PHRC Webinar Series | Tuesday, May 8 @ 1pm

GreenBuild

Sarah Klinetob Lowe, PHRC & Chris Hazel, EEHR

Pennsylvania Housing Research Center
206B Sackett Building | University Park, PA 16802
P: 814-865-2341
phrc@psu.edu
www.PHRC.psu.edu

Continuing Education

At end of the program, you can register for a certificate to receive the following credits for this session:

- **1.0 PA Dept L&I Contact Hour**
- **1.0 PDH**
- **1.0 AIA LU|HSW (PHRCWEB518)**
- **1.0 ICC Contact Hour (0.1 CEU) (15641)**
- **1.0 NARI hour/CEU**

Poll #1 – Who's who?

1 credit earned on completion of this course will be reported to AIA CES for AIA members following registration at the end of program.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of
handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Description

The GreenBuild duplex is a set of two 1,250ft² solar-powered homes designed to the Department of Energy's Zero Energy Ready Home Standard (ZERH). The homes were initially designed by students through the 2014-15 Department of Energy's Race to Zero Competition, and are a collaborative project between the Energy Efficient Housing Research Group (EEHR) in the Penn State School of Architecture and Landscape Architecture and the State College Community Land Trust (SCCLT), a nonprofit affordable housing entity that focuses on providing affordable owner-occupied housing for moderate income families in State College Borough. The homes are currently under construction by Envinity Inc., a State College design-build firm, and are expected to be completed and sold by May 2018 to two income-qualified families.

This webinar will explore the Department of Energy's Zero Energy Ready Home (ZERH) Standard and outline the design, construction, and cost of the GreenBuild duplex as a case study of the ZERH standard.

9

Learning Objectives

- **Examine the energy efficient design requirements for the Department of Energy's Zero Energy Ready Home (ZERH) Standard**
- **Gain insight on solar photovoltaic design for Pennsylvania, which reduces the home's environmental impact**
- **Explore the unique case study design and decision-making process for the State College Community Land Trust (SCCLT)'s ZERH-certified GreenBuild duplex**
- **Discuss the high performance systems chosen in the SCCLT ZERH duplex as they relate to balancing initial cost, long-term energy efficiency, and occupant health and comfort**

10

PHRC Webinar Series | Tuesday, May 8 @ 1pm

GreenBuild

Sarah Klinetob Lowe, PHRC & Chris Hazel, EEHR

Pennsylvania Housing Research Center
206B Sackett Building | University Park, PA 16802
P: 814-865-2341
phrc@psu.edu
www.PHRC.psu.edu

NARI CEU Approved

PREFERRED EDUCATION PROVIDER

EEHR | HAMER CENTER | PHRC

Intros

Client
State College Community Land Trust (SCCLT)
2013-present

S·C·C·L·T GreenBuild

EEHR

Design & Research Facilitator
Hamer Center for Community Design / Energy Efficient Housing Research Group (EEHR)
2013-present

2014-2015	2015-2017	2017-2018
2015 Race to Zero Design Team	Energy Efficient Housing Research Group	Envinity, Inc.
1. Community design charrettes 2. Strong design concepts 3. Systems analysis	1. Research-based design documents 2. Design process documentation 3. Systems documentation	1. Final construction documents 2. Final built homes

ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

12

Intros

Client
State College Community Land Trust (SCCLT)
2013-present

S·C·C·L·T GreenBuild

EEHR

Design & Research Facilitator
Hamer Center for Community Design / Energy Efficient Housing Research Group (EEHR)
2013-present

2014-2015	2015-2017	2017-2018
2015 Race to Zero Design Team	Energy Efficient Housing Research Group	Envinity, Inc.
1. Community design charrettes 2. Strong design concepts 3. Systems analysis	1. Research-based design documents 2. Design process documentation 3. Systems documentation	1. Final construction documents 2. Final built homes

ZERO ENERGY READY HOME U.S. DEPARTMENT OF ENERGY

13

Intros

Client
State College Community Land Trust (SCCLT)
2013-present

Design & Research Facilitator
Hamer Center for Community Design / Energy Efficient Housing Research Group (EEHR)
2013-present

2014-2015
2015 Race to Zero Design Team

1. Community design charrettes
2. Strong design concepts
3. Systems analysis

2015-2017
Energy Efficient Housing Research Group

1. Research-based design documents
2. Design process documentation
3. Systems documentation

2017-2018
Envinity, Inc.

1. Final construction documents
2. Final built homes

14

Intros

Client
State College Community Land Trust (SCCLT)
2013-present

Design & Research Facilitator
Hamer Center for Community Design / Energy Efficient Housing Research Group (EEHR)
2013-present

2014-2015
2015 Race to Zero Design Team

1. Community design charrettes
2. Strong design concepts
3. Systems analysis

2015-2017
Energy Efficient Housing Research Group

1. Research-based design documents
2. Design process documentation
3. Systems documentation

2017-2018
Envinity, Inc.

1. Final construction documents
2. Final built homes

15

Intros

Client
State College Community Land Trust (SCCLT)
2013-present

Design & Research Facilitator
Hamer Center for Community Design / Energy Efficient Housing Research Group (EEHR)
2013-present

2014-2015
2015 Race to Zero Design Team

1. Community design charrettes
2. Strong design concepts
3. Systems analysis

2015-2017
Energy Efficient Housing Research Group

1. Research-based design documents
2. Design process documentation
3. Systems documentation

2017-2018
Envinity, Inc.

