PASSIVEHOUSE AS AN ECOSYSTEM

AN OUTLINE OF CARBON LOADS IN A THREE-PART ECOSYSTEM:

I. PASSIVEHOUSE BUILDING
II. RENEWABLE ENERGY
III. THE SITE

PHILIPPE CAMPUS, AIA
PRINCIPAL, PHILIPPE CAMPUS ARCHITECT LLC

DEFINITIONS AND BACKGROUND

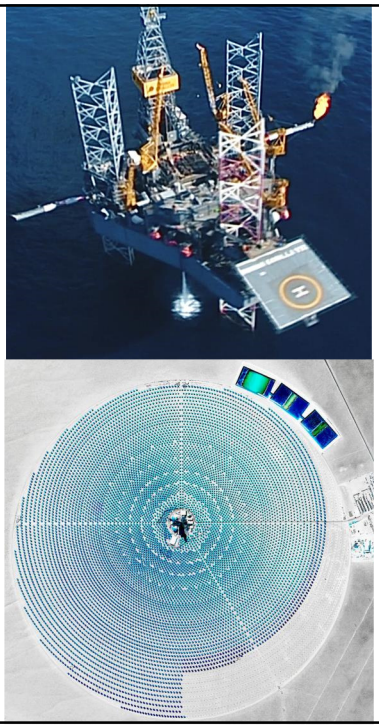
CARBON FOOTPRINT:
The best estimate of the full impact on climate change of a material or action, caused by the release of CO2 in the atmosphere

CARBON TOE-PRINT: a common abuse of the CARBON FOOTPRINT, which misses or hides some, or most of the CO2 emissions caused

DIRECT & INDIRECT CO2 : the CO2 emissions from all the steps, starting at the origin of the material or action

The Concept of Carbon Footprint was created in the early 1980's by:

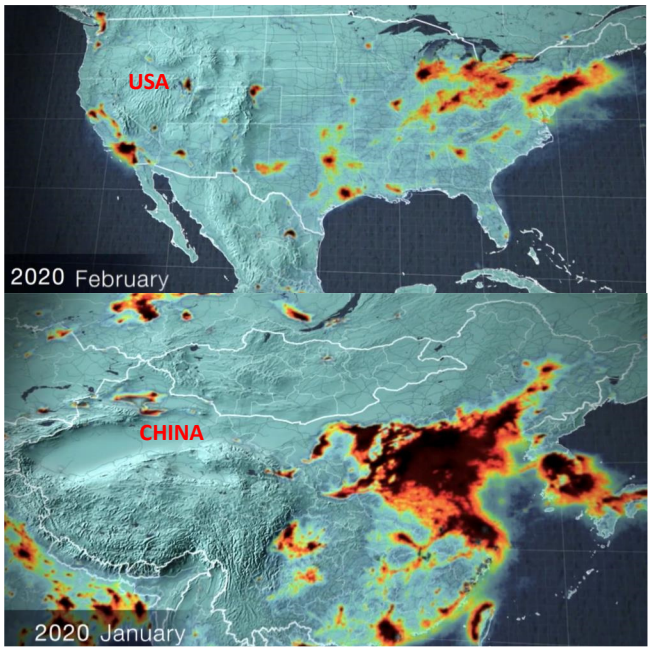
a) Global Footprint Network (footprintnetwork.org), a Swiss NGO
b) The New York Times (national newspaper)
c) William McDonough, architect & author of "Cradle to Cradle"
d) Burger King, the multinational fast food corporation
e) US Department of Energy (DOE.gov)
f) British Petroleum, 2nd largest oil Co. (not state owned)



DEFINITIONS AND BACKGROUND

ECOSYSTEM: (A. G. Tansley 1935)
A functional unit of ecology where organisms interact with each other and the environment they depend on to survive.

CO2 & CO2e:
CO2: a colorless & odorless gas with a GWP of 1
CO2e: (Carbon Dioxide Equivalent) a way to calculate the equivalent amount of Carbon Dioxide for other Greenhouse gases (GHG). Methane (CH4) has a GWP of 21. each ton of CH4 is multiplied by 21 to get the CO2e

