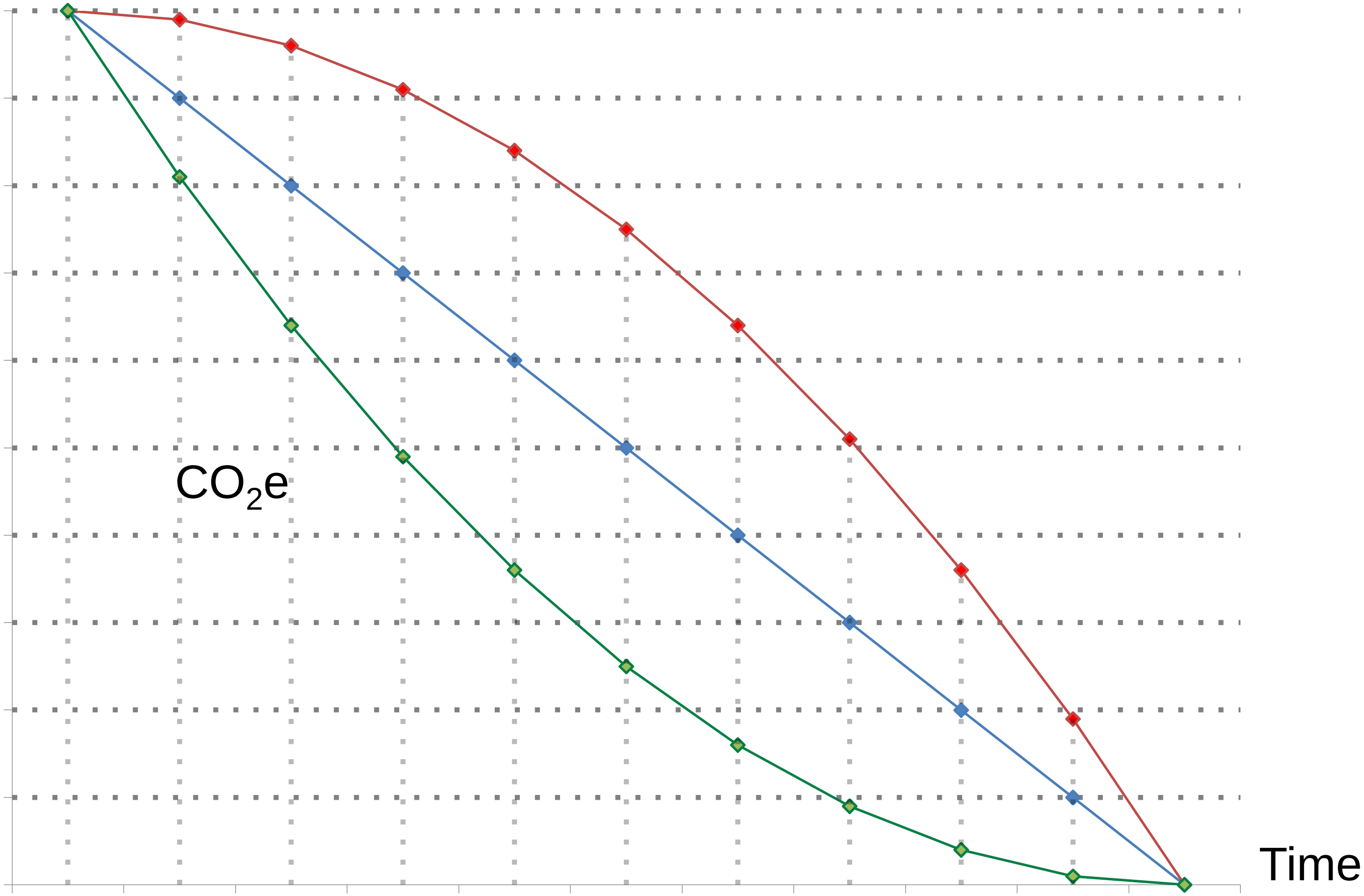
Time Value of CO_2e savings

The importance of embodied CO_2e



Larry Strain

Siegel & Strain Architects

www.siegelstrain.com

1Context & Definitions

2Case Study – Portola Valley Town Center

3Reducing embodied Carbon

- Materials
- Reusing Existing Buildings
- Size - impact on embodied CO_2

CONTEXT / DEFINITIONS

Carbon Dioxide (CO_2) – a colorless, odorless gas 1.98kg/m^3

1 Ton = 505 cubic meters

1 lb + 2.5 cubic feet

DEFINITIONS

Carbon Dioxide (CO_2) GWP = 1

Other greenhouse gasses:

Methane	GWP = 21
Nitrous Oxide	GWP = 310
HFC's	GWP = 140 to 11,700
HC's – Pentane	GWP = <25
HFO's	GWP = <7

* Next generation of Blowing agents

ENVIRONMENTAL IMPACTS - BUILDING OPERATIONS

Buildings **operations** annually in

the US, are responsible for:

- 39% of energy consumption
- 71% of electricity consumption
- 12% of the fresh water
- 42 Quads of Energy (Quad = I quadrillion btu's or 7.5 gigawatts. U.S. uses about 100 Quads of energy)
- **~38% of CO_2 emissions**

Source: A National Green Research Agenda USGBC

ENVIRONMENTAL IMPACTS - BUILDING CONSTRUCTION

Building **construction** annually in the U.S. is responsible for:

- 12% of energy consumption
- 40% of non-industrial waste, 170 million tons (2003), 81 tons diverted
- 25% of global wood harvest
- 8 quads of energy
- **10 -12% of CO_2 Emissions**

ENVIRONMENTAL IMPACTS – OPERATING / EMBODIED

Buildings **operations** annually in

the US, are responsible for **~38% of CO_2 emissions**

Building **construction** annually

in the U.S. is responsible for **10 - 12% of CO_2 Emissions**

ENVIRONMENTAL IMPACTS – OPERATING / EMBODIED

Buildings **operations** annually in

the US.   **38% of CO_2 emissions**

300+ billion sf

Building **construction** annually

in the U.S.   **10 -12% of CO_2 Emissions**

~10 billion sf

Construction Sources of CO_2e

Construction Materials

- Extraction, Harvest
- Manufacture – primary, secondary
- Transport

Construction Activity

- Equipment – grading, hauling, cranes, etc.
- Labor - transportation
- Energy Use – tools, temp facilities

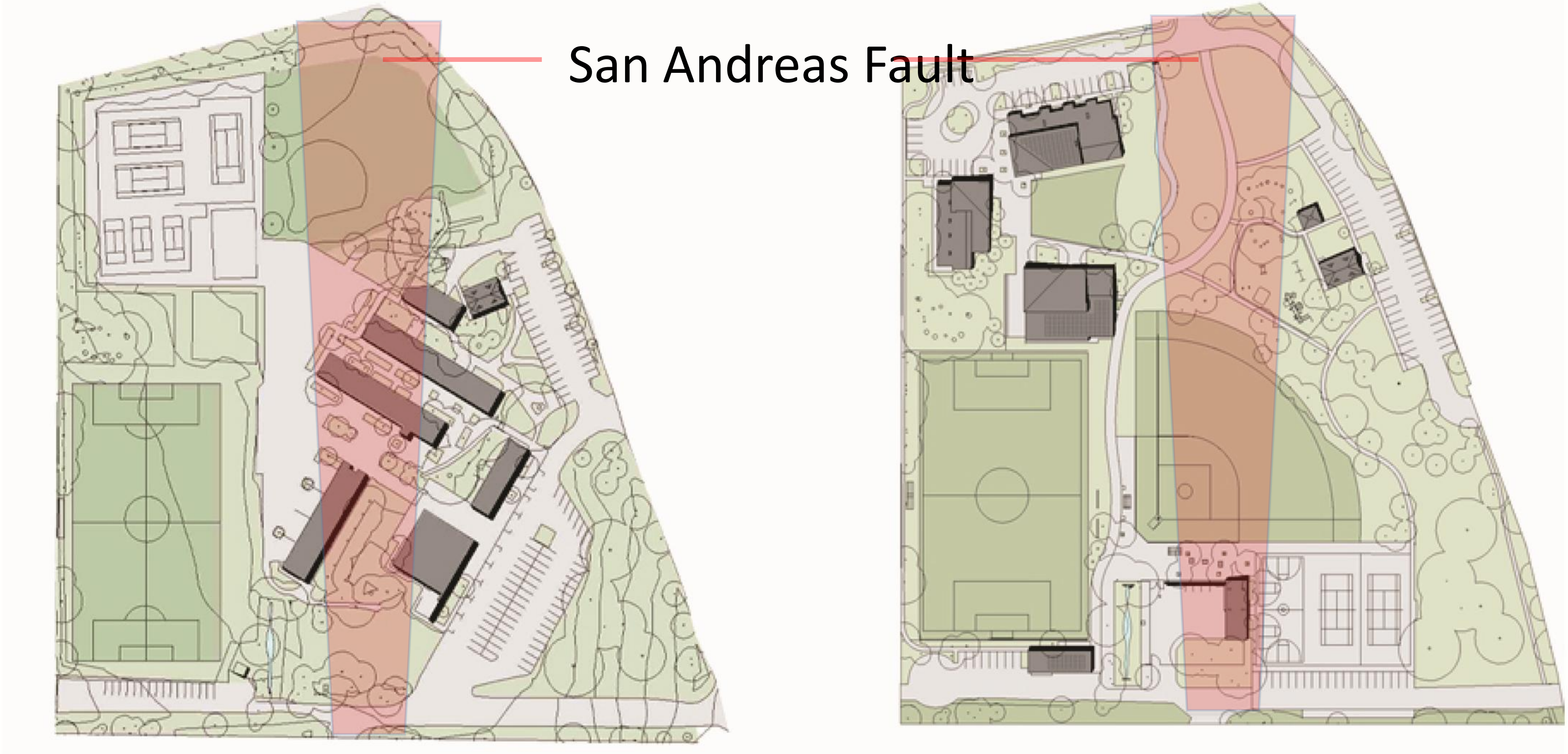


PORTOLA VALLEY TOWN CENTER

Design Team

Mechanical **– Rumsey Engineer**s
Electrical – **IDeAs**
Photovoltaics – **High Sun Engineers**
Structural – **Forrell/Elsesser**
Landscape **– Lutsko Associates**
Civil - **BKF**

SIEGEL & STRAIN Architects | Goring & Straja Architects



BEFORE

Old Town Center	SF	% of Total
Building Footprint	25,000	5.1%
Paving	165,900	33.9%
Playing Fields	96,000	19.6%
Landscape	203,000	41.4%

AFTER

New Town Center	SF	% of Total
Building Footprint	20,500	4.2%
Paving	146,400	29.9%
Playing Fields	100,000	20.4%
Landscape	223,000	45.5%

SIEGEL & STRAIN Architects | Goring & Straja Architects

Total Reclaimed Lumber: 20,000 board ft.

+ glulams for countertops & tree trunks

for columns

Additional materials recycled:

Reused on site

> *all of the concrete for base rock*

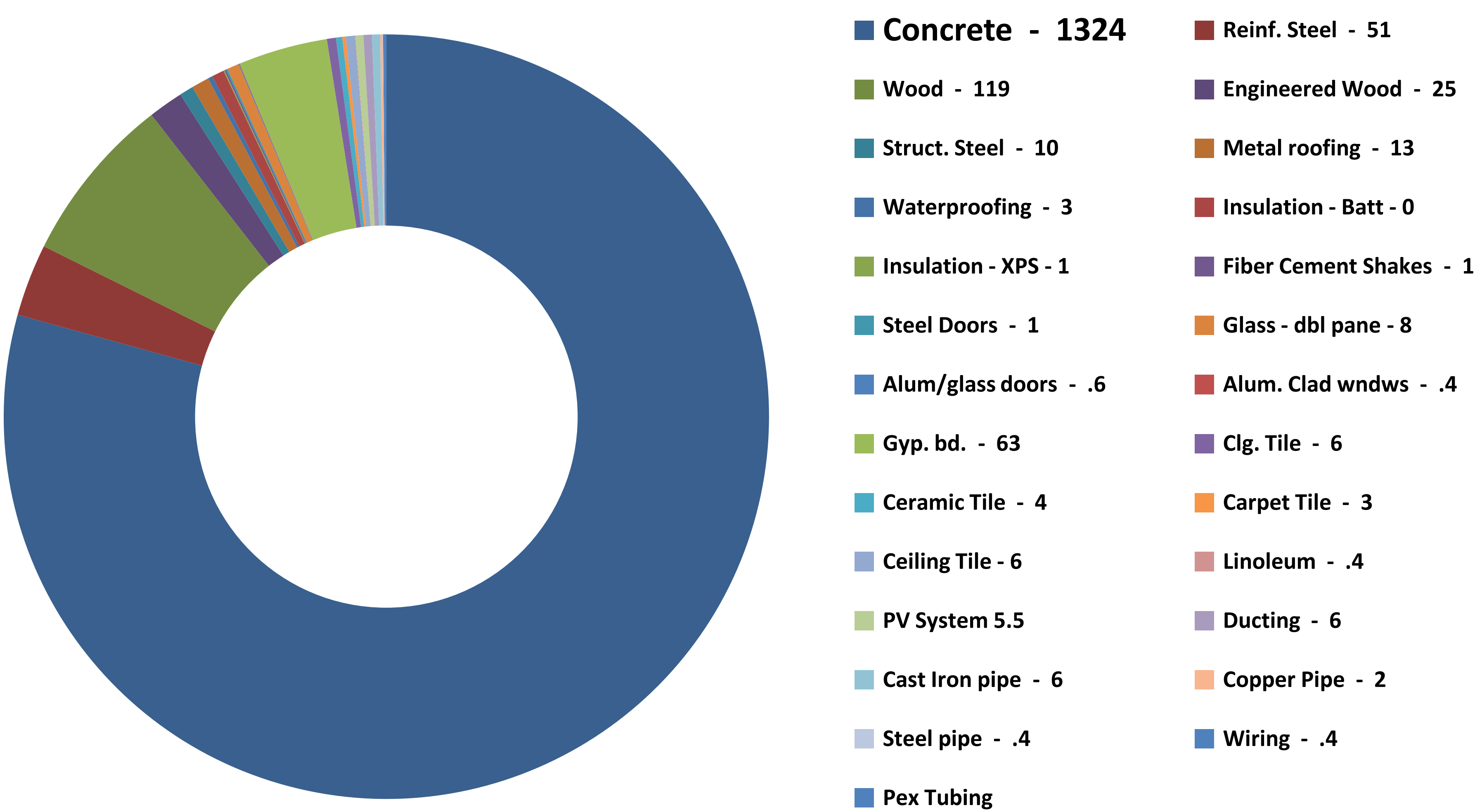
> all of the asphalt paving and CMU for
winterization and trail maintenance