1. Final construction documents
2. Final built homes

16

Intros

Client
State College Community Land Trust (SCCLT)
2013-present

Design & Research Facilitator
Hamer Center for Community Design / Energy Efficient Housing Research Group (EEHR)
2013-present

2014-2015
2015 Race to Zero Design Team

1. Community design charrettes
2. Strong design concepts
3. Systems analysis

2015-2017
Energy Efficient Housing Research Group

1. Research-based design documents
2. Design process documentation
3. Systems documentation

2017-2018
Envinity, Inc.

1. Final construction documents
2. Final built homes

17

Outline

Introductions
- Zero Energy Ready Home standard
- Solar PV system design basics in PA

History & Context
- State College Borough & GreenBuild site
- State College Community Land Trust

Design & Construction
- Design overview of GreenBuild duplex
- Construction lessons learned
- Financials to date

18

Intro: Zero Energy Ready Home Standard

High Energy Efficiency Home Design

Ready for Renewable Energy

Intro: Zero Energy Ready Home Standard

High Energy Efficiency Home Design

Ready for Renewable Energy

ZERH: Energy Efficient Home

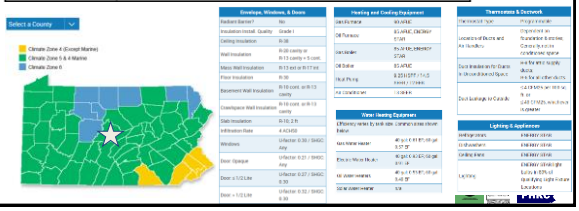
Exhibit 1: DOE Zero Energy Ready Home Mandatory Requirements for All Labeled Homes

	Area of Improvement	Mandatory Requirements
Energy Efficiency	1. ENERGY STAR for Homes Baseline	☐ Certified under ENERGY STAR Qualified Homes Program Version 3 or 3.1 [10, 11]
	2. Envelope[12]	☐ Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific U, SHGC values, and exceptions. [13] ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 or 2015 IECC levels[14, 15]
	3. Duct System	☐ Duct distribution systems located within the home's thermal and air barrier boundary or an optimized location to achieve comparable performance [16]
	4. Water Efficiency	☐ Hot water delivery systems (distributed and central) shall meet efficient design requirements [17]
	5. Lighting & Appliances[18]	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. ☐ 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets ☐ All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified
Occupant Health	6. Indoor Air Quality	☐ Certified under EPA Indoor airPLUS [11]
Future Proofing	7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [19]

www.energy.gov/eere/buildings/zero-energy-ready-home

1. ENERGY STAR Baseline

Area of Improvement	Mandatory Requirements
1. ENERGY STAR for Homes Baseline	☐ Certified under ENERGY STAR Qualified Homes Program Version 3 or 3.1 [10, 11]



2. Envelope Requirements

Area of Improvement	Mandatory Requirements
2. Envelope[12]	☐ Fenestration shall meet or exceed ENERGY STAR requirements. See End Note for specific U, SHGC values, and exceptions. [13] ☐ Ceiling, wall, floor, and slab insulation shall meet or exceed 2012 or 2015 IECC levels[14, 15]

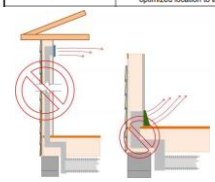
TABLE R402.1.1
INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a]

CLIMATE ZONE	FENESTRATION U-FACTOR[b]	SKYLIGHT[b] U-FACTOR	GLAZED FENESTRATION SHGC[b, k]	CEILING R-VALUE	WOOD FRAME WALL R-VALUE	MASS WALL R-VALUE[i]	FLOOR R-VALUE	BASEMENT[c] WALL R-VALUE	SLAB[d] R-VALUE & DEPTH	CRAWL SPACE[c] WALL R-VALUE
1	NR	0.75	0.25	30	13	3/4	13	0	0	0
2	0.40	0.65	0.25	38	13	4/6	13	0	0	0
3	0.35	0.55	0.25	38	20 or 13+5[h]	8/13	19	5/13[f]	0	5/13
4 except Marine	0.35	0.55	0.40	49	20 or 13+5[h]	8/13	19	10/13	10, 2 ft	10/13
5 and Marine 4	0.32	0.55	NR	49	20 or 13+5[h]	13/17	30[f]	15/19	10, 2 ft	15/19
6	0.32	0.55	NR	49	20+5 or 13+10[h]	15/20	30[f]	15/19	10, 4 ft	15/19
7 and 8	0.32	0.55	NR	49	20+5 or 13+10[h]	19/21	38[f]	15/19	10, 4 ft	15/19

https://codes.iccsafe.org/public/document/IECC2012/chapter-4-re-residential-energy-efficiency

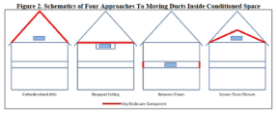
3. Duct Requirements

Area of Improvement	Mandatory Requirements
3. Duct System	☐ Duct distribution systems located within the home's thermal and air barrier boundary or an optimized location to achieve comparable performance[16]



Pacific Northwest National Laboratory, "Ducts should not be located in exterior wall cavities." https://basc.pnnl.gov/sites/default/files/images/HVAC217_roductinest1_DS_11-21-12.JPG

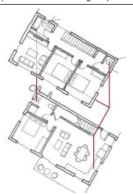
Figure 2. Schematics of Four Approaches To Moving Ducts Inside Conditioned Space



https://www.energyvanguard.com/blog/67675/5-Good-Ways-1-Bad-Way-to-Get-Your-Ducts-Inside-Conditioned-Space

4. Water Efficiency

Area of Improvement	Mandatory Requirements
4. Water Efficiency	☐ Hot water delivery systems (distributed and central) shall meet efficient design requirements[17]



