BUILDING INNOVATION
Conference

Transforming to Zero Carbon: Building Science Workforce Development Designed for Today's Viewers

Holly Jamesen Carr
Building Technologies Office
U.S. Department of Energy

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Agenda

1. Where did it start?
2. What it is?
3. How can I get it?

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Who's in the room??

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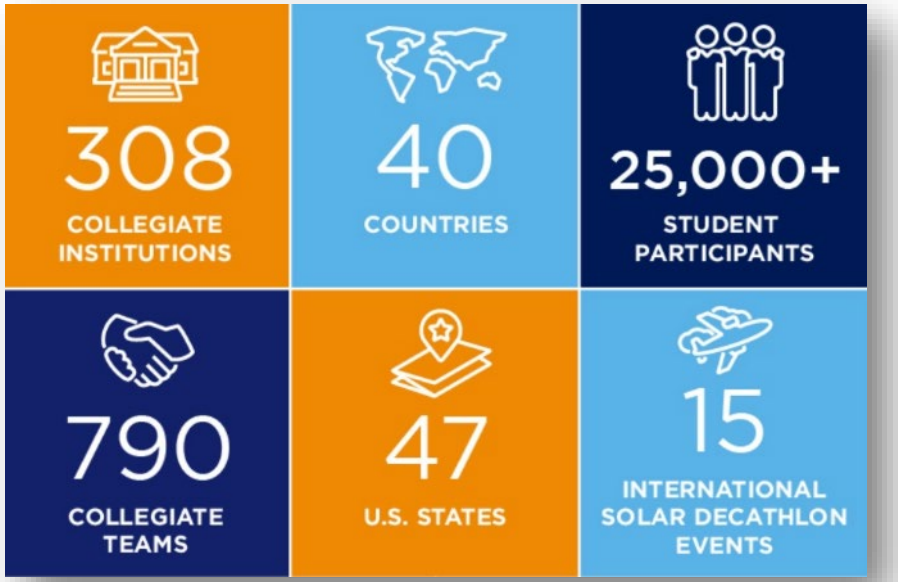
Building Science Education Series

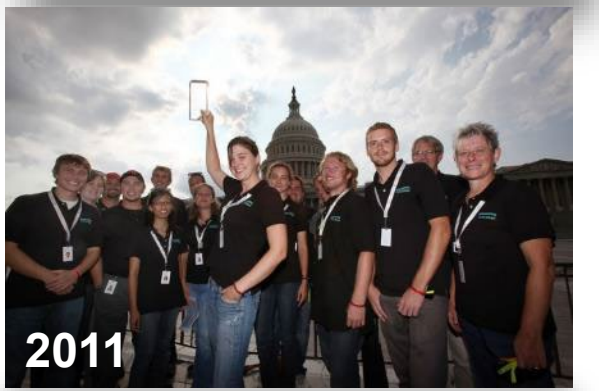
Where did is start?

U.S. DEPARTMENT OF ENERGY

Solar Decathlon

The Solar Decathlon prepares innovators to design and construct high-performance, low-carbon buildings through collegiate competitions, professional continuing education, and high school programs.





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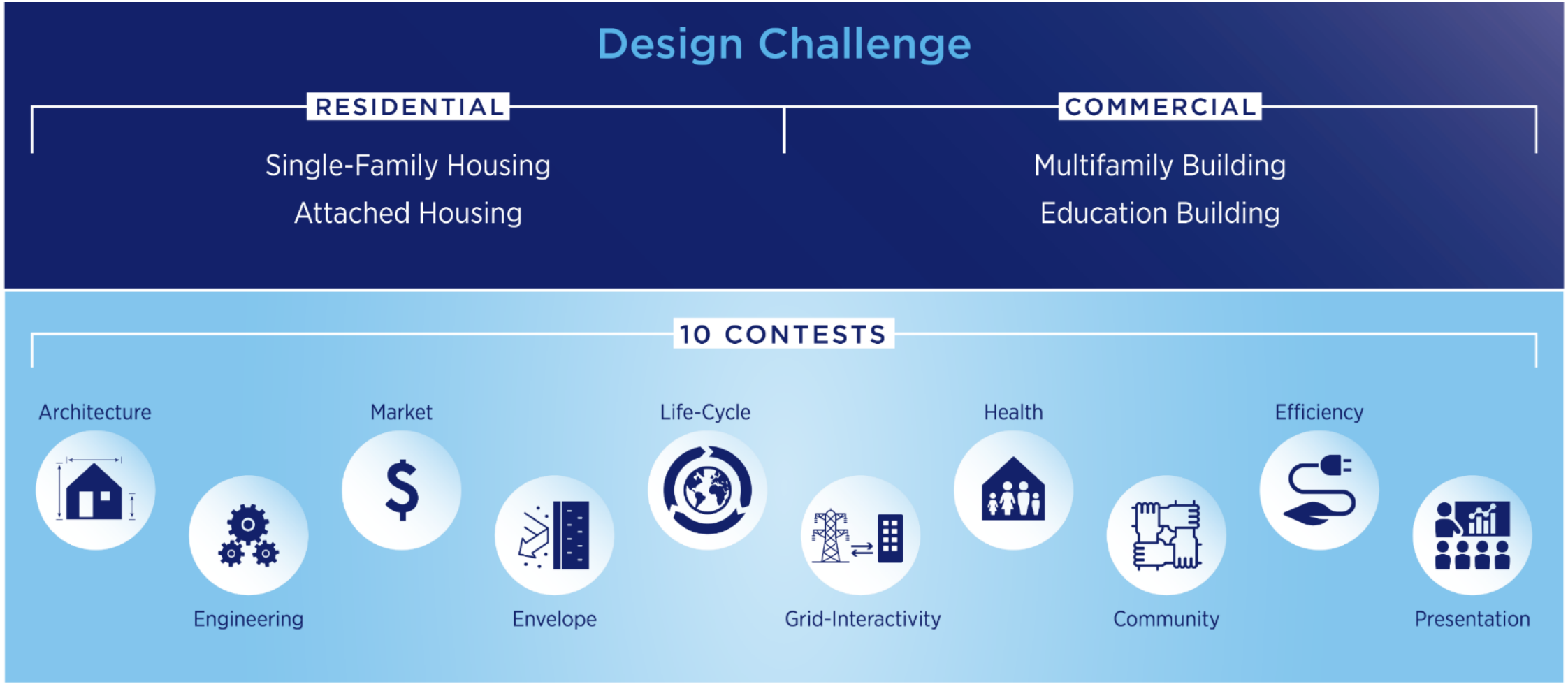
Solar Decathlon

Solar Decathlon Design Challenge Structure



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Solar Decathlon

Typical Design Challenge Student Experience

Project Design
(In classroom)

October-January

Sem-final Event
(Virtual)
February

Competition Event
(NREL)

April

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Solar Decathlon

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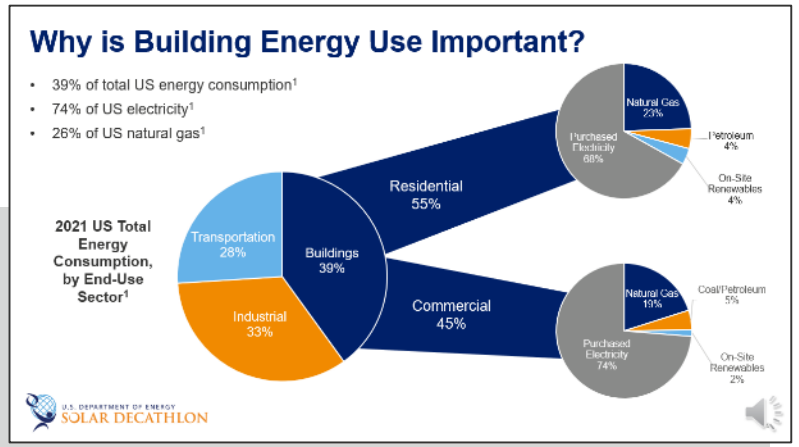
Building Science Education Series

What is it?

Approach

- PowerPoint slides with voiceover
  - Compatible with visual and auditory learners
- Short episodes, dense information
  - Digestible, to-the-point, easy to go back and rewatch
  - Most episodes ~10 minutes long
- Layered Content
  - Start with the basics, then build on them
- Scripted but conversational tone
- Peer review process



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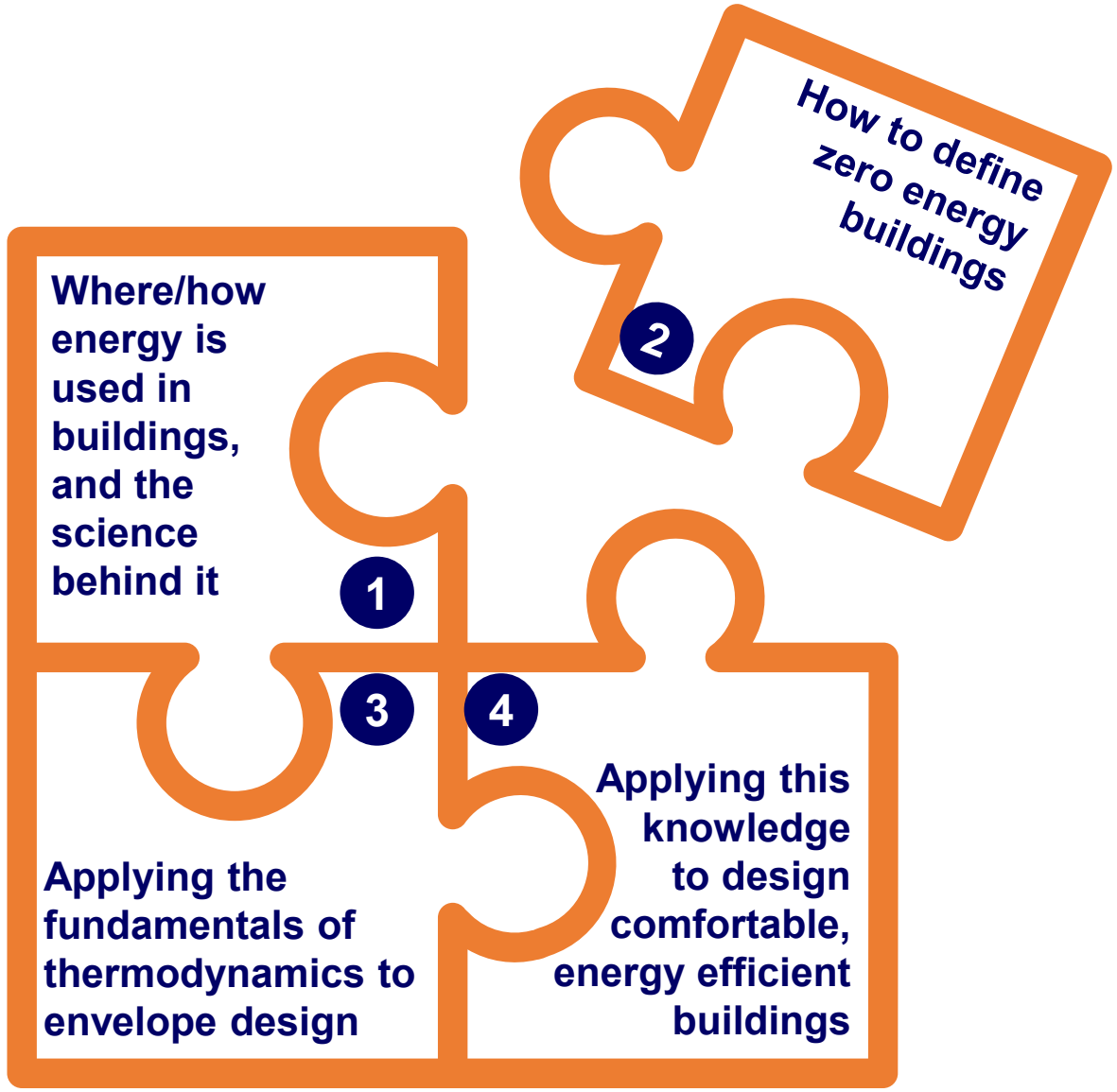
Learning Objectives

Connecting the pieces between what they learn in school, and how it is applied in real world building design and construction