Recycled off site

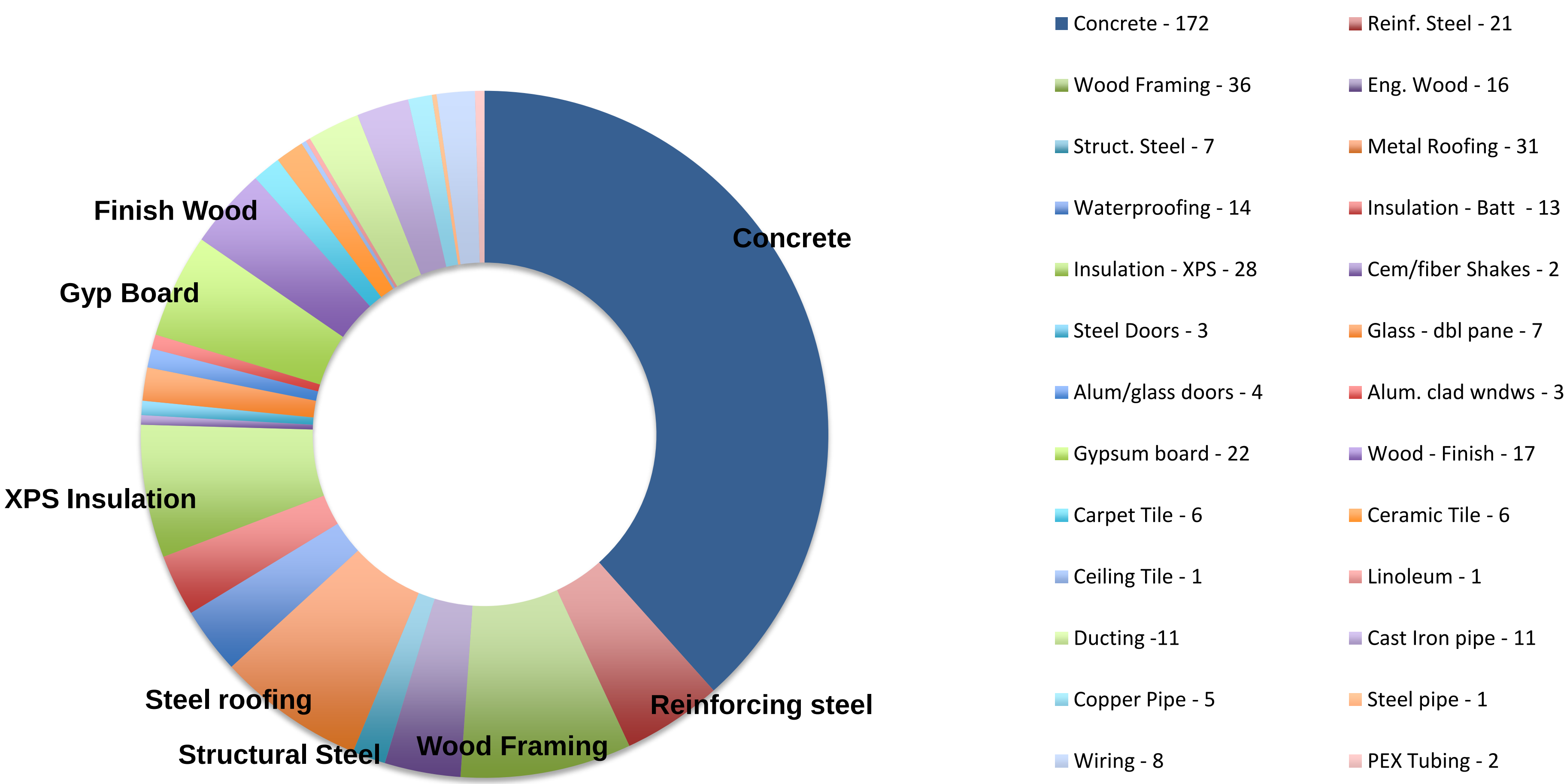
> all of the rebar, pipe & misc. metals


EXIT

PVTC - Building Materials: Weight – 1670 tons

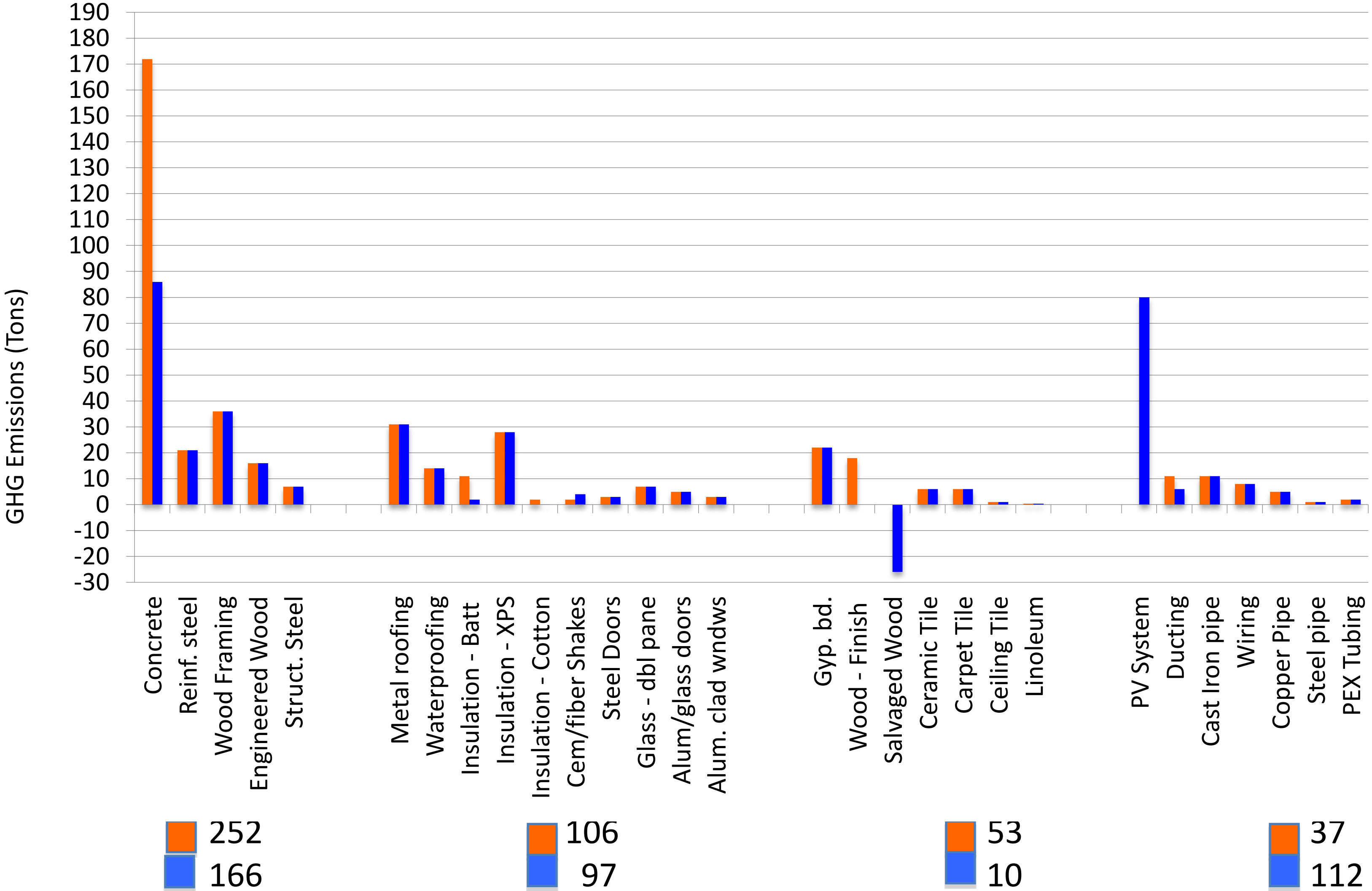


PVTC - Building Materials: GHG emissions – 449 tons



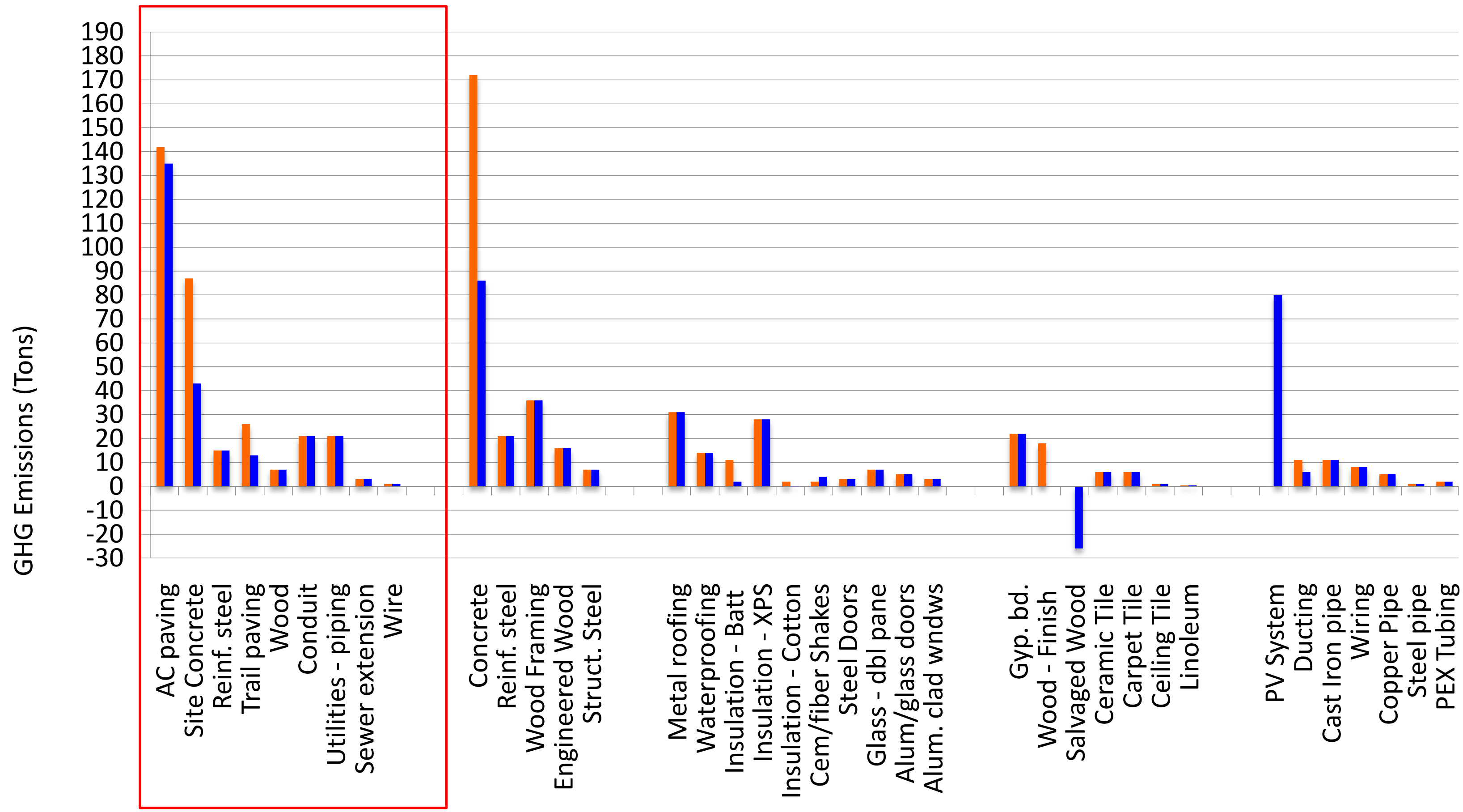
GHG Emissions – Construction Materials - **Buildings**

- Base Case – 449 Tons
- As Built– 386 Tons - Reduction - 63 Tons (15%)



