

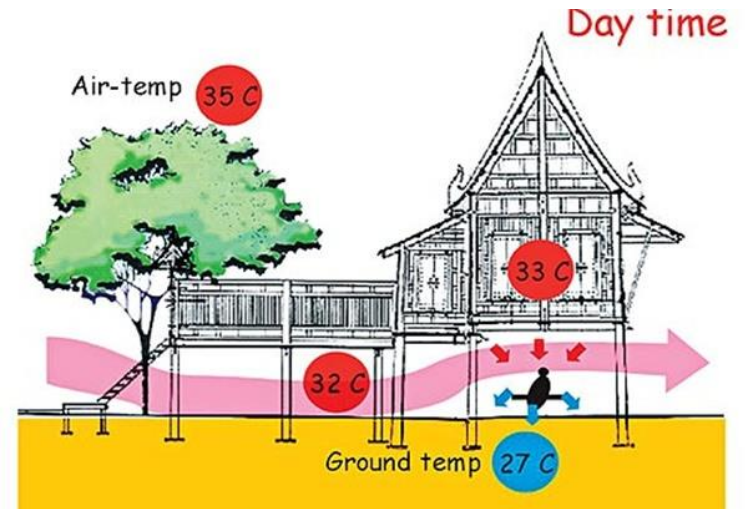
Thermal Performance and Carbon Reduction Potentials of Hempcrete Walls for Knockdown Houses of the National Housing Authority (NHA) of Thailand