Topics of Building Science Education

- Buildings and Energy
- 6 episodes

Module 1

- Zero Energy Buildings
- 7 episodes

Module 2

- Building Envelopes
- 16 episodes

Module 3

- HVAC Systems
- 10 episodes

Module 4

- Lighting
- 4 episodes

Module 5

- Plug Loads
- 2 episodes

Module 6

- Embodied Environmental Impact
- 3 webinars

Module 7

- Renewable Energy
- 3 episodes

Module 8

- Additional Optional Content
- 9 episodes

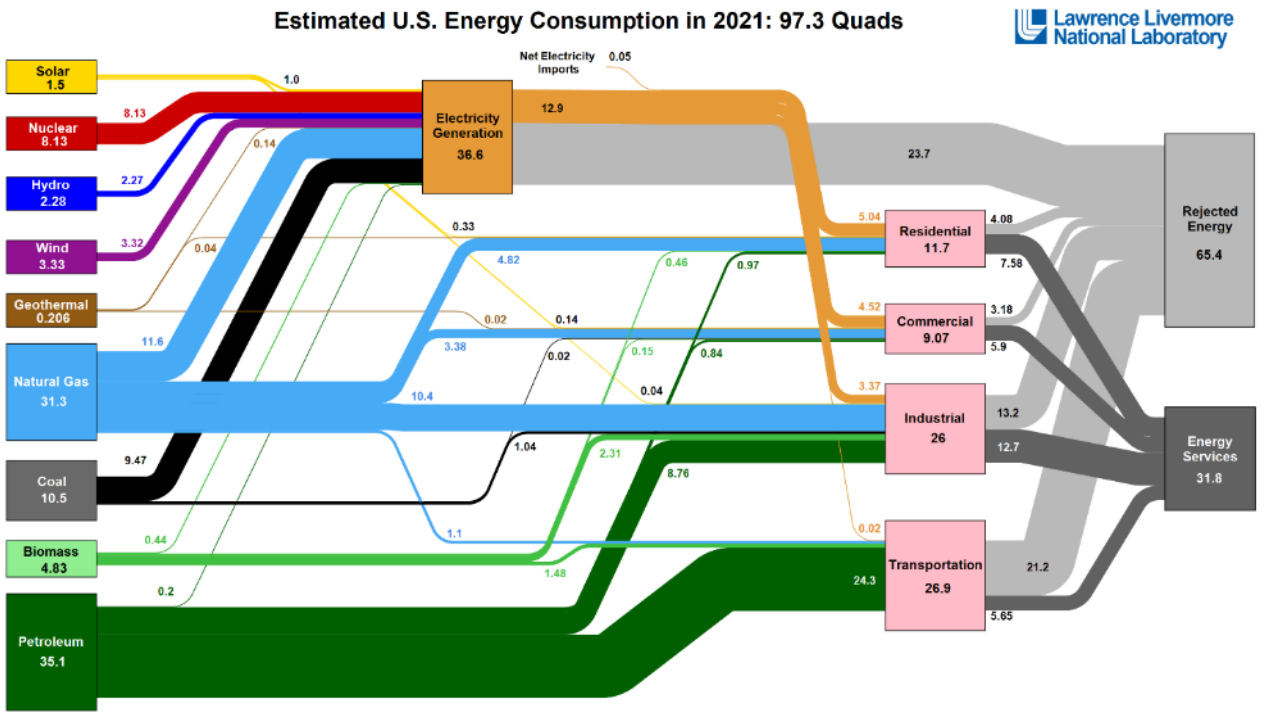
Module 9

- Student-Led Construction and Fundraising
- 4 episodes

Module 10

Module 1: Buildings and Energy

- The Impact of Buildings
- Measuring Power and Energy
- Energy Flows in the United States
- Buildings and the Electrical Grid
- Reading an Electricity Bill
- Building and Energy Codes



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Module 2: Zero Energy Buildings

- Defining Zero Energy
- Site Energy vs. Source Energy
- The Cost of Zero Energy Buildings
- Setting Goals
- Historically Informed Architecture
- Passive Design Strategies (Part 1&2)

Module 3: Building Envelopes

- First Law of Thermodynamics
- Fourier's Law (Part 1&2)
- R-Values and Insulation
- Area Calculations
- Temperature Difference and Weather Files
- Calculating R-Value for a Wall (Part 1,2,&3)
- Insulation Materials
- Insulation Applications
- Intro to Windows and Fenestration
- Advanced Window Technologies
- Infiltration
- Building Envelope Control Layers
- Commissioning

Module 4: HVAC Systems

- Understanding Thermal Efficiency
- COP, SEER, and EERs
- Heating Systems
- Heat Pumps
- Sample Load Calculations
- Ventilation Air for Buildings
- The Science of Water Heating
- Water Heating Technologies
- Controls
- Thermal Energy Storage

Module 5: Lighting

History of Lighting

Lighting Technologies

Terms and Definitions

Practical Applications

Module 6: Plug Loads

What are Plug Loads?

Plug Load Strategies

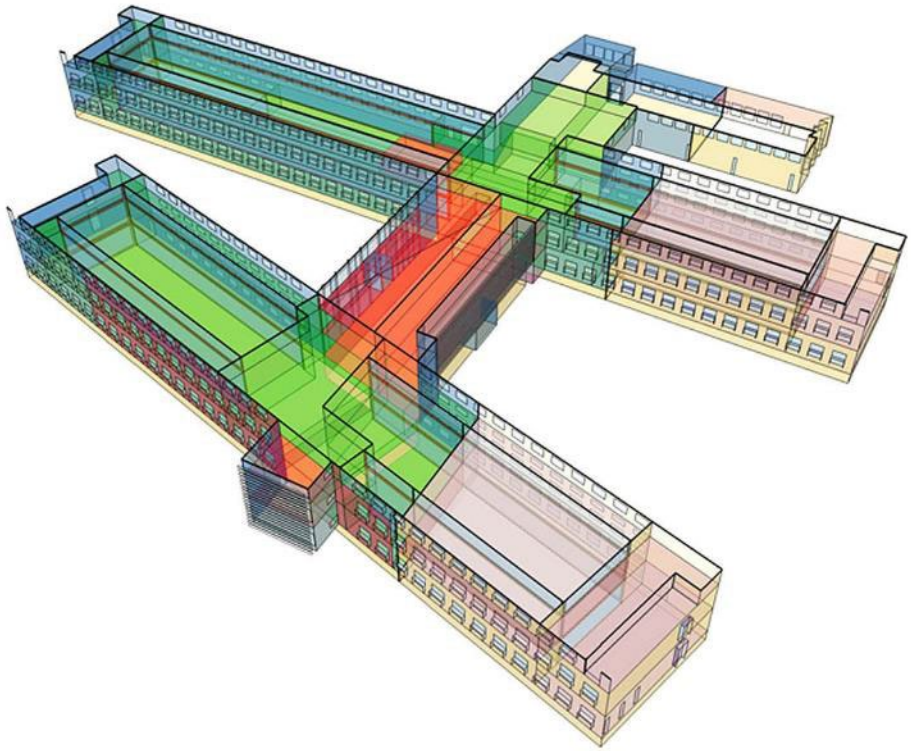
Module 7: Embodied Environmental Impacts

Emissions and the Built Environment

Building Lifecycle

Lifecycle Assessments

Buildings and the Grid

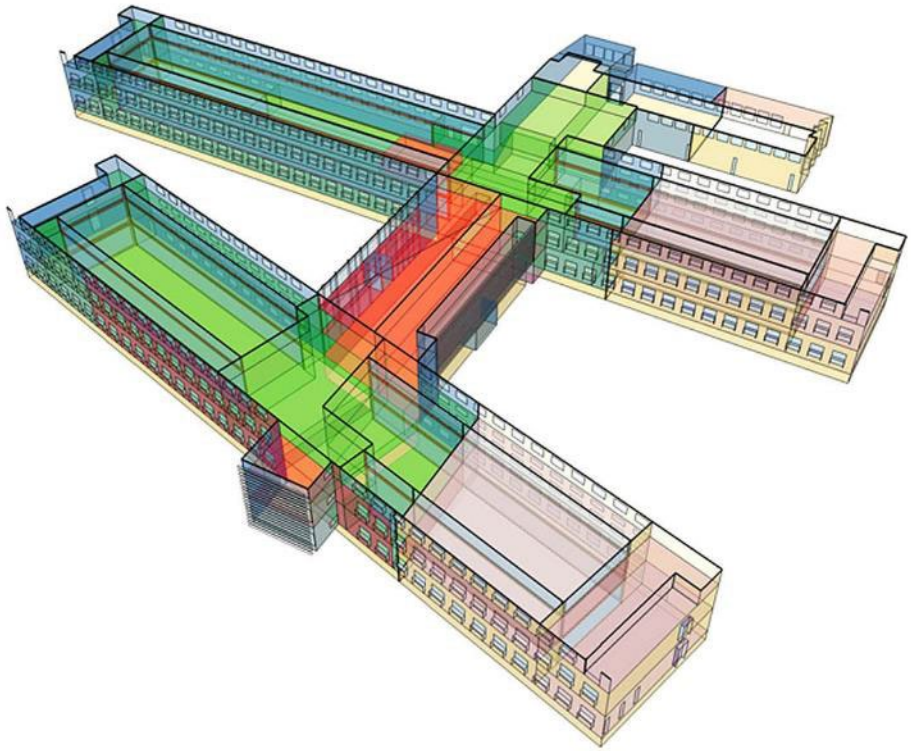


Module 8: Renewable Energy

- Solar 101
- NREL's PV Watts Calculator
- Other Renewable Energy Sources
- Current State of Buildings and the Grid
- The Future of Buildings and the Grid
- Buildings Leading the Change

Module 9: Optional Content

- Discovery Elementary
- What is Good Design?
- Designing for Zero Energy: Using Modeling to Make Decisions
- REM/Rate
- Creating the Winning Team
- LED Technology Development

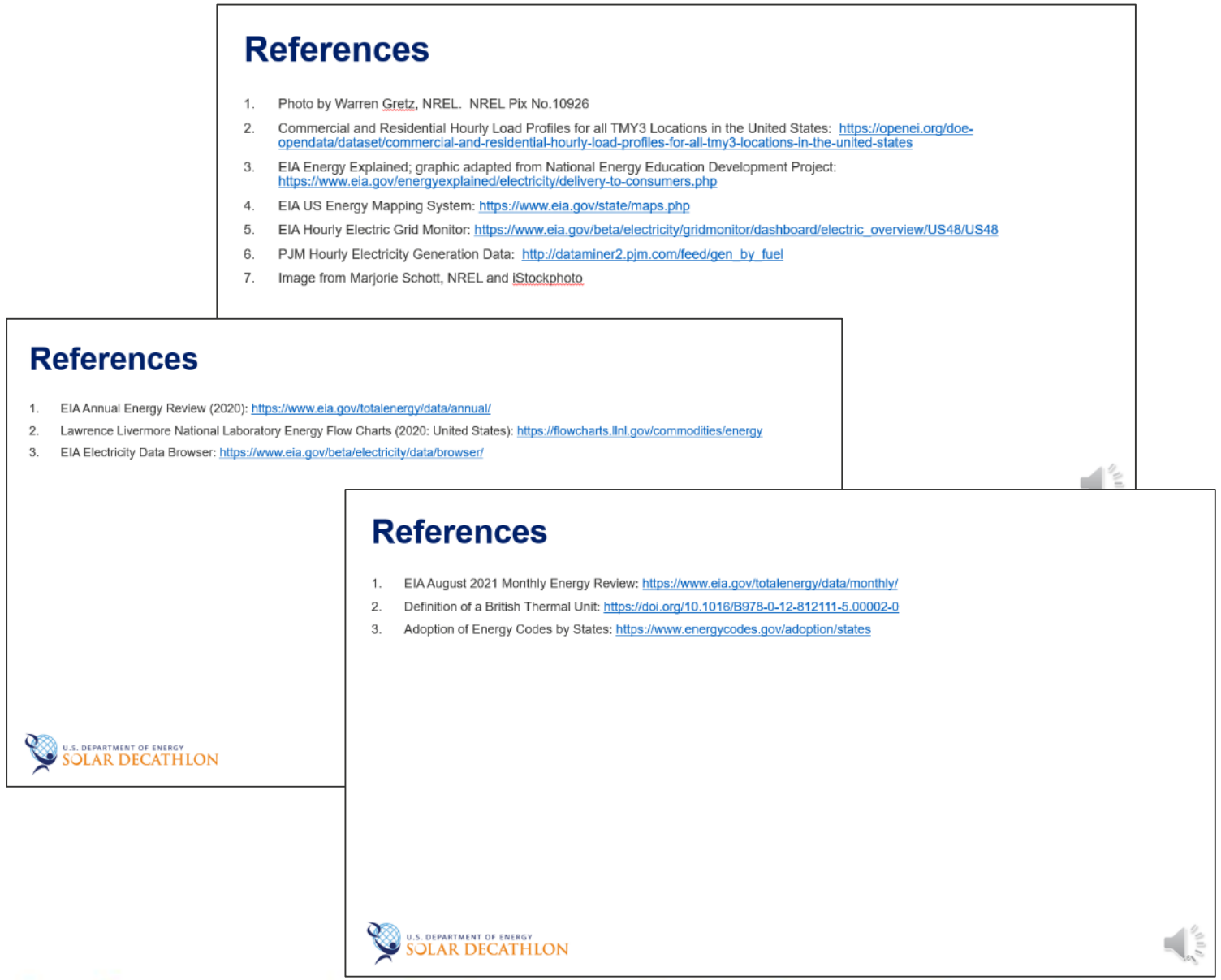


Resources

- All stats, graphics, and images are cited

Each episodes includes a *References* slide

- Sources used for each episode
- Additional resources on each topic for further reading



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Solar Decathlon

Solar Decathlon Student Version

- Hosted on Canvas
  - Students receive unique Canvas link when they register for Solar Decathlon
- Students must pass the quiz at the end of each episode to earn their certificate of completion

As of August 2023:

- 2,427 Students visited the course
- 178,755 Assignments completed
- 1,636 Certificates of completion awarded

Differentiating Collegiate Programs

ZERO ENERGY DESIGN DESIGNATION

U.S. DEPARTMENT OF ENERGY

BUILDING SCIENCE EDUCATION + ZERO ENERGY DESIGN PRACTICUM

Recognizes post-secondary academic programs that prepare students for 21st century building careers.