GHG Emissions - Construction Materials – **Buildings + Site**

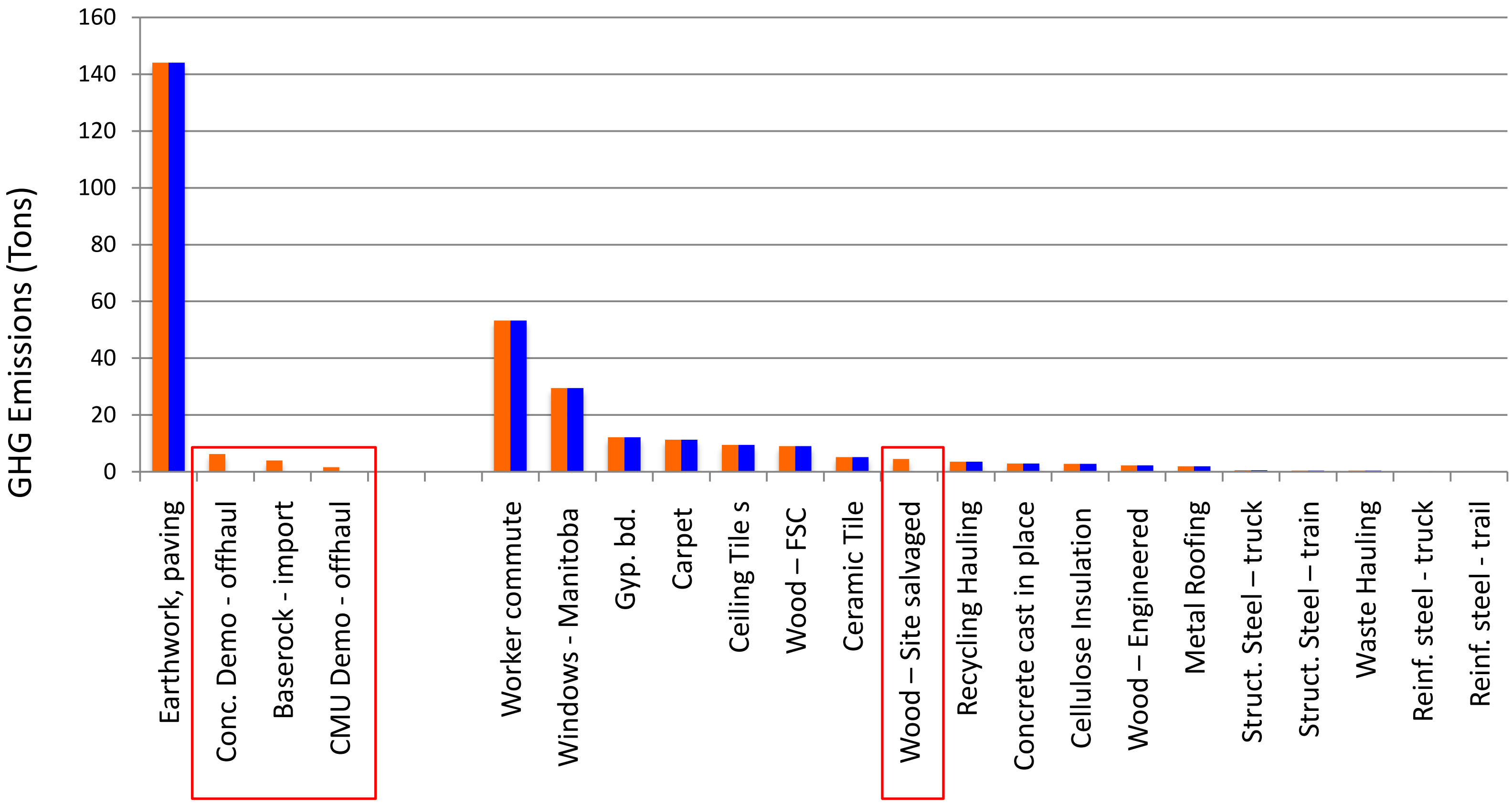
- Base Case – 772 Tons
- As Built – 645 tons - Reduction - 127 tons (17%)



	Site	Structure	Envelope	Finishes	MEP
Base Case	323	252	106	53	37
As Built	259	156	97	10	112

GHG Emissions – **Construction Vehicle Emissions**

- Base Case – 306 tons
- As Built – 290 - Reduction - 16 tons (9%)



Site
- 156
- 145

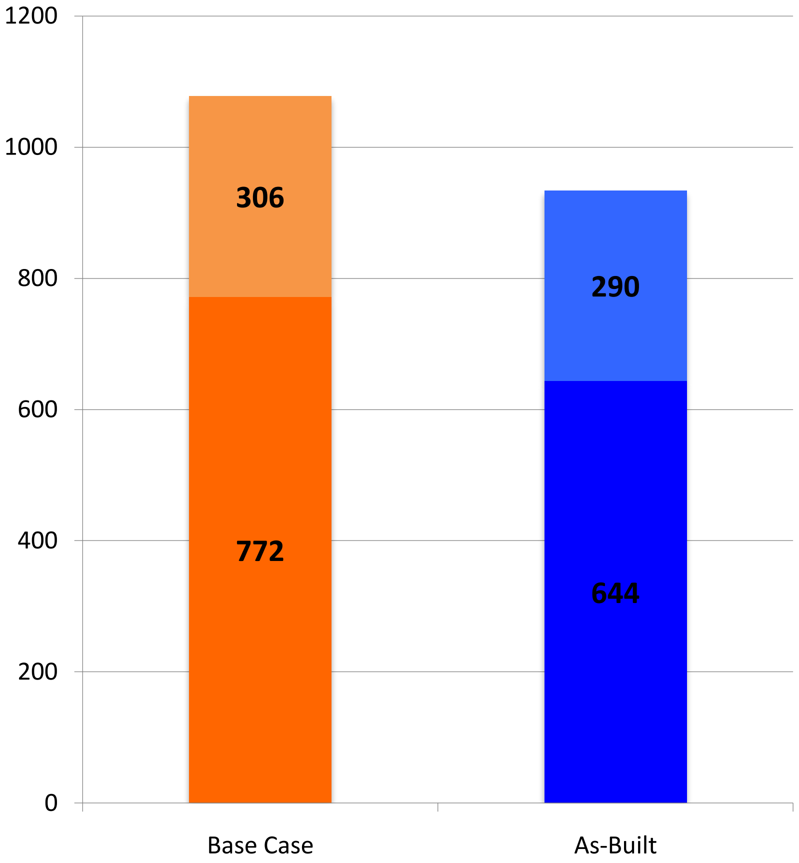
Buildings
- 150
- 145

Vehicular Emissions from Construction **Portola Valley Town Center** **2009**

Material	Quant.	Dist. miles	Trips	Total miles	mpg	gals.	CO_2 lbs/gal	tons CO^2	CO_2 saved	Source	Notes
Sitework - Grading, trenching, paving	$400,000							144		.36t/k$ [1]	EPA Estimate
Concrete Demo - offhaul	1300 tons	20	137	2740	5	548	22.5	6.2	-6.2	CR	
CMU Demo - offhaul	300tons	40	17	720	5	144	22.5	1.6	-1.6	CR	
Baserock - import	1600 tons	20	89	1780	5	356	22.5	4	-4	CR	
Site Total								**155.8**	**145**		
Concrete cast in place	660 yds	20	66	1320	5	264	22.5	2.95		LEED sub.	
Structural Steel – 2125 miles – train	40 tons	2125		2125	50	42.5	22.5	0.48		S&S	
31.5 miles - truck		31.5	2	252	5	50.4	22.5	0.55		S&S	
Wood – Engineered - Windsor, CA – 100 mi	50K bd.ft.	100	10	1000	5	200	22.5	2.25		LEED sub.	
Wood – FSC - CA & WA– 400 mi	63K bd.ft.	400	10	4000	5	800	22.5	9		LEED sub.	
Wood – Salvaged on site	28K bd.ft.	400	5	2000	5	400	22.5	4.5	-4.5	S&S	
Reinforcing steel - 750 miles – rail	24.8 tons	750		750	50	15	22.5	0.17		LEED sub.	
50 miles truck		50	2	100	5	20	22.5	0.23		S&S	
Metal Roofing - Adelanto, CA - 391 miles	12.5 tons	850		850	5	170		1.9		LEED sub.	
Windows - Steinbach, Manitoba – 3270 mi	4207 sf	3270	4	12080	5	2416	22.5	29.45		S&S	
Gyp. bd. - Empire City, NV – 270 mi	63 tons	540	10	5400	5	1080	22.5	12.15		LEED sub.	
Carpet - Dalton, GA – 2450 mi	2.5 tons	4900		4900	5	980	22.5	11.25		On-line	
Ceramic Tile - El Paso, TX - 1160	4.4 tons	2320		2320	5	464	22.5	5.2		LEED sub.	
Cellulose Insulation - Sac., CA – 125 mi	50 tons	250		1250	5	250	22.5	2.8		LEED sub.	
Ceiling Tile - MN, WI, MS avg. 2,100 miles	6.4 tons	4200		4200	5	840	22.5	9.45		On-line	
Worker commute, 17 months, 355 work days	6 workers	40 m/d	355	85,200	16	5325	20	53.25		CR	
Recycle Hauling	515 tons	20	80	1,600	5	320	22.5	3.6		S&S	
Waste Hauling	1.4 tons	40	5	160	5	32	22.5	0.4		S&S	
									-16.3		
Building Total CO_2								**150**	**145.5**		
[1] Potential for Reducing GHGEmission in the Construction Sector - EPA				**Project Total**				**305.8**	**289.5**		

GHG Emissions - Totals

- Base Case – 1,078 tons
- As Built – 924 tons Reduction - 144 tons (14%)



Portola Valley Town Center – Calculating CO_2e

	Material	Baseline – Standard			As-Built – Reduced carbon			Savings	
		Quant. tons	ton CO_2 / ton	Total CO_2 / ton	Quant. tons	ton CO_2 / ton	Total CO_2 / ton	Tons of CO_2	Source
Structure	Concrete	1324	0.13	172.4	1324	0.07	86	-86	ICE
	Reinforcing steel	51	0.4	21.42	51	0.4	21.4	0	ICE
	Wood	80	0.45	36	80	0.45	36	0	ICE
	Engineered Wood	24.6	0.65	16	24.6	0.65	16	0	ICE
	Structural Steel	10	0.68	6.8	10	0.68	6.8	0	ICE
	Structure Total			252			166	-86	

Weight

CO_2/ton material

Total emissions

Weight

CO_2/ton material

Total emissions

Source of CO_2 emissions data

www.circularecology.com/ice-database.html

Portola Valley Town Center

	Material	Baseline			Reduced Carbon			t saved
		Quant. t	t CO_2 / t	Total CO_2 / t	Quant. t	t CO_2 / t	Total CO_2 / t	
Structure	Concrete	1324	0.13	172.1	1324	0.07	86.1	-86
	Reinf. steel	51	0.42	21.4	51	0.42	21.4	0
	Wood Framing	80	0.45	36.0	80	0.45	36.0	0
	Engineered Wood	24.6	0.65	16.0	24.6	0.65	16.0	0
	Struct. Steel	9.8	0.68	6.7	9.8	0.68	6.7	0
	Structure Total			**252.2**			**166.1**	**-86**
Envelope	Metal roofing	12.5	2.50	31.25	12.5	2.50	31.3	0
	Ice and water shield	3.3	4.20	13.86	3.3	4.20	13.9	0
	Insulation – Batt	7.5	1.50	11.25	47	0.04	1.9	-9
	Insulation - XPS	6500 bf	8.67	28.20	6500 bf	8.67	28.2	0
	Insulation - Cotton	1.0	1.50	1.50	3	0.04	0.1	-1
	Metals - Sunscreen	1.5	0.68	1.02	1.5	0.68	1.02	
	Fiber Cement Shakes	1.1	2.11	2.32	2.2	1.80	4.0	2
	Steel Doors	1.2	2.50	3.00	1.2	2.50	3.0	0
	Glass - double pane	8.32	0.85	7.07	8.32	0.85	7.1	0
	Alum. stile/rail doors	0.59	8.20	4.84	0.59	8.20	4.8	0
	alum. Clad frames	0.38	8.20	3.12	0.38	8.20	3.1	0
	Envelope Total			**107.4**			**98.3**	**-9**
Finishes	Gyp. bd.	63	0.35	22.1	63	0.35	22.0	0
	Wood - Finish	39	0.45	17.6	0.0	0.45	0.0	-18
	Salvaged Wood	0	0.00	0.0	39	-0.67	-26.1	-26
	Ceiling Tile	6.4	0.20	1.3	6.4	0.20	1.3	0
	Ceramic Tile	4.4	1.40	6.2	4.4	1.40	6.2	0
	Carpet Tile	2.5	2.30	5.8	2.5	2.30	5.8	0
	Linoleum	0.4	1.20	0.4	0.35	1.20	0.4	0
	Finishes Total			**53.2**			**9.5**	**-44**
MEP	PV System	0	0	0	5.5		80	+80
	Ducting	6.0	1.75	10.5	3	1.75	5.3	-5
	Cast Iron pipe	5.7	1.90	10.8	5.7	1.90	10.8	0
	Copper Pipe	1.6	3.00	4.8	1.6	3.00	4.8	0
	Steel pipe	0.4	2.70	1.0	0.38	2.70	1.0	0
	PEX Tubing	0.5	4.00	1.8	0.5	4.00	1.8	0
	Wiring	0.3	3.00	7.8	0.346	3.00	7.8	0
	MEP Total			**36.8**			**112**	**+75**
Totals	**Building Total CO_2**			**449.6**			**386**	**-80**
	Building sf			**23273.0**			**23273.0**	
	lbs CO2/sf			**38.6**			**33.2**	**-5.4**