By: Shivaram Punathambekar

5. Lighting & Appliances

Area of Improvement	Mandatory Requirements
5. Lighting & Appliances[10]	☐ All installed refrigerators, dishwashers, and clothes washers are ENERGY STAR qualified. ☐ 80% of lighting fixtures are ENERGY STAR qualified or ENERGY STAR lamps (bulbs) in minimum 80% of sockets ☐ All installed bathroom ventilation and ceiling fans are ENERGY STAR qualified

www.homedepot.com

https://www.gulfpower.com/residential/savings-and-energy/rebates-and-programs/appliances

https://www.a-hardwareexpress.com/info/energy-star

PHRC

6. Indoor Air Quality Requirements

Area of Improvement	Mandatory Requirements
6. Indoor Air Quality	☐ Certified under EPA Indoor airPLUS [11]

EPA Indoor airPLUS QUALIFIED HOME

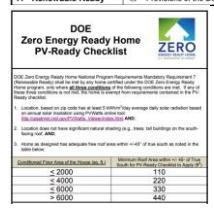
https://www.epa.gov/indoorairplus

https://www.epa.gov/sites/production/files/2018-03/documents/indoor_airplus_construction_specifications.pdf

PHRC

7. Renewable Ready

Area of Improvement	Mandatory Requirements
7. Renewable Ready	☐ Provisions of the DOE Zero Energy Ready Home PV-Ready Checklist are Completed [19]



DOE
Zero Energy Ready Home
PV-Ready Checklist

Conditioned Floor Area of the House (sq. ft.)	Minimum Roof Area within +/- 45° of True South for PV-Ready Method to Apply (ft²)
≤ 2000	110
≤ 4000	220
≤ 6000	330
> 6000	440

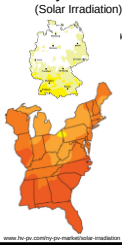
https://www.energy.gov/sites/prod/files/2015/05/f22/PV-Ready%20Checklist.pdf

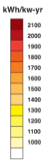
1. **Min. sun requirements** in the home's zip code
   5 kWh/m²/day average solar radiation
2. **Little to no shading** on the home's site
   - Trees, tall buildings to the south, power lines
   - Dormers, vent stacks
3. **Free roof space +/- 45 degrees of true south**

PHRC

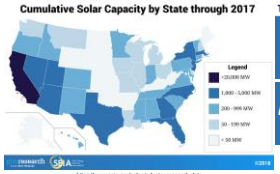
Solar - 1. Minimum Sun

Germany vs. Eastern US
(Solar Irradiation)



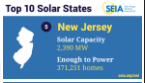


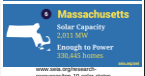
Cumulative Solar Capacity by State through 2017



https://www.seia.org/solar-industry-research-data

Top 10 Solar States SEIA





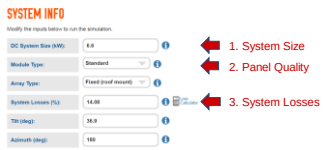
www.seia.org/research-resources/top-10-solar-states-2017

www.hv-pv.com/my-pv-market/solar-irradiation

Solar - PVWatts.NREL.gov

Solar Radiation

1. Location



2. Array Rack Type

3. Roof Tilt

4. Roof Orientation

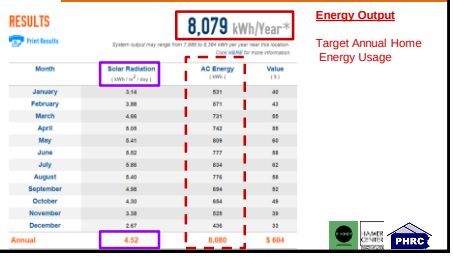
Energy Output

1. System Size
2. Panel Quality
3. System Losses

Solar - PVWatts.NREL.gov

Solar Radiation

Min. Requirement:
5 kWh/m²/day



Energy Output

Target Annual Home Energy Usage

Solar - 2. Shading, Common Causes

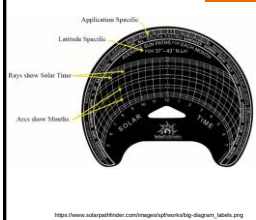
Site Shading

1. Tall Southern Buildings
2. Trees
3. Poles
4. Utility lines (existing)

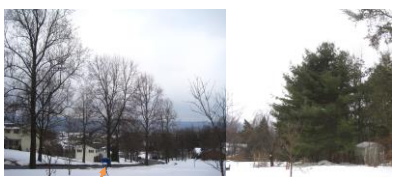
Home Shading

1. Dormers
2. Chimneys
3. Vent stacks
4. Landscaping
5. Utility lines (installed)

Solar - 2. Shading, Solar Pathfinder



Solar Pathfinder: GreenBuild



Pathfinder *(ground height)*

Solar - 3. Roof Orientation

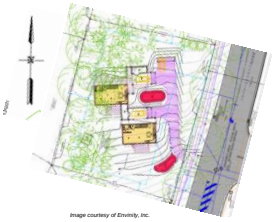


Image courtesy of Enviroty, Inc.

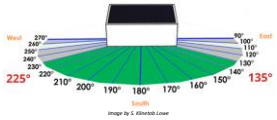
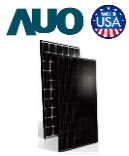


Image by S. Klinkob Lowe

Conditioned Floor Area of the House (sq. ft.)	Minimum Roof Area within +/- 45- of True South for PV-Ready Checklist to Apply (ft²)
≤ 2000	110
≤ 4000	220
≤ 6000	330
> 6000	440

GreenBuild Solar PV System

Image courtesy of Enviroty, Inc.