Available for collegiate programs of study:

- Stand-alone degrees
- Specialty tracks
- Certificates

Three-year designation, renewable

Learn more:

- https://www.energy.gov/eere/buildings/zero-energy-design-designation
- Email ZEDD@ee.doe.gov

Recognized Programs of Study

ZERO ENERGY DESIGN DESIGNATION

Ball State University (Muncie, Indiana)
- Bachelor of Architecture
- Master of Architecture

The Catholic University of America (Washington, D.C.)
- Master of Science in Net Zero Design/Master of Architecture Joint Degree

Illinois Institute of Technology (Chicago, Illinois)
- Master of Engineering in Architectural Engineering
- Master High Performance Buildings

University of Cincinnati (Cincinnati, Ohio)
- Net Zero Energy Design Track in the Architectural Engineering Program

Hawkeye Community College (Waterloo, Iowa)
- Sustainable Construction and Design Program

Vermont Technical College (Randolph Center, Vermont)
- Bachelor of Science in Architectural Engineering Technology

University of Missouri (Columbia, Missouri)
- Bachelor of Science in Architectural Studies

University of Colorado, Boulder (Boulder, Colorado)
- Bachelor of Science in Architectural Engineering

Howard University (Washington, D.C.)
- Master of Architecture with an Equitable High-Performance Energy Design Concentration

Western Washington University (Bellingham, Washington)
- Bachelor of Science in Energy, Science, and Technology Net Zero Energy Design Track

Myongji University (Seoul, Korea)
- Zero Energy Design Certificate for Bachelor of Architecture, College of Architecture
- Zero Energy Design Certificate for Bachelor of Traditional Architecture
- Zero Energy Design Certificate for Bachelor of Space Design

Appalachian State University (Boone, North Carolina)
- Master of Science in Technology with a Sustainable Building Design and Construction Concentration
- Bachelor of Science in Building Sciences with a Sustainable Buildings Concentration

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How can I get it?

Why SD Professionals training needed?

Biden Administration goals:

- Reducing U.S. greenhouse gas emissions 50-52% below 2005 levels in 2030.
- Reaching 100% carbon pollution-free electricity by 2035.
- Achieving a net-zero emissions economy by 2050.

Petinelli Headquarters | Brazil | LEED Platinum | LEED Zero Energy
Photo: © Petinelli

Tax Credits: 25C, 25D, 45L

Equipment Type	Credit Amount (25C, 25D)
Heating, Cooling, and Water Heating	
Heat pumps	30% of cost, up to $2,000
Heat pump water heaters	
Biomass stoves	
Geothermal heat pumps	30% of cost
Solar (water heating)	
Efficient air conditioners*	30% of cost, up to $600
Efficient heating equipment*	
Efficient water heating equipment*	
Other Energy Efficiency Upgrades	
Electric panel or circuit upgrades for new electric equipment*	30% of cost, up to $600
Windows, including skylights*	
Insulation materials*	30% of cost
Exterior doors*	30% of cost, up to $500 ($250 each)
Home energy audits*	30% of cost, up to $150

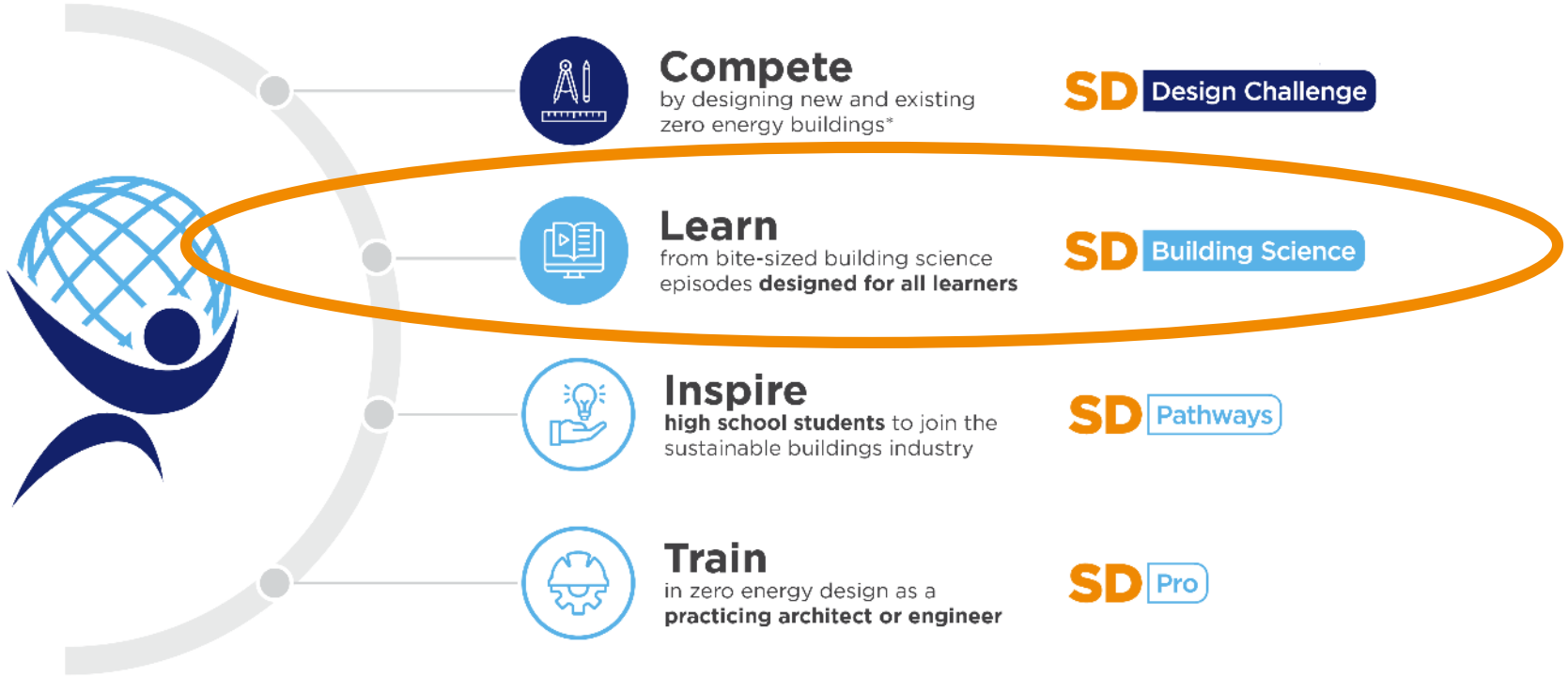
*Subject to a cap of $1,200/year

Building Type	ENERGY STAR Tier	Zero Energy Ready Tier
Single Family Manufactured	$2,500	$5,000
Multifamily (per dwelling)	$500	$1,000
Multifamily (per dwelling, prevailing wages)	$2,500	$5,000

Our Goal:

Educate students and working professionals on building science principles that are paramount to the successful design of high-performance, energy efficient buildings.

Expanding beyond Solar Decathlon



* Competition open for college students.

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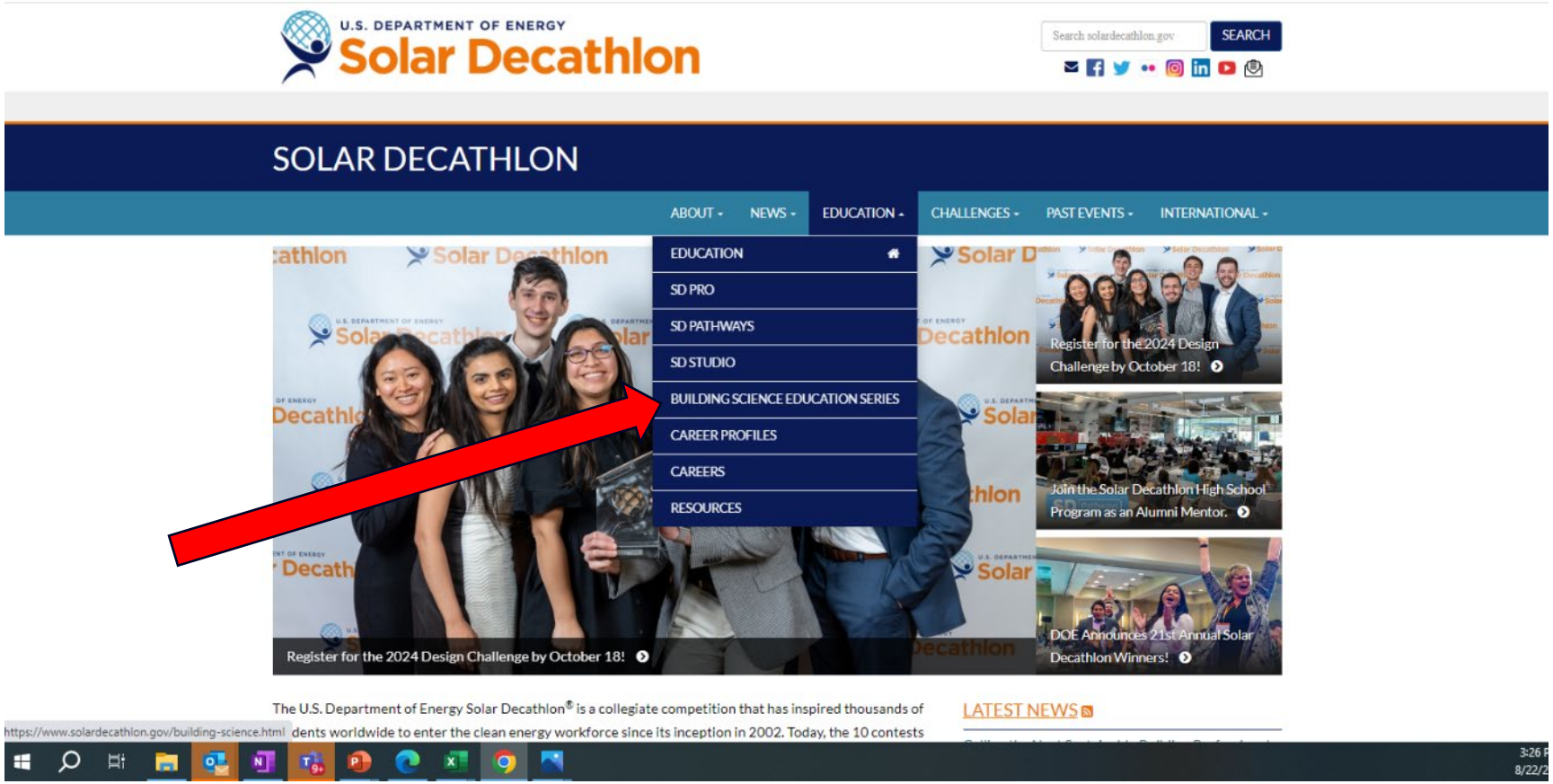
Solar Decathlon

Building Science Education Series – Available to all!