56% - Structure
43% - As-Built

23% - Envelope
25% - As-Built

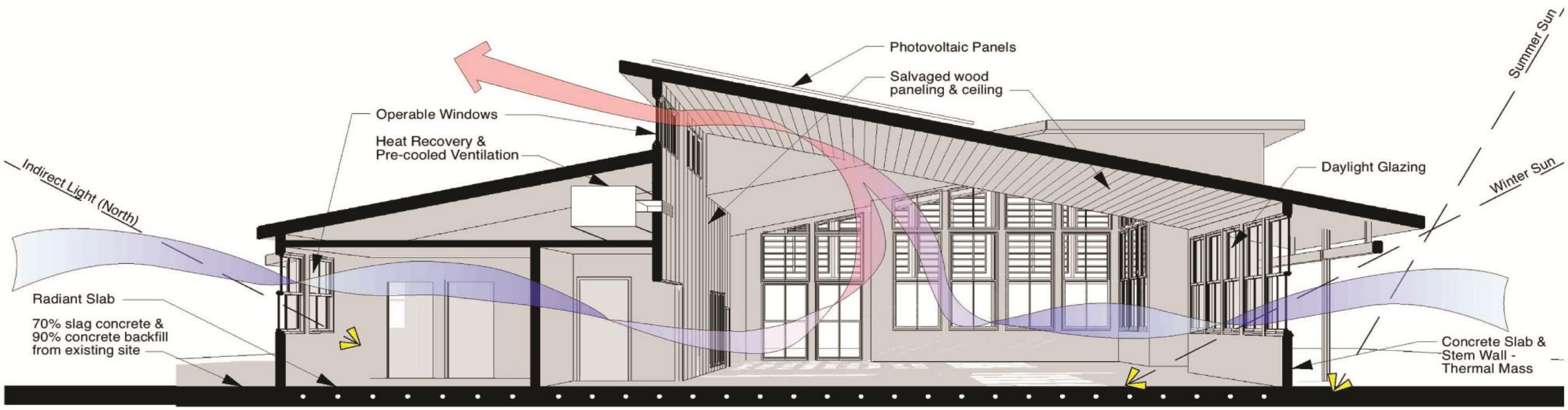
12% - Finishes
2% As-Built

8% - MEP
29% As-Built
(with PV's)

Reducing Embodied GHG – Lessons Learned

- Tackle high volume materials first - Concrete – 80 tons CO_2 saved
- Limit energy intensive, high carbon materials – XPS insulation - 28 tons CO_2
- Salvaged and recycled materials make a difference – Wood - 34 tons CO_2 saved
- Distance matters – On-site materials - 16 tons CO_2 saved; windows from Canada – 30 tons
- Sitework matters – Grading / paving vehicles – 140 tons CO_2 (EPA Estimate)

PORTOLA VALLEY TOWN CENTER



Construction vs Operating Emissions

Passive Design

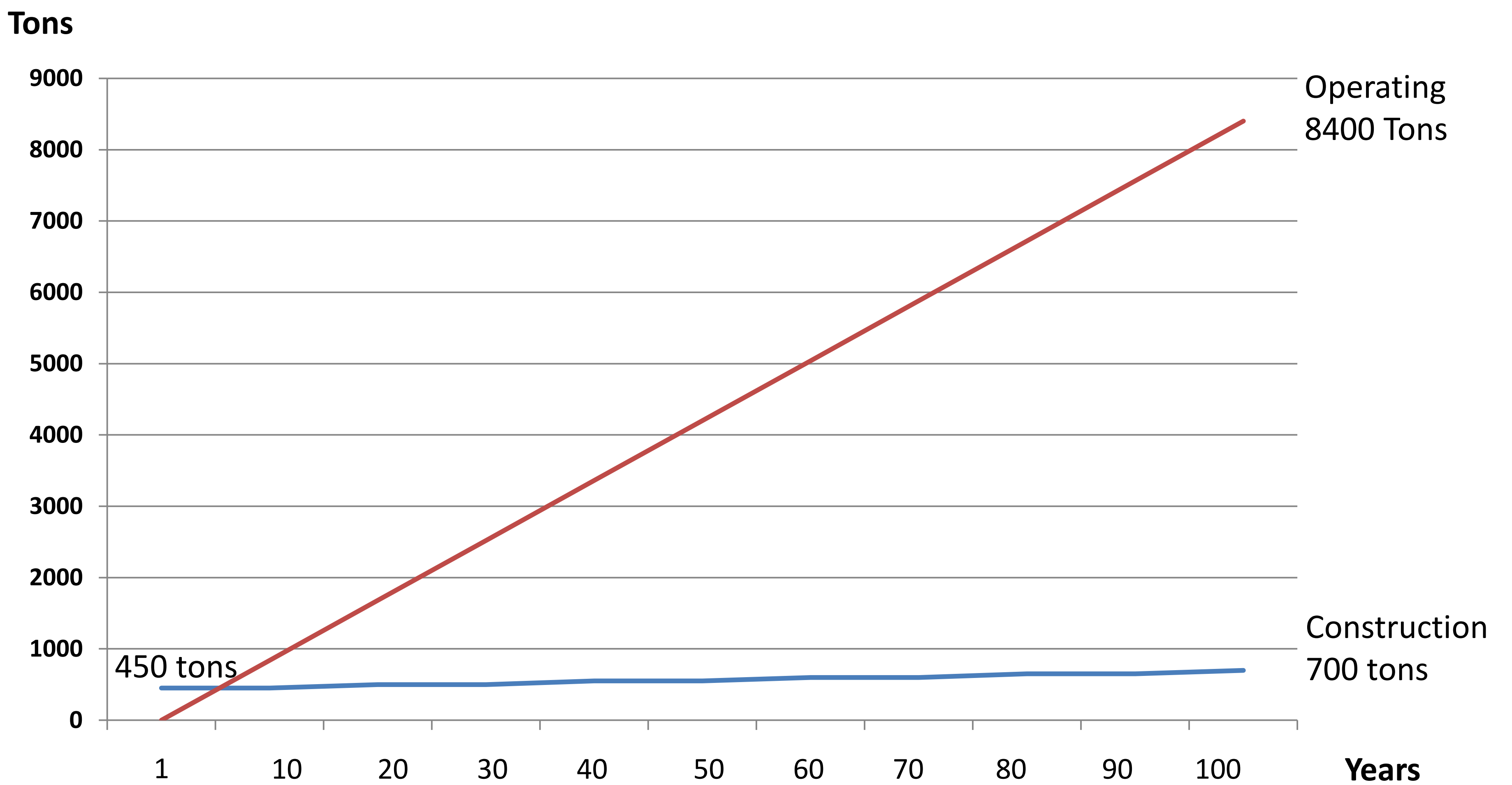
- Daylighting
- Natural Ventilation
- Thermal Mass
- Well insulated shell
- External Shading
- Reflective Roofs

Efficient Systems:

- Radiant Slabs – 97% efficient Boilers
- Ultra efficient air conditioners – SEER 19
- 100% outside air ventilation – 30% above ASHRAE
- Indirect energy recovery between inlet and relief air
- 76 KW Photovoltaic roof top system
- Low-flow fixtures – waterless urinals, dual flush