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Chulalongkorn University

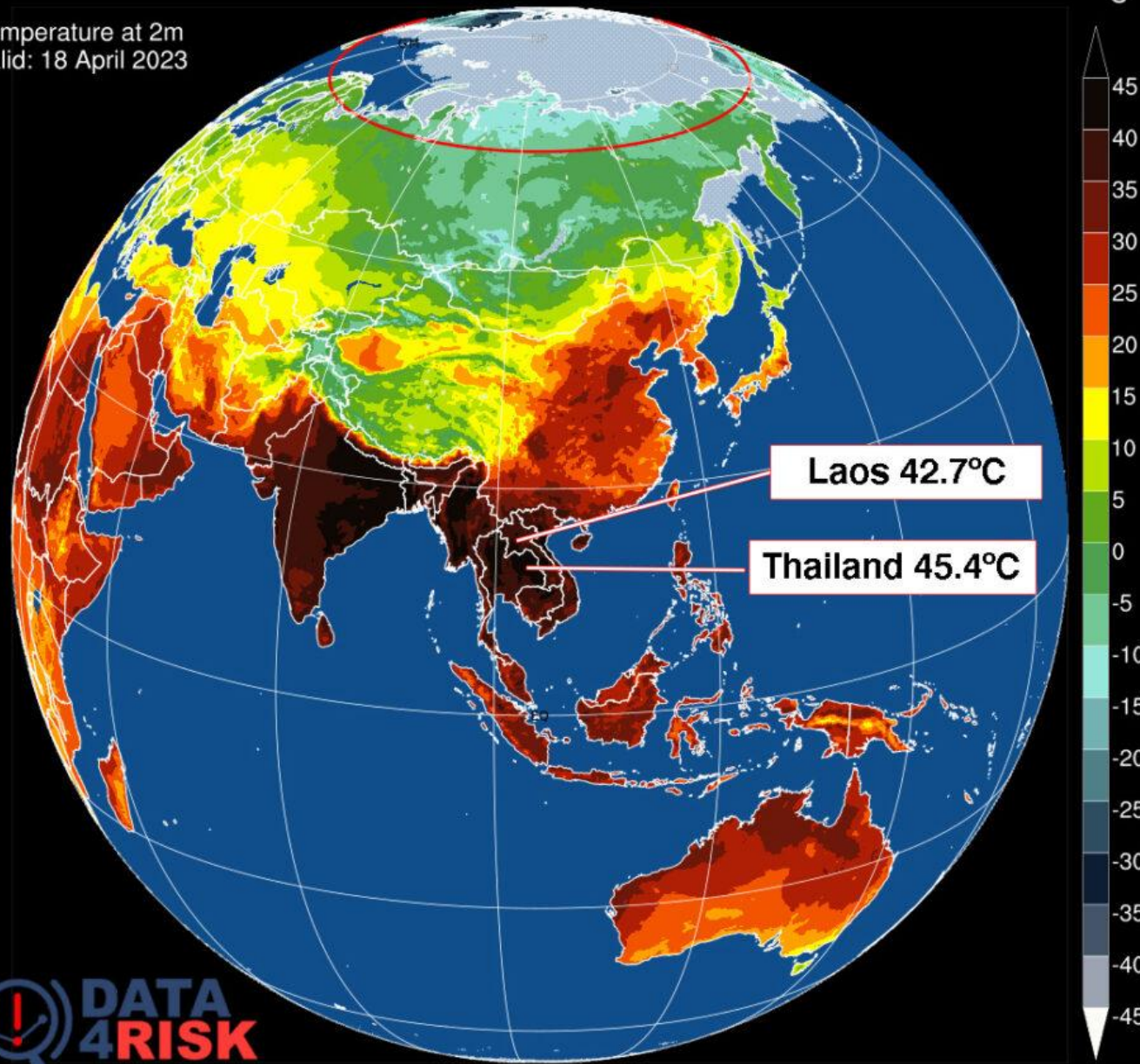
TRADITIONAL THAI HOUSES



<https://www.thestudioparkthailand.com/traditional-thai-house-ruen-kaew/>

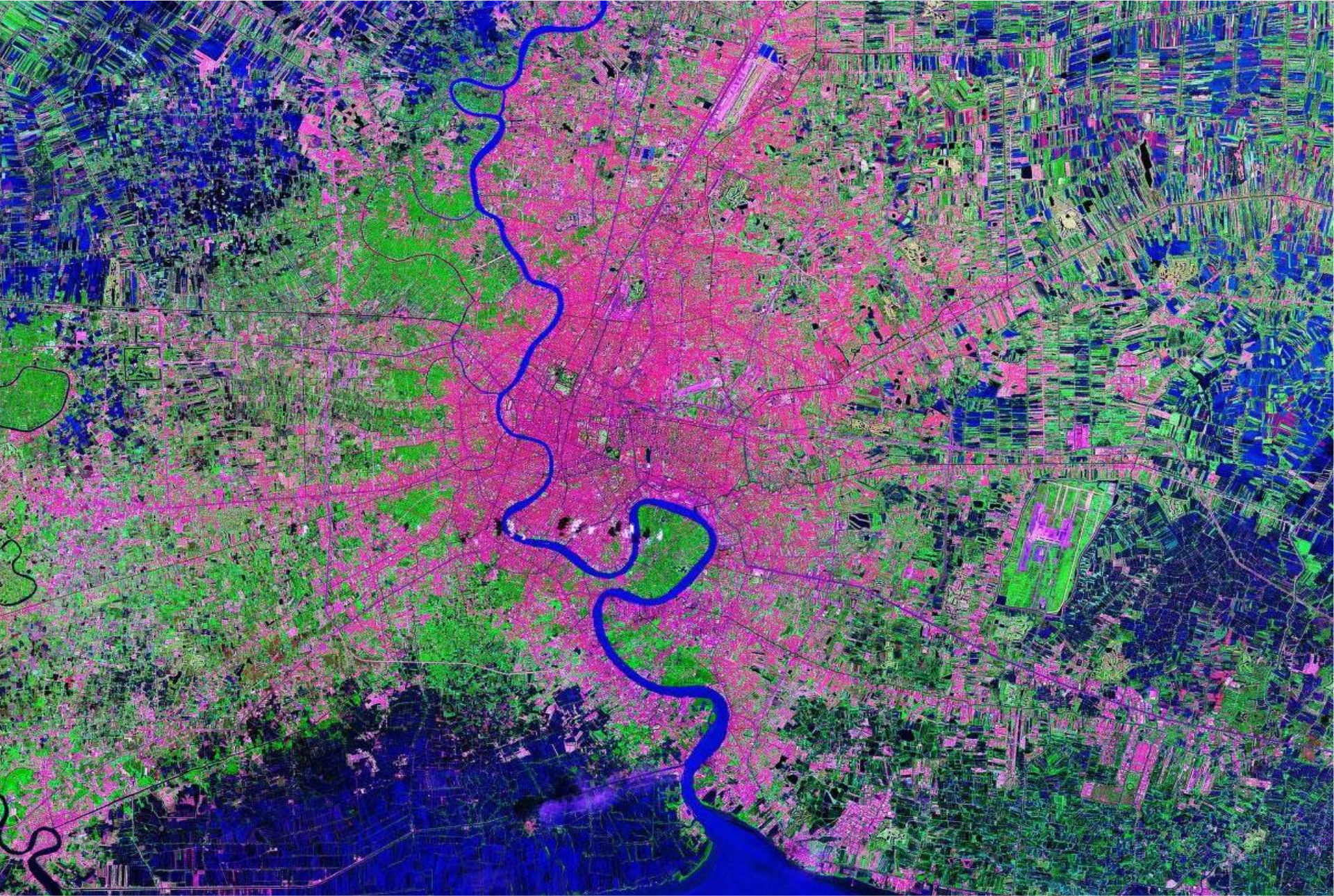


Temperature at 2m
Valid: 18 April 2023



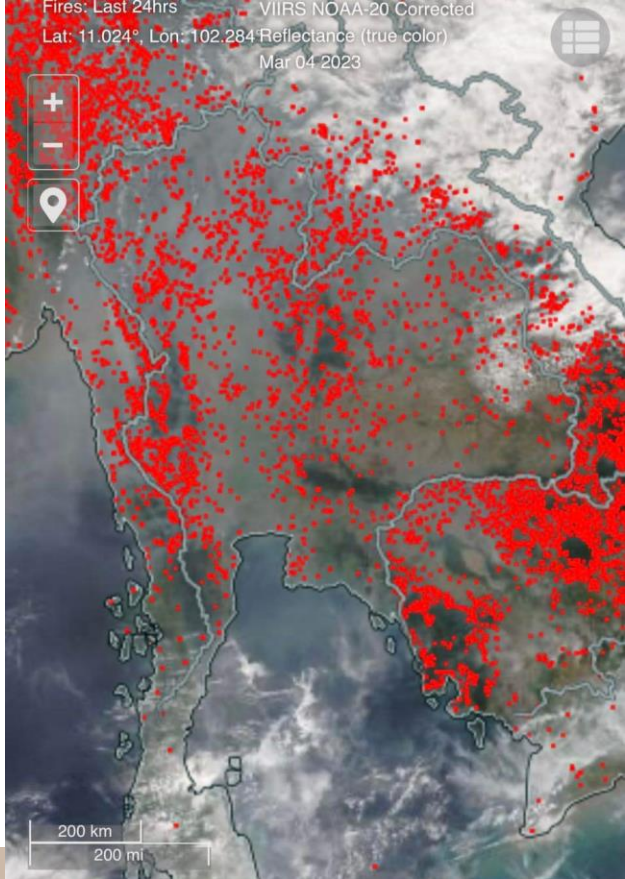
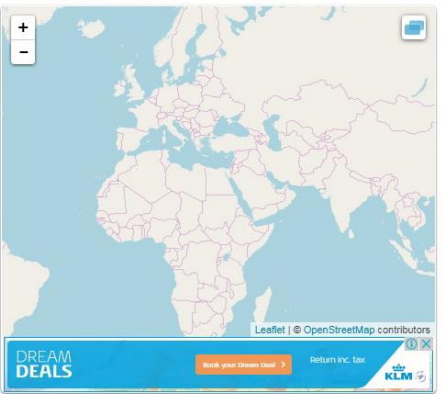
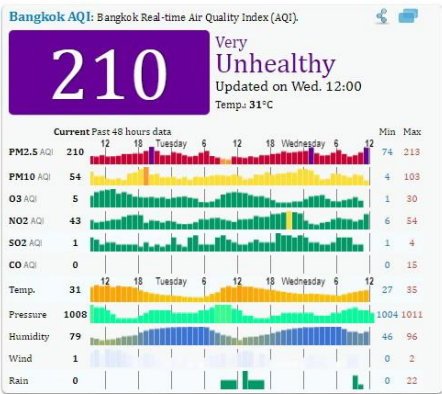
data4risk.com

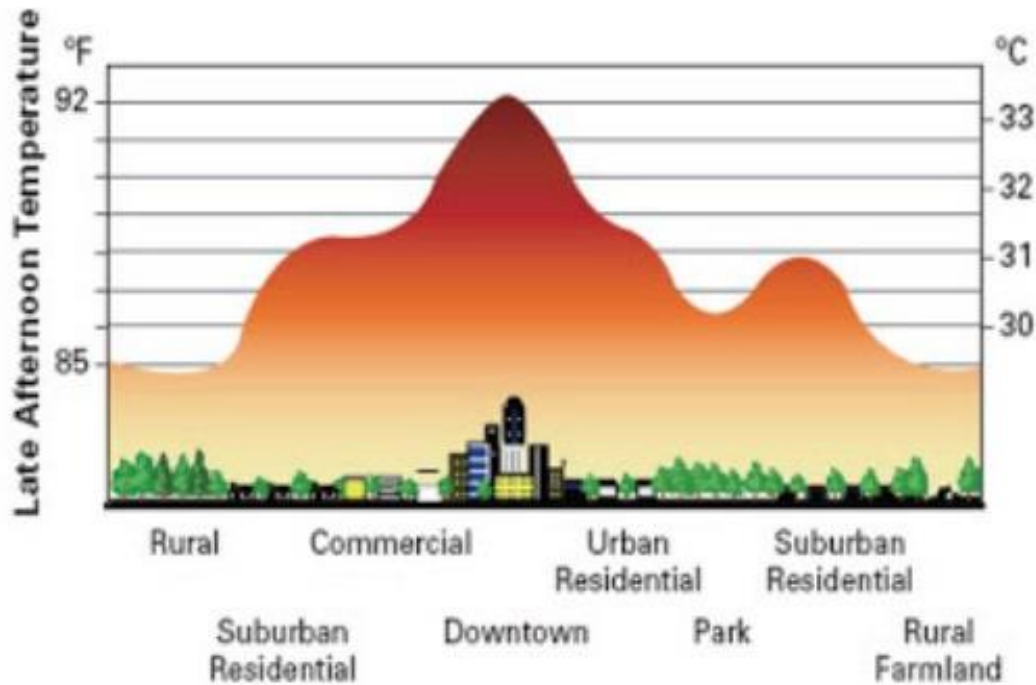
<https://www.data4risk.com/extreme-heat-waves-in-april-2023-in-asia-and-europe/>