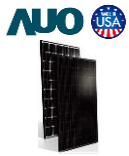
http://solar.auo.com/?sn=15644&lang=en-US

www.sma-america.com/Products/Images/sunny-boy/50-US-60-US/SunnyBoy-5-6-US.png

Image courtesy of Enviroty, Inc.

GreenBuild Solar PV System

Image courtesy of Enviroty, Inc.



http://solar.auo.com/?sn=15644&lang=en-US

www.sma-america.com/Products/Images/sunny-boy/50-US-60-US/SunnyBoy-5-6-US.png

Image courtesy of EEHR

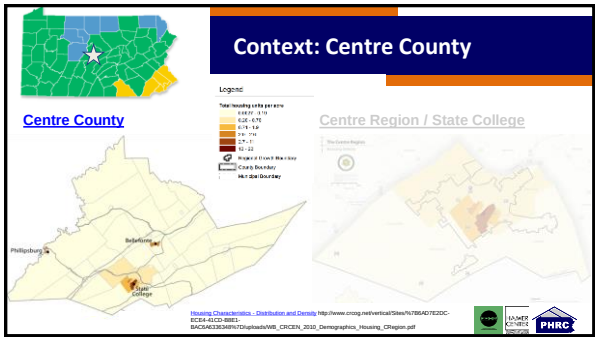
Poll #2 – Head Count

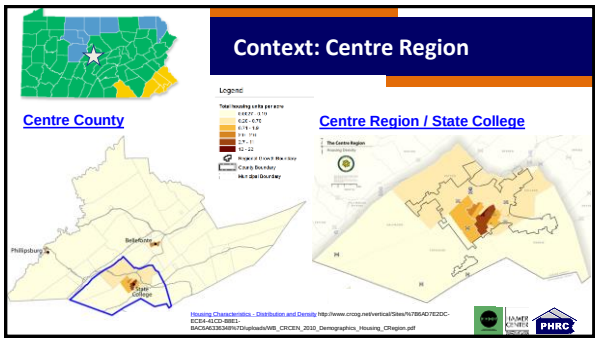
Certificate Password:

PASSWORD: ZERH-PA18

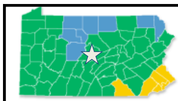
Note: Password is *case sensitive*

38

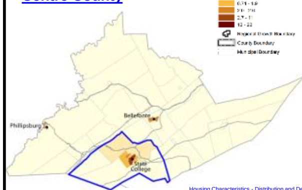


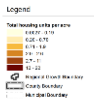


Context: State College Borough

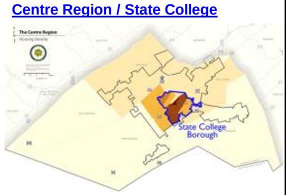


Centre County





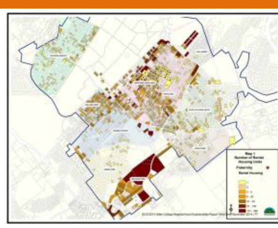
Centre Region / State College



Housing Characteristics - Distribution and Density http://www.crcog.net/vertical/Sites/%7B6AD7E2DC-ECE4-41CD-B8E1-BAC6A6336348%7D/uploads/WB_CRCEN_2010_Demographics_Housing_CRegion.pdf

Context: State College Borough

http://www.statecollegepa.us/images/pages/N768/Neighborhood%20Map%204%20Small.png



2014 Neighborhood Sustainability Report. http://www.statecollegepa.us/DocumentCenter/View/9972/2014-Neighborhood-Sustainability-Report

What is a Community Land Trust?

What is a **Community Land Trust**?

Community Land Trusts keep homes affordable and in the hands of the community by only putting the homes, not the land they occupy, on the market for low- to moderate-income people.

1. **Land Lease**
2. Resale Formula

"Shared Equity"

Lawrenceville Corporation CLT Infographic https://drive.google.com/file/d/0B2XZP_654G5DbzYwNXZERVNXRk0/view

43

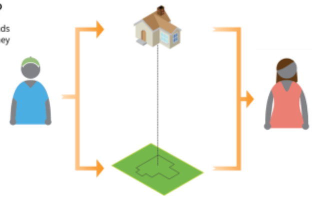
What is a Community Land Trust?

What is a **Community Land Trust**?

Community Land Trusts keep homes affordable and in the hands of the community by only putting the homes, not the land they occupy, on the market for low- to moderate-income people.

1. **Land Lease**
2. **Resale Formula**

"Shared Equity"



Lawrenceville Corporation CLT Infographic
https://drive.google.com/file/d/0B2KZP_654G5DbzYwNXZERVNXRkk0/view

44

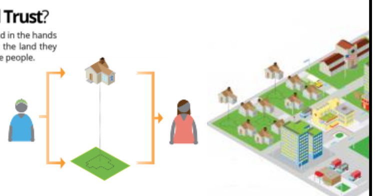
What is a Community Land Trust?

What is a **Community Land Trust**?

Community Land Trusts keep homes affordable and in the hands of the community by only putting the homes, not the land they occupy, on the market for low- to moderate-income people.