Embodied Emissions / Operating Emissions – over 100 years

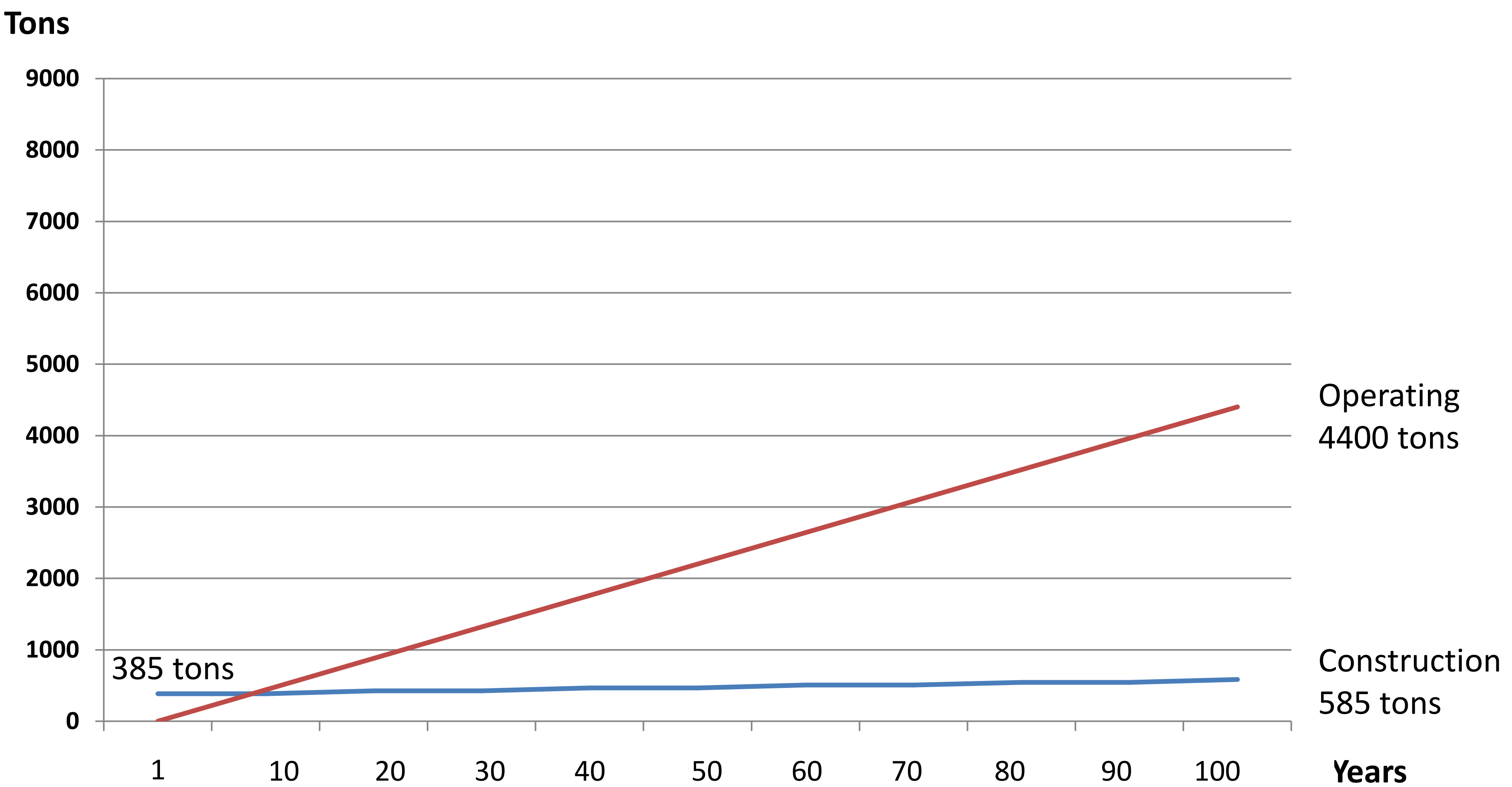
Standard Building



Construction = 8% of Operating

Embodied Emissions / Operating Emissions – over 100 years

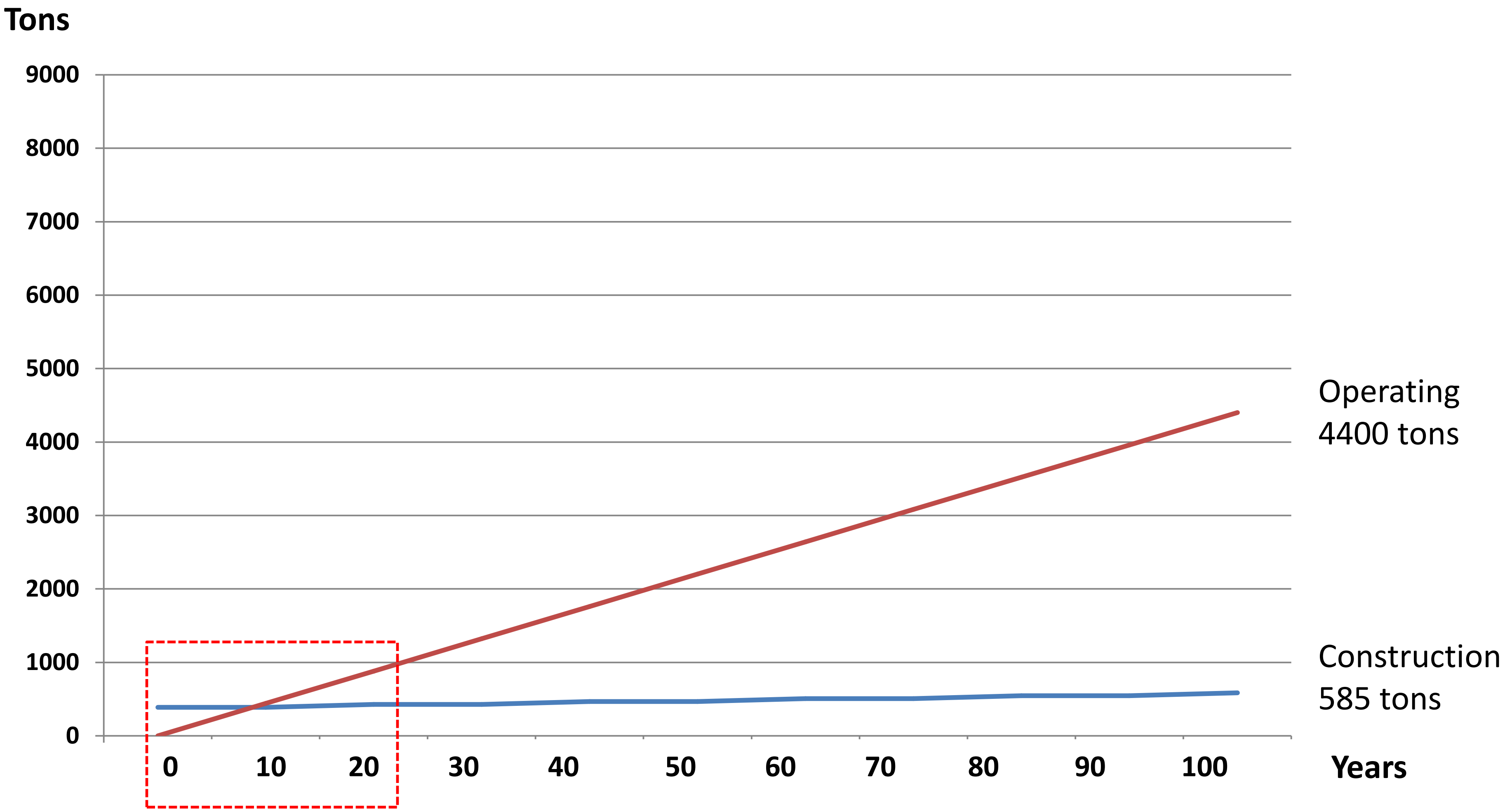
Efficient, Low Carbon Building



Construction = 13% of Operating

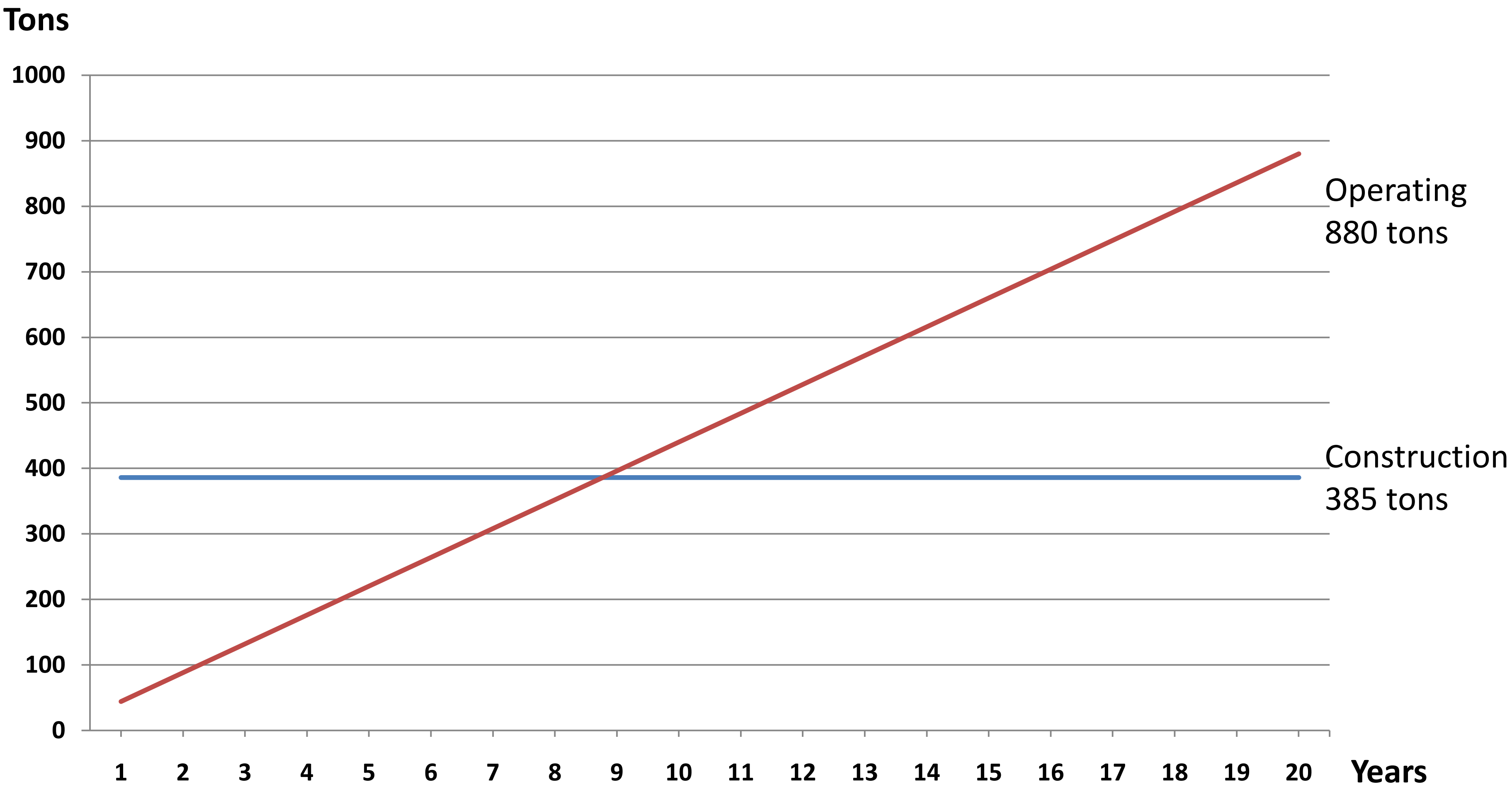
Embodied Emissions / Operating Emissions

Efficient, Low Carbon Building



Embodied Emissions / Operating Emissions – over 20 years

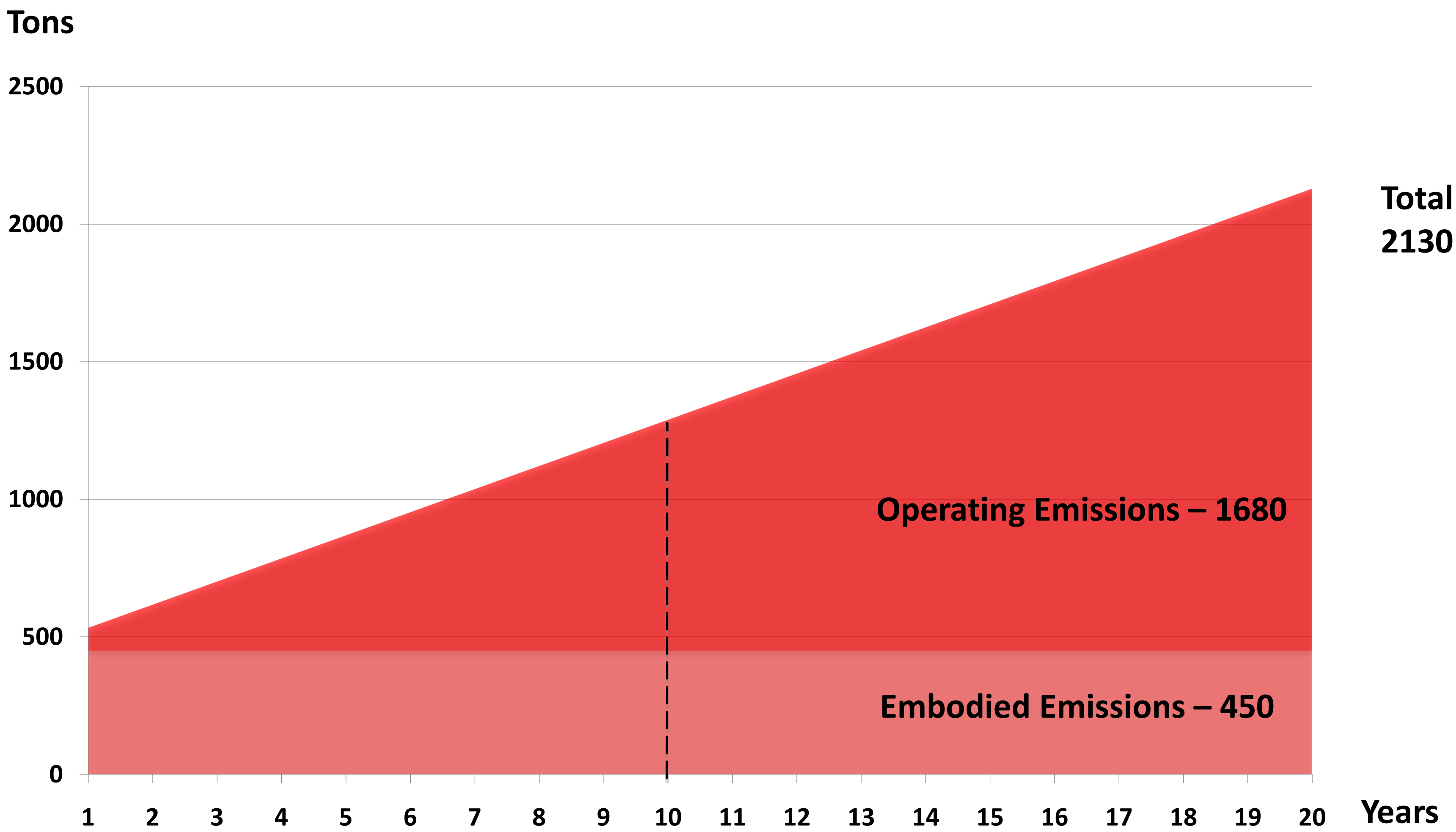
Efficient, Low Carbon Building



Construction = 43% of Operating

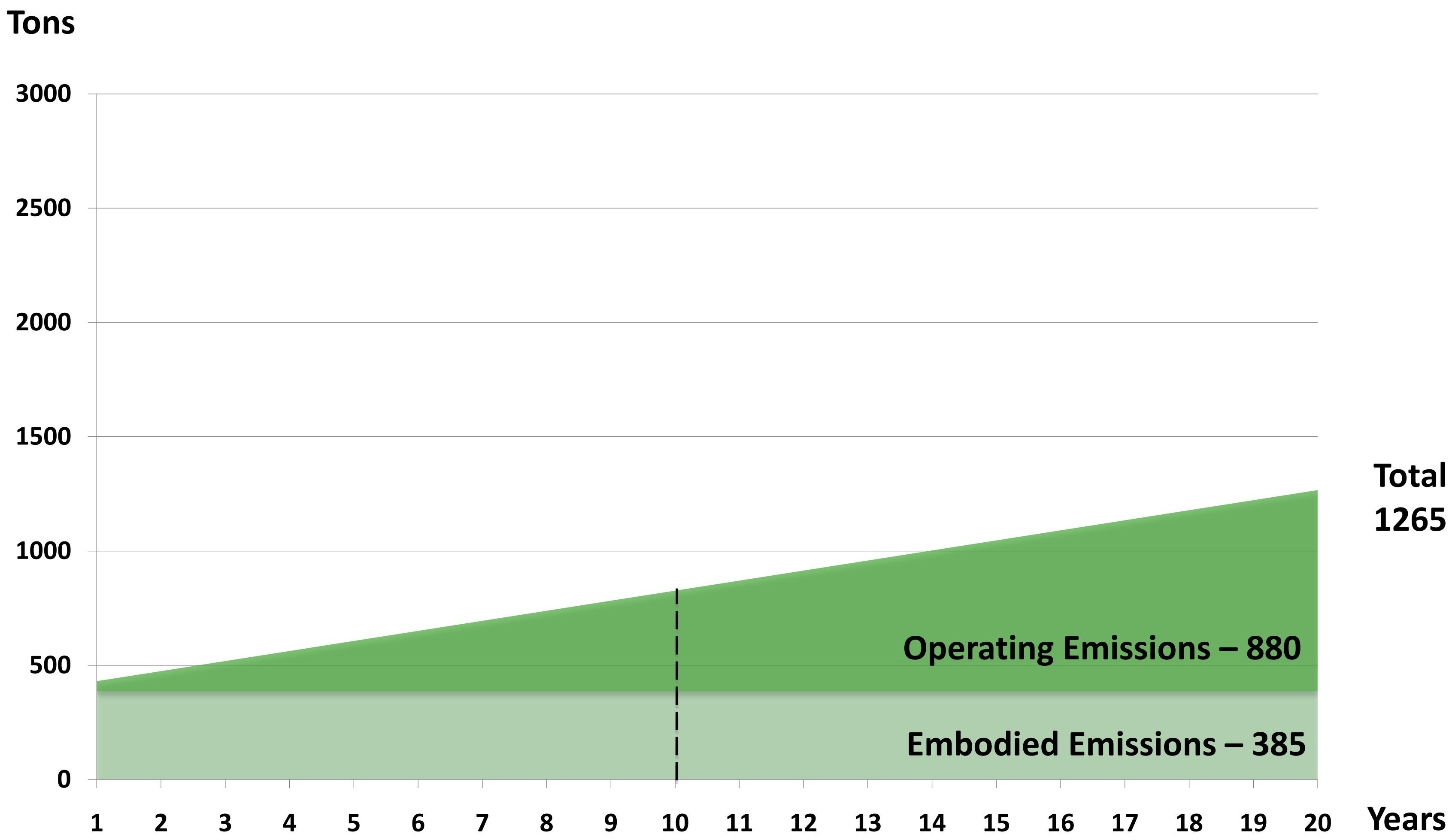
Embodied Emissions & Operating Emissions are additive

