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NORTHEAST SUSTAINABLE ENERGY ASSOCIATION

Carbon and Energy in Efficient Building Envelopes: A Comparative Case Study in Life Cycle Phases

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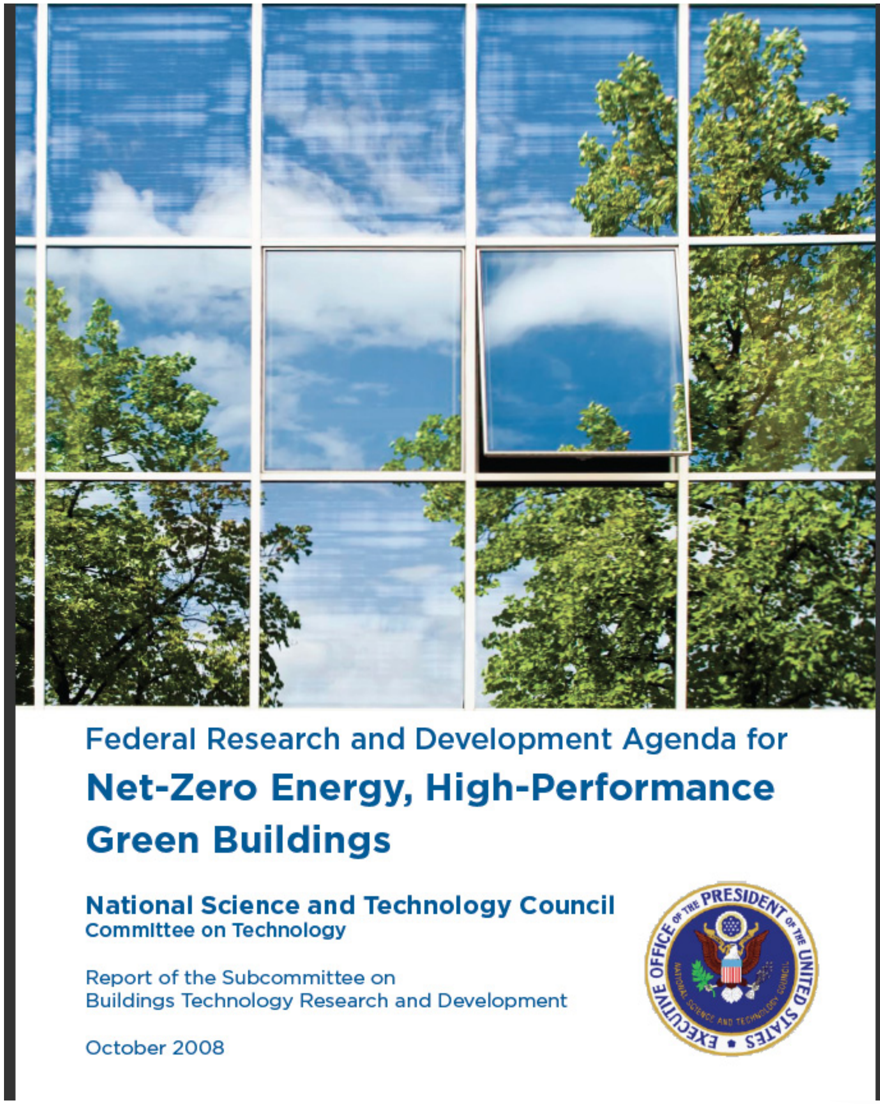
CONTEXT



Federal Research and Development Agenda for

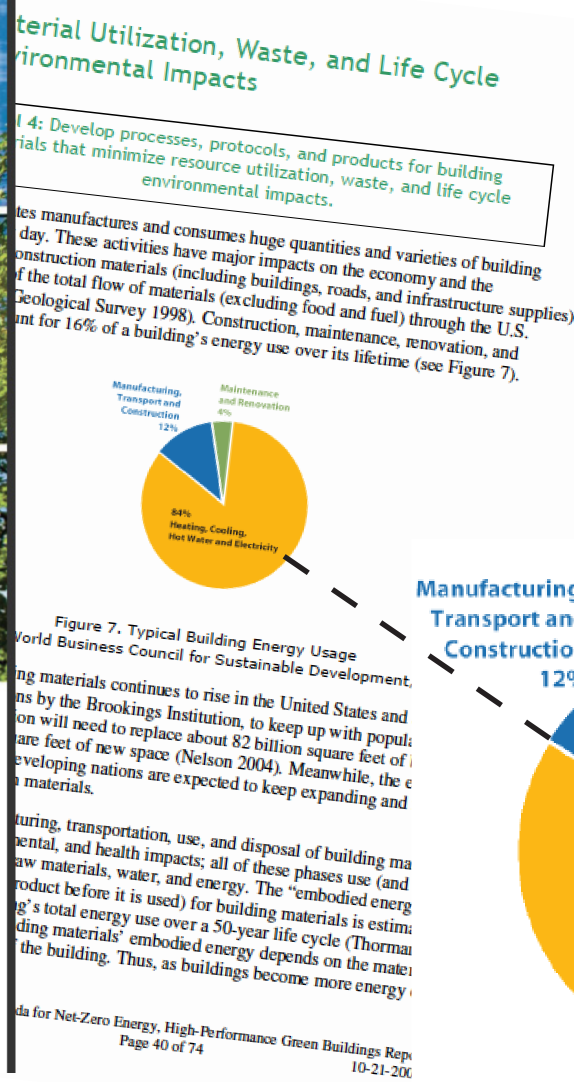
Net-Zero Energy, High-Performance Green Buildings

National Science and Technology Council

Committee on Technology

Report of the Subcommittee on
Buildings Technology Research and Development

October 2008



terial Utilization, Waste, and Life Cycle
vironmental Impacts

l 4: Develop processes, protocols, and products for building
rials that minimize resource utilization, waste, and life cycle
environmental impacts.

tes manufactures and consumes huge quantities and varieties of building
day. These activities have major impacts on the economy and the
onstruction materials (including buildings, roads, and infrastructure supplies)
f the total flow of materials (excluding food and fuel) through the U.S.
Geological Survey 1998). Construction, maintenance, renovation, and
unt for 16% of a building's energy use over its lifetime (see Figure 7).