1. **Land Lease**
2. **Resale Formula**

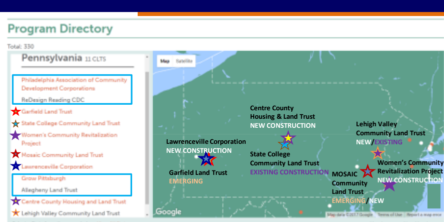
"Shared Equity"



Lawrenceville Corporation CLT Infographic
https://drive.google.com/file/d/0B2KZP_654G5DbzYwNXZERVNXRkk0/view

45

CLTs: Pennsylvania



http://cltnetwork.org/directory/

46

State College Community Land Trust (SCCLT)

Private, nonprofit, community-based organization.	Focus is on buying, rehabilitating, and selling houses.
Formed in 1996 at the request of State College Borough.	Over 30 households.
Acquires properties through donation or purchase.	Separates ownership of the land from the home.

State College Community Land Trust (SCCLT)

Private, nonprofit, community-based organization.	Focus is on buying, rehabilitating, and selling houses.
Formed in 1996 at the request of State College Borough.	Over 30 households.
Acquires properties through donation or purchase.	Separates ownership of the land from the home.



State College Community Land Trust(SCCLT)

Private, nonprofit, community-based organization.	Focus is on buying, rehabilitating, and selling houses.
Formed in 1996 at the request of State College Borough.	Over 30 households.
Acquires properties through donation or purchase.	Separates ownership of the land from the home.

2017 Income Guidelines

# People	Minimum	Maximum
1	$31,500	$42,000
2	$36,000	$48,000
3	$40,500	$54,000
4	$45,000	$60,000
5	$48,600	$64,800
6	$52,200	$69,600

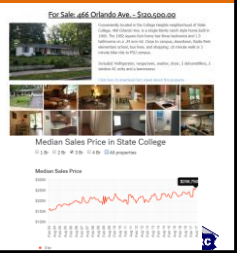
Mean and Median Salaries of Full-Time* Employees in the College of Engineering, as of Sept. 30, 2015

A. Faculty	Full-Time Employees	Mean Salary	Median Salary
Professor	143	$ 154,552	$ 145,044
Associate Professor	59	$ 111,983	$ 114,336
Assistant Professor	72	$ 89,523	$ 92,016
Instructor	28	$ 65,309	$ 62,028
Other	61	$ 60,240	$ 56,270
B. Staff	**Full-Time Employees**	**Mean Salary**	**Median Salary**
Executive/Administrator/Managerial	32	$ 105,668	$ 204,876
Other Professional Non-Faculty	123	$ 66,698	$ 63,300
Clerical/Secretarial	135	$ 41,886	$ 39,288
Technical, Service and Other	60	$ 53,010	$ 48,173



State College Community Land Trust(SCCLT)

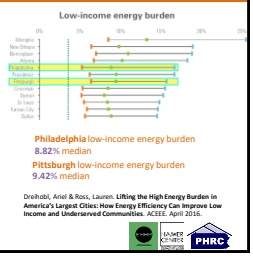
Private, nonprofit, community-based organization.	Focus is on buying, rehabilitating, and selling houses.
Formed in 1996 at the request of State College Borough.	Over 30 households.
Acquires properties through donation or purchase.	Separates ownership of the land from the home.



State College Community Land Trust(SCCLT)

Private, nonprofit, community-based organization.	Focus is on buying, rehabilitating, and selling houses.
Formed in 1996 at the request of State College Borough.	Over 30 households.
Acquires properties through donation or purchase.	Separates ownership of the land from the home.

"What is the point of buying your home if you can't afford to live in it?"
- Peg Hambrick (Board Member SCCLT)



State College Community Land Trust(SCCLT)

Private, nonprofit, community-based organization.	Focus is on buying, rehabilitating, and selling houses.
Formed in 1996 at the request of State College Borough.	Over 30 households.
Acquires properties through donation or purchase.	Separates ownership of the land from the home.

"What is the point of buying your home if you can't afford to live in it?"
- Peg Hambrick (Board Member SCCLT)

Financing GreenBuild

COSTS:
LAND: $150,000 (OWNED BY SCCLT)
HOMES: $500,000 (COST NOT TO EXCEED)

FUNDING:
LAND: $150,000
(BOUGHT BY STATE COLLEGE BOROUGH)
GRANT BY WPPSEF: $100,000
LOAN BY WPPSEF: $400,000

EEHR + SCCLT

The **Energy Efficient Housing Research Group (EEHR)** is concerned with the **study, design, and implementation of Responsible Housing**. We define Responsible Housing as well-designed homes that are **affordable**; **sustainable**; and **healthful**. EEHR is an outreach arm of the Hamer Center for Community Design within the Penn State College of Arts and Architecture. The group is a multidisciplinary team of faculty, graduate, and undergraduate students from across the university dedicated to the investigation of Responsible Housing in order to inform better housing and more resource-conscious living.

Private, nonprofit, community-based organization.

Formed in 1996 at the request of State College Borough.

Acquires properties through donation or purchase.

Focus is on buying, rehabilitating, and selling houses.

Over 30 households.

Separates ownership of the land from the home.

"What is the point of buying your home if you can't afford to live in it?"
- Peg Hambrick (Board Member: SCCLT)

EEHR + SCCLT

The **Energy Efficient Housing Research Group (EEHR)** is concerned with the **study, design, and implementation of Responsible Housing**. We define Responsible Housing as well-designed homes that are **affordable**; **sustainable**; and **healthful**. EEHR is an outreach arm of the Hamer Center for Community Design within the Penn State College of Arts and Architecture. The group is a multidisciplinary team of faculty, graduate, and undergraduate students from across the university dedicated to the investigation of Responsible Housing in order to inform better housing and more resource-conscious living.

Private, nonprofit, community-based organization.

Formed in 1996 at the request of State College Borough.

Acquires properties through donation or purchase.