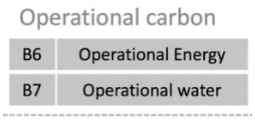


CREDIT: PBS program "a year to change the world" atmospheric NO2 as a CO2 proxy

I. PASSIVEHOUSE BUILDING

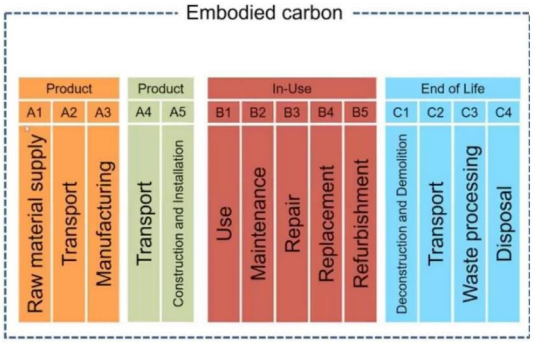
"CRADLE TO GRAVE" CO2 FOOTPRINT ANALYSIS

Embodied CO2 data comes from the 44,000 EPD records, BIM models and estimates in the EC3 database. CO2 factors of Electricity & other fuels, and of End-Of-Life emissions, come from the EPA database

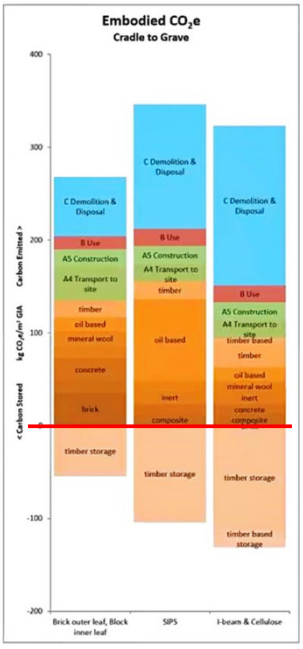


EMBODIED vs OPERATIONAL CO2
Quantifying materials and energy is much less complex than:
- Estimating the impact of users behavior B1 & B2
- Factoring the impact of repairs B3-B5

ADD to the list:
- Renewable energy
- BEV charging at home



CREDIT: The Passivehouse Network



I. PASSIVEHOUSE BUILDING

PASSIVEHOUSE (EMBODIED) CO2

PASSIVEHOUSE ENVELOPE ASSEMBLY

- DOUBLE WALL CAVITY
- FRAMING + EXTERIOR INSULATION
- FRAMING + INTERIOR INSULATION
- ICF + INSULATION LAYER
- FOUNDATIONS
- WINDOWS & DOORS

CONSTRUCTION METHODS

- SITE BUILT
- PANELIZED
- PREFABRICATED

MECHANICAL SYSTEMS

- HVAC EQUIPMENT & DUCTS
- HRV & ERV SYSTEMS
- DOMESTIC HOT WATER & PIPING






I. PASSIVEHOUSE BUILDING

CONSTRUCTION EQUIPMENT CO2, OPERATIONS CO2 and MATERIALS CO2

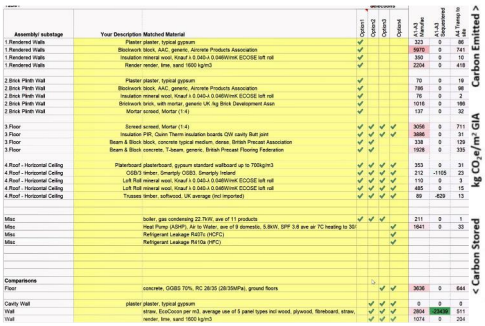


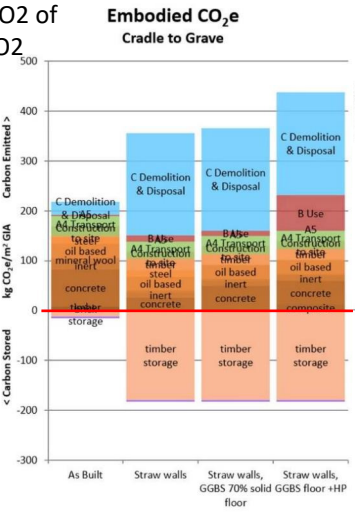

I. PASSIVEHOUSE BUILDING

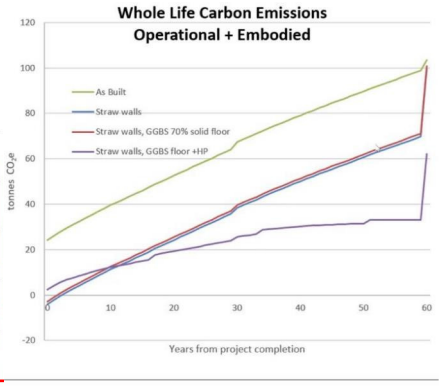
PH RIBBON:

A New Tool for Passivehouses

The Passivehouse Energy Modeling software (PHPP) gains the ability to analyze the CO2 of embodied, operational and end of life CO2 by linking PHPP with the EC3 database







if Operational varies then adjust these cells

Operational	Option 1	Option 2	Option 3	Option 4
Space Heating kWh/m2.a	13.2	13.2	13.2	13.2
Final Energy kWh/m2.a (excl PV)	41.1	41.1	41.1	41.1
tonnes CO_2e (incl PV if any)	74.7	74.7	74.7	25.9
kgCO2e/m² GIA (incl PV if any)	533.5	533.5	533.5	185.3