Figure 7. Typical Building Energy Usage
Vorld Business Council for Sustainable Development,

ng materials continues to rise in the United States and
ns by the Brookings Institution, to keep up with popul
on will need to replace about 82 billion square feet of
are feet of new space (Nelson 2004). Meanwhile, the e
eveloping nations are expected to keep expanding and
materials.

turing, transportation, use, and disposal of building ma
ental, and health impacts; all of these phases use (and
aw materials, water, and energy. The "embodied energ
roduct before it is used) for building materials is estim
g's total energy use over a 50-year life cycle (Thomas
ding materials' embodied energy depends on the mate
the building. Thus, as buildings become more energy

da for Net-Zero Energy, High-Performance Green Buildings Rep
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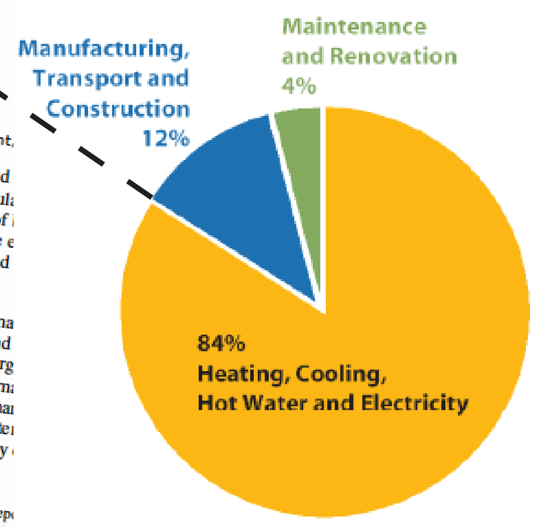
10-21-20



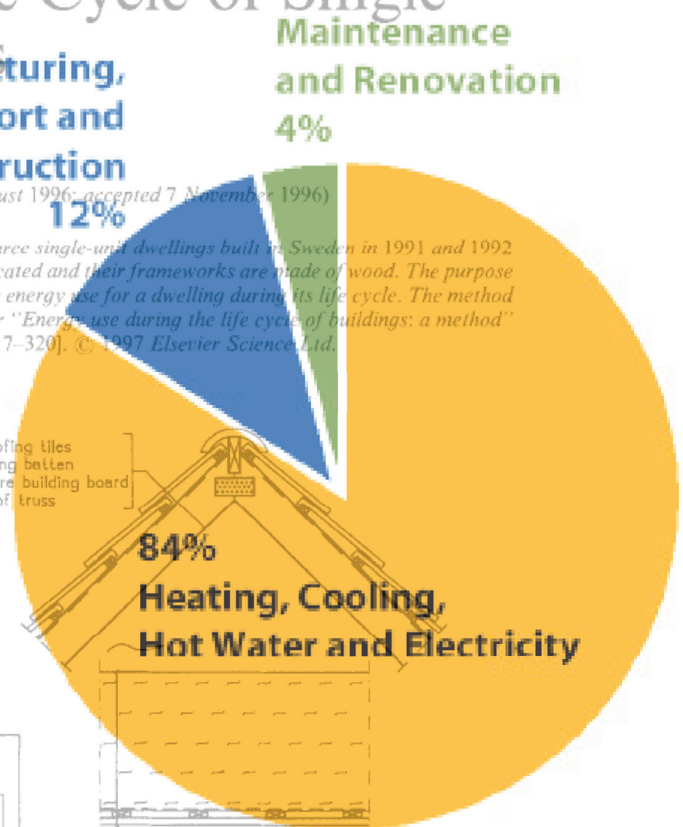
CONTEXT

Energy use during the Life Cycle of Single-Unit Dwellings: Examples

K. ADALBERTH*

(*Received* 14 *May* 1996; *revised* 28 *August* 1996; *accepted* 7 *November* 1996)

The energy use during the life cycle of three single-unit dwellings built in Sweden in 1991 and 1992 is presented. These houses were prefabricated and their frameworks are made of wood. The purpose of this study is to gain an insight into the energy use for a dwelling during its life cycle. The method used is described in the companion paper "Energy use during the life cycle of buildings: a method" [Building and Environment, 1997, 32, 317–320]. © 1997 Elsevier Science Ltd.



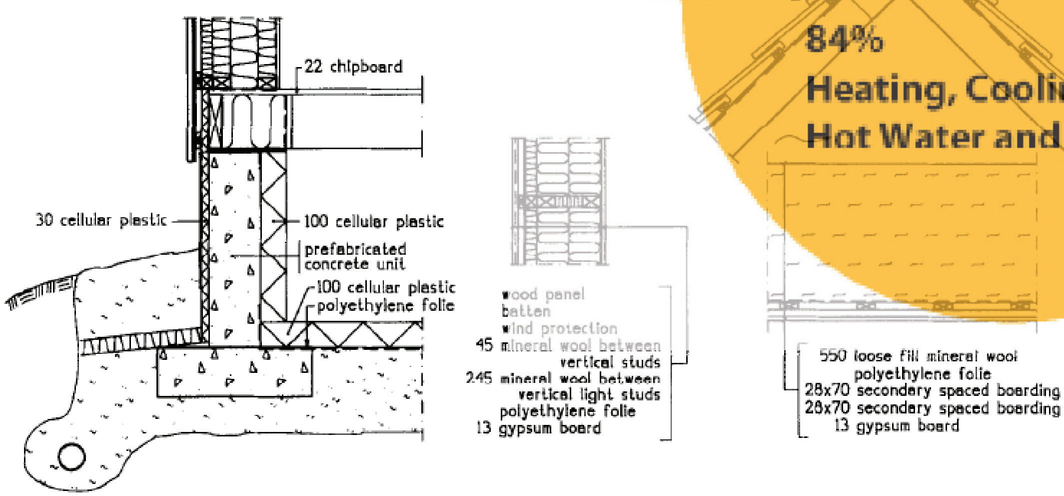
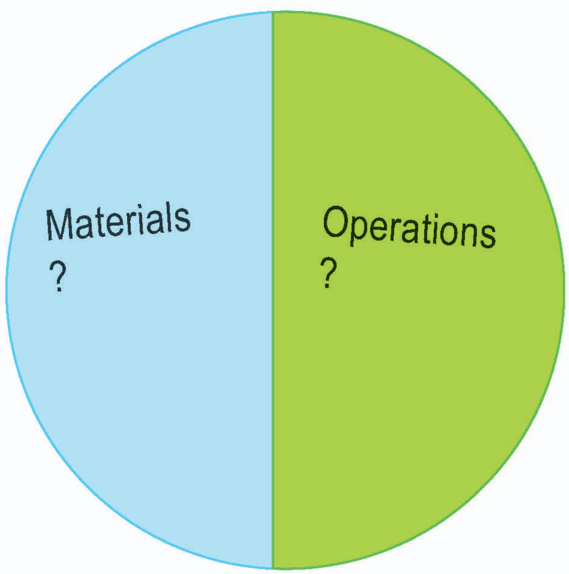


Fig. 2. Different constructions: foundation, external walls and roof in house 1. All measurements in the figure are in mm.