BANGKOK METROPOLITAN AREA

Bangkok Air Pollution: Real-time Air Quality Index (AQI)

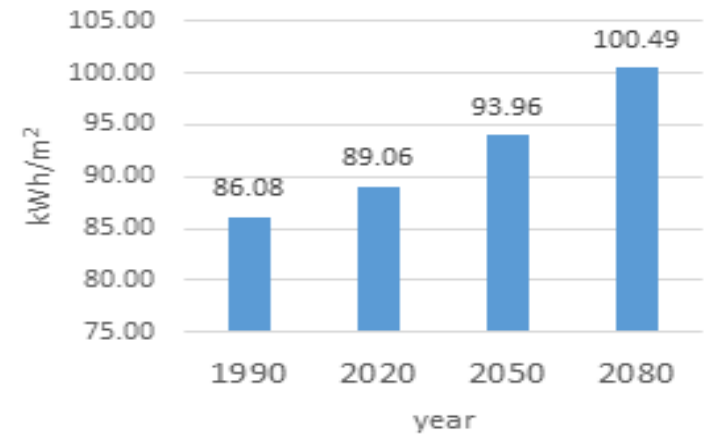
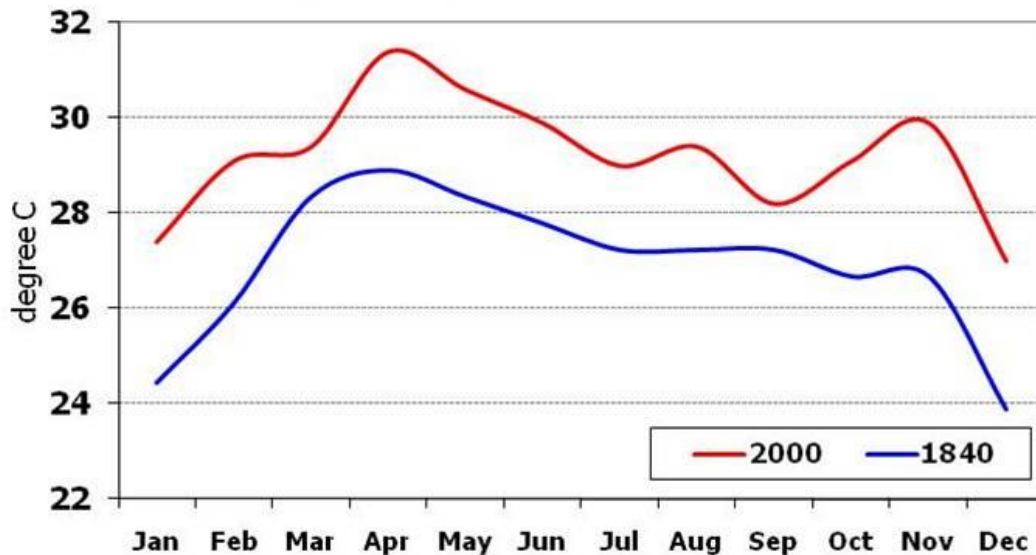




Urban Heat Island

- Not enough green area
- Not enough water retention
- Too many concrete pavement
- Too many cars
- Too many air-conditioners

Bangkok Temperatures Year 1840 & Year 2000



ที่มา: ภัฏฐา ตระกูลไทย และอรรรจน์ เศรษฐบุตร (2559). ผลกระทบจากภาวะอากาศเปลี่ยนแปลงต่อการใช้พลังงานอาคารในเขตร้อนชื้น

MODERN THAI HOUSES



Medium/high-income housing (150 – 500 k USD)



NHA Low-income housing (10 k USD)



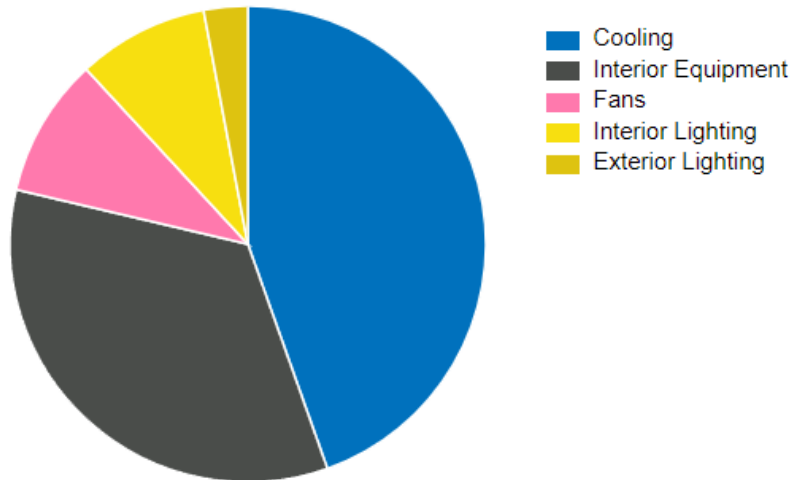
<https://www.pd.co.th/en/article/detail/716/stilt-house-season-ii-modern-thai-style-concept>

TYPICAL HOUSE: ENERGY USE INDEX

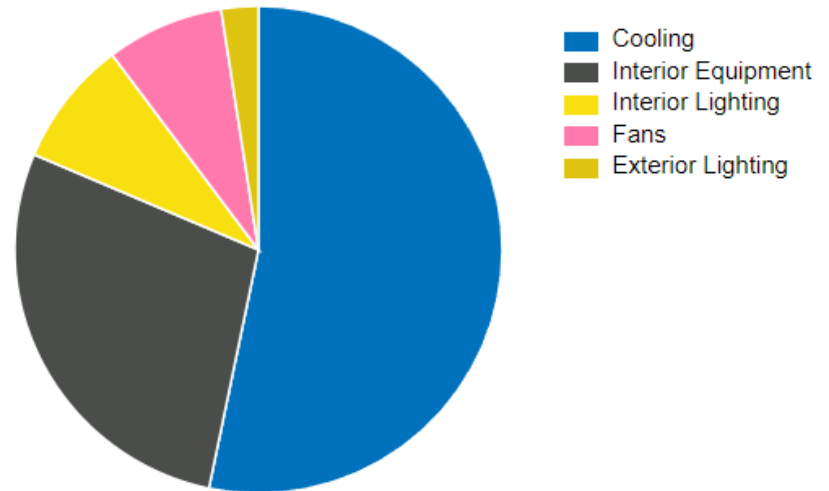
Base Case	House Orientation (kWh/y)				Average Consumption (kWh/y)	EUI (kWh/m ² .y)*	Electric Bill/month** (Baht)
	North	South	East	West			
Normal house	12,669	12,733	12,833	13,078	12,828.25	78.70	5,954.45
Elder & WFH house	15,564	15,686	15,814	16,008	15,768.00	96.74	7,318.98

