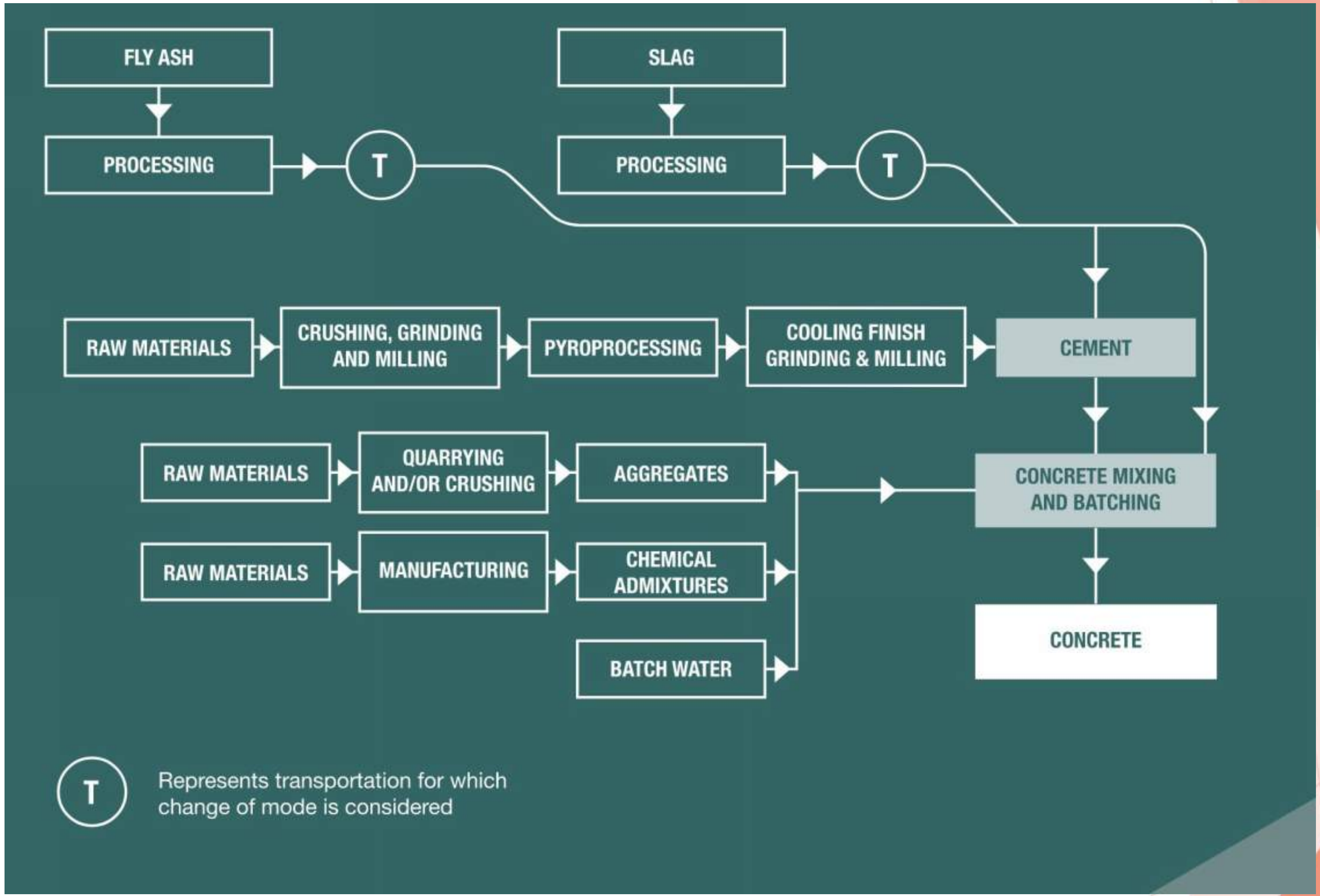
CarbonCure for Ready Mix

Reducing Concrete's Carbon Footprint

Carbon Neutrality

ECOPact
The Green Concrete

CO_2 reduction	
ECOPact	30-50%
ECOPact PRIME	50-70%
ECOPact MAX	>70%



Source: www.ECOpact.com

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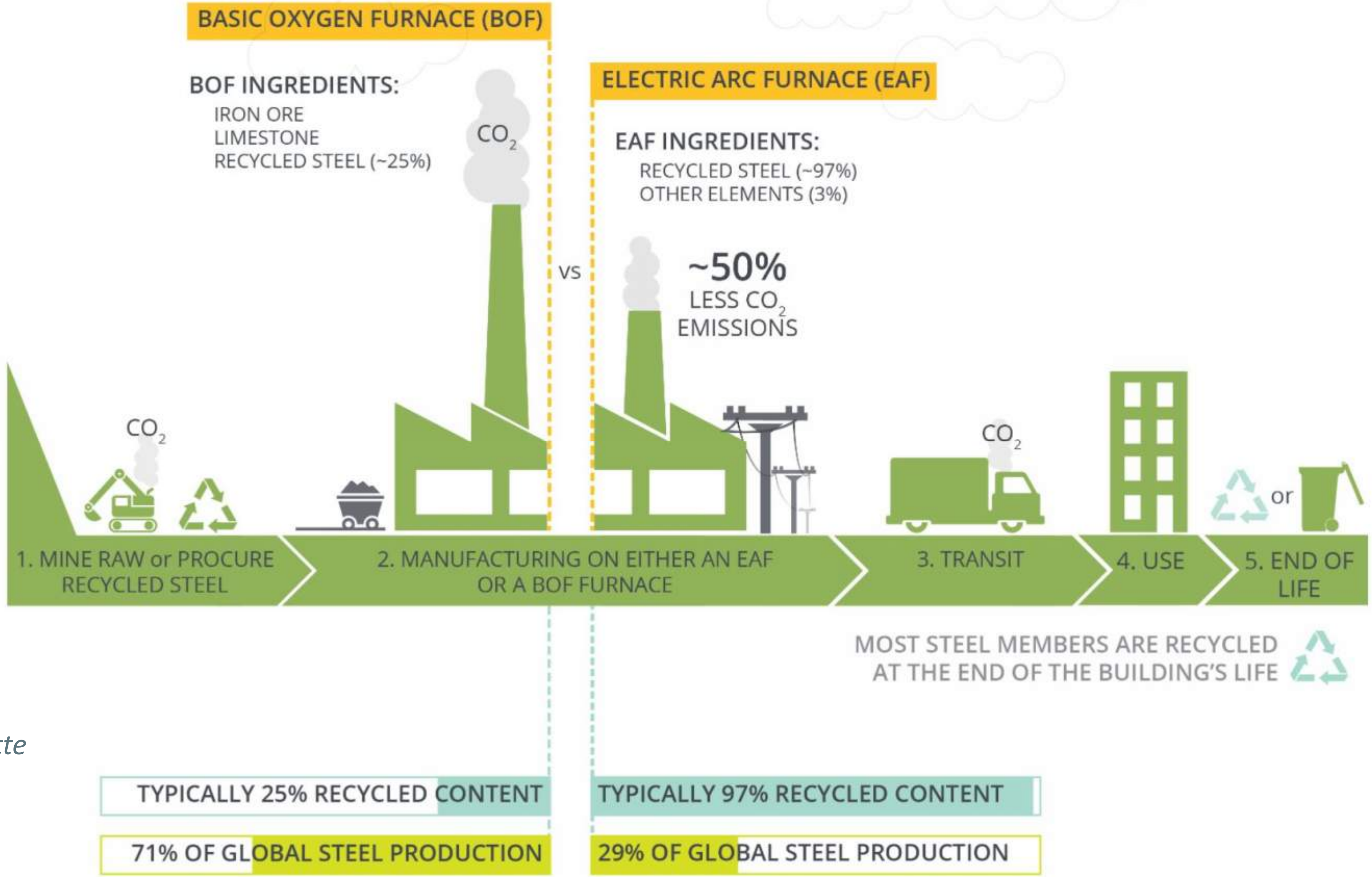
Reducing Steel's Carbon Footprint

Carbon Neutrality

Using steel from electric arc furnaces (EAF) is the best way to reduce embodied emissions in steel, because EAFs use high levels of recycled material and can be powered by renewable energy sources.

Source: Carbon-Smart Materials Palette
Architecture 2030
Embodied Carbon Network



Concept Rendering Pentucket High School

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Total Power & Carbon Offset

Value Analysis

Why this is critical to students who want to save the World?

A 112,800 sqft AIA 2030 Challenge-compliant School takes over 14 years to off-set it's embodied Carbon. (School building only)

School Building Systems:

- 112,800 sqft School
- 15 W/sf (assumes microinverters on low slope roof for average high quality PV panel)
- 1,192 kWh/kW/yr (NREL PVWatt Calculator Tool, subject to site solar potential evaluation)

EUI 20 to kWh Consumption: 20,000 BTU/sf/yr x 112,800 sf ÷ 3412 BTU/kWh = 661,196 kWh/yr

System rating: 661,196 kWh/yr ÷ 1,192 kWh/kW/yr = 555 kW.