CONTEXT

Total Lifecycle ~~Energy Use~~ carbon emissions in Buildings

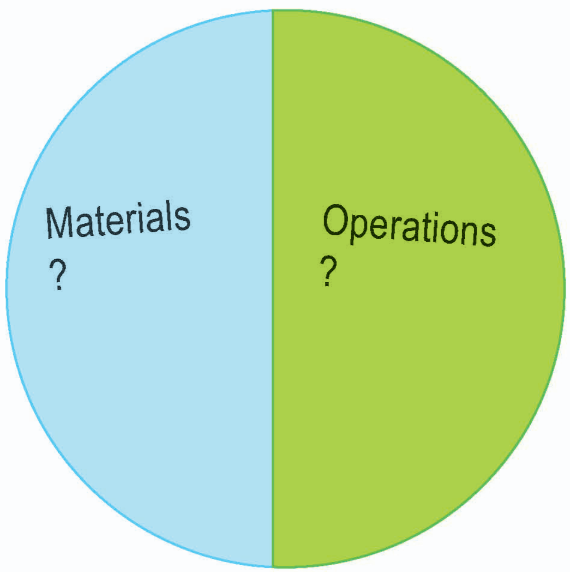


Variable 1: What is the grid energy mix? What if it is low on fossil fuels?

CONTEXT

carbon emissions

Total Lifecycle ~~Energy Use~~ in Buildings



Variable 2: What if this is a highly efficient building (high-performance envelope, equipment)?

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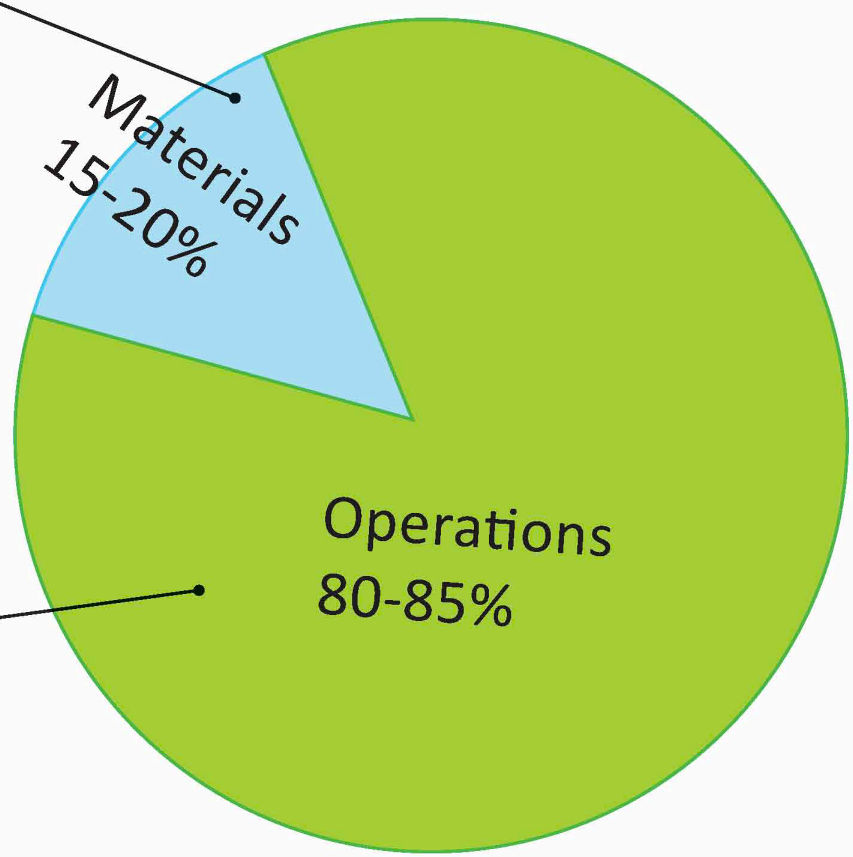
CONTEXT

carbon emissions

Total Lifecycle ~~Energy Use~~ in Buildings

If this were a car, this would be the energy to make the car in the first place



and this would be the energy to drive the car for its entire life.

STUDY

Question: Is it worth it to upgrade the envelope of this building? I.e., do the operations savings exceed the additional material investment (measured in energy and CO_2-equivalents)?

STUDY


TWO OTHERWISE IDENTICAL MULTI-FAMILY APARTMENT BUILDINGS. ONE DESIGNED TO THE PASSIVE HOUSE STANDARD, THE OTHER DESIGNED TO THE EARTH ADVANTAGE STANDARD.

STUDY

Primary Question

Is the Stellar Apartment Passive House Upgrade worth from an environmental impact point of view?

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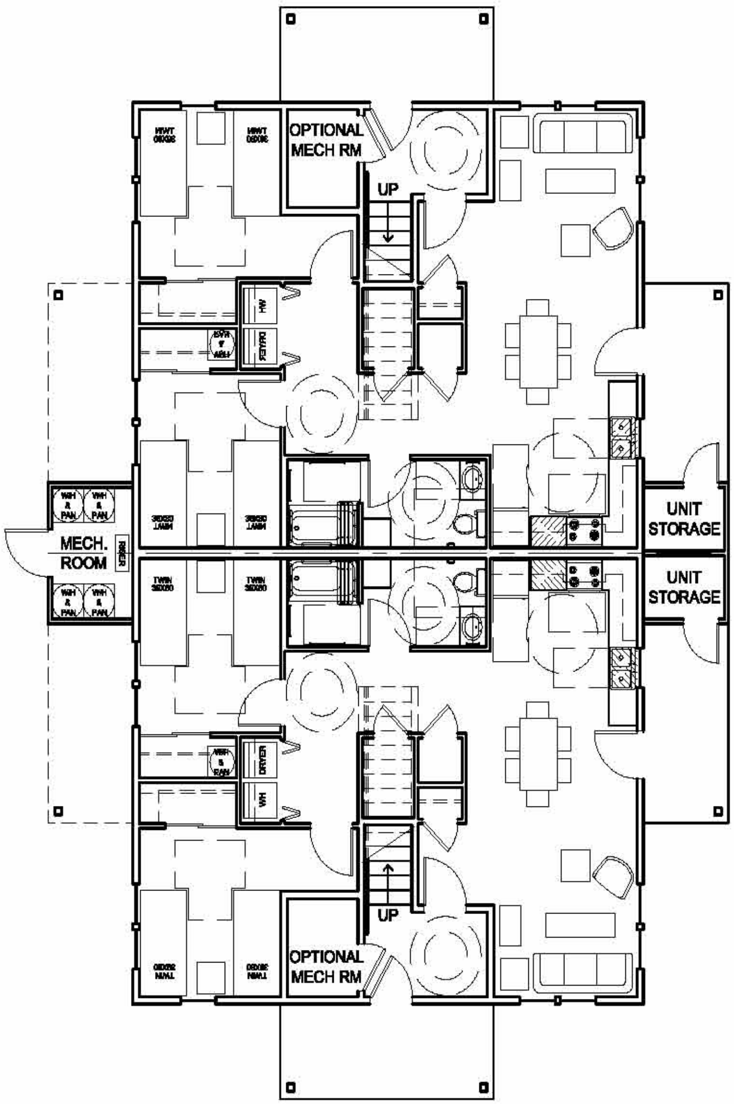
STUDY