Also available through PNNL Building Science Education Solution Center (DOE)

ENERGY.GOV
Office of
ENERGY EFFICIENCY & RENEWABLE ENERGY

Pacific Northwest
NATIONAL LABORATORY

www.solardecathlon.gov/building-science.html

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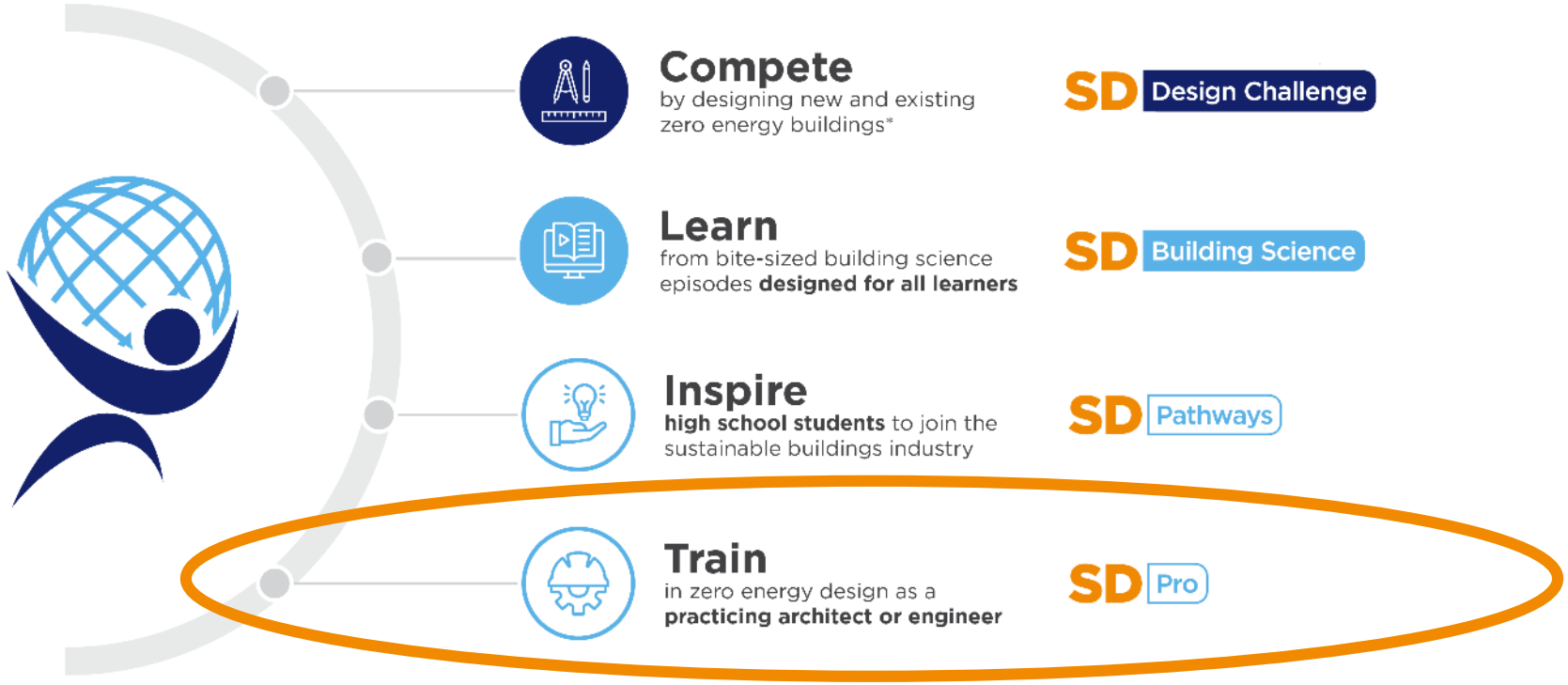
Solar Decathlon

Building Science Education Series – Available for CEUs

- Organizations hosting Building Science Education for their members:
  - USGBC
  - ASHRAE
  - EEBA
  - AIA

Expanding beyond Solar Decathlon



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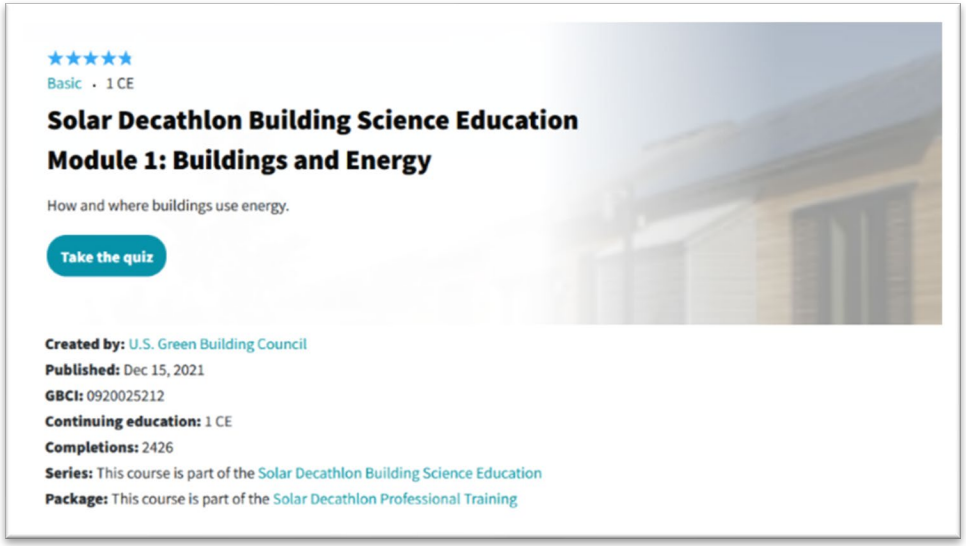
Solar Decathlon

SD Professionals Training Program (SD Pro)

Entegrity Headquarters | Arkansas | LEED Platinum | LEED Zero Energy
Photo: © Entegrity



Building Science Education Series

Live weekly cohort sessions

Net zero project design activity

Building Science Education Series

Solar Decathlon Professional Training

Module 1: Buildings and Energy

75 minutes • Basic

1 CE hours

Solar Decathlon Professional Training

Module 2: Zero Energy Buildings

Basic

.5 CE hours

Solar Decathlon Professional Training

Module 3: Building Envelopes, Part...

Intermediate

1.5 CE hours

Solar Decathlon Professional Training

Module 3: Building Envelopes, Part...

Intermediate

1 CE hours

Solar Decathlon Professional Training

Module 4: HVAC Systems, Part 1

Intermediate

1 CE hours

Solar Decathlon Professional Training

Module 4: HVAC Systems, Part 2

Intermediate

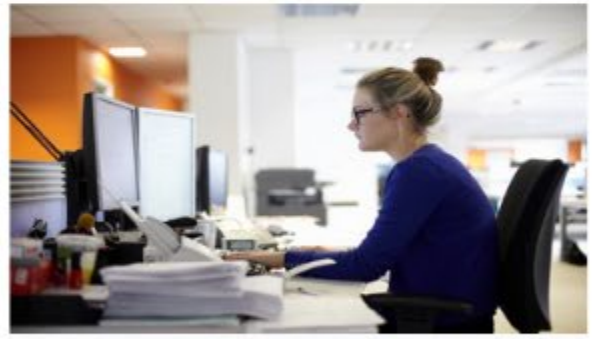
1 CE hours

Solar Decathlon Professional Training

Module 5: Lighting

Intermediate

1 CE hours



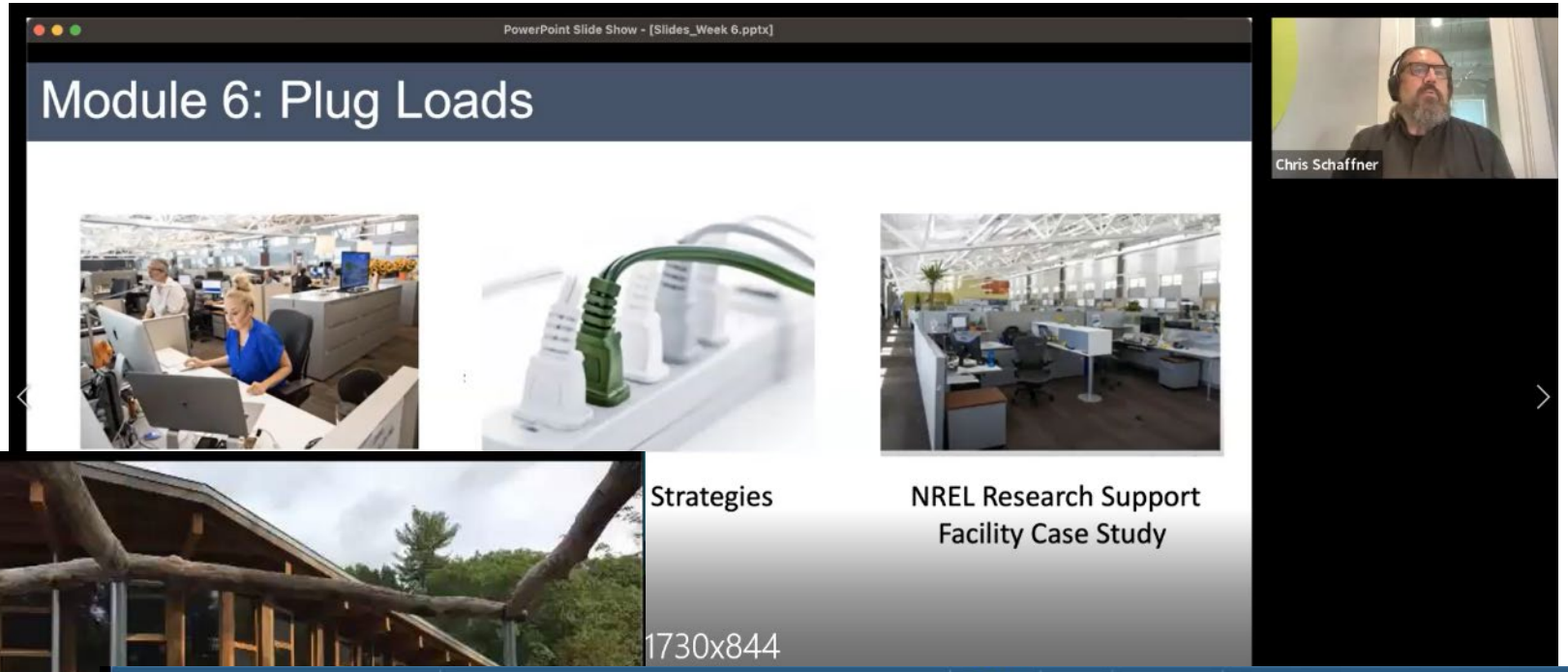
Solar Decathlon Professional Training

Module 6: Plug Loads

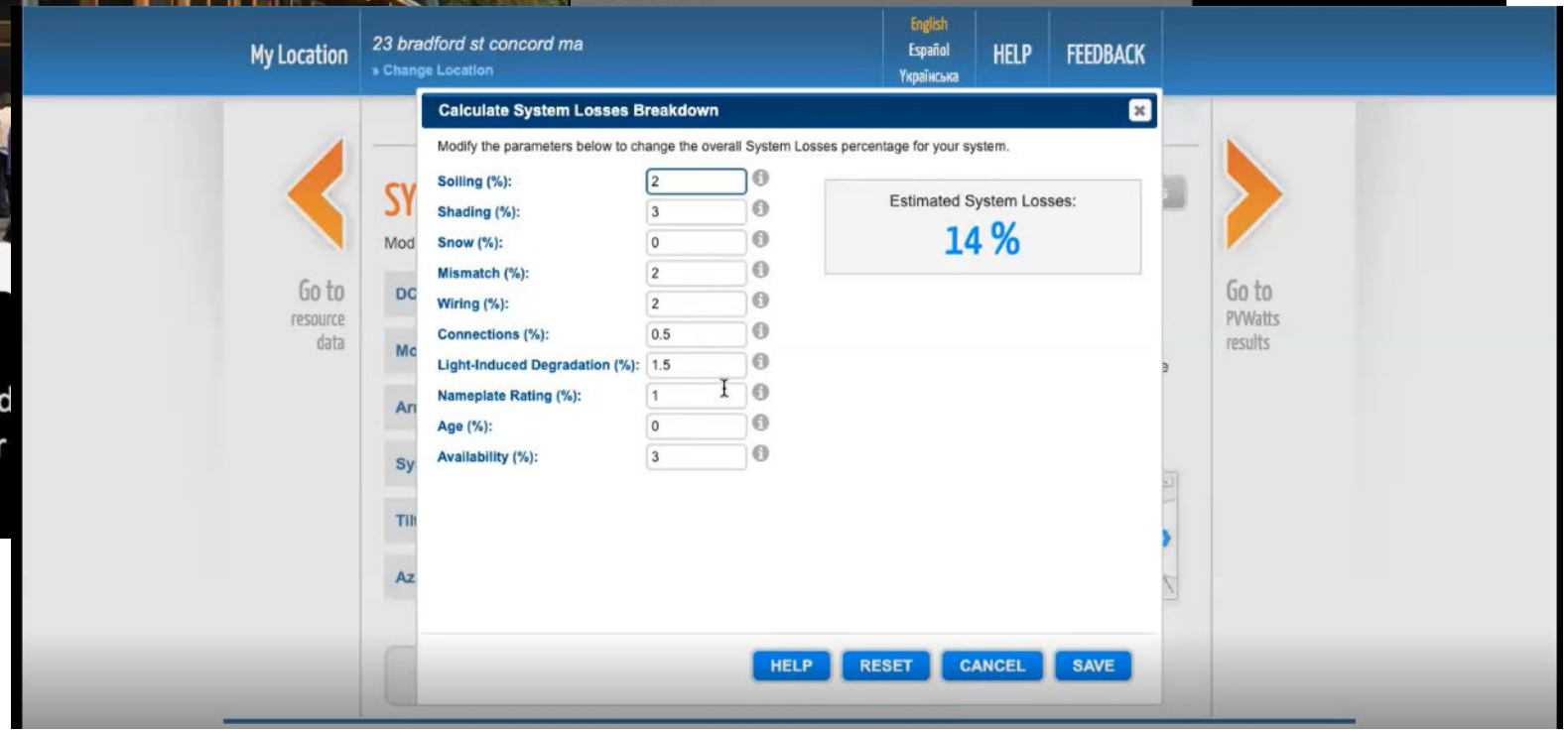
Intermediate

.5 CE hours

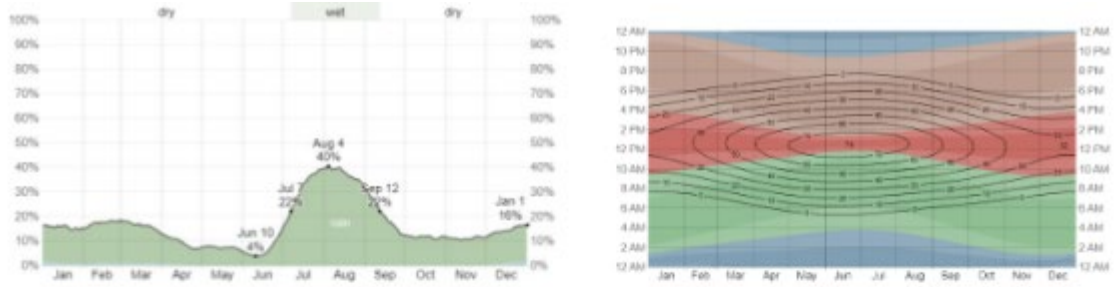
Live Cohort


PowerPoint Slide Show - [Slides_Week 6.pptx]
Module 6: Plug Loads
Chris Schaffner
Strategies
NREL Research Support Facility Case Study
1730x844