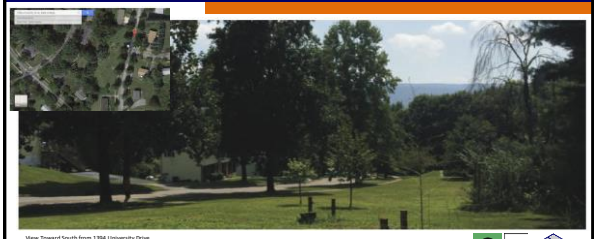
Focus is on buying, rehabilitating, and selling houses.

Over 30 households.

Separates ownership of the land from the home.

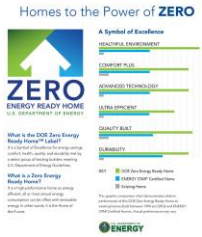
"What is the point of buying your home if you can't afford to live in it?"
- Peg Hambrick (Board Member: SCCLT)

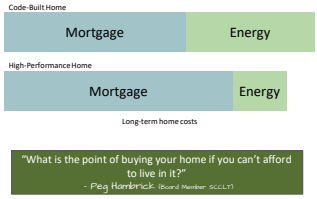
1394 University Drive



View Toward South from 1394 University Drive
(Above): Google Earth View of Site

Long Term Affordability





"What is the point of buying your home if you can't afford to live in it?"
- Peg Hambrick (Board Member SCCLT)

Student Design

Fourth Year Architecture Studio (Images from The Designing of GreenBuild Charrette Report)
(Right): Photo of Community Design Charrette at Penn State

Race to Zero Competition

2017 Race to Zero Competition at National Renewable Energy Laboratory by NREL
(Left): Race to Zero Competition Logo

Community Charrettes

- Race to Zero Students
- PSU Faculty
- PSU Staff
- Architecture Students
- Engineering Students
- SCCLT Board Members
- SCCLT Homeowners
- Community Members

Community Design Charrette at Penn State

Community Charrettes

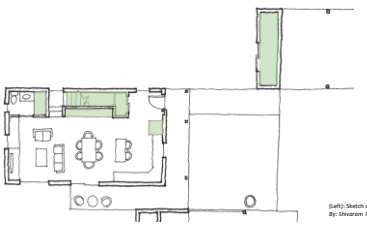
Community Design Charrette at Penn State
(Right): The Designing of GreenBuild Charrette Report

Design Goals Development

ZERO ENERGY READY HOME
U.S. DEPARTMENT OF ENERGY

DOE Zero Energy Ready Homes Logo
(Left): Photo of Community Design Charrette at Penn State

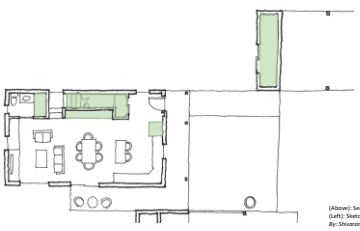
Design Goals Development

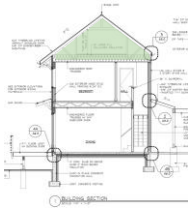


1. **Storage**
2. Individuality
3. Universal Design & Flexibility
4. Vision of Sustainability

(Left): Sketch of GreenBuild Duplex (2016)
By: Shivaram Punathambekar

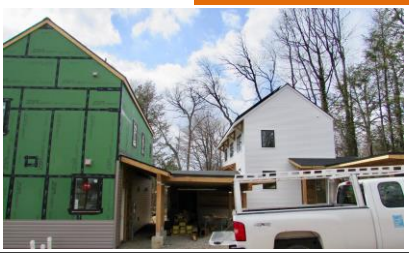
Design Goals Development





(Above): Section of GreenBuild by Eminity Inc
(Left): Sketch of GreenBuild Duplex (2016)
By: Shivaram Punathambekar

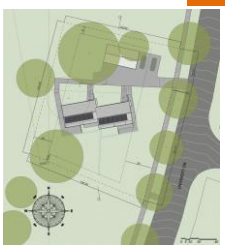
Design Goals Development



1. Storage
2. **Individuality**
3. Universal Design & Flexibility
4. Vision of Sustainability

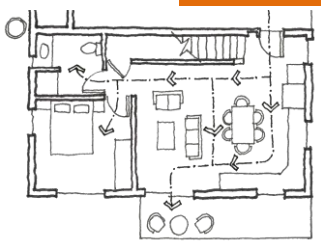
GreenBuild Construction (April 5, 2018)

Individuality



(Far Left): Site Plan for 2015 Race to Zero Competition
Updated Site Plan of GreenBuild Duplex (2016)
by ZEHR

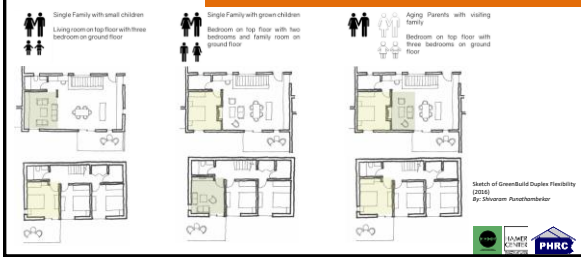
Design Goals Development



1. Storage
2. Individuality
3. **Universal Design & Flexibility**
4. Vision of Sustainability

Sketch of GreenBuild Duplex Accessibility (2016)
By: Shivaram Punathambekar

Design Goals Development



Sketch of GreenBuild Duplex Flexibility (2016)
By: Shivaram Punathambekar

Design Goals Development

1. Storage
2. Individuality
3. Universal Design & Flexibility
4. **Vision of Sustainability**

Rendering for 2015 Race to Zero Competition

Design Update


2015 Race to Zero Design


2016 Energy Efficient Housing Research Group Design


2018 GreenBuild Duplex Under Construction

Technical Goals

1. **Minimize Site Disturbance**
2. Durable and Secure Envelope
3. Easily Constructible
4. Fresh Air & Comfort
5. Low Maintenance