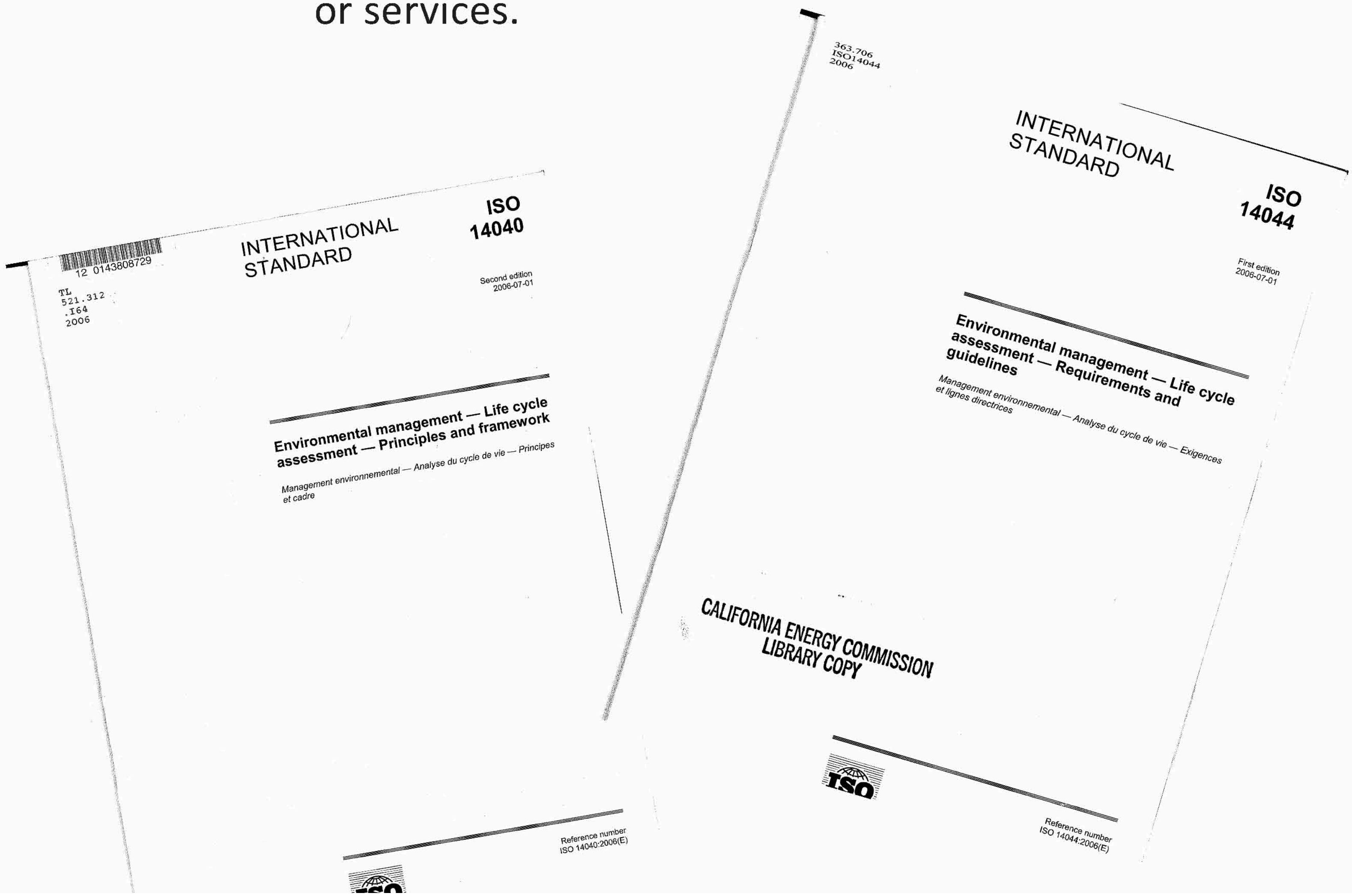


drawings from Bergsund Delaney

CONTEXT

STUDY

As defined by the International Organization of Standards, a life cycle assessment is a very specific set of steps for estimating the potential environmental impact of products or services.



STUDY

	A	B	C	D	E	F	G	H	I	J	K	L
1	RAINETTE VERTE											
2	MATERIAL TAKEOFFS											
3												
4	SP	ATH	BLD-IT	BEES	SM	filled when data in row has been imputed into respective program						
5				NA								
6	MATERIAL					COMPONENT	QUANTITY / DIMENTIONS	VOLUME (cu.m.)	DENSITY COEFFICIENT (kg/cu.m.)	MASS (kg)	END-OF-LIFE PROCESS, SM	NOTE
7	Concrete											assume a
8						Footing (4)	4 @ 1.07 cu.m.	4.28000	2403	10284.8		like stated
9						Pad Below Cistern - no. 6 conc.	1 @ 130 x 30 x 30cm	0.11700	2403	281.2		
10						Steps	1 @ 65 x 130 x 50cm w/ cutout	0.32500	2403	781.0		assume s
11			4.9720		11948		1 @ 65 x 100 x 50cm w/ cutout	0.25000	2403	600.8	landfilled	
12	Steel Framing											mass: (74
13						Tube Steel, 200mm x 100mm x 4mm	8 @ 460cm	0.08832	7740	683.6		all steel p
14							4 @ 360cm	0.03456	7740	267.5		all tube st
15							4 @ 240cm	0.02304	7740	178.3		
16							2 @ 195cm	0.00936	7740	72.4		
17							8 @ 110cm	0.01968	7740	152.3		
18					1393.2		2 @ 105cm	0.00504	7740	39.0		
19						Steel Framing Tab	28 @ 4mm x 12cm	0.00004	7740	0.3		
20						Tube Steel @ Roof, 50mm x 50mm x 6mm	4 @ 453cm	0.02020	7740	156.3		
21							5 @ 252.5cm	0.01452	7740	112.4		
22				335.7			5 @ 151.4cm	0.00865	7740	67.0		
23				28.2		Steel Bar Legs, 50mm x 50mm x solid	4 @ 36cm	0.00360	7740	27.9		check len
24				1755.6		Steel Tube Deck Support	864 linear cm x 4 square cm	0.00346	7740	26.7	"recycling" - dummy process	sizes in d
25	Small Steel Hardware											
26						Screws (Wood to Steel)	8mm welded stud or self-tapping screws @ 30cm o.c.		7740	0.0		too difficu
27					not included	Nails			7850	0.0	NA	too difficu
28						Coat Hooks, 10mm Steel Rod	5 @ 7.5cm	0.00003	7850	0.2	"recycling" - dummy process	rolled ste
29	Other Steel Parts											
30						Steel Roof Gutter	.875cm x 65.5cm x 480 linear cm	0.02407	7740	186.3		3, a4.1
31						Secondary Roof Scupper	.875cm x 24.25cm x 497 linear cm	0.01055	7740	81.6		4, a4.2
32				401.7		Roof Panel Clip @ Ends of Lexan	4 @ 480 linear cm	0.01728	7740	133.7		3-4, a4.1;
33						Plate Steel Floor, 5mm	1.46 square meters	0.00730	7740	56.5	"recycling" - dummy process	note a4.2
34					not included	Sink (Stainless)			7740	0.0	NA	spec shee
35						6" Diam. Stainless Steel Flue	16 guage @ 390 linear cm.	0.00299	7740	23.1		
36						Flue to Frame Steel Strap	3cm x 87cm x 6mm	0.00016	7740	1.2	"recycling" - dummy process	
37						Flue Cap						unable to
38					not included	Stove Combustion Air Intake					NA	1, a2.4
39				167.34		Stove - Steel	spec. sheet	na	na	143.0	"recycling" - dummy process	
40	Paint											not able t
41						Exposed Steel	Black					
42						Plywd. Floor/Ceiling - Water-based Polyurathane						
43						Veneer Plywd. Desk - Matte Black	50 square cm					www.devi
44					not included	Veneer Plywd. Vanity - Foam					NA	www.devi
45	Veneer Plywood											differing d
46						Flooring, 23mm	7.9 square meters	0.18160	600	109.0		note on a
47			0.2079	124.7		Substrait Below Stl. Plate, 18mm	1.46 square meters	0.02628	600	15.8		subtract n
48						Desk	2 @ 240cm x 44cm x 2cm	0.02112	600	12.7		dims aver
49						Bench Base	55cm x 185cm x 2cm	0.02035	600	12.2		
50						Bed Frame	72cm x 185cm x 2cm	0.03996	600	24.0		
51						Countertop, 4cm	0.1748 square meters	0.00699	600	4.2		
52			0.0926	55.6		Backsplash, 4cm	9.4cm deep, 112 cm long	0.00420	600	2.5		
53			0.5249		0.5	Veneer Plywood Ceiling, 12mm	2 layers @ 9.35 square meters	0.22440	600	134.6	municipal incinerator	
54	Wood											
55						Deck Planks, 5.08cm x 9cm	8 @ 163cm	0.05960	380	22.6		