*Energy use intensity (EUI), Interior floor area approx. 163 m²

** 5.57 Baht/Unit



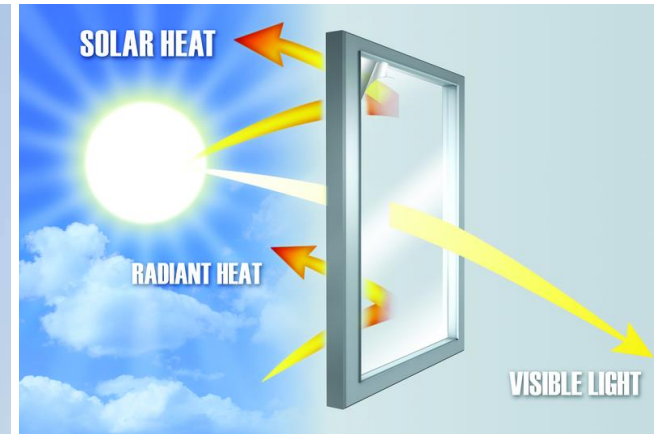
Normal house – Annual Energy Overview



Elder & WFH house– Annual Energy Overview

ENERGY CONSERVATION MEASURES

Case	Proposed items
Propose 1	Roof insulation
Propose 2	Improve wall performance
Propose 3	Shading at Front Façade
Propose 4	Improve glass performance
Propose 5	Tree Shading
Propose 6	PU Foam in Windows Frame
Propose 7	Solar cell for shading
Propose 8	Daylight sensor
Propose 9	Hot water from CDU
Propose 10	Combined Option XX + XX + XX



ENERGY SAVING

Case	Proposed items	Cost (baht/sq.m.)	Annual Consumption (kWh/y)	EUI (kWh/m2.y)*	Electric Bill/month** (Bath)	Energy Saving (%)
Basecase	Normal SENA house		16,008	98	7,430	-
Propose 1	Roof insulation					
- Propose 1.1	[Add] 3 inch fiberglass insulation <u>under concrete roof tile</u>		15,383	94	7,140	3.90%
Propose 2	Improve wall performance					
- Propose 2.1	[Add] 10 cm Single light weights block wall at <u>all exterior wall</u>		15,439	95	7,166	3.55%
Propose 3	Shading at Front Façade					
- Propose 3.1	[Add] Shading at Front Façade_Option 1		15,508	95	7,198	3.12%
Propose 4	Improve glass performance					
- Basecase	[Basecase] 6 mm_Ocean green float glass , SHGC 0.6	~ 300-500	16,008	98	-	0.00%
- Propose 4.1	[Add] 6 mm_SolarTAG PLUS_CS135	~ 800-1000	15,228	93	7,068	4.87%
- Propose 4.2	[Add] 6 mm_SolarTAG PLUS_CS214	~ 800-1000	14,311	88	6,643	10.60%
- Propose 4.3	[Add] 12.76 mm_Lamitag Solartag-TBL-120 6+0.76+6	TBC	14,925	91	6,928	6.77%
- Propose 4.4	[Add] XX mm_Th-Low-e double glazing e=0.1 on surface 2	TBC	14,286	87	6,631	10.76%
- Propose 4.5	[Add] ~ 6 mm_Low-e Laminate 3+3	~ 1500-1700	14,897	91	6,915	6.94%
- Propose 4.6	[Add] 31.52 mm_6+1.52+6+12A+6 (Insulated Low-E)	~ 5000-5500	13,658	84	6,340	14.68%
Propose 5	Tree Shading					
- Propose 5.1	[Add] Tree on South and West façade		15,960	98	7,408	0.30%
Propose 6	PU Foam in Windows Frame					
- Propose 6.1	[Add] PU Foam in Aluminum Windows Frame		15,956	98	7,406	0.32%
Propose 7	Solar cell for shading					
- Propose 7.1	[Add] Solar cell 5 kW (For Shading)		15,841	97	7,353	1.04%
Propose 8	Daylight sensor					
- Propose 8.1	[Add] Daylight sensor 1.Dining room and 2.living room		15,458	95	7,175	3.44%
Propose 9	Hot water from CDU					
- Propose 9.1	[Add] Hot water for CDU		15,873	97	7,368	0.84%
Propose 10	Combined Option					
- Propose 10	Combined Option: 1.1+2.1+3.1+4.5+7.1+8.1+9.1		12,197	75	5,661	23.81%

*Energy use intensity (EUI), Interior floor area approx. 163 m² ** 5.57 Baht/Unit

Electric bill saving /year (baht)

21,227.27

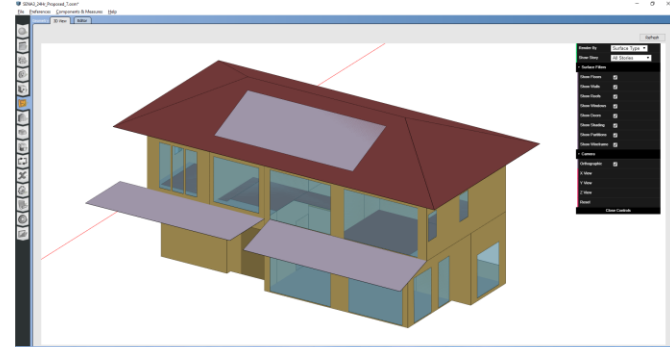
= Combined items

CONSTRUCTION COST

Materials	Proposed items	% Saving	Area (m ²)	Material Cost (baht/m ²)	Labor cost (baht/m ²)	Total cost (baht/m ²)	Total cost (baht)
Propose case							
Insulation	3 inch fiberglass insulation under concrete roof tile	3.5-4%	160	200	-	200	32,000
	3 inch fiberglass insulation on fl.2 Ceiling (Optional)	0.5-3%	97	150	-	150	14,550
Exterior wall	10 cm Light weights block at all exterior wall	3-3.5%	210	240	60	300	63,000
Shading	Shading at Front Façade	2.5-3%	50	577	94	671	33,550
Glass	6 mm_Low-e Laminate 3+3 at AC Room windows and door (Guardian)	6-7%	66	1,500	-	1,500	98,715
Lighting control	Daylight sensor 1.Dining room and 2.living room (~ 3,000 baht/room)	3-3.5%	2	3,000	-	3,000	6,000
Propose case cost							233,265
Base case							
Exterior wall	10 cm Precast concrete	3-3.5%	210	300	-	300	63,000
Glass	6 mm_Green float glass	6-7%	66	500	-	500	32,905
Base case cost							95,905.00
Net increasing cost							137,360.00

NET ZERO: OPERATIONAL ENERGY

- **Energy Saving**
 - 20-24% by better envelope
 - 50% by better envelope +3 kW Solar PV
 - **100% by better envelope + 8 kW Solar PV**
- **Construction Cost: 4.5% or 150,000 THB (PV excluded)**
 - Energy saving = 16,000 – 21,000 THB/year
 - Payback = 7 years
- **For TYPICAL house + 3kW Solar PV**
 - Sell back to grid: 2-4 kWh/day (150-300 THB/month)
- **For WFH house + 3 kW Solar PV**
 - Need to buy 2-14 kWh/day



Embodied Carbon Calculator

The screenshot displays a software interface for embodied carbon calculation. The main window shows a 3D model of a building structure with a red roof and a grey frame. The interface includes a menu bar at the top with options like File, Architecture, Structure, Systems, Insert, Annotate, Analyze, Massing & Site, Collaborate, View, Manage, Add-Ins, ABT, Archilizer, DiRoots, JOTools, Proving Ground, pyRevit, Extensions, and a window icon. Below the menu bar is a toolbar with icons for SelectByProperty, Sheet Duplicator, Filter Generator, AlignViewsOverSheets, ExplodedViewByLevel, text, About, Feedback, Help, Info, on/off, MIM, plot, and Sheet Duplicator. The Properties panel on the left shows the 3D View settings, including View Template, View Name, Dependency, Title on Sheet, Workset, Edited by, Phasing, Phase Filter, Phase, IFC Parameters, IFCExportAs, Fire Protection, and FireRatingR. The Project Browser on the left shows a tree view of the project structure, including plot UO vorm, plot UO wap, werk, and various Structural Plans. The Milieu-Impact Monitor window on the left shows key figures for the construction, including CO2 emission, shadow price, BVO, and BVO lifespan, along with a pie chart and a gauge chart.