Standard – code compliant building



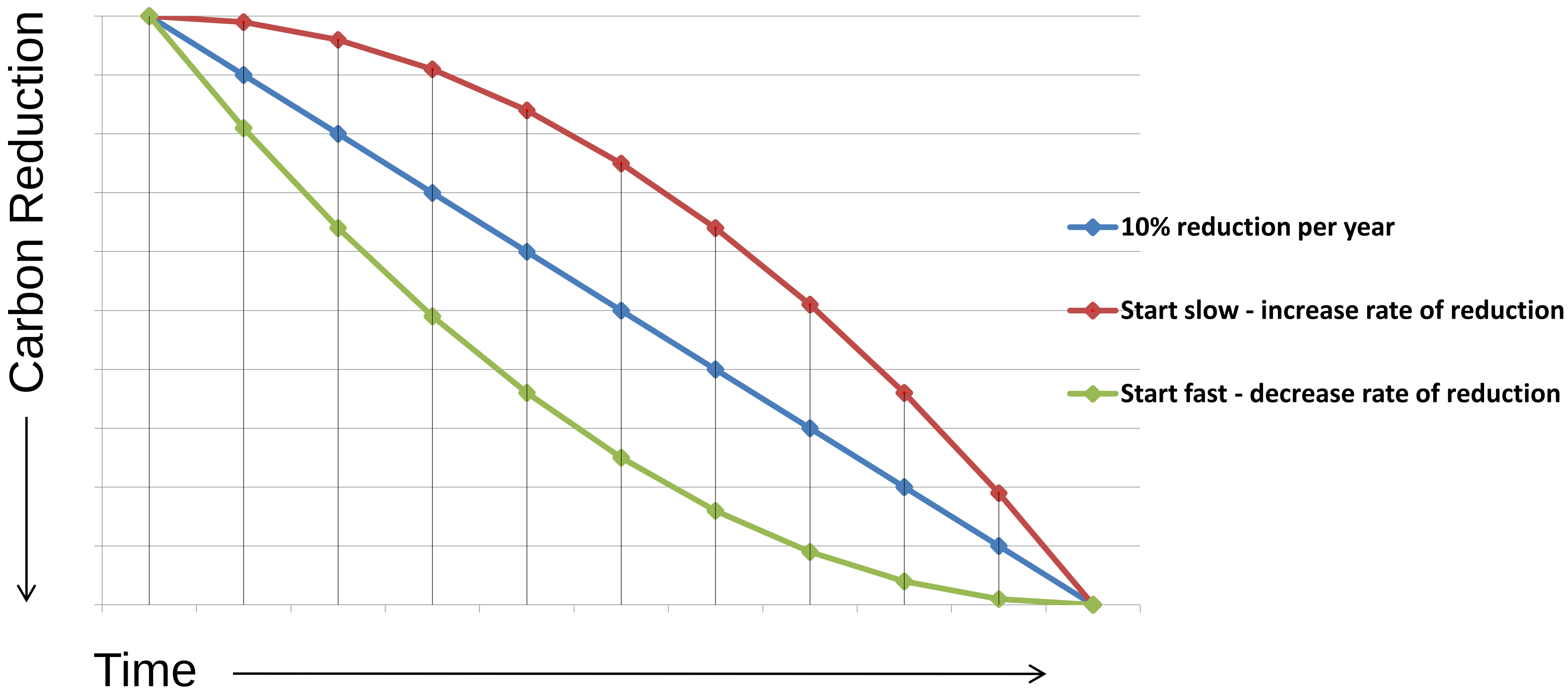
Embodied Emissions & Operating Emissions are additive

Efficient, Low Carbon Building



WHY FOCUS ON EMBODIED CARBON?

- Time Value of Carbon Savings
  Carbon saved now is worth more than Carbon later
  (area under the line is total carbon emitted)



PORTOLA VALLEY TOWN CENTER

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Data Sources

Databases

- NREL Database (US specific)
- ICE Database (Inventory of Carbon and Energy)
  Bath University - UK / EU / Global data
- Ecoinvent (Global / European data)
- Franklin Data (transportation of materials)

Carbon Analysis Programs

- Athena Institute- reasonably transparent
  - Assembly Calculator – free
  - Impact Estimator – fee for download
- SimaPro – free demo, reasonably transparent
- URBEMIS – free, transparent
- EPA WAste Reduction Model (WARM) – free, transparent
- ConstructCO2 – beta

LCA Tools

Software & Developer	Description	Intended Users	Impacts Considered	Datasets Available	Cost
BUILDING-SPECIFIC LCA TOOLS					
Athena EcoCalculator for Assemblies Athena Sustainable Materials Institute	Shows full life-cycle impacts from load-bearing systems based on a limited library of commercial and residential assembly types.	Design & construction professionals	Acidification Eutrophication Fossil-fuel depletion Global warming Ozone depletion Respiratory effects Smog	North America	Free
Athena Impact Estimator for Buildings Athena Sustainable Materials Institute	Analyzes full life-cycle impacts from assemblies and whole buildings, based on region and building type; can integrate energy modeling data.				
eTool LCA eTool	Analyzes full life-cycle and cost impacts from whole buildings; can integrate energy modeling data. Under development: aims to capture more impact categories and be usable worldwide.	General users through LCA professionals	Global warming Energy consumption Water consumption	Australia (North America and U.K. data under development)	Free–$$$ (various subscription programs)
Green Footstep Rocky Mountain Institute	Analyzes the carbon impact of a building, including site disturbance, construction, and operations.	Design & construction professionals	Global warming potential	Global	Free
GENERAL LCA TOOLS					
GaBi PE International	Used by LCA practitioners to model life-cycle impacts for a variety of products and systems and even entire industries; can be used for building-level LCA but not designed specifically for that application.	LCA professionals	User-defined (many available categories)	Global	$–$$$ (various subscription programs)
openLCA GreenDelta				Datasets must be imported by users.	Free, but users may need to purchase LCI database
SimaPro PRé Sustainability				Global	$–$$$ (various subscription programs)
DATABASES					
BEES **(Building for Environmental and Economic Sustainability)** National Institute for Standards and Technology	Analyzes full life-cycle impacts from generic building materials and some branded building products; cost may be included. Results can be viewed in spreadsheet form or presented as a weighted "performance score."	Design & construction professionals	Acidification Air pollution Ecological toxicity Eutrophication Fossil-fuel depletion Global warming Habitat alteration Human health IAQ Ozone depletion Respiratory effects Smog Water consumption	North America	Free
ICE **(Inventory of Carbon & Energy)** University of Bath (U.K.)	Database of 200 building materials' cradle-to-gate carbon and energy impacts.	Design & construction professionals; software developers	Embodied carbon Embodied energy	Global	Free downloads of updated spreadsheets
U.S. LCI Database National Renewable Energy Laboratory (NREL)	Stores life-cycle data for a variety of industrial materials and processes; can be accessed by anyone and also informs many of the LCA tools listed here.	LCA professionals; software developers	A variety of quantified "flows" to and from nature, focusing on depletion and contamination of natural resources	North America	Free

What's Missing

We need better embodied carbon Data

We need Baseline / average numbers for different materials

We also need best and worst for that material

- Manufacturer reporting
- Third party verified

We need data on building reuse vs new construction

We need to measure other impacts – ecological, social, health

Reducing Embodied Carbon

Materials

WHAT MAKES A MATERIAL GREEN?

Durable	lasts longer, lower life cycle impacts
Renewable	well managed resources, current solar income
Biodegradable	becomes food
Efficient	do more with less, resources go farther
Energy efficient	low embodied energy
Recycled/able	conserve virgin resources, and mfg. energy
Non-toxic	human and eco system health
Local	support local economy, minimize transport impacts
Bldg. perform.	improve building performance





WHAT MAKES A MATERIAL LOW EMBODIED CO_2?

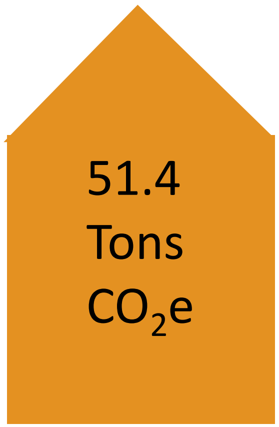
Durable	lasts longer, lower life cycle CO_2 impacts
Renewable	sequesters CO_2
Biodegradable	becomes food
Efficient	do more with less CO_2, resources go farther
Energy efficient	low embodied energy, low embodied CO_2
Recycled/able	conserve virgin resources, mfg. energy, & CO_2
Non-toxic	human and eco system health
Local	support local economy, minimize transport & CO_2 impacts
Bldg. perform.	improve building performance, minimize CO_2





Reducing Embodied CO_2e

(lower emission materials / fewer materials?)



Typical Home
(Full Basement)

Fiberglass Insulation
Vinyl frame windows
Vinyl Siding
Comp shingle roofing
2x4 framing
OSB Sheathing
15% fly-ash concrete

Source: NAHB estimates based on Athena Impact Estimator, the Department of Housing and Urban Development's Utility Model and regressions developed from the Department of Transportation's National Household Travel Survey Data.

Reducing Embodied CO_2e

(lower emission materials / fewer materials?)

51.4 Tons CO_2e

Typical Home
(Full Basement)

Fiberglass Insulation
Vinyl frame windows
Vinyl Siding
Comp shingle roofing
2x4 framing
OSB Sheathing
15% fly-ash concrete

43.9 Tons CO_2e

“Greener” Materials
(Full Basement)

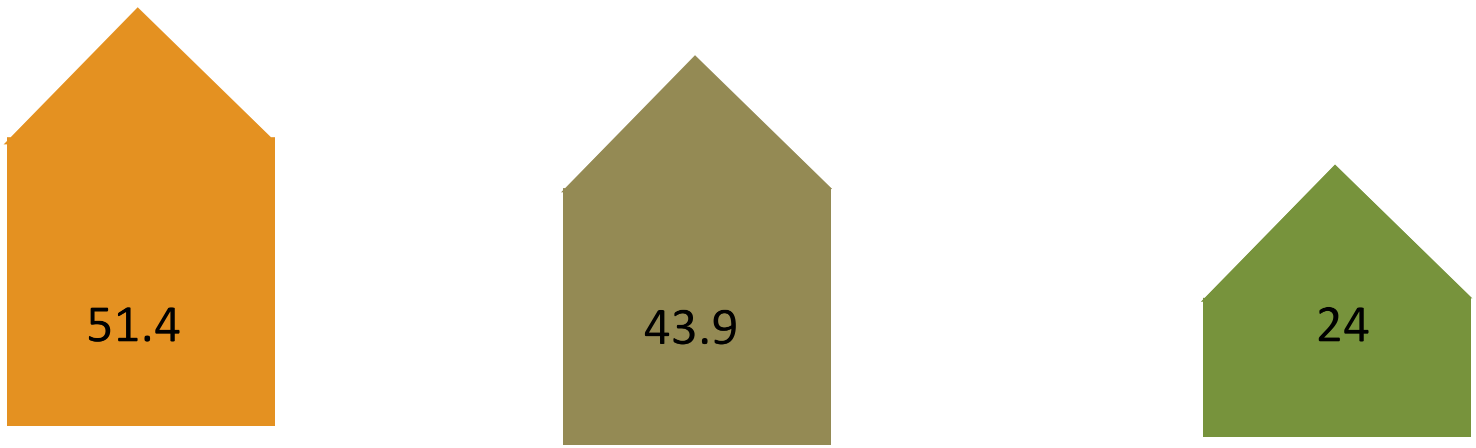
-3.64 Cellulose Insulation
-1.94 Wood frame windows
-1.77 Wood Siding
+2.89 Steel roofing – more durable
+0.32 2x6 framing – more insulation
-1.36 Plywood
-1.98 35% fly-ash concrete

7.5 ton reduction

Source: NAHB estimates based on Athena Impact Estimator, the Department of Housing and Urban Development’s Utility Model and regressions developed from the Department of Transportation’s National Household Travel Survey Data.

Reducing Embodied CO_2e

(lower emission materials / fewer materials?)



Typical Home
(Full Basement)

Fiberglass Insulation
Vinyl frame windows
Vinyl Siding
Comp shingle roofing
2x4 framing
OSB Sheathing
15% fly-ash concrete

"Greener" Materials
(Full Basement)

-3.64 Cellulose Insulation
-1.94 Wood frame windows
-1.77 Wood Siding
+2.89 Steel roofing – more durable
+0.32 2x6 framing – more insulation
-1.36 Plywood
-1.98 35% fly-ash concrete

7.5 ton reduction

"Greener" Materials
-19.9 (No Basement)

-3.64 Cellulose Insulation
-1.94 Wood frame windows
-1.77 Wood Siding
+2.89 Steel roofing – more durable
+0.32 2x6 framing – more insulation
-1.36 Plywood
-1.98 35% fly-ash concrete

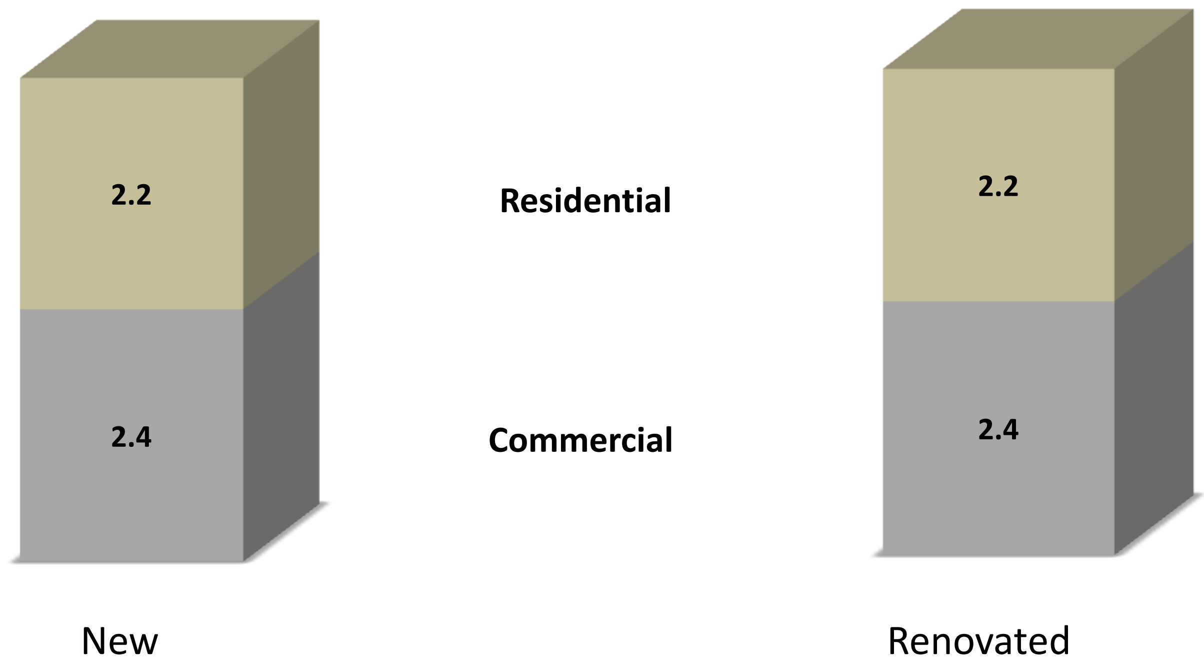
27.4 ton reduction

Source: NAHB estimates based on Athena Impact Estimator, the Department of Housing and Urban Development's Utility Model and regressions developed from the Department of Transportation's National Household Travel Survey Data.