Life Cycle Assessment (LCA) can help translate

→

materials and energy (inputs) to itemized processes and associated impacts (using industry aggregated data).

STUDY

MODEL

- SimaPro
- Life cycle inventory data mostly from EcoInvent databases
- Modeling our replacement schedule and data point choices after the 2012 Oregon Department of Environmental Quality study "A Life Cycle Approach to Prioritizing Methods of Preventing Waste from the Residential Construction Sector in the State of Oregon" that was conducted by Quantis.

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STUDY

Earth Advantage

Hybrid Prescriptive- and Performance-based Standard

• 10-15% increase in energy performance beyond code (by modeling)

Passive House

Strict Performance-Based Standard

• Highly insulated, airtight building shell

• Very Low Annual heat requirement

• Very Low Primary Energy Use

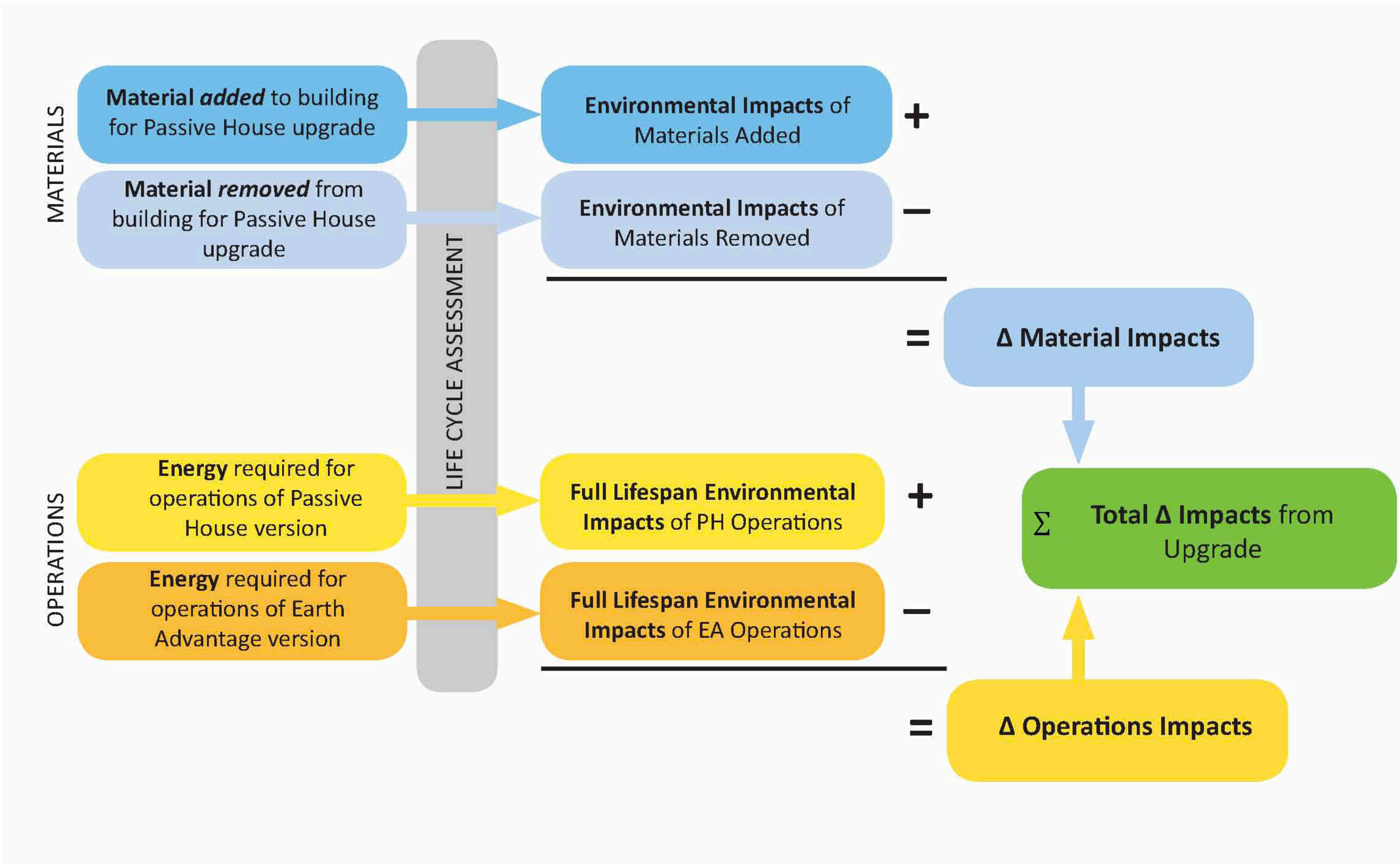
$\leq$ 120 kWh/m^2/year (38.1 kBtu/sf/yr)

STUDY

Primary Question

Is the Stellar Apartment Passive House Upgrade worth it from an environmental impact point of view?