Milieu-Impact Monitor

Kengetallen constructies:

CO ₂ emissie (kg)	3198055
(kg/m ³ BVO)	150.85
schaduwpijs (€)	298770
(€/m ³ BVO)	14.09
(€/m ³ BVO/jaar)	0.28
BVO (m ³)	21200
levensduur (jaar)	50

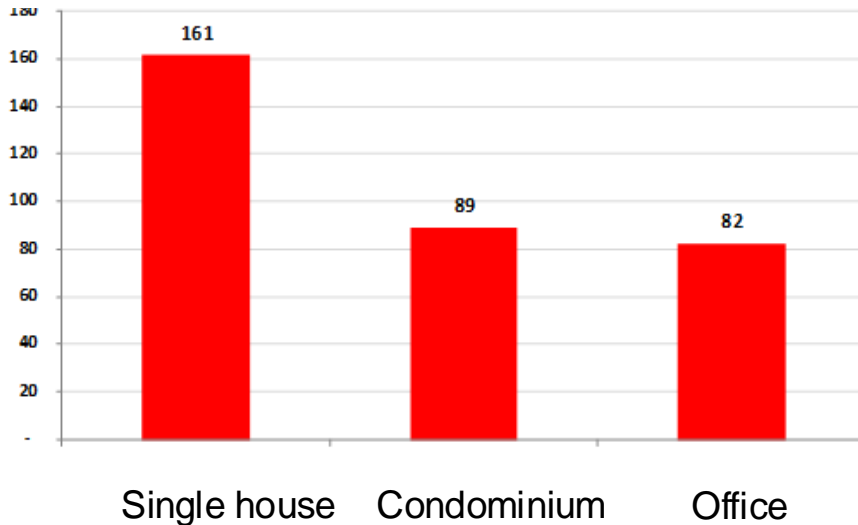
CO₂ emissie per Revit category

schaduwpijs per €/m³ BVO/jaar

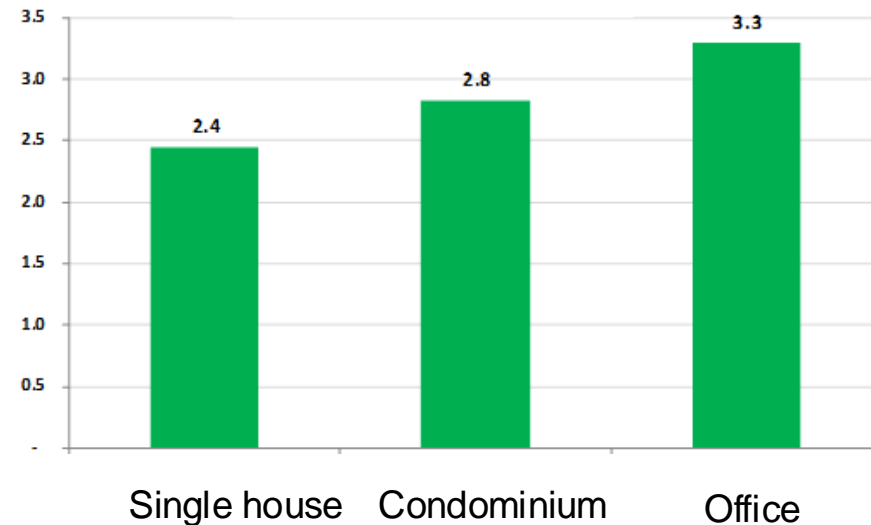
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Lifetime CO₂ emissions of 3 building types (30 years): Thailand

Ton of CO₂/occupant

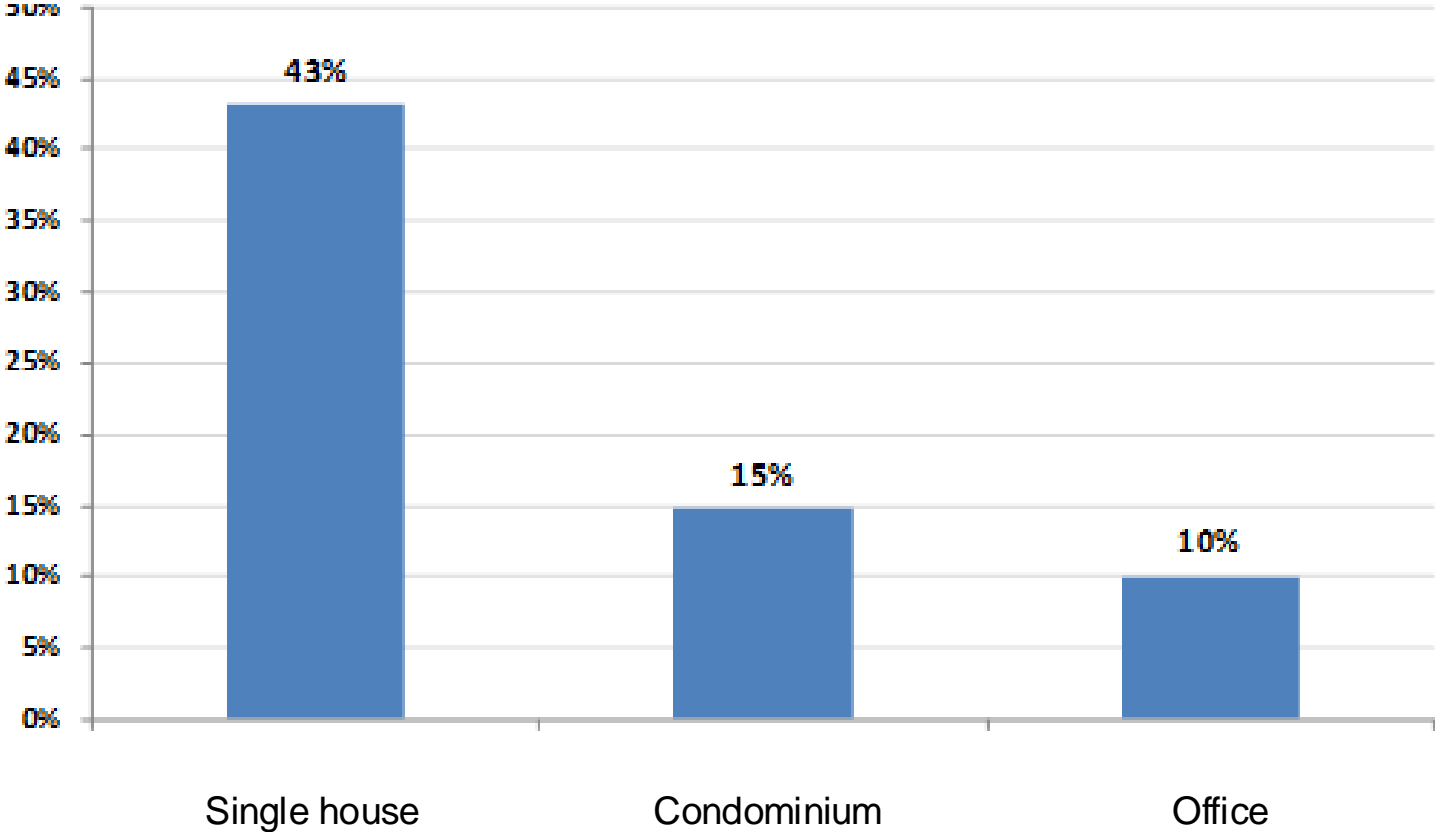


Ton of CO₂/sq.m. area



The emission per occupant from single house is the highest. However, the emission per unit area is the highest in office building as it is normally used in the daytime when the outside air is hot and the building needs air-conditioning.