Embodied	Option 1	Option 2	Option 3	Option 4
All categories, tonnes CO2e A-C	28.7	24.7	26.1	36.1
RIBA kgCO2e/m² GIA	205.2	176.5	186.4	257.6
LETI kgCO2e/m² GIA	205.2	176.5	186.4	228.8

CREDITS: T. Martel & Building Performance Interactive

CARBON REDUCTION STRATEGIES

LOW CARBON/ CARBON SEQUESTRATION

INSULATION:

- MINERAL WOOL-slag * (if 75% recycled content)
- CELLULOSE (up to 85% recycled content)
- STRAW (37-51% of cellulose)
- WOOL & RECYCLED (85%) COTTON
- CORK
- HEMPCRETE

[URETHANE FOAMS]

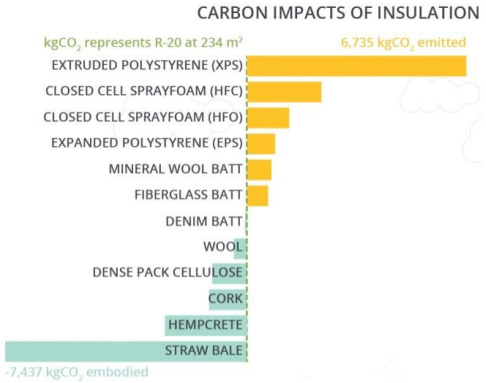
EPS: gwp of 7

XPS: gwp of 1,430

Medium Density Closed Cell Spray Foam with Water as blowing Agent: gwp of 1

Bio-Based (SOY) gwp of 1

(Doesn't include the CO2e of Urethane, Polyiso, etc)



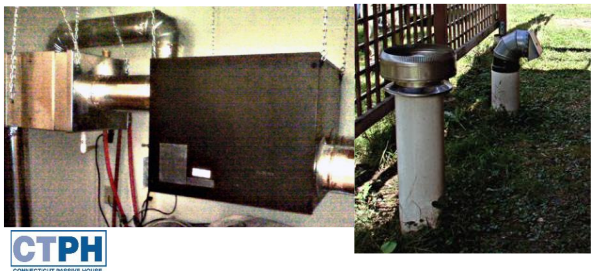
CREDIT: 2030 Inc/Architecture 2030

* Some mineral wool is made with molten rocks

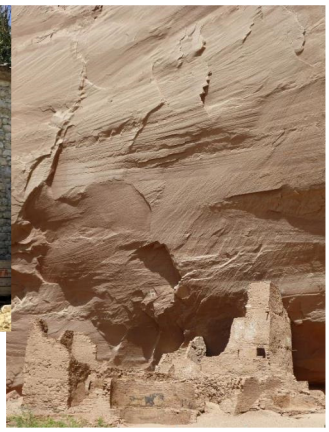
CARBON REDUCTION STRATEGIES

ZERO ENERGY, WITH "ZERO BTU"

DOING A MORE "PASSIVE" PASSIVEHOUSE
WITH THERMAL (MASS) HEAT/COOL STORAGE
TROMBE WALL: MASONRY WALL BEHIND GLASS
ADDING THERMAL MASS TO WALLS & FLOORS
The challenge: absorbing enough energy
PCM (Phase Change Materials)
Pre-Heat & Pre-Cool : Earth Tubes & Ground Loops
Heat exchangers



30" thick 18th century stone walls: night time ventilation cooling (8hr lag time)



Passive solar heat has been used for thousands of years

THE PASSIVE DESIGN EXPERT: EDWARD MAZRIA, 2021 AIA GOLD MEDAL WINNER

CARBON REDUCTION STRATEGIES

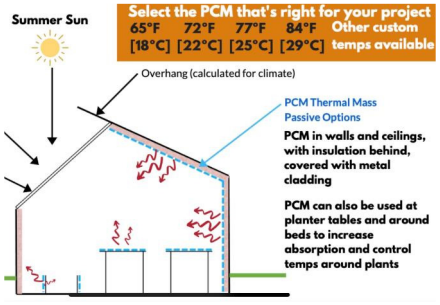
ZERO ENERGY, WITH "ZERO BTU"

DOING A MORE "PASSIVE" PASSIVEHOUSE: EXPERIMENTING WITH PCM (Phase Change Materials)