STUDY


MATERIALS
Material *added* to building for Passive House upgrade
Material *removed* from building for Passive House upgrade
LIFE CYCLE ASSESSMENT
Environmental Impacts of Materials Added
+
Environmental Impacts of Materials Removed
–
=
Δ Material Impacts
OPERATIONS
Energy required for operations of Passive House version
Energy required for operations of Earth Advantage version
Full Lifespan Environmental Impacts of PH Operations
+
Full Lifespan Environmental Impacts of EA Operations
–
=
Δ Operations Impacts
∑ Total Δ Impacts from Upgrade

STUDY

parts removed

16" Blown-in Fiberglass Insulation in Attic, R-49

"Intermediate Framing"

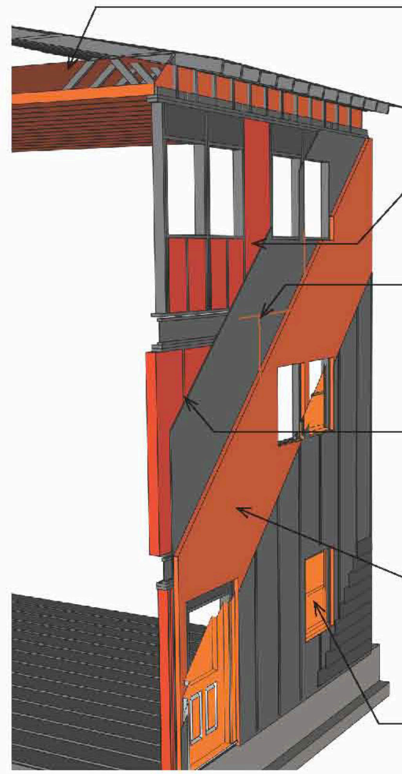
Insulated window and door headers with EPS Type IX rigid foam

2x6 wood stud framing, 16" o.c.

R-21 Fiberglass Batt Insulation in Walls

Double Glazed, Low-e, Argon-Filled, Vinyl-frame Windows

parts added



20" Mineral Wool Insulation in Attic, R-73.2

"Advanced Framing" 2x6 wood stud framing, 24" o.c.

SIGA Air-Sealing Tape at Plywood Sheathing Joints

5.5 inches Blown-in Fiberglass Insulation in Stud Wall Cavity

2.5 in. of Exterior Polyisocyanurate Rigid Foam Insulation

Double Glazed, Low-e, Argon-Filled 'Heat Mirror' Windows

Envelope

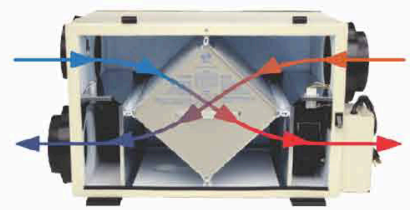
STUDY

parts removed

Trickle Vents to Supply Make-Up Ventilation Air

Electrical Resistance Wall Heaters

parts added



Heat Recovery Ventilators (HRV)

Duct work from HRVs to individual rooms

Electrical Resistance In-line Duct Heaters

Mechanical

STUDY

The additional materials will be responsible for emitting

50 MT CO_2e

as a result of the Passive House Upgrade.

STUDY

The additional materials will be responsible for emitting

50 MT CO_2e

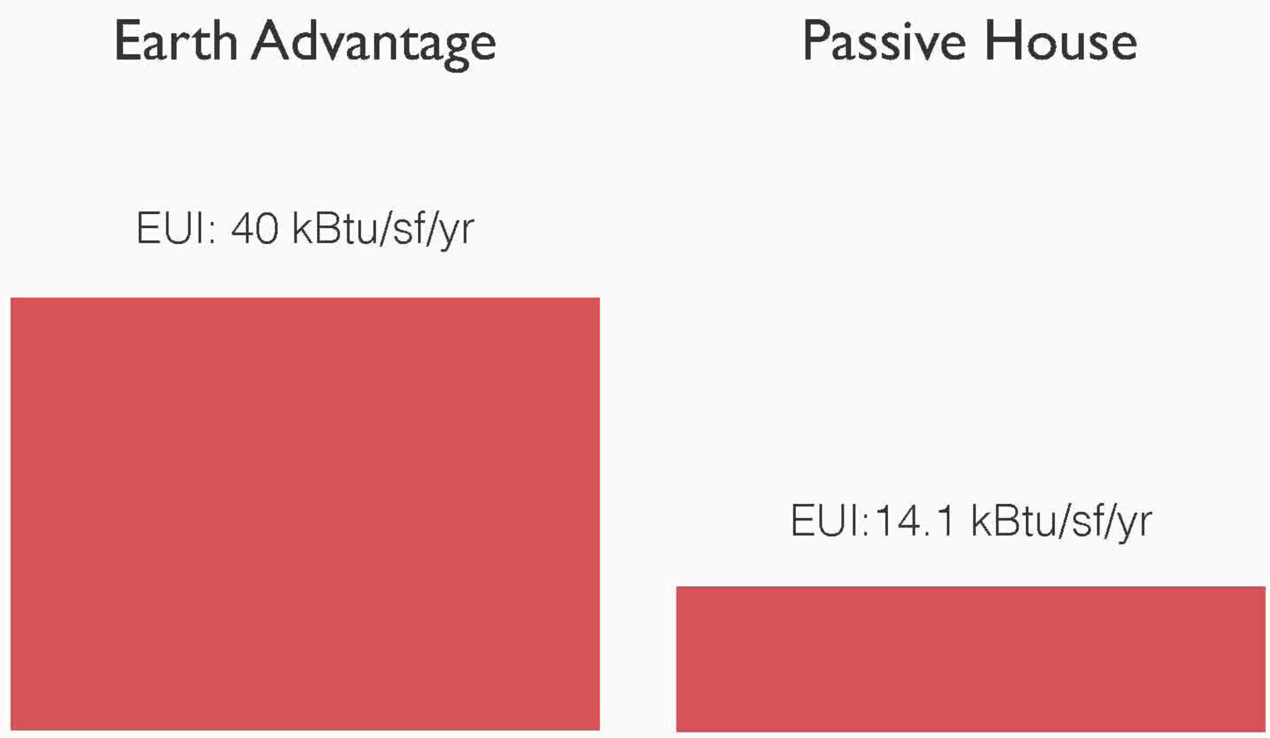
as a result of the Passive House Upgrade.

roughly equivalent to:

1 year's GHG emissions from 10 cars

[EPA]