Lifetime CO₂ emissions of 3 building types (30 years): Thailand



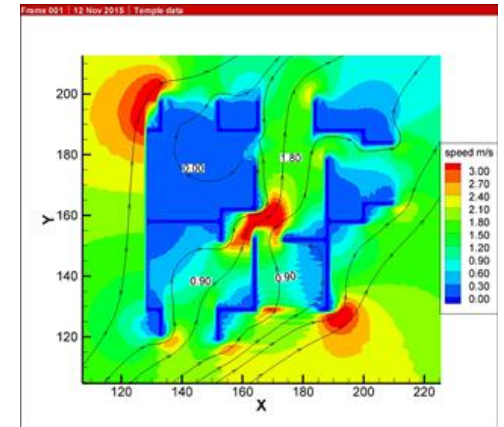
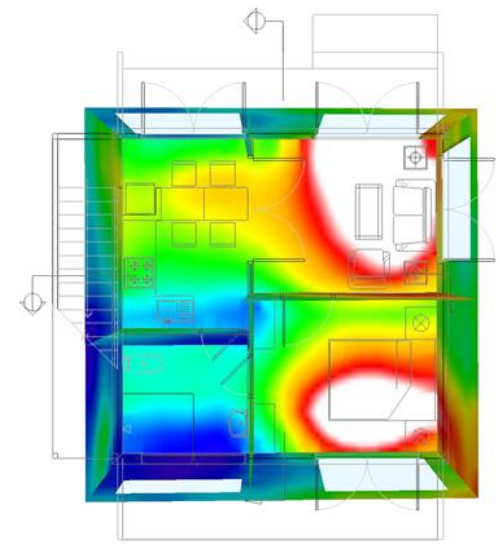
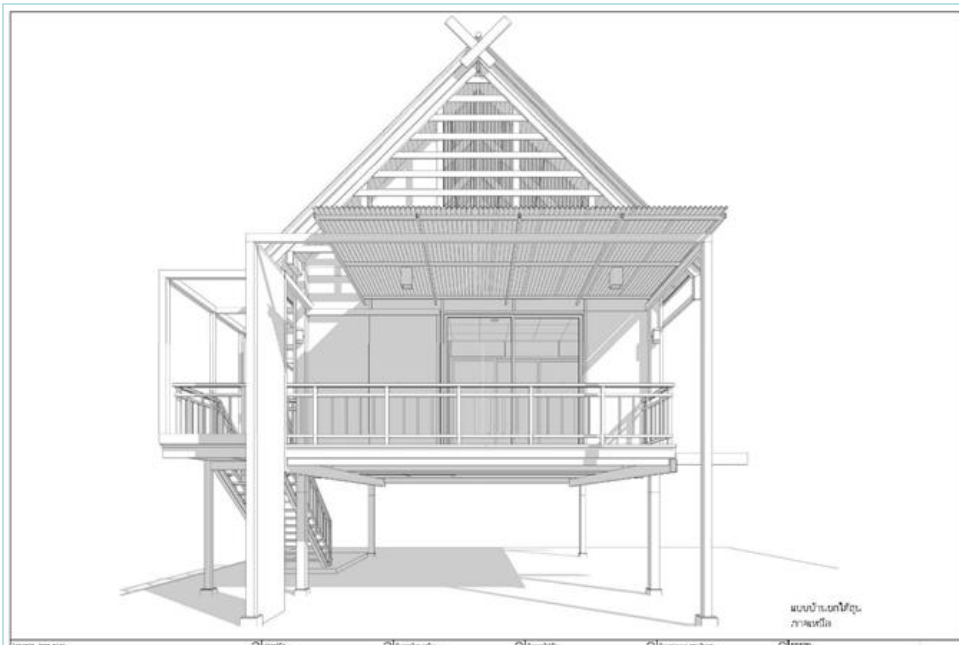
43% of carbon emission from a house comes from building materials (Embodied carbon). For condominium and office buildings, it is only 15% and 10%.

Project Knockdown House

National Housing Authority (NHA)

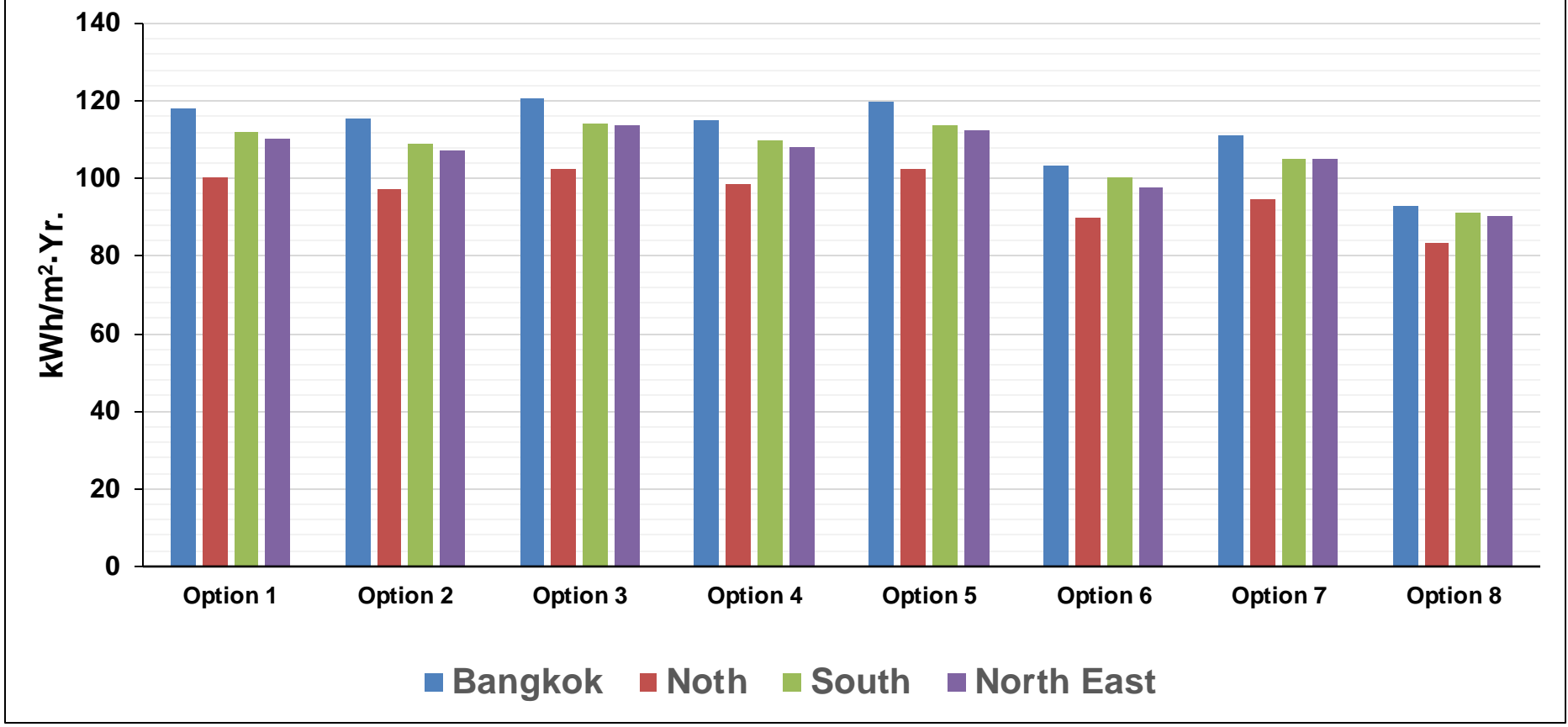
Low-cost – 15 k USD, 36-sq.m., Tropical Design
4 Regions of Thailand, Energy Saving
Low-carbon (Embodied + Operation)