Reducing Embodied Carbon

Existing Buildings

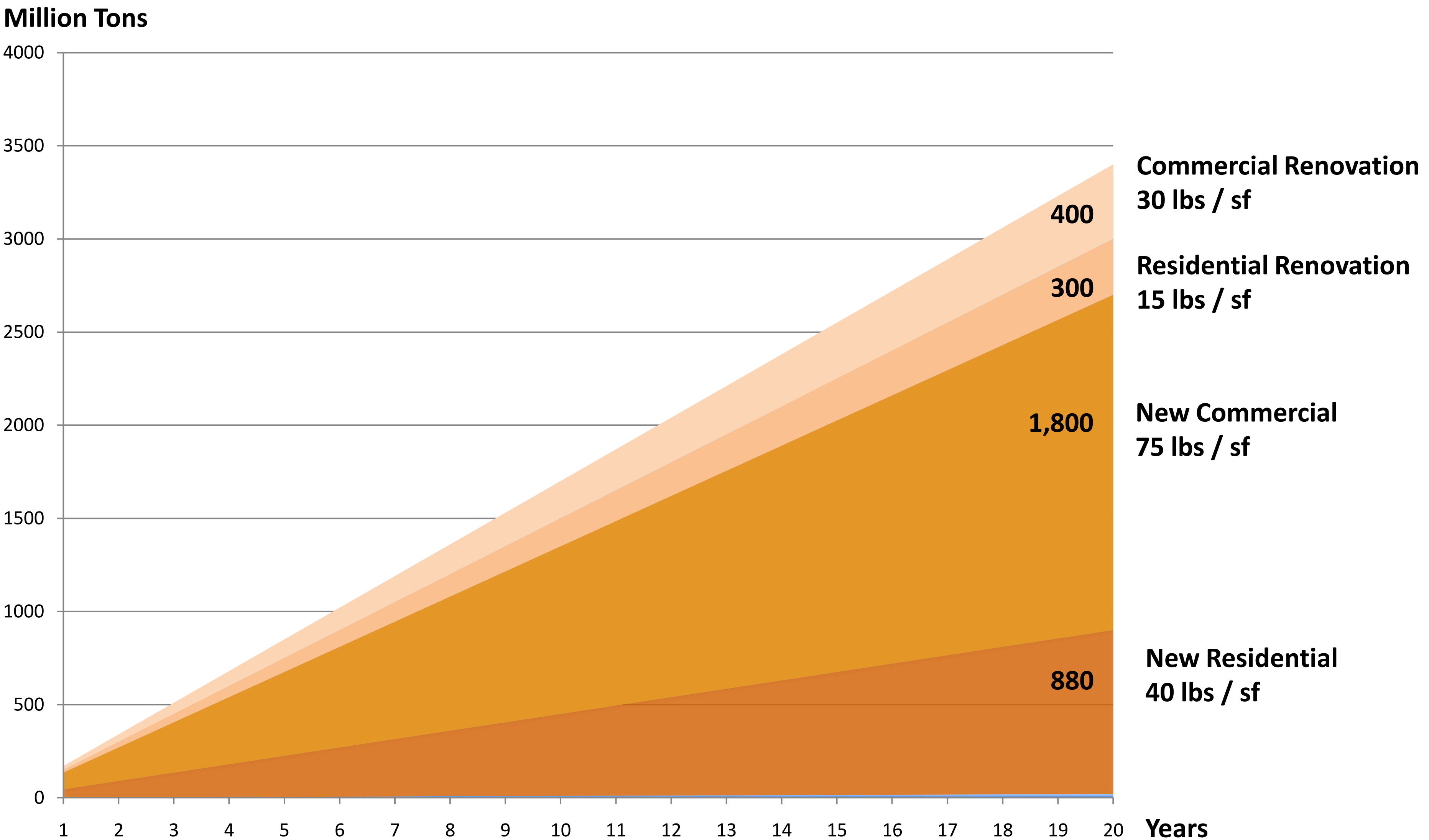
Annual Construction – Billions of Square Feet



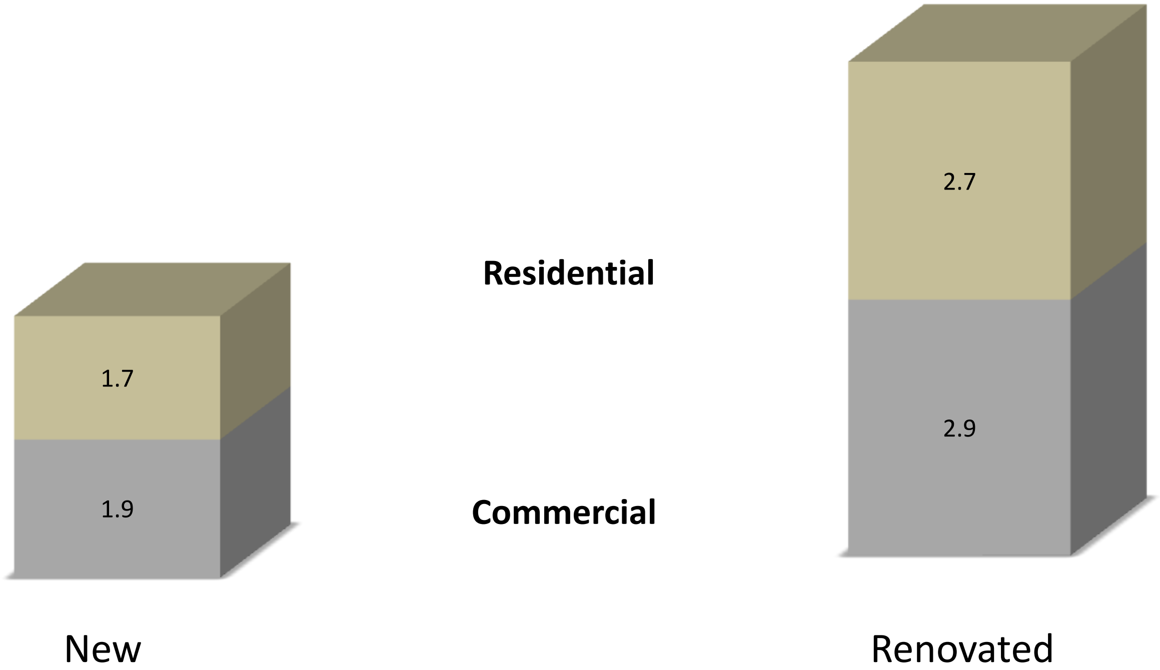
~4.6 Billion S.F.

~4.6 Billion S.F.

Embodied emissions over 20 years – 3.38 billion tons (4.6 billion sf new, 4.6 billion sf renovated)



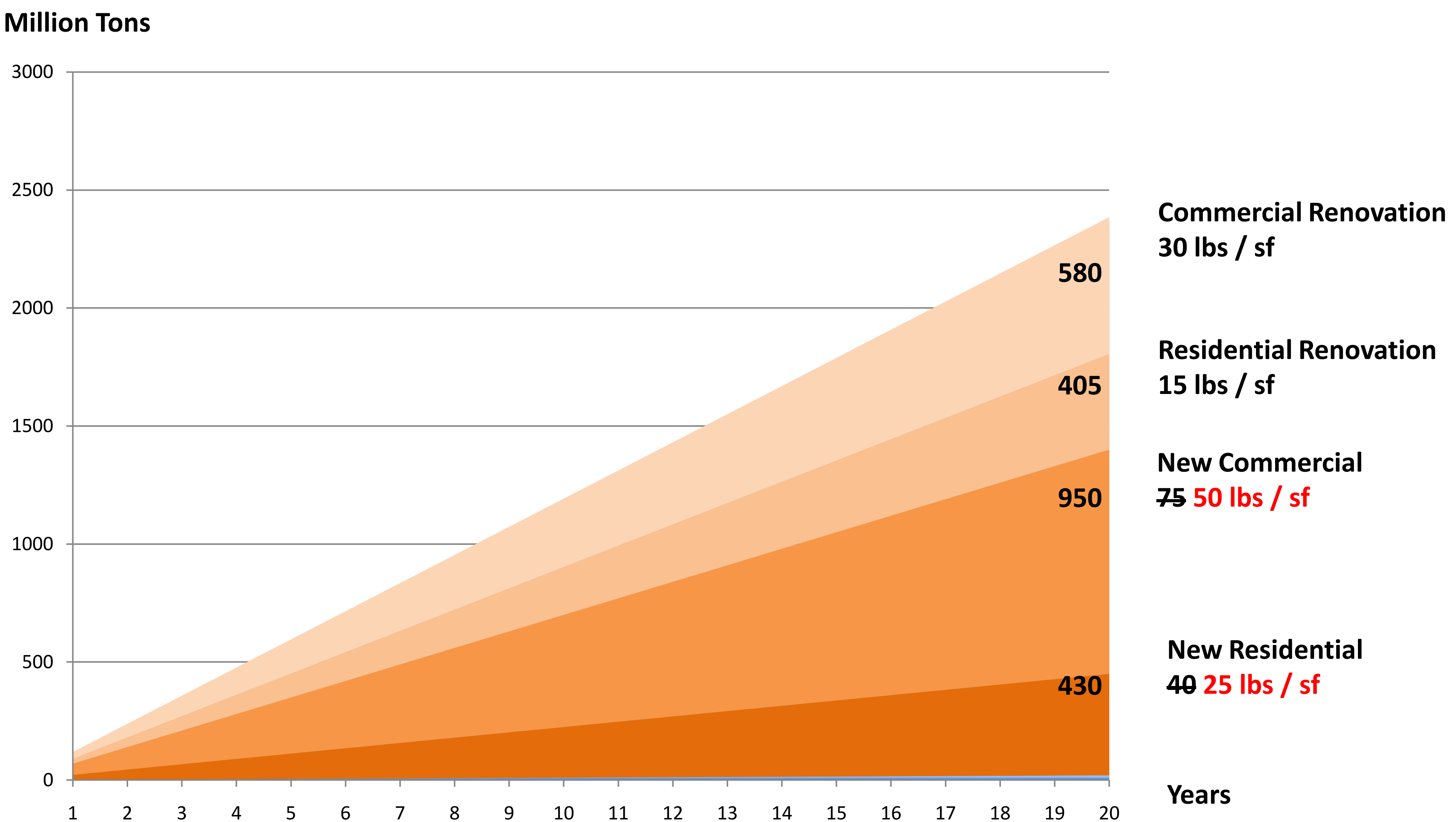
Annual Construction – Revised



~3.6 Billion S.F.

~5.6 Billion S.F.

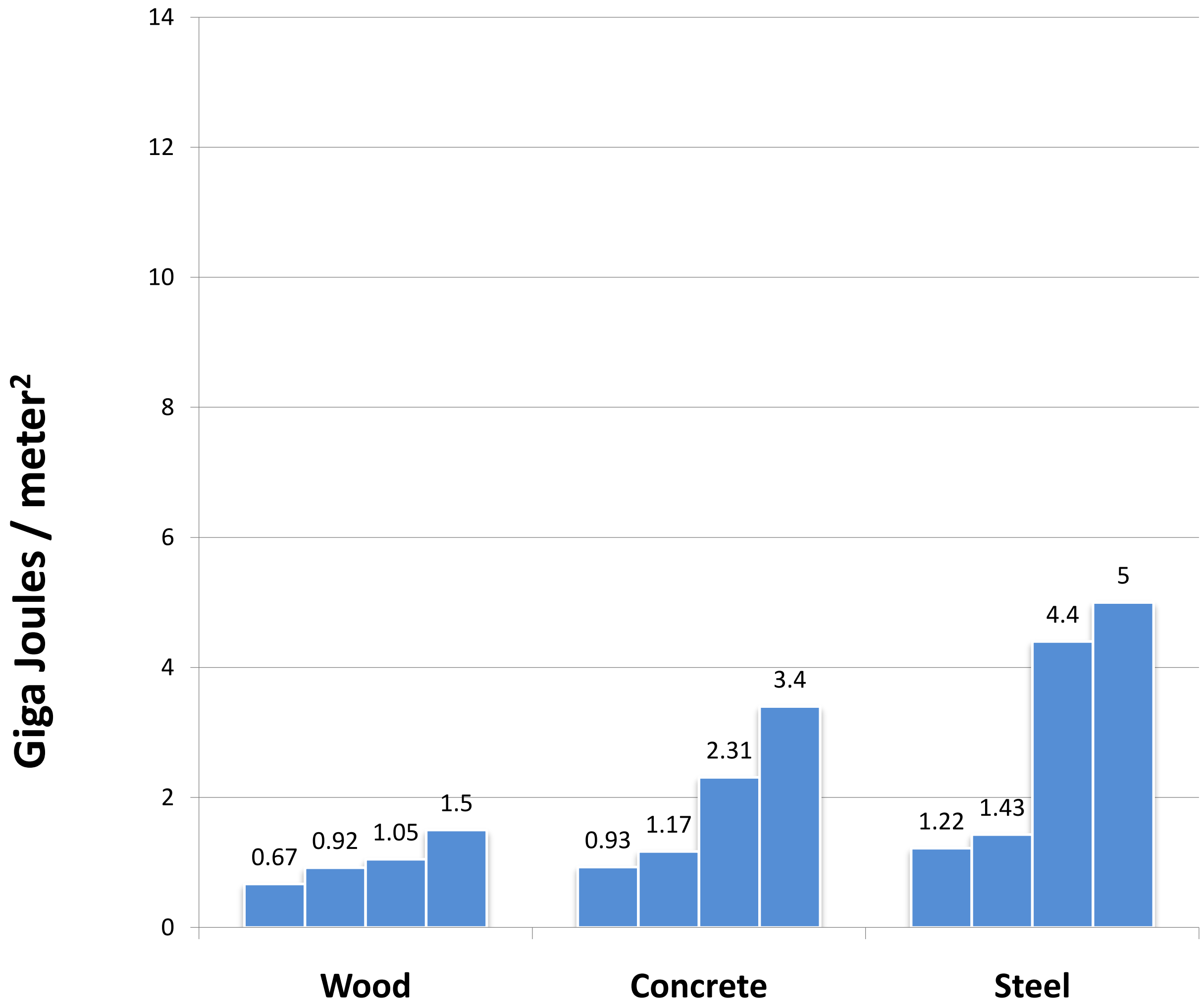
Reduce embodied emissions over 20 years – 2.36 billion tons + reduce new construction, increase renovations