Size of Array: (555 kW x 1,000) ÷ 15 W/sf ÷ (0.9 coverage ratio) = **41,111 sqft of PV area**

Consider for Embodied Carbon: (*On average 1 kWh of electricity produces 1 pound of carbon in the US*)

Assuming AIA 2030 Challenge's 30% Embodied Carbon Reduction

Embedded carbon: 84.6 lbs/sqft x 112,800 sqft = 9,542,880 lbs of carbon to offset.

Time to offset: 9,542,880 kWh) ÷ 661,196 kWh/yr = **14.5 years**

(school only; this does not account for transportation, fuel-fired generators, etc…)

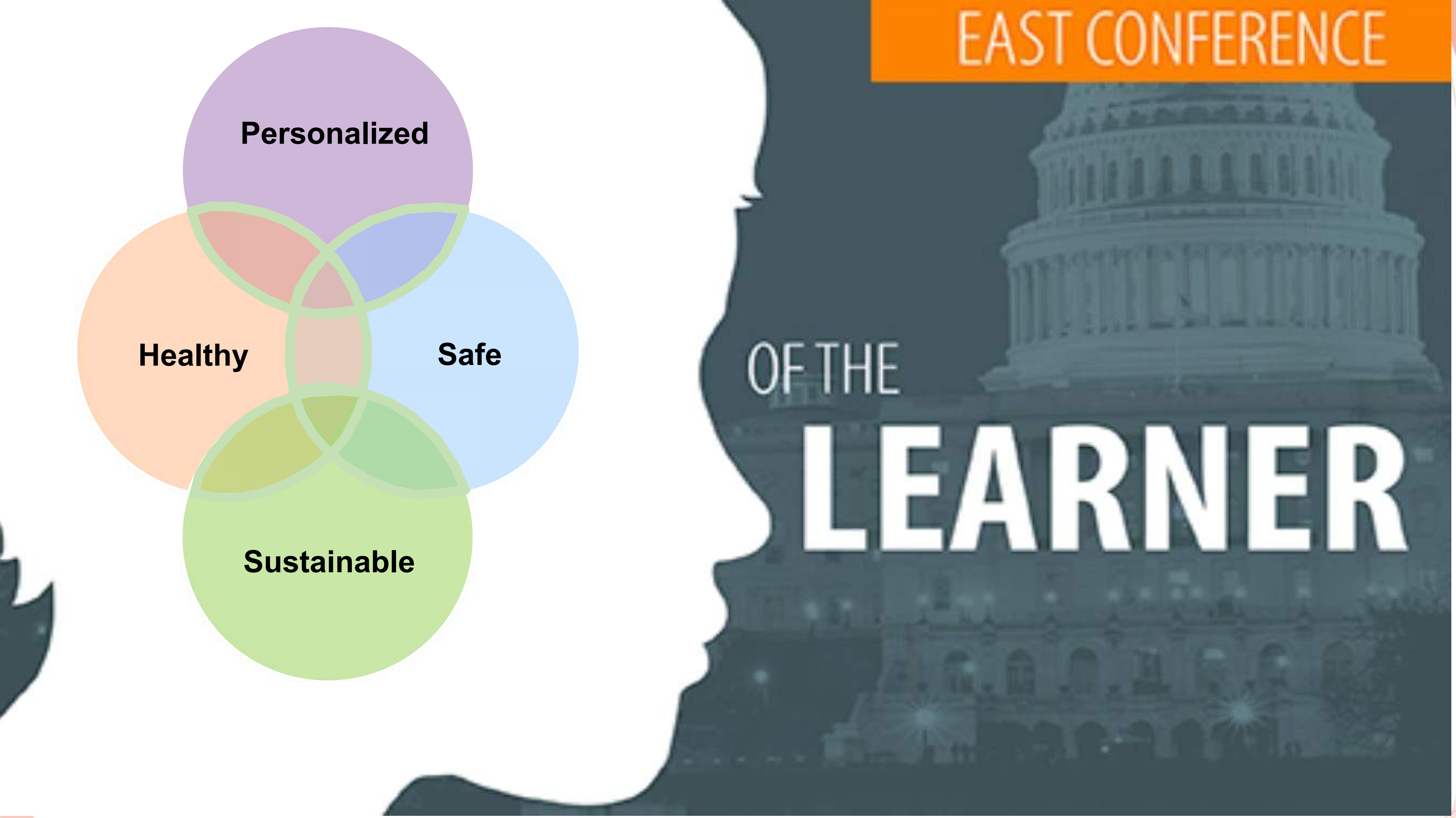

Image Credit: A4LE Conference Website

Student-influenced Learning Environment

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ASSOCIATION FOR LEARNING ENVIRONMENTS
Enhancing the Educational Experience

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