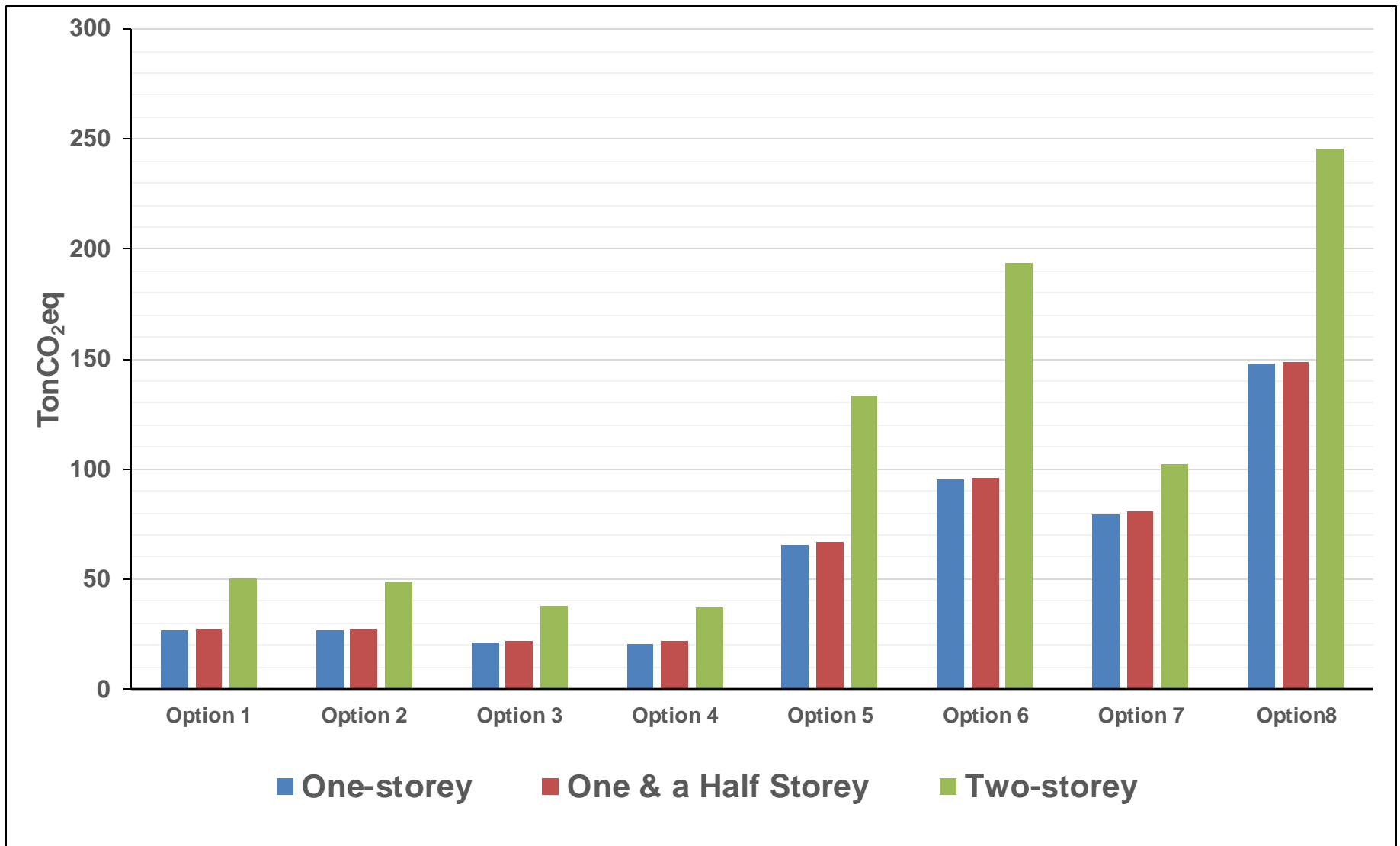
Eight envelope options

1. Red brick wall + single clear glass + no insulation (**Base case**)
2. Change clear glass to tinted glass (SHGC = 0.5)
3. Change red brick to concrete blocks (U-value up to 4.2 W/m².C)
4. Change red bricks to autoclaved aerated concrete (U-value down to 1.2 W/m².C).
5. Change red bricks to precast concrete
6. Change red bricks to fiber cement board with 3" foam insulation
7. Add 3" foam insulation on the ceiling
8. **Combined options: 2 + 6 + 7**