PANEL MATERIAL: Thermoplastic 20 mil Top & Bottom
PANEL WIDTH: 23.75" OR 16" (603mm or 406mm)
PANEL LENGTH: 23.75" (603mm)
GENERAL PANEL THICKNESS: 0.25" (6.3mm)
MAX CENTER RIDGE THICKNESS: 0.16" (mm)
THERMAL CAPACITY +100btu/sf ; [2,496 J/m2]
PHASE CHANGE MATERIAL Mineral Based/Inorganic
TEMPERATURES 65F(18C), 72F(22C), 77F(25C), 80F(27C)
LATENT HEAT ~86 btu/lb; [~200 j/g]
SPECIFIC HEAT 1.35 btu/lb; [3.14 j/g]
THERMAL CONDUCTIVITY ~0.15 W/ft/K Liquid, ~0.38 W/ft/K Solid
WEIGHT 1.3 lbs/sf [5.7 kg/m2]
FLAMMABILITY ASTM E84|UL723 - CLASS A FIRE RATED
MANUFACTURED: USA - International Patents Pending

4 x 100 btu 12x12 PCM tiles

TEMPLOK PCM Tiles

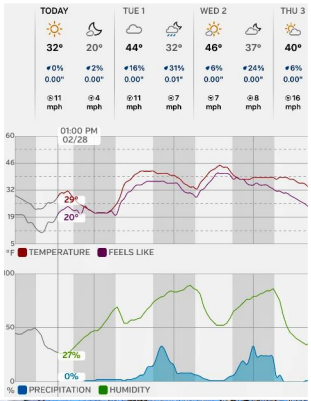


CREDIT: INSOLCORP WEBSITE

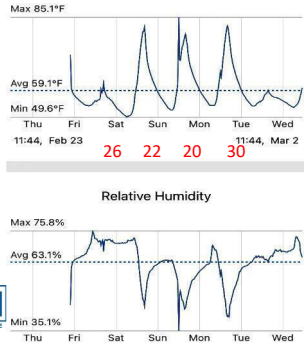
CARBON REDUCTION STRATEGIES

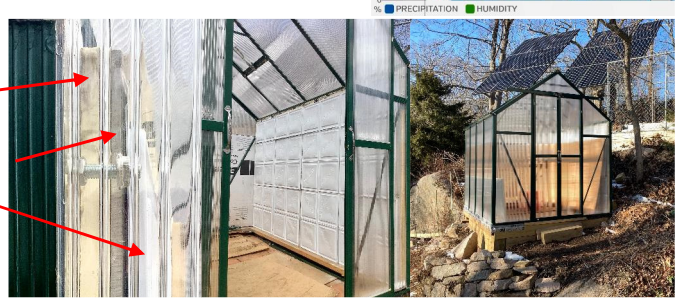
PHASE 1: A MINI SOLAR GREENHOUSE

6'x8' with 5/8" R1.6 double plexiglass
R10.6 North wall (1-1/2" Polyiso)
Ceramic tile floor in sand bed
R7 timber base
40 PCM tiles on cement board (=4,000 BTU)
EXPERIMENTING WITH PCM (Phase Change Materials)



Passive solar heat has been used for thousands of years

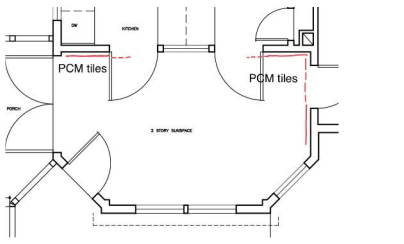




CARBON REDUCTION STRATEGIES

ZERO ENERGY, WITH "PASSIVE BTU"

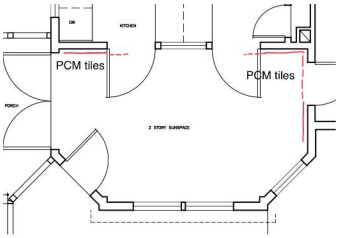
DOING A MORE "PASSIVE" PASSIVEHOUSE
STEP II: 6,800 BTU of PCM Tiles
No heating. 1 Ceiling fan running 24Hs @ low speed

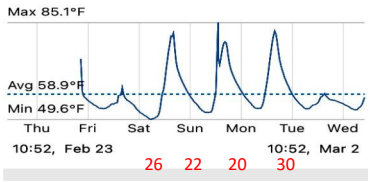


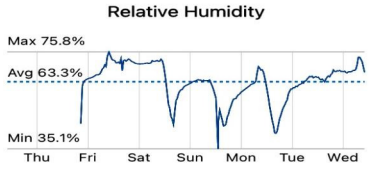
CARBON REDUCTION STRATEGIES

ZERO ENERGY, WITH "PASSIVE BTU"