Photo from 2015 Race to Zero Work Session

Technical Goals

1. Minimize Site Disturbance
2. **Durable and Secure Envelope**
3. Easily Constructible
4. Fresh Air & Comfort
5. Low Maintenance

Photo from 2015 Race to Zero Work Session

Technical Goals

1. Minimize Site Disturbance
2. Durable and Secure Envelope
3. **Easily Constructible**
4. Fresh Air & Comfort
5. Low Maintenance

Photo from 2015 Race to Zero Work Session

Technical Goals

1. Minimize Site Disturbance
2. Durable and Secure Envelope
3. Easily Constructible
4. **Fresh Air & Comfort**
5. Low Maintenance

Photo from 2015 Race to Zero Work Session

Technical Goals

1. Minimize Site Disturbance
2. Durable and Secure Envelope
3. Easily Constructible
4. Fresh Air & Comfort
5. **Low Maintenance**

Photo from 2015 Race to Zero Work Session

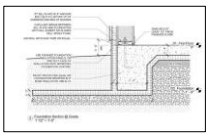
Technical Goals

Rendering of GreenBuild Duplex (2017) by ZEYR

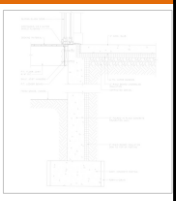
Passive Solar + Right-to-Light

Site Section of GreenBuild (2016) by ZEYR
(Left): Site Plan of GreenBuild (2016) by ZEYR

Minimizing Site Disturbance



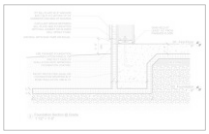
EEHR Foundation Detail (2016)

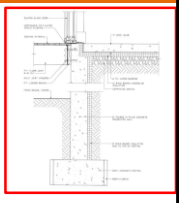


Site Slope

GreenBuild Construction (December 18, 2017)

Insulated Foundation





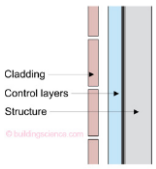
Envinity Foundation Detail

Insulated Foundation

GreenBuild Construction (November 27, 2017)

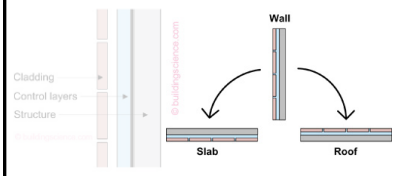
GreenBuild Construction (December 12, 2017)

Envelope Durability



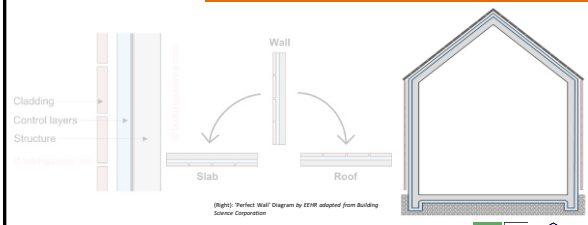
'Perfect Wall' Diagram by Joe Lstiburek at Building Science Corporation

Continuous Control Layers



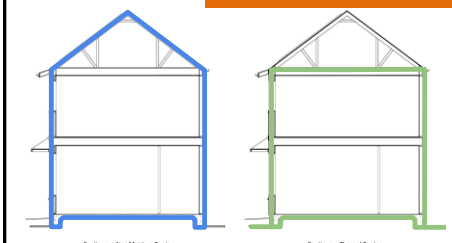
'Perfect Wall' Diagram by Joe Lstiburek at Building Science Corporation

Continuous Control Layers



(Right): 'Perfect Wall' Diagram by EEHR adopted from Building Science Corporation

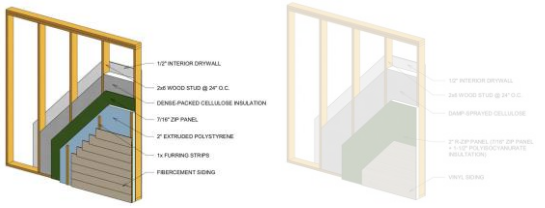
Continuous Control Layers



Continuous Air + Moisture Barrier

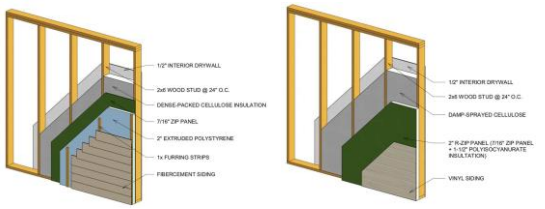
Continuous Thermal Barrier

Wall System



EEHR Designed Wall System

Wall System



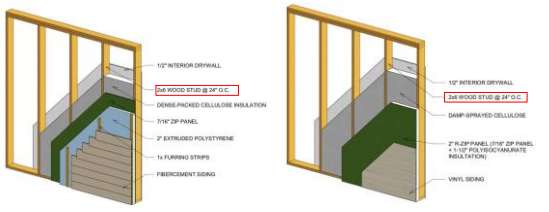
EEHR Designed Wall System

Envinity Designed Wall System

Insulated ZIP Sheathing

GreenBuild Construction (January 3, 2018)

Optimum Value Engineered Framing



EEHR Designed Wall System

Envinity Designed Wall System

OVE Framing

GreenBuild Construction (January 10, 2018)