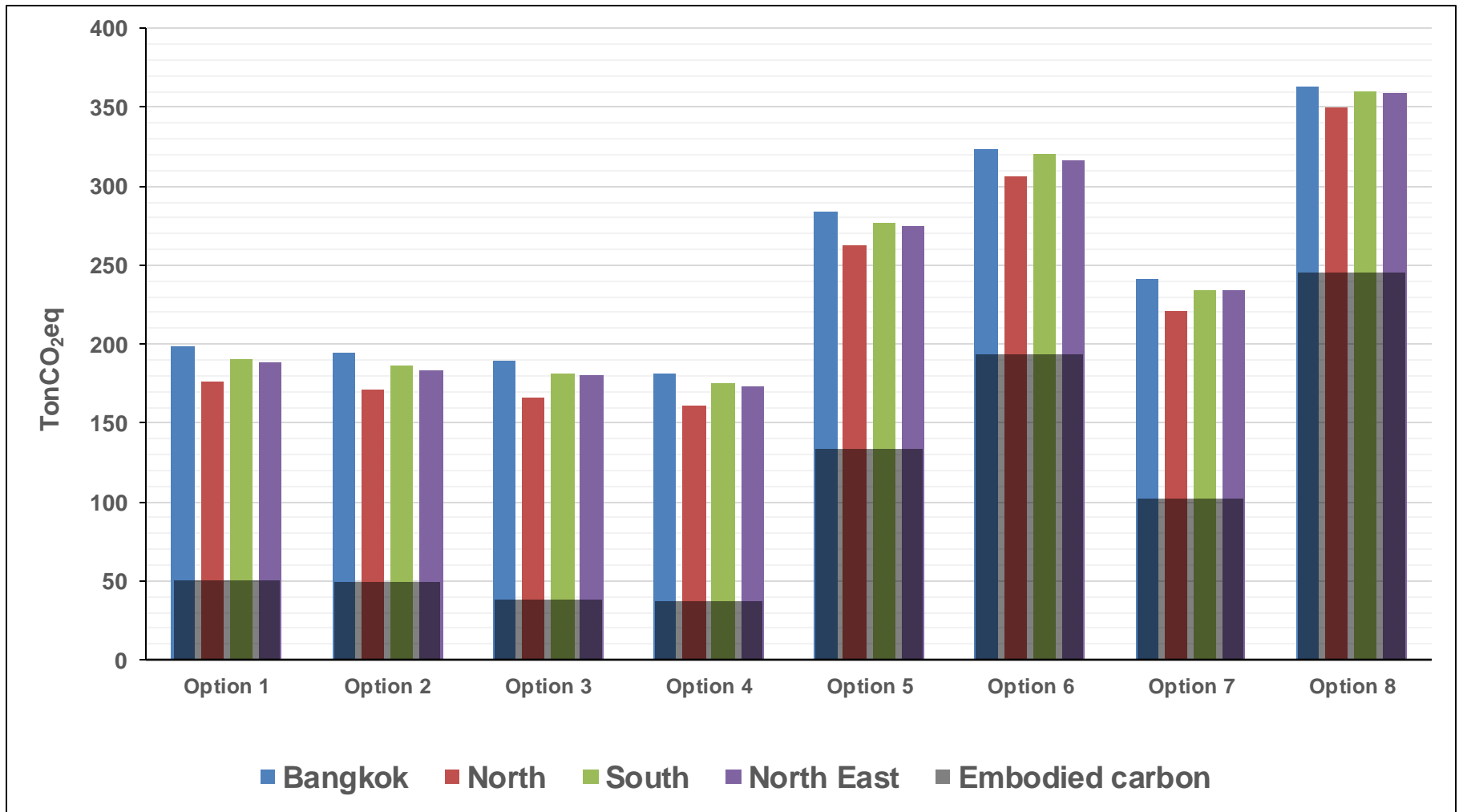


Energy Use Index (EUI) in kWh/m².year of the NHA Knockdown Houses Designed with Eight Energy Saving Options for 4 Regions of Thailand

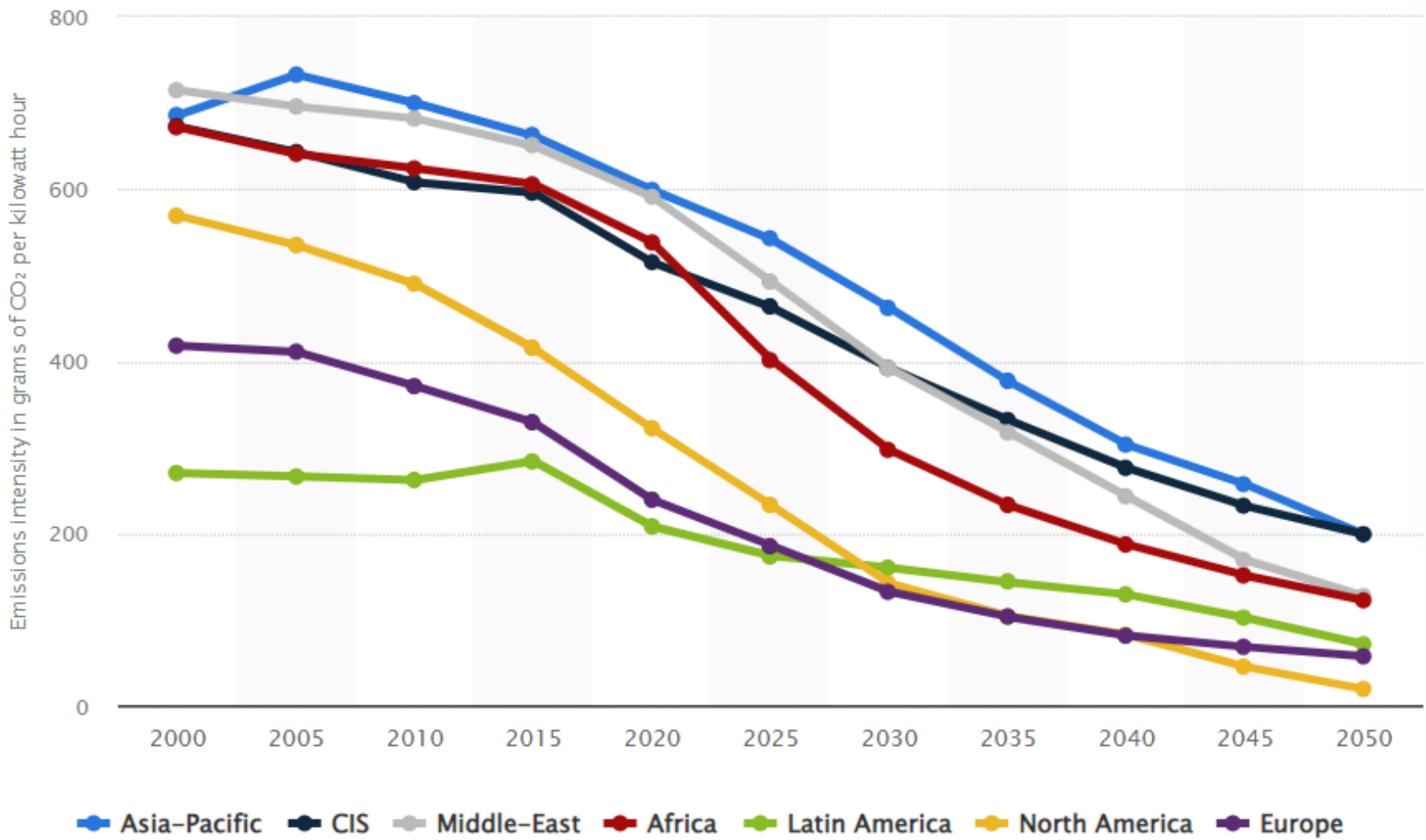
Option 8: tinted glass with 3” foam insulation in exterior walls and 3” foam insulation in ceiling is the best in all 4 climates of Thailand.



Embodied Carbon (TonCO₂eq) of the three designs (one-storey, one and a half story, and two-story houses using 8 options



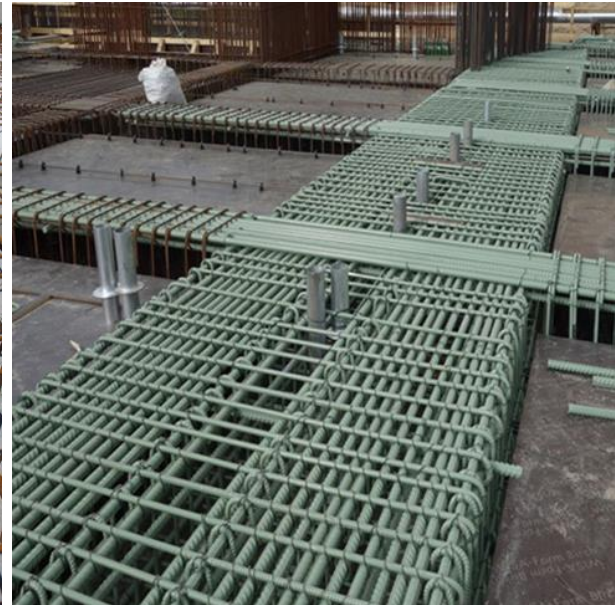
Combined Embodied and 30-year Operational Carbon (TonCO₂eq)



© Statista 2024

Forecasted CO₂ intensity of electricity generation worldwide from 2000 to 2050, by region (in grams of carbon dioxide per kilowatt hour)

CARBON SINK & LOW-EMBODIED MATERIALS



CROSS LAMINATED TIMBER

BUBBLE DECK

EPOXY REBAR



Project Hempcrete House



Hempcrete
 