DOING A MORE "PASSIVE" PASSIVEHOUSE
STEP II: 68 12x12 PCM tiles = 6,800 BTU
No heating. 1 Ceiling fan running 24Hs @ low speed





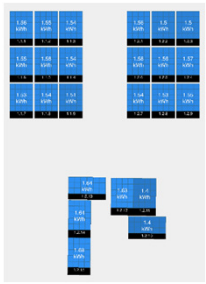


COST: PCM tiles: +/- $250.00 + Labor &
2 (4'x8') sheets of plywood

II. RENEWABLE ENERGY

COMPONENTS:

- SOLAR PHOTOVOLTAIC
- WIND TURBINES
- GEOTHERMAL ENERGY
- SMALL HYDROPOWER TURBINES
- ON-SITE RENEWABLE ENERGY STORAGE



ANALYSIS (system size)

- RULES OF THUMB
- PRIOR DATA (Electrical bills)
- ELECTRIC LOADS (PER)
- FUTURE TREND

SITING & INSTALLATION:

- ON-SITE SOLAR POTENTIAL
- INSTALLATION METHODS

II. RENEWABLE ENERGY

ANALYSIS (system size)

- RULES OF THUMB
- PRIOR DATA (Electrical bills)
- ELECTRIC LOADS (PER)
- FUTURE TRENDS (climate forecast)

BIGGEST ISSUE: UNDERSIZED PV SYSTEMs

- Don't rely on just 1 year of electrical bills
- Look for the highest annual electrical use
- Add 10% (minimum) capacity:
  Climate will get worse & panels loose 10-20% efficiency over 20 years
- Seasonal panel tilt adjustments add 10% in yearly output. (not with roof installation)
- Seasonal shading gets worse over time
- Don't wait! PVs pay you back the next day

		CRITICAL	AMP	Load(kWh)	Hrs/day	kWhr/Day	V
HVAC							
HP		Compress		3.94	6.00	23.64	
		Fan		7.00	6.00	42.00	
		Pump		5.80	6.00	34.80	
HP DWH				1.70	2.00		
ERV				0.08	24.00	1.80	120V
Appliances							
Refr-Freezr				0.08	24.00	1.90	120V
Refr bsmt				0.04	24.00	1.07	120V
Wine Cab				0.04	24.00	0.85	120V
Induction top			40A			240V	
Hair Dryer				1.50	0.30	0.45	120V
Hood				0.40	0.30	0.12	120V
Lights		1st flr		0.35	3.50	1.23	120V
		2nd flr		0.35	3.00	1.05	120V
Plug loads				0.30	6.00	1.80	120V
AV loads			15A	0.50	2.25	1.13	120V
Telcom			15A			120V	
Cptr				0.05	3.00	0.15	120V
		Generator size		22.12		111.98	
		Optional					

Simple PV Sizing Worksheet

1: CALCULATE DAILY LOAD

Description	Qty.	×	Watts	×	Hours	=	Load (Wh / Day)
DC lamps	4		15		5		300
DC fan	1		30		5		150
DC TV	1		50		3		150
					Total		600

2: CALCULATE TOTAL BATTERY STORAGE NEEDED

Load (Wh / Day)	×	Days Storage	÷	Depth of Discharge	=	Total Capacity Needed (Wh)
600		3		50%		3,600

3: CALCULATE INDIVIDUAL BATTERY STORAGE

Battery Voltage	×	Battery Ah Rating	=	Capacity (Wh)
12		100		1,200

4: CALCULATE QUANTITY OF 12 VOLT BATTERIES NEEDED

Capacity Needed (Wh)	÷	Battery Capacity (Wh)	=	Total Number Batteries
3,600		1,200		3

5: CALCULATE TOTAL ARRAY SIZE

Total Load (Wh / Day)	÷	Insolation (Sun Hrs. / Day)	=	Power Needed (W)	÷	Efficiency (Rating Factor	=	Array Size (W)
600		5		120		65%		185

6: CALCULATE QUANTITY OF PV MODULES NEEDED

Array Size (W)	÷	Module Size (W)	=	Quantity Modules
185		60		3

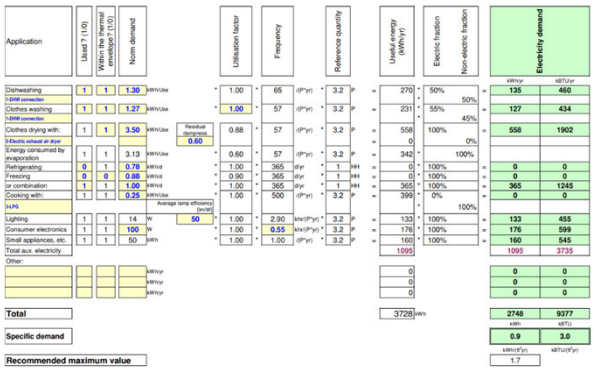
This sizing method assumes an MPPT charge controller is used.