STUDY

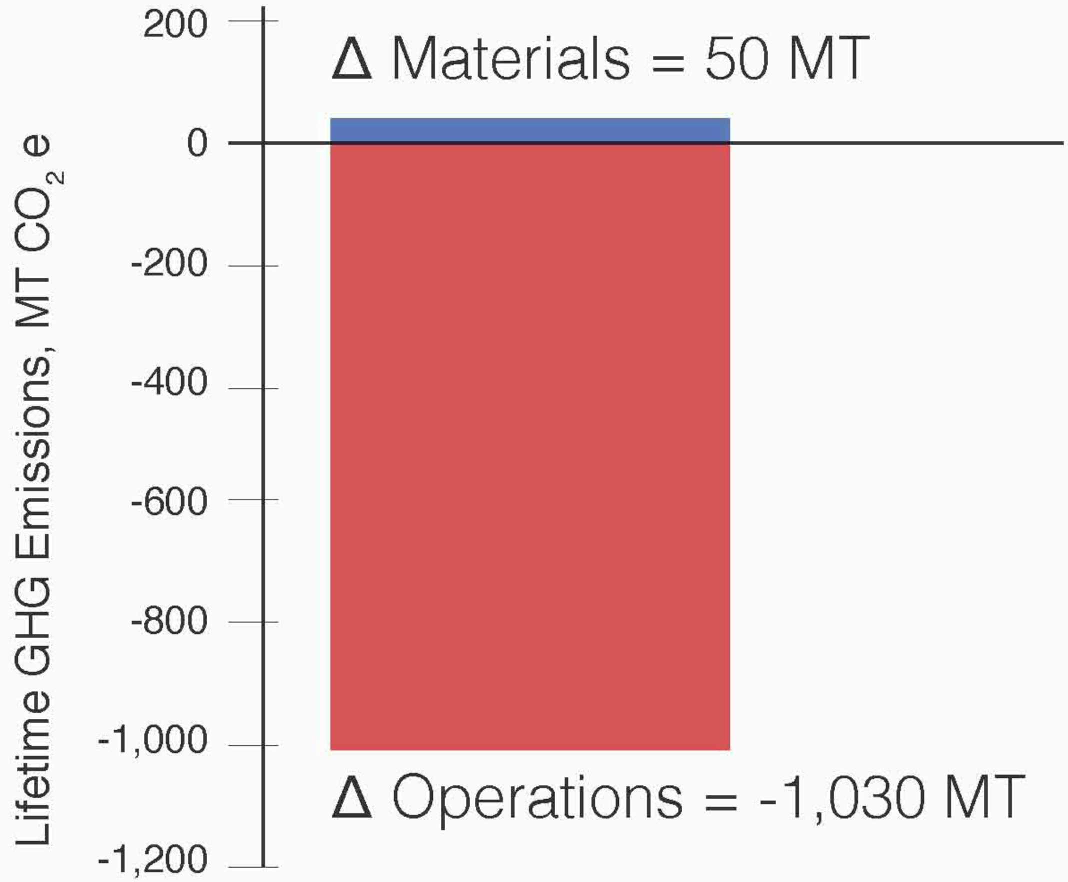


The improved operations will be responsible for a reduction of

1,030 MT CO_2e

of emissions as a result of the upgrade.

STUDY



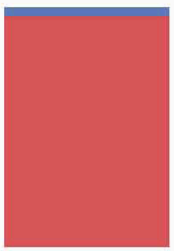
Overall, the building's emissions will be reduced by

980 MT CO_2e

as a result of the upgrade.

STUDY

Is the Passive House upgrade worth it from an environmental impact point of view?



Yes.

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Payback Time on Energy and Emissions "Investments"

IMPLICATIONS

Range of Energy Use Intensity (EUI) values for Earth Advantage Version

Range of Scenarios for Defining Energy Grid Mix in kg-CO2-equivalents/kWh

Each cell: energy / GWP

	33 kBtu/sf-yr	40 kBtu/sf-yr	50 kBtu/sf-yr	75 kBtu/sf-yr
0.7524 US Avg.	1.1 / 1.2	.8 / .8	.6 / .6	.4 / .4
0.4533 NWPP	2.2 / 2.0	1.6 / 1.4	1.1 / 1.0	.7 / .6
0.0687 EWEB	5.7 / 14.9	4.1 / 10.4	3.0 / 7.5	1.8 / 4.1