Walden Pond Visitors Center
•6000 GSF Build
•100kW + Solar


My Location
23 bradford st concord ma
» Change Location
English
Español
Українська
HELP
FEEDBACK
Calculate System Losses Breakdown
Modify the parameters below to change the overall System Losses percentage for your system.
Soiling (%): 2
Shading (%): 3
Snow (%): 0
Mismatch (%): 2
Wiring (%): 2
Connections (%): 0.5
Light-Induced Degradation (%): 1.5
Nameplate Rating (%): 1
Age (%): 0
Availability (%): 3
Estimated System Losses:
14 %
HELP
RESET
CANCEL
SAVE
Go to resource data
Go to PVWatts results

Design Activity



Above: Site Avg - Hourly Temp, Precipitation, Solar Elevation and Azimuth, and Daily Solar Energy kWh/ Sq M.

Below: Site Sun and Wind throughout the year - Westward vantage point

Images courtesy of Jonathan Boehmer, Backcountry Construction LLC

SD Professionals Case Study

Meet Chris Reinhart

Chris' Personal SD Pro Learning Objectives

Big Picture

Another "touch" with the DOE Solar Decathlon content.

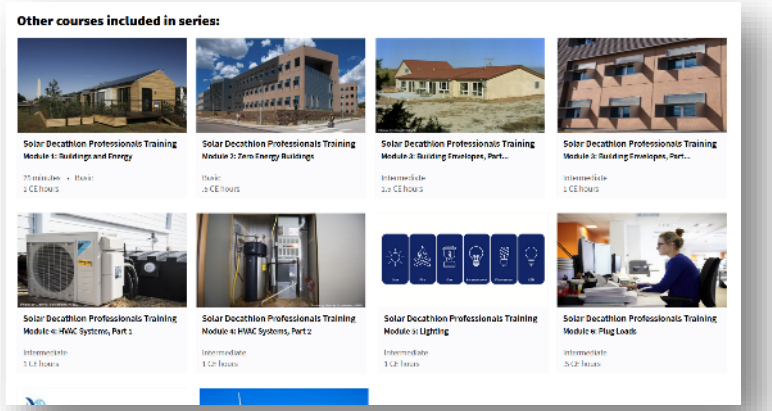
Teacher "peer observation"
--
how do others teach this content?

Targeted

Develop a method to move GoogleEarth 3d data into Rhino for analysis.

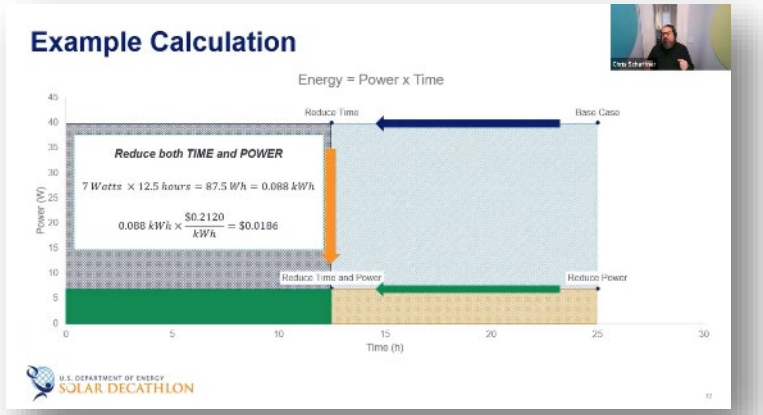
Expand my ability to use performance simulation software (add ClimateStudio to my "toolbox").

The Process – My Experience



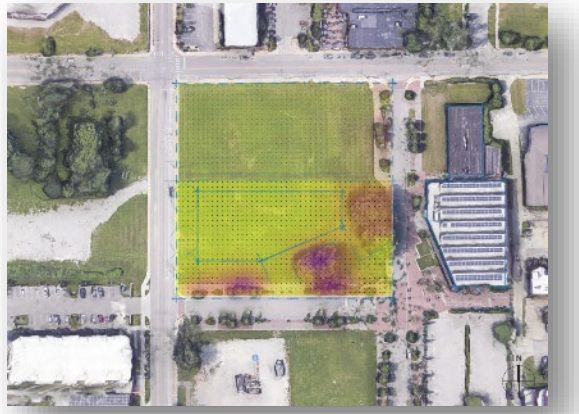
Online Videos and Quizzes

Great refresher.
Brief distillations of most important concepts.



Weekly Live Sessions over 10 Weeks

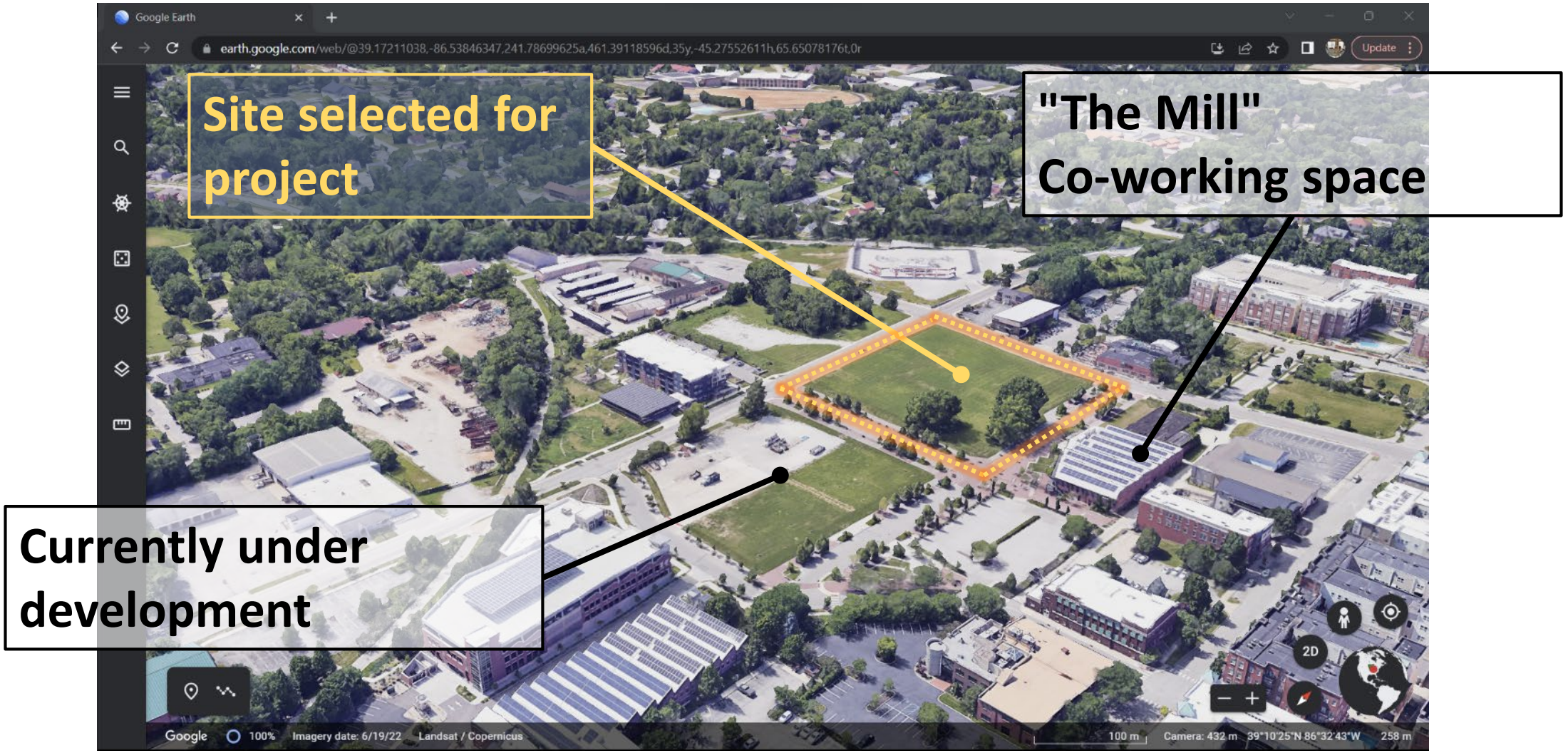
Opportunity to ask questions, dig deeper, hear others' perspectives.



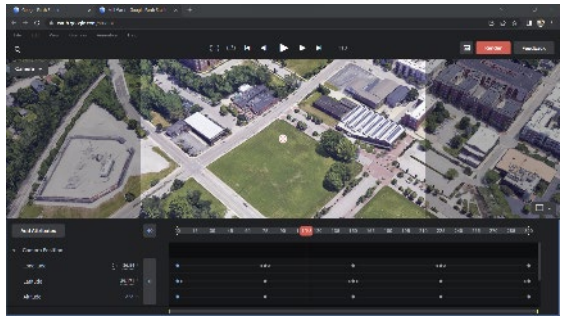
Personal Project Exploration

Putting the knowledge to use. Moving from theory to application.