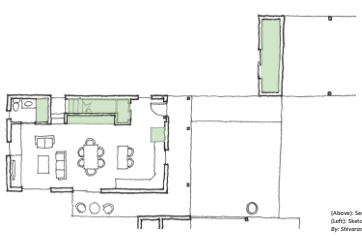
OVE Framing

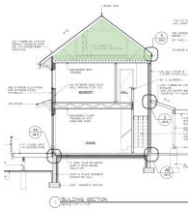
GreenBuild Construction (January 3, 2018)

Systems Integration

GreenBuild Construction (February 8, 2018)

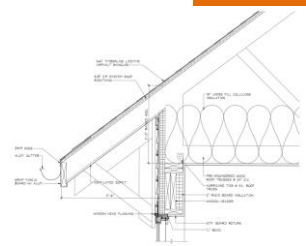
Storage in Small Homes





(Above): Section of GreenBuild *by Enviroty Inc.*
(Left): Sketch of GreenBuild Duplex (2018)
By: Shivaram Punathambekar

Raised Heel Truss

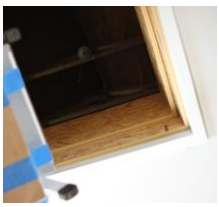


(Above): GreenBuild Construction (January 9, 2018)
(Left): GreenBuild Roof Detail
By: Enviroty Inc.

Raised Heel Truss

GreenBuild Construction (March 1, 2018)

Attic Hatch



GreenBuild Construction (February 12, 2018)

Air-Sealing - Integrated Sheathing

GreenBuild Construction (January 10, 2018)

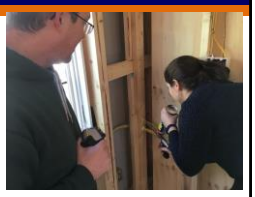
Air-Sealing - Foam Everything!

GreenBuild Construction (February 8, 2018)

Air-Sealing - First Blower Door Test

GreenBuild Construction (February 12, 2018)

Air-Sealing - More Sealing

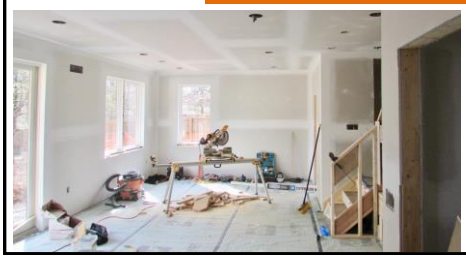


GreenBuild Construction (February 12, 2018)

Cavity Insulation

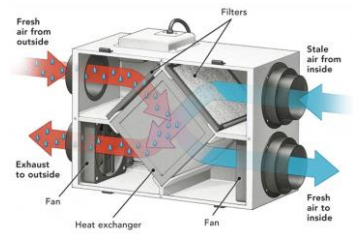
GreenBuild Construction (February 15, 2018)

Drywall Installation



GreenBuild Construction (April 5, 2018)

Fresh Air Ventilator

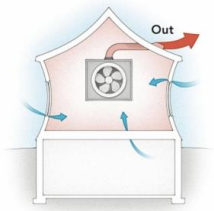


Energy Recovery Ventilator Diagram - *Green Building Advisor*

Ductwork

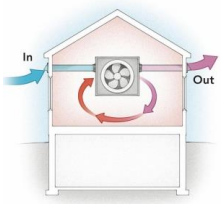
GreenBuild Construction (January 31, 2018)

Exhaust-Only Ventilation



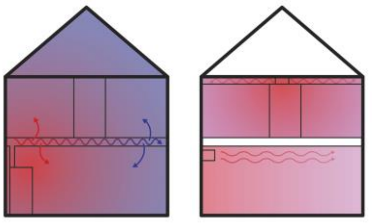
Exhaust Only Ventilation by Green Building Advisor

Balanced Ventilation



Balanced Ventilation by Green Building Advisor

Right-Sized Space Conditioning



High-Load Furnace | Uneven Conditioning| *by ZEMI*

Right-Sized Mini Split | Even Conditioning | *by ZEMI*

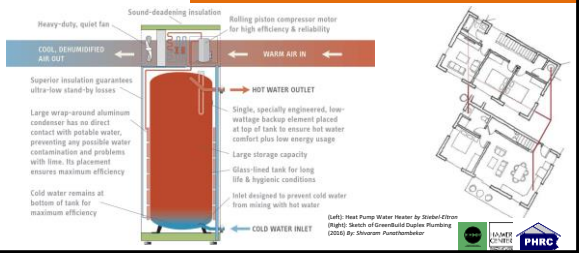
Low-Load Space Conditioning

(Above): Mitsubishi Mini Split Indoor Unit *by Mitsubishi Electric*
(Left): GreenBuild Construction (April 5, 2018)

Low-Load Space Conditioning

GreenBuild Construction (February 12, 2018)

WaterSense Plumbing



(Left): Heat Pump Water Heater *by Stiebel-Eltron*
(Right): Sketch of GreenBuild Duplex Plumbing (2016) *By: Shivaram Punathambekar*

Building Science Report

Building Science Report
(Left) Rendering of GreenBuild (2016) *by EEHR*

Evaluations / Certificate / Questions?

This concludes The American Institute of Architects Continuing Education Systems Course

Link to Certificate:

www.cvent.com/d/75qh9h/4W

This was the last webinar for the 2017-2018 season.

Have a great summer!

Pennsylvania Housing Research Center
206B Sackett Building | University Park, PA 16802
P: 814-865-2341
phrc@psu.edu
www.PHRC.psu.edu