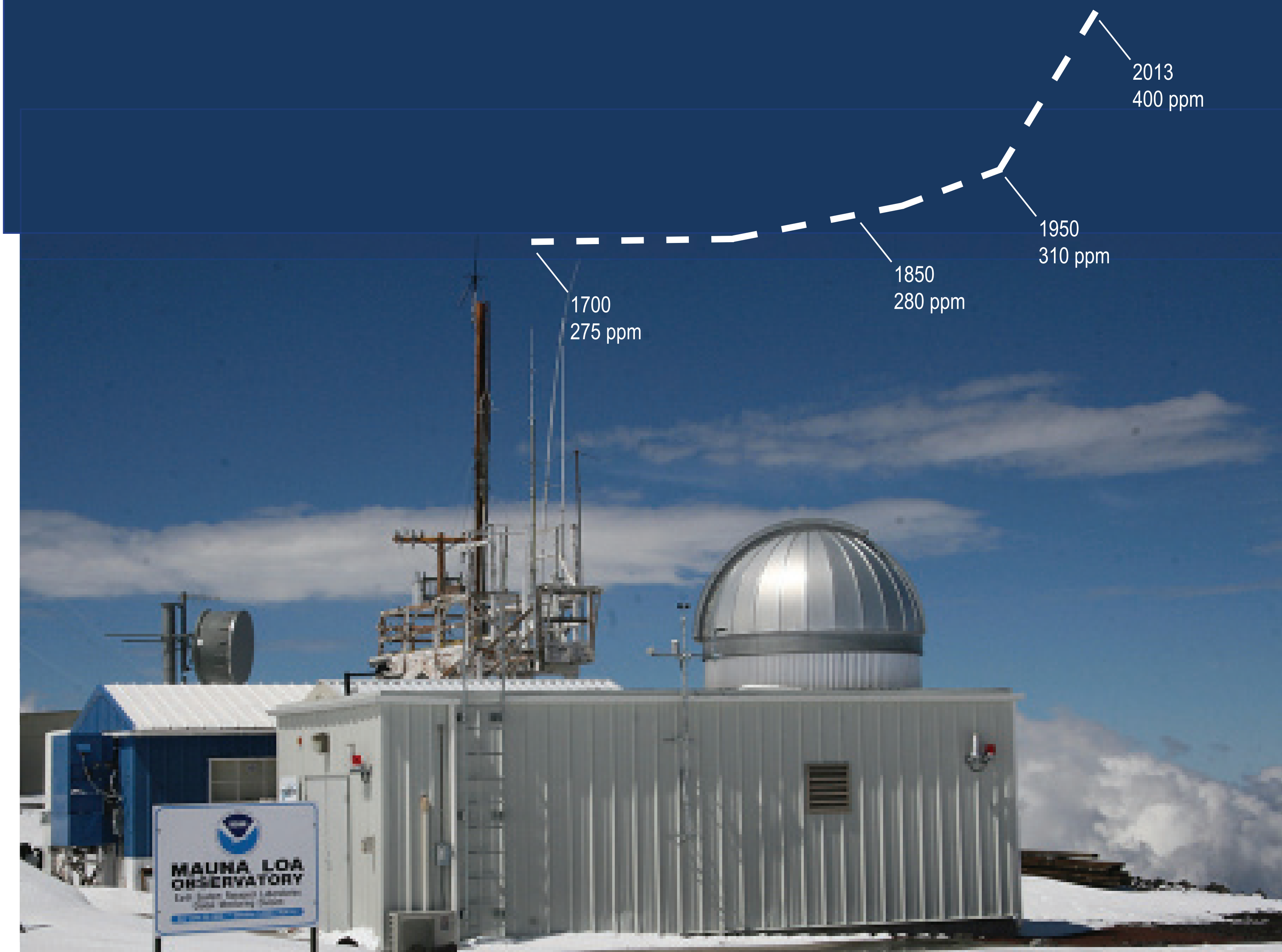
energy
GWP

Insulation Material	R-value R/inch	Density lb/ft^3	Emb. E MJ/kg	Emb. Carbon $kgCO_2/kg$	Emb. Carbon $kgCO_2/ft^2 \cdot R$	Blowing Agent (GWP)	Bl. Agent kg/kg foam	Blowing Agent GWP/ bd-ft	Lifetime GWP/ $ft^2 \cdot R$
Cellulose (dense-pack)	3.7	3.0	2.1	0.106	0.0033	None	0	N/A	0.0033
Fiberglass batt	3.3	1.0	28	1.44	0.0165	None	0	N/A	0.0165
Rigid mineral wool	4.0	4.0	17	1.2	0.0455	None	0	N/A	0.0455
Polyisocyanurate	6.0	1.5	72	3.0	0.0284	Pentane (GWP=7)	0.05	0.02	0.0317
Spray polyurethane foam (SPF) – closed-cell (HFC-blown)	6.0	2.0	72	3.0	0.0379	HFC-245fa (GWP=1,030)	0.11	8.68	1.48
SPF – closed-cell (water-blown)	5.0	2.0	72	3.0	0.0455	Water (CO_2) (GWP=1)	0	0	0.0455
SPF – open-cell (water-blown)	3.7	0.5	72	3.0	0.0154	Water (CO_2) (GWP=1)	0	0	0.0154
Expanded polystyrene (EPS)	3.9	1.0	89	2.5	0.0307	Pentane (GWP=7)	0.06	0.02	0.036
Extruded polystyrene (XPS)	5.0	2.0	89	2.5	0.0379	HFC-134a[1] (GWP=1,430)	0.08	8.67	1.77

1. XPS manufacturers have not divulged their post-HCFC blowing agent, and MSDS data have not been updated. The blowing agent is assumed here to be HFC-134a.

[Environmental Building News]

IMPLICATIONS



IMPLICATIONS

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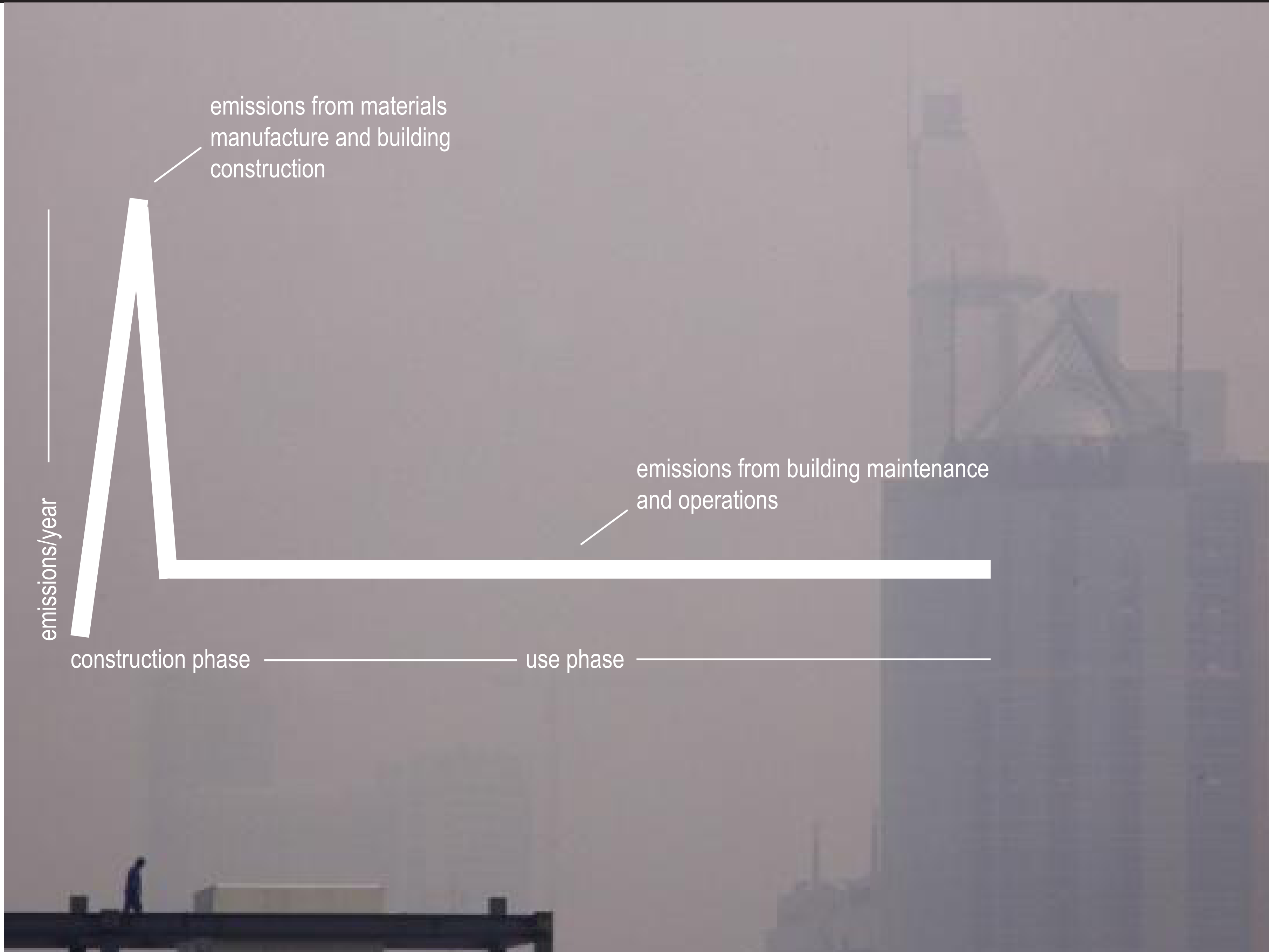

IMPLICATIONS