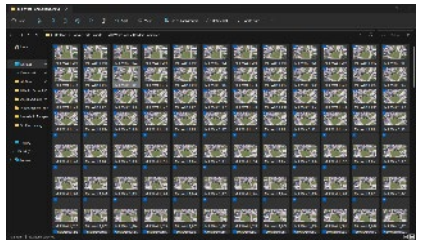
My Project Site



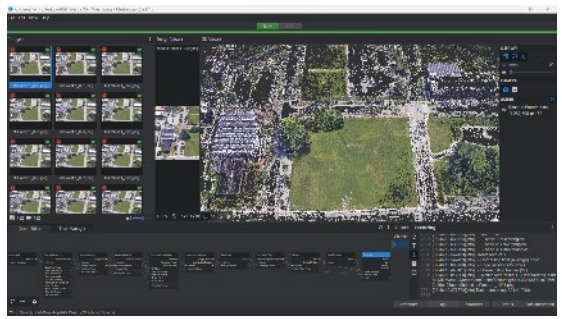
3d Data: GoogleEarth Studio to Rhino



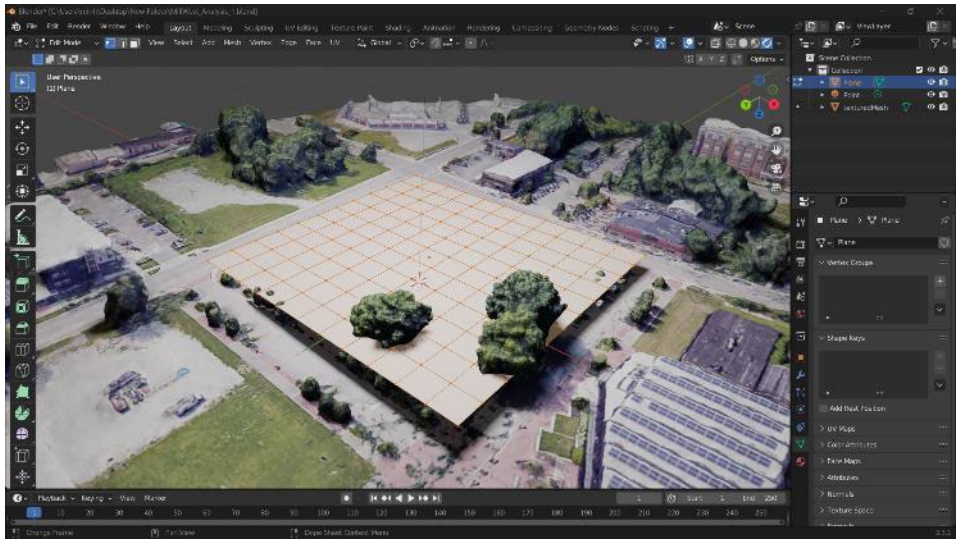
GoogleEarth Studio

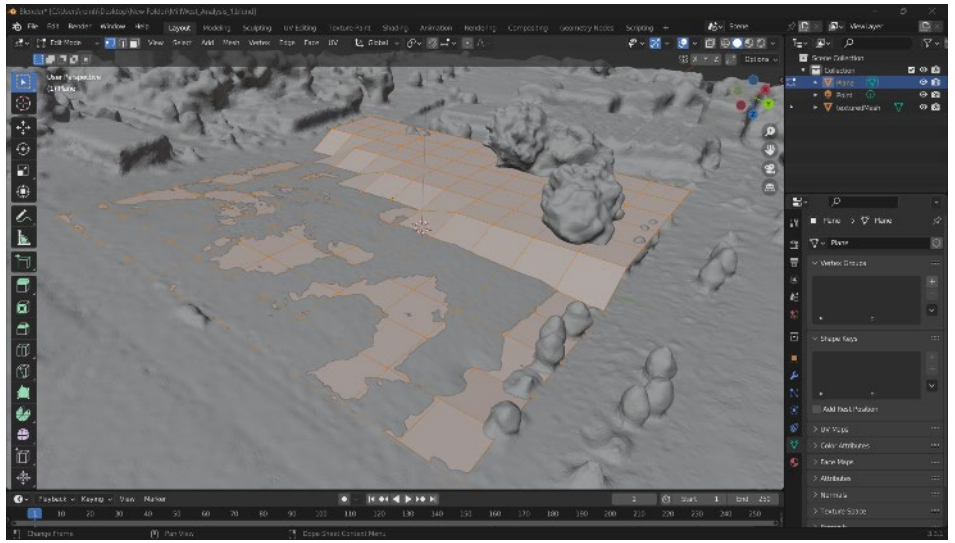


Rendered Images



AliceVision Meshroom



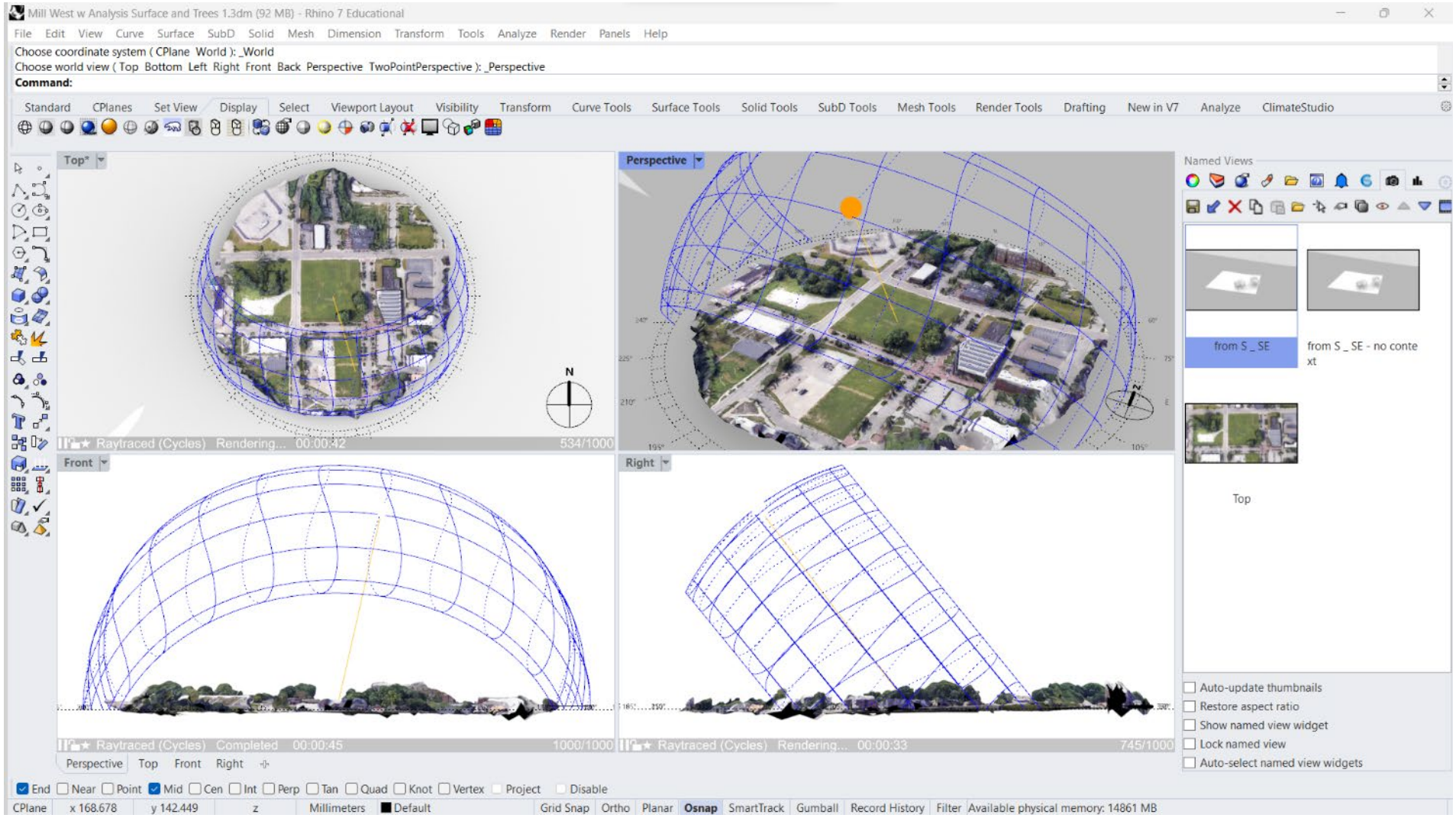


Blender

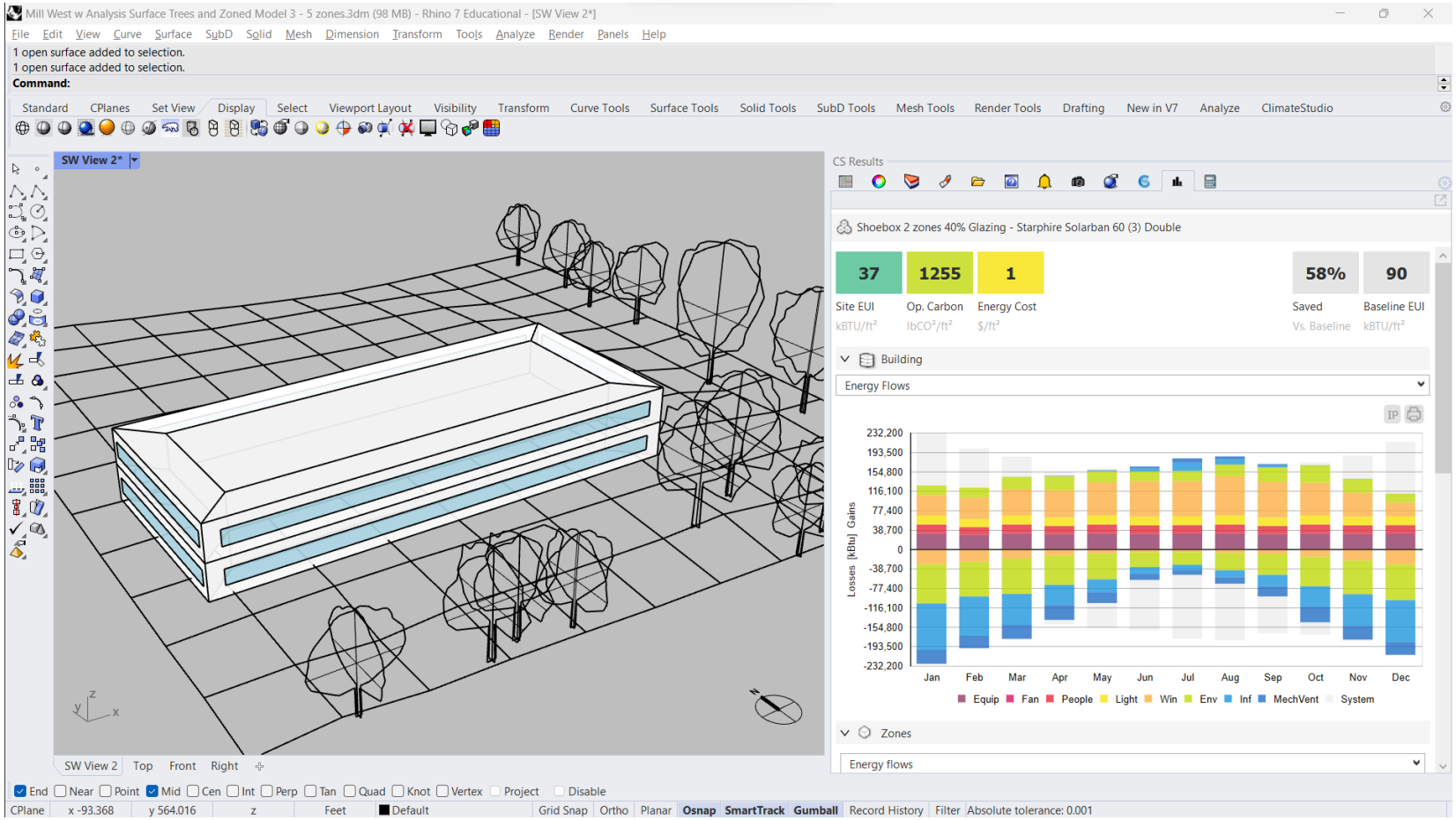
3d Data: GoogleEarth Studio to Rhino

IMPORT FBX FILE

Rhino:
Ready for analysis!



Analysis: Shoebox Design, Energy



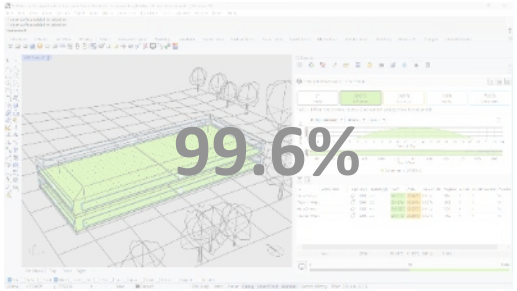
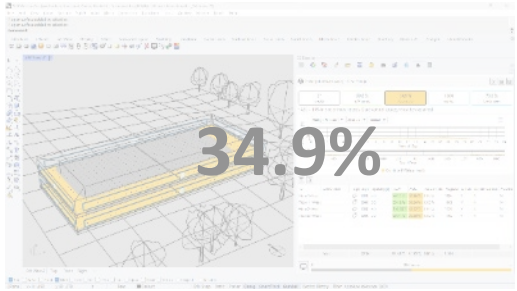
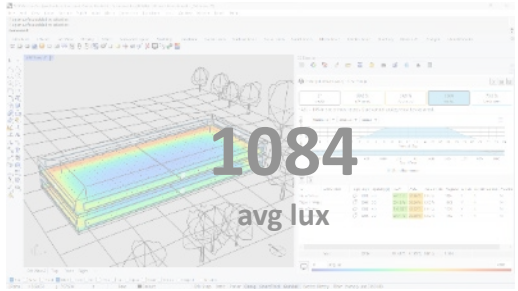
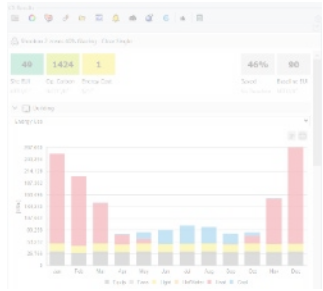
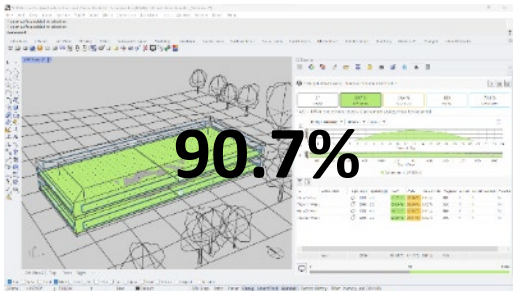
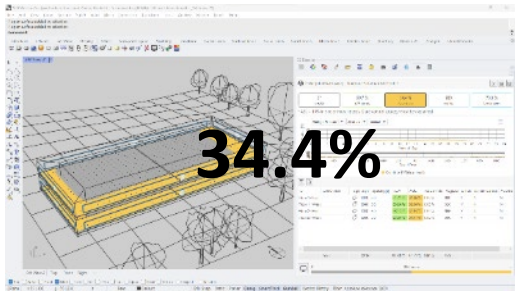
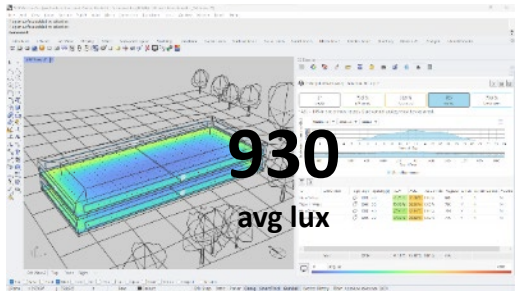
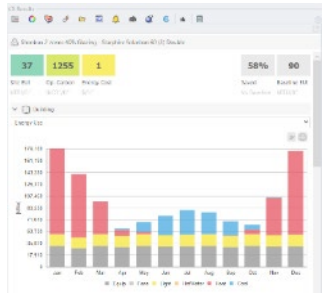
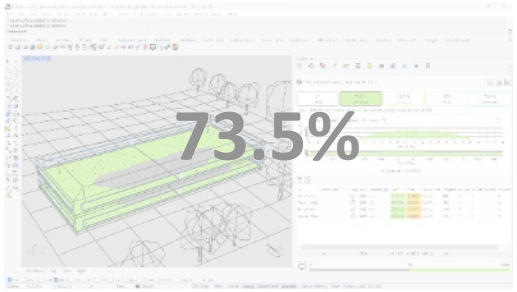
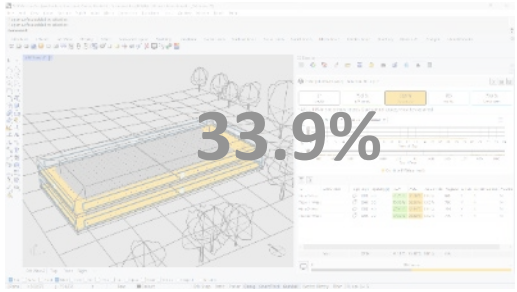
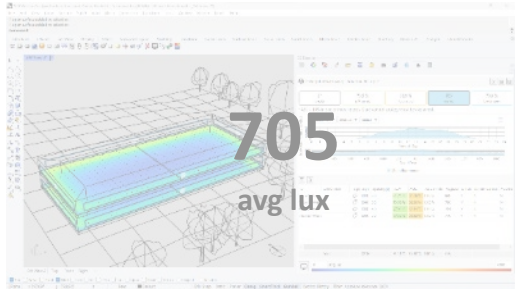
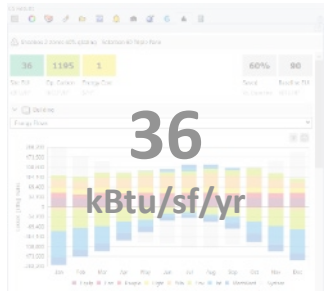
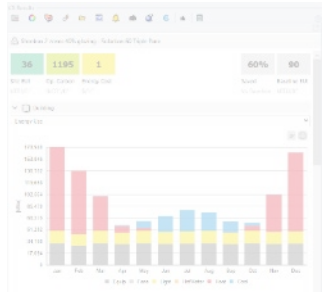
Rhino with ClimateStudio:
Let the fun begin!