CREDIT: I Woofenden Home Power Mag

II. RENEWABLE ENERGY

PASSIVEHOUSE ANALYSIS: PER

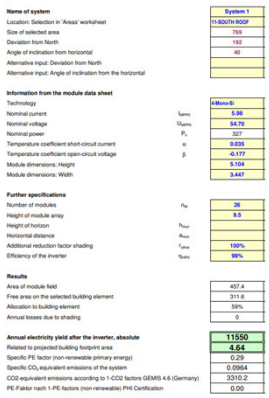
- ELECTRIC LOADS
- PV SYSTEM PRODUCTION
- **P**RIMARY **E**NERGY **R**ENEWABLE - ANALYSIS



Application	Used ? (1/0)	Within the thermal envelope? (1/0)	Nom. demand		Utilisation factor	Frequency		Reference quantity		Useful energy (kWh/yr)	Electric fraction	Non-electric fraction	Electricity demand kWh/yr	Electricity demand kBTU/yr
Dishwashing	1	1	1.30	kWh/Use	1.00	65	d/(P*yr)	3.2	P	270	50%	50%	135	460
↳ DHW connection														
Clothes washing	1	1	1.27	kWh/Use	1.00	57	d/(P*yr)	3.2	P	231	55%	45%	127	434
↳ DHW connection														
Clothes drying with:	1	1	3.50	kWh/Use	0.88	57	d/(P*yr)	3.2	P	558	100%	0%	558	1902
↳ Electric exhaust air dryer				Residual dampness 0.60										
Energy consumed by evaporation	1	1	3.13	kWh/Use	0.60	57	d/(P*yr)	3.2	P	342	100%			
Refrigerating	0	1	0.78	kWh/d	1.00	365	d/yr	1	HH	0	100%		0	0
Freezing	0	0	0.88	kWh/d	0.90	365	d/yr	1	HH	0	100%		0	0
or combination	1	1	1.00	kWh/d	1.00	365	d/yr	1	HH	365	100%		365	1245
Cooking with:	1	1	0.25	kWh/Use	1.00	500	d/(P*yr)	3.2	P	399	0%	100%	0	0
↳ LPG				Average lamp efficiency [lm/W]										
Lighting	1	1	14	W	50	1.00	2.90	kHr/(P*yr)	3.2	P	133	100%	133	455
Consumer electronics	1	1	100	W		1.00	0.55	kHr/(P*yr)	3.2	P	176	100%	176	599
Small appliances, etc.	1	1	50	kWh		1.00	1.00	d/(P*yr)	3.2	P	160	100%	160	545
Total aux. electricity													1095	3735
Other:				kWh/yr										
				kWh/yr									0	0
				kWh/yr									0	0
													0	0
Total										3728	kWh		2748	9377
Specific demand													0.9	3.0
Recommended maximum value													1.7	