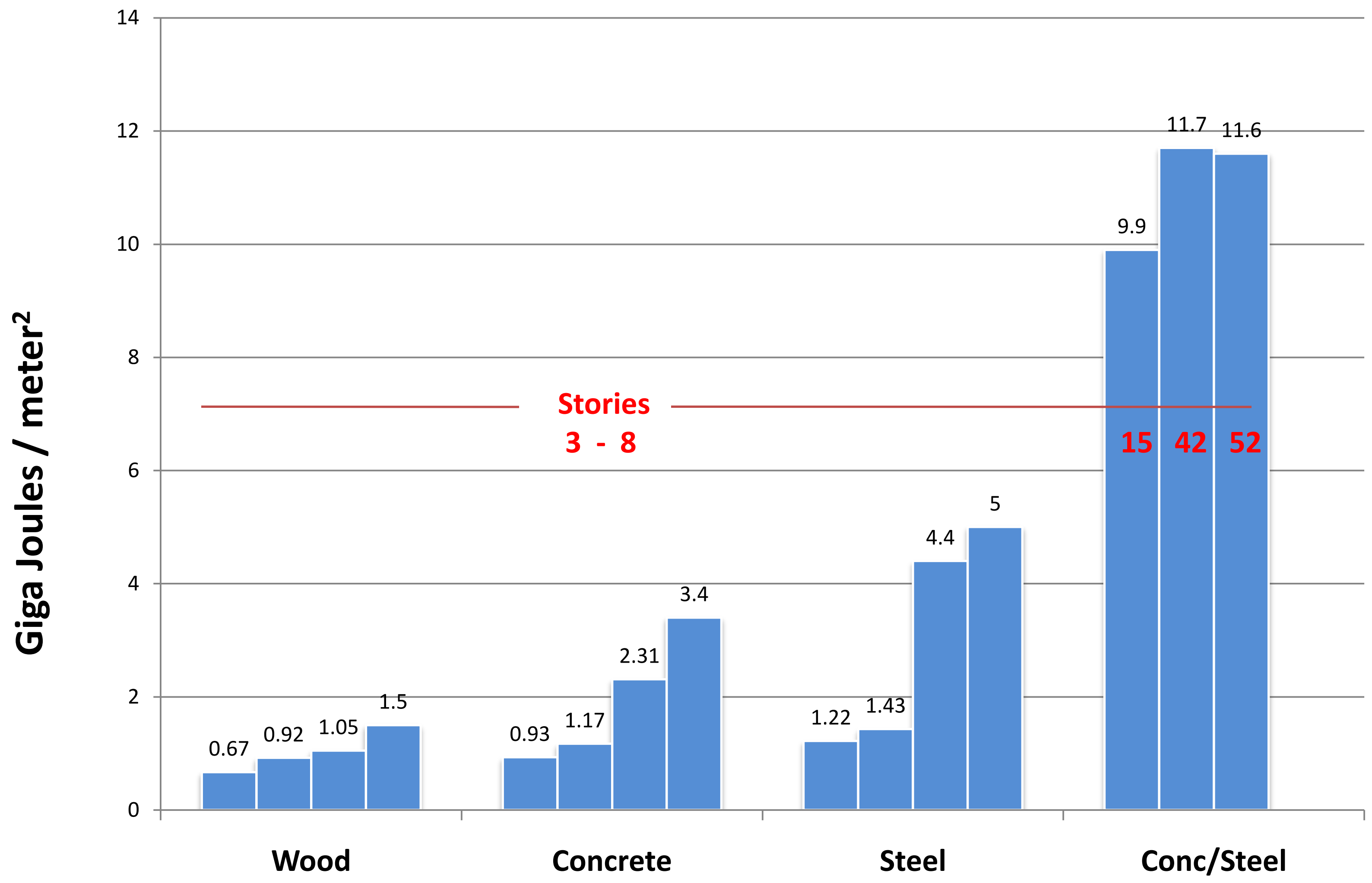
Reducing Embodied Carbon

Other strange unverified theories

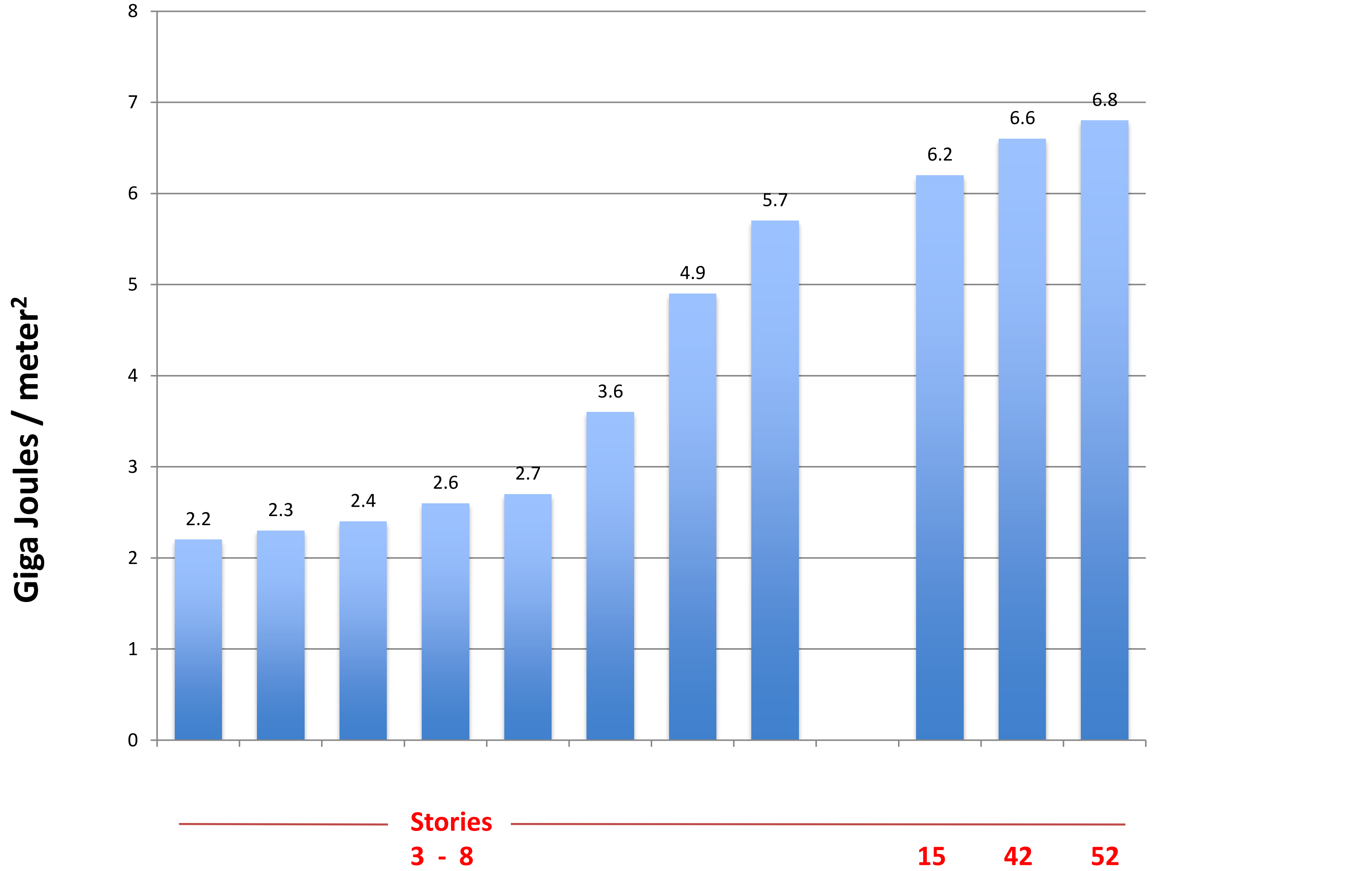
Embodied Energy - Structure



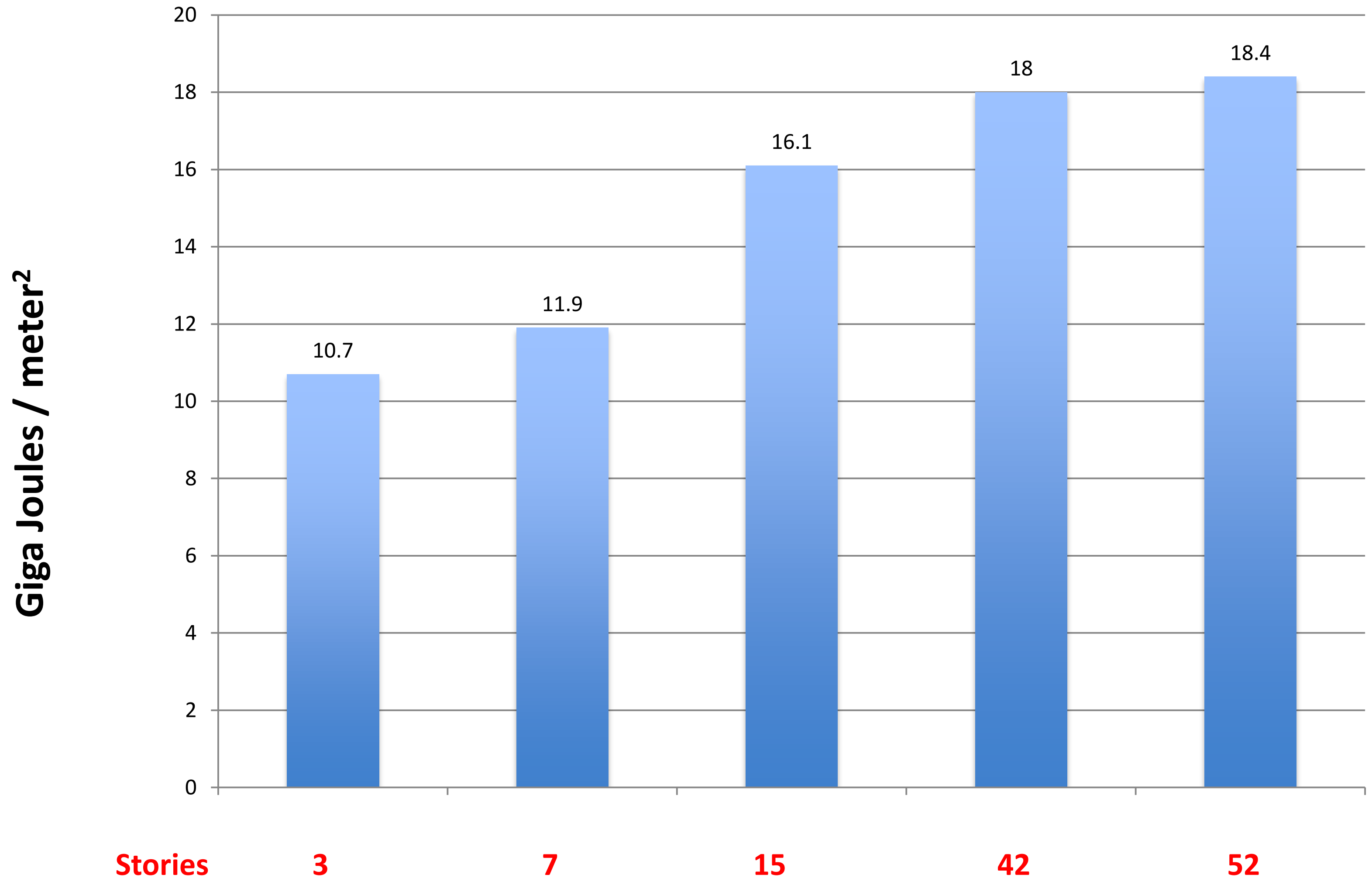
Embodied Energy - Structure + Height



Embodied Energy – Non-Structural Materials + Height



Embodied Energy – Total Materials + Height



Measurement

" . . . the fact that careful measurement is a way of discovering new things, not just checking the status quo. Monitoring is not just a necessary handmaiden of science - it is the real thing."

(Economist, March 6, 2010, "Monitoring Greenhouse Gases: Highs and Lows")

Reducing Embodied Carbon

Thank You