Began exploration using:

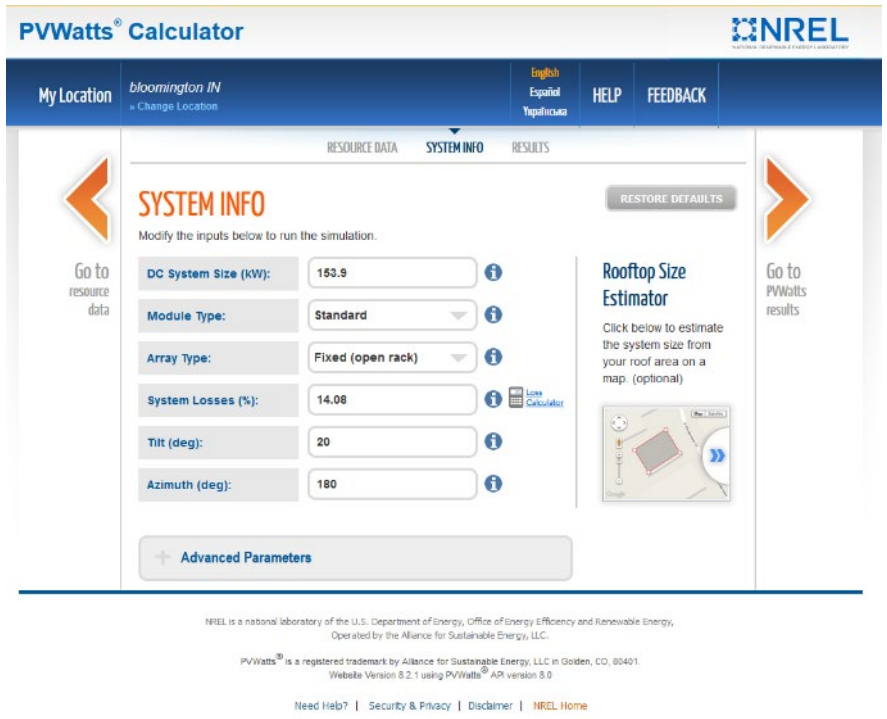
- 90.1-2019 opaque envelope baselines
- 40% WWR

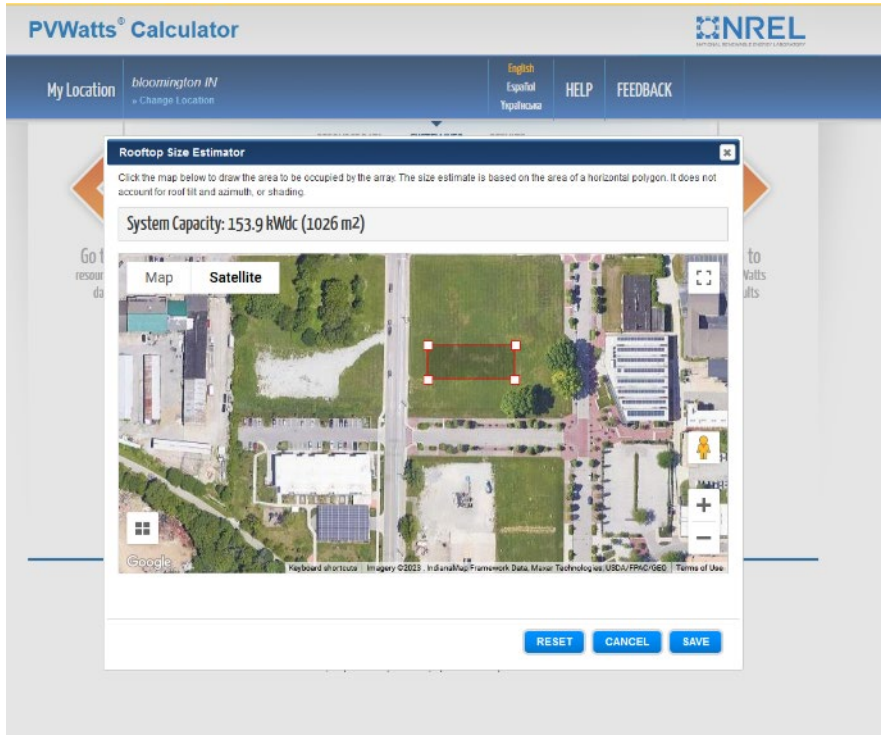
Analysis: Shoebox Design, Energy + Daylight

90.1-2019 Defaults for envelope, 40% WWR

	sDA	ASE	Lux	Site EUI: Energy Flows	Site EUI: Total Energy
Single Pane Tvis: 0.877 U: 1.024 SHGC: 0.818					
Double Pane Tvis: 0.74 U: 0.292 SHGC: 0.494					
Triple Pane Tvis: 0.533 U: 0.12 SHGC: 0.307					

PV Watts: How Many kWh Can I Generate?



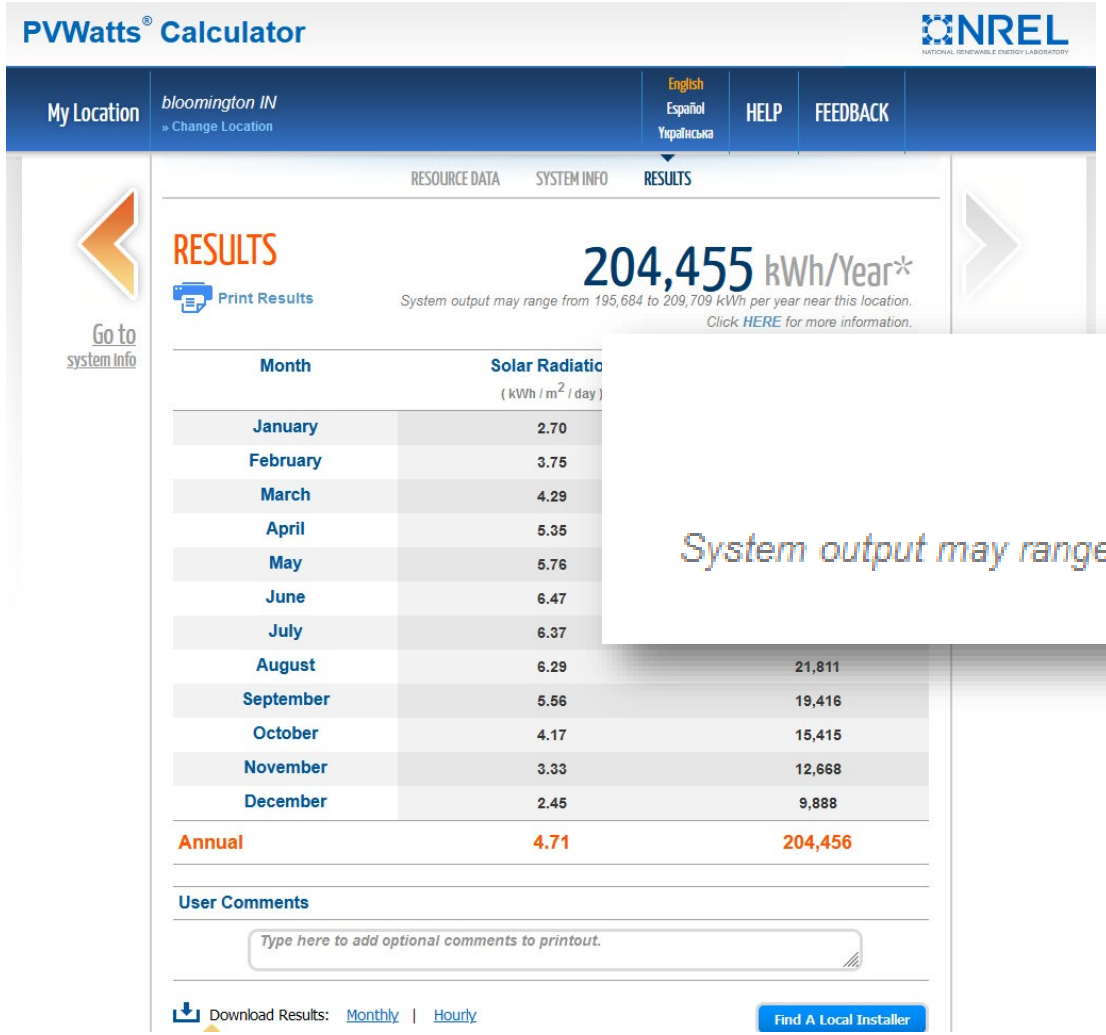


System Info:
Easy to use – reasonable defaults are pre-populated.

Harvest Area:
Graphical sketch method using map.

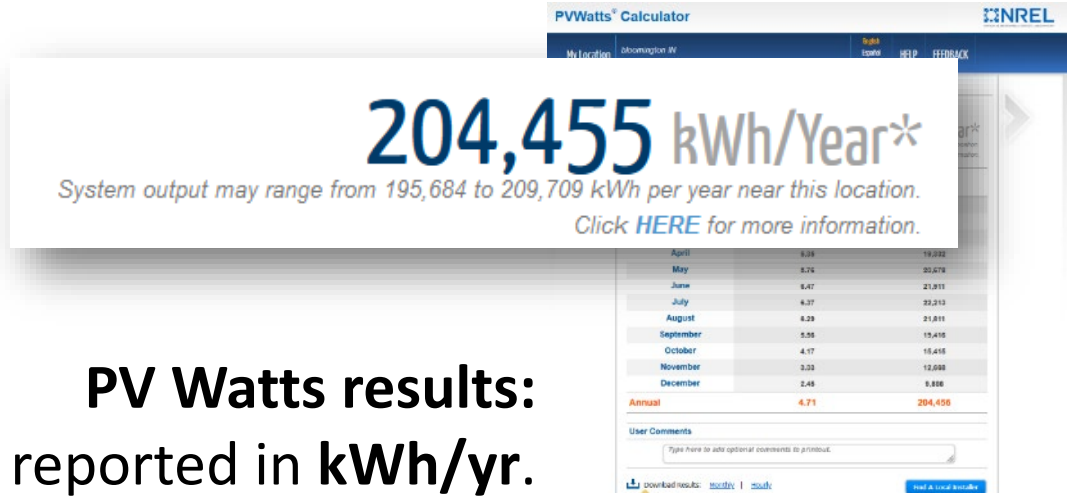
Checked with numeric total: 1,026 m^2
1,026 m^2 = 11,043 ft^2 *(approx. 68% of total roof area)*

PV Watts: PV Generation Estimate



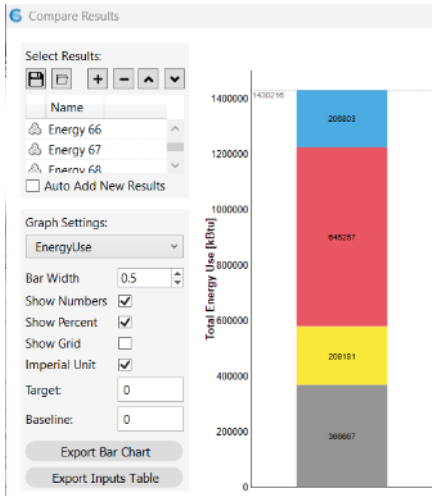
PV Watts Output:
Rough estimate of PV Potential.