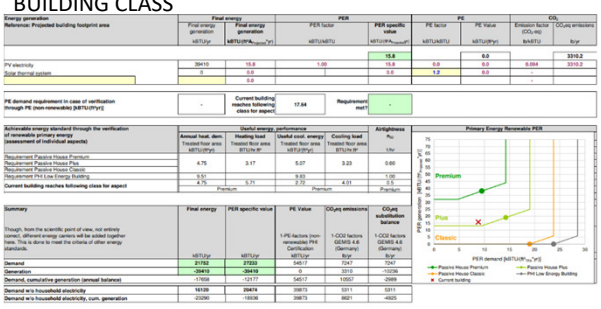
1- ELECTRIC LOADS

2- PV SYSTEM SIZE & ANNUAL OUTPUT

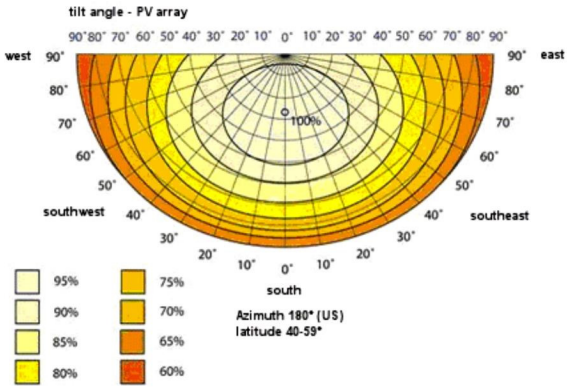


Name of system		System 1
Location: Selection in 'Areas' worksheet		11-SOUTH ROOF
Size of selected area		769
Deviation from North		192
Angle of inclination from horizontal		40
Alternative input: Deviation from North		
Alternative input: Angle of inclination from the horizontal		
Information from the module data sheet		
Technology		c-Mono-Si
Nominal current	I_{MPP}	5.58
Nominal voltage	U_{MPP}	54.70
Nominal power	P_N	327
Temperature coefficient short-circuit current	α	0.035
Temperature coefficient open-circuit voltage	β	-0.177
Module dimensions: Height		5.104
Module dimensions: Width		3.447
Further specifications		
Number of modules	n_M	26
Height of module array		9.5
Height of horizon	h_{Hori}	
Horizontal distance	A_{Hori}	
Additional reduction factor shading	r_{Shad}	100%
Efficiency of the inverter	η_{Inv}	98%
Results		
Area of module field		457.4
Free area on the selected building element		311.6
Allocation to building element		59%
Annual losses due to shading		0
Annual electricity yield after the inverter, absolute		11550
Related to projected building footprint area		4.64
Specific PE factor (non-renewable primary energy)		0.29
Specific CO_2 equivalent emissions of the system		0.0964
CO_2-equivalent emissions according to 1-CO2 factors GEMIS 4.6 (Germany)		3310.2
PE-Faktor nach 1-PE-factors (non-renewable) PHI Certification		0.00

3- PER: DETERMINES BUILDING CLASS



II. RENEWABLE ENERGY



SITING & INSTALLATION:

- ON-SITE SOLAR POTENTIAL

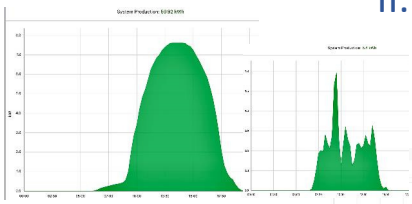
Orientation and shading

- INSTALLTION METHODS

Ground, Pole or Roof mount

CTPH
CONNECTICUT PASSIVE HOUSE

8.28 Kw PV System



ANNUAL SOLAR ENERGY

2016: 7.96 MWh

2017: 7.49 MWh

2018: 7.15 MWh

2019: 7.58 MWh

2020: 7.50 MWh

Average: 7.54MWh

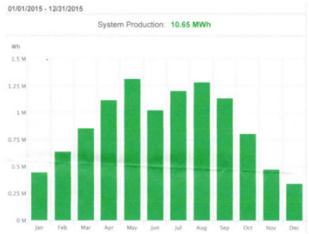
(628KWh/Month)

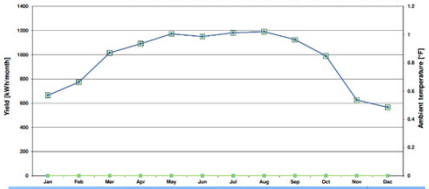
CTPH
CONNECTICUT PASSIVE HOUSE

II. RENEWABLE ENERGY

2 cases: Enerphit (in progress) & Certified Passivehouse

8.51 Kw PV System





II. RENEWABLE ENERGY

PV ENERGY STORAGE/OFF-GRID OPTIONS

BACK UP GENERATOR VS BATTERY STORAGE

LP GENERATORS
- NOISY
- INNEFFICIENT (30%)
- SLOW TRANSFER (everything shuts down & restarts)
- NEED OWN FUEL SOURCE
- USES ENERGY TO SELF TEST (17 hrs/yr)
- ANNUAL MAINTENANCE

LITHIUM BATTERY BACKUP
- SEAMLESS TRANSFER
- DAILY POWER STORAGE & USE
- SAVES 1.7 Kw FOR EACH 1 Kw STORED
- INTEGRATES WITH RENEWABLE ENERGY
- NO OPERATIONAL C02
- LOCATED INDOORS (protected)
- EXPANDABLE (add modules)

III. THE SITE

THE TREES, THE GRASS, THE BIRDS, THE INSECTS, THE BACTERIA AND THE LAWN MOWER

Trees: 20% leaves & stems, 60% trunk & 20% roots
CO2 Potential of mature trees: 48 Lbs. of CO2 per year, (after 30 years of growth) For every cut tree = 1,440 lbs. loss of CO2, if replanted.
Grass & Plants CO2 potential: Organic lawn: 0.01 lbs./SF/Yr. 10,000 SF = 100 lbs/yr
Native wild grasses & plants: 0.025 lbs./SF/Yr. (=250 lbs/yr)
Living Soil: a teaspoon of healthy soil contains 100 million to a billion of bacteria (recycle nutrients & decompose organic matter)

CREDIT: PBS program "a year to change the world"

More than CO2: trees reduce erosion, absorb 25% or rainfall, slow down high winds, reduce soil evaporation, shelter the majority of wild animals and plants, and provide some foods and medications.
If carbon input is greater than the output, the surplus is converted to biomass through biosynthesis

CREDIT: PBS program "a year to change the world"

85 mi/hr Shear winds, August 28, 2020. 50' tall maple tree

III. THE SITE

+ ASSESSING THE SITE CO2 REDUCTION POTENTIAL

of Mature trees & age
Groundcover types & condition
Types of subsoil (clay, sand, rocks) & impact on building siting
Health of soils
Drainage & erosion issues
Prevailing Wind speed & directions
Solar orientation
Research weather related risks (high winds, floods, landslide, lightning…)

- OPERATIONAL CO2 (&CO2e) FORM SITEWORK

Site preparation: Tree cutting, stumps removal, brush clearing
[tip: shred everything vegetal for later mulching]
Earthwork, including stockpiling
[tip: reuse everything, remove only if no other option]
Erosion control & protection of remaining natural assets
Site restoration & Biodynamic landscaping
[tip: maximize CO2 reduction w solar orientation, using native plants, using rain gardens, & minimizing maintenance]

III. THE SITE USE & MAINTENANCE

SYNTHETIC FERTILIZERS

Typ use: 25 lbs. for 5000 SF grass, 4 - 6 times/ Yr
Sulfur is the only fertilizer which is a by-product of petroleum extraction.
Most fertilizers today are mined and processed
Nitrogen uses the most energy: 25 lbs bag = 68 lbs of CO2

SYNTHETIC PESTICIDES

The US uses 1 Billion lbs. of synthetic pesticides a year in gardens, parks, homes and farms.
Persistent pesticides kill beneficial soil organisms, contaminate water, cause severe reactions in people and some are known carcinogens

LIVING YARD

- Food for wildlife & insects
- Many wildlife habitats
- Shelter and hiding places
- Rich in organic fertilizer
- Natural rain & erosion control
- Acts as Carbon Sink

MOWED, STERILE & HOSTILE

- No food for wildlife & insects
- No refuge for wildlife
- No hiding from predators
- No organic matter as fertilizer
- No shelter from rain, snow
- No erosion mitigation
- Large release of CO2 from use

III. THE SITE USE & MAINTENANCE

SITEWORK CO2

SITE PREPARATION:

CUT 10 MATURE TREES (16" dia):	14,400 lbs
(no bucket lift & chainsaws CO2)	
6 TREES NOT REPLANTED: (48x10x6)	2,900 lbs
BRUSH CLEARING 5,000 SF:	125 lbs
Credit for 100% mulching (128x0.5x6x0.44)	-165 lbs
TOTAL:	17,300 lbs

CO2 (&CO2e) FROM YARD MAINTENANCE

Mower (riding): 19 lbs. CO2/ Hr
Mower (self propelled): 8.5 lbs. CO2/ Hr
Mower (push): 5.2 lbs. CO2/ Hr
Leaf blower: 4.5 lbs. CO2/Hr

THE WORKS:

Mowing an average US lawn:
10,700 SF (1/4 Acre) +/- 45 min (16 Hrs/Yr.
Leaf blowing: 7 Hrs/ Yr.

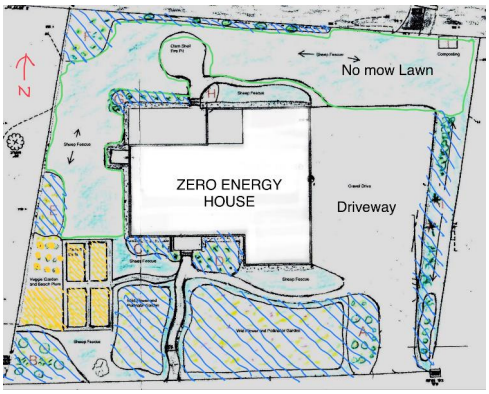
EXAMPLE: Yearly CO2 for 10,000 Sf lawn, paved driveway, composite decks, PVC fences

Fertilizing program: (4x)	240 lbs
Pesticides (est) (3x)	90 lbs
Mower (riding):	130 lbs
Trimmer & leaf blower	45 lbs
Pressure wash deck, driveway	15 lbs
TOTAL:	520 lbs CO2/Yr

III. THE SITE USE & MAINTENANCE

PLANNING A NATURAL GARDEN FROM SCRATCH

Alicia & Bill Freeman's property



THANK YOU

CTPH
CONNECTICUT PASSIVE HOUSE