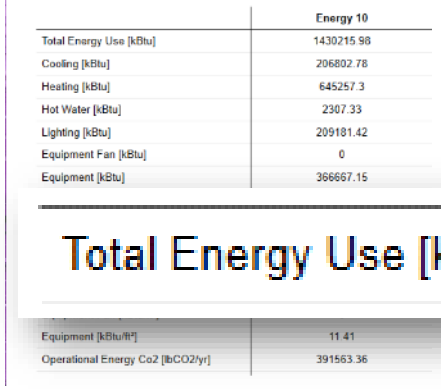
Mind the Gap



PV Watts results:
PV production reported in **kWh/yr**.

1 kWh = 3.412 kBtu
204,455 * 3.412 = **697,600 kBtu**





	Energy 10
Total Energy Use [kBtu]	1430215.98
Cooling [kBtu]	206802.78
Heating [kBtu]	645257.3
Hot Water [kBtu]	2307.33
Lighting [kBtu]	209181.42
Equipment Fan [kBtu]	0
Equipment [kBtu]	366667.15
Equipment [kBtu/ft²]	11.41
Operational Energy Co2 [lbCO2/yr]	391563.36

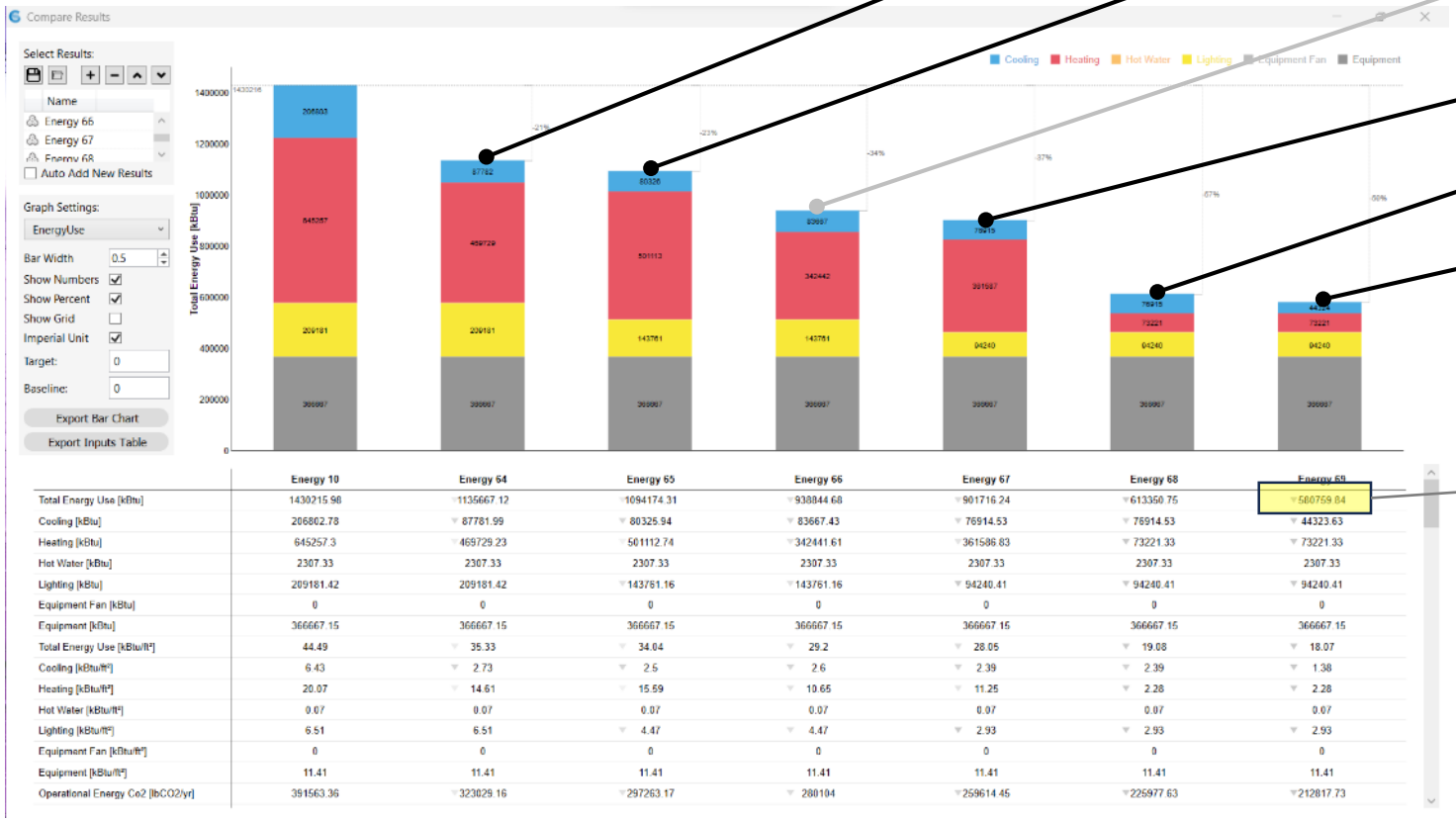
ClimateStudio results:
Total energy reported in **kBtu/yr**.

Total Energy Use [kBtu]	1430215.98

Initial Results:
1,430,215 kBtu needed
697,600 kBtu generated
732,615 kBtu/yr deficit

Close the Gap

ClimateStudio results:
Able to compare iterations against each other and see all inputs/outputs side-by-side.



	Energy 10	Energy 64	Energy 65	Energy 66	Energy 67	Energy 68	Energy 69
Total Energy Use [kBtu]	1430215.98	1135667.12	1094174.31	938844.68	901716.24	613350.75	580759.84
Cooling [kBtu]	206802.78	87781.99	80325.94	83667.43	76914.53	76914.53	44323.63
Heating [kBtu]	645257.3	469729.23	501112.74	342441.61	361586.83	73221.33	73221.33
Hot Water [kBtu]	2307.33	2307.33	2307.33	2307.33	2307.33	2307.33	2307.33
Lighting [kBtu]	209181.42	209181.42	143761.16	143761.16	94240.41	94240.41	94240.41
Equipment Fan [kBtu]	0	0	0	0	0	0	0
Equipment [kBtu]	366667.15	366667.15	366667.15	366667.15	366667.15	366667.15	366667.15
Total Energy Use [kBtu/ft²]	44.49	35.33	34.04	29.2	28.05	19.08	18.07
Cooling [kBtu/ft²]	6.43	2.73	2.5	2.6	2.39	2.39	1.38
Heating [kBtu/ft²]	20.07	14.61	15.59	10.65	11.25	2.28	2.28
Hot Water [kBtu/ft²]	0.07	0.07	0.07	0.07	0.07	0.07	0.07
Lighting [kBtu/ft²]	6.51	6.51	4.47	4.47	2.93	2.93	2.93
Equipment Fan [kBtu/ft²]	0	0	0	0	0	0	0
Equipment [kBtu/ft²]	11.41	11.41	11.41	11.41	11.41	11.41	11.41
Operational Energy Co2 [lbCO2/yr]	391563.36	323029.16	297263.17	280104	259614.45	225977.63	212817.73

Double-Pane
R-33 to R-38 Roof

LPD, 0.64 to 0.44 W/sf

Include ground plane effects (oops!)

Add light dimming

GSHP, Heat COP 0.81 to 4.0

Cooling COP 3.4 to 5.9

580759.84

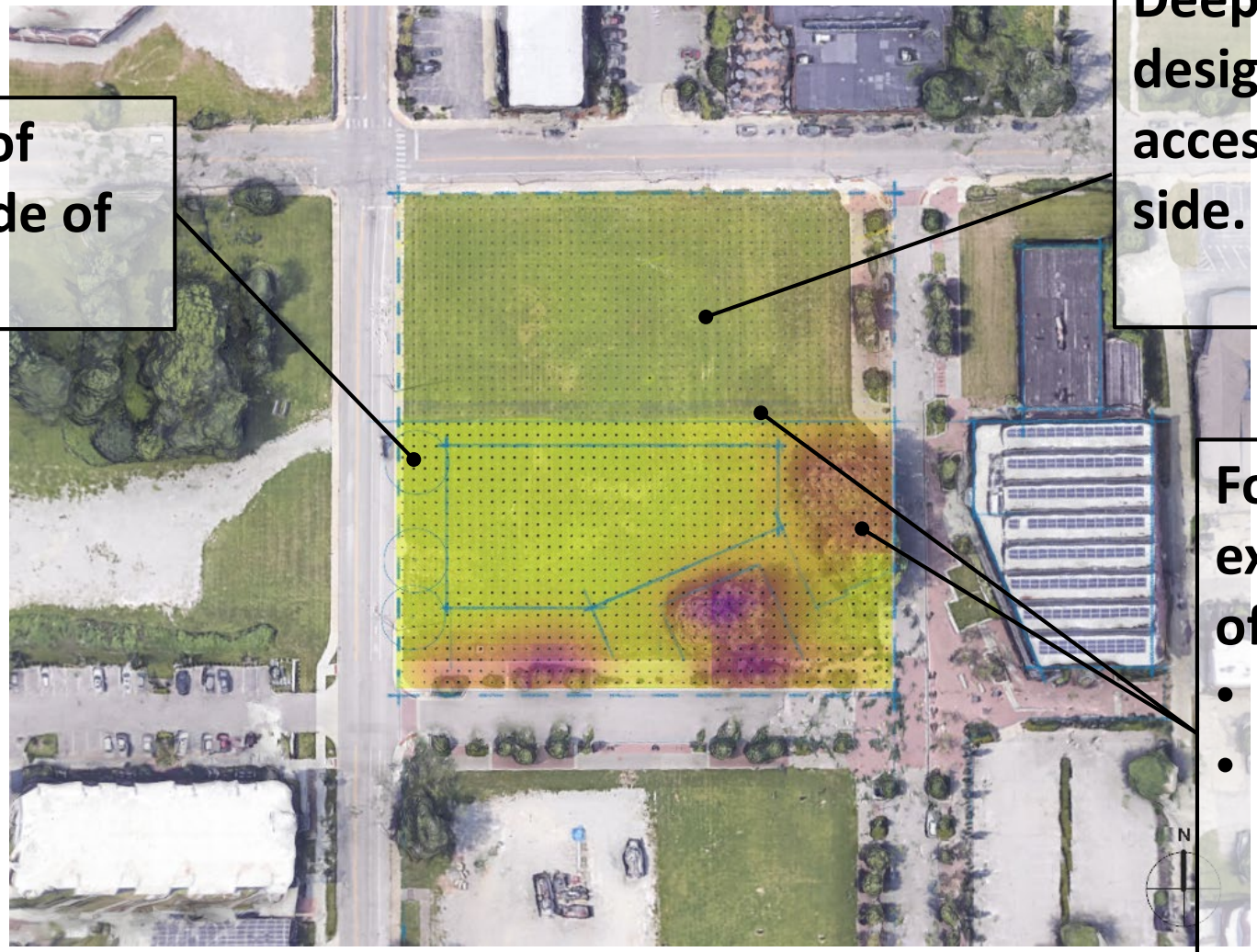
Moment of truth:
Can we offset our energy use with our renewable production?

Success!

Total Energy Use				
Final ClimateStudio Iteration	**580,759**	**kBtu/year**		
PV Watts production estimate	204,455	kWh/year	1 kWh = 3.412 kBtu	
PV Watts production estimate	**697,600**	**kBtu/year**		
Renewable Production %	***120%***			

Onward!

Explore impact of trees on west side of site.



Deepen understanding of design impacts on solar access for north half of side.

Focus on contextual and experiential dimensions of design:

- Expand plaza
- Riff on existing geometry

Chris' Personal SD Pro Learning Objectives

Big Picture

Another "touch" with the DOE SD content.

Teacher "peer observation" -- how do others teach this content?

Targeted

Develop a method to move GoogleEarth 3d data into Rhino for analysis.

Expand my ability to use performance simulation software (add ClimateStudio to my "toolbox").

Chris' Personal SD Pro Learning Objectives

Big Picture

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Teacher "peer observation" -- how do others teach this content?

Targeted

Develop a method to move GoogleEarth 3d data into Rhino for analysis.

Expand my ability to use performance simulation software (add ClimateStudio to my "toolbox").

Increased confidence with net zero understanding and ability.

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–Solar Decathlon Faculty

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–Industry Professional

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Thank You!

Questions?

Holly.carr@ee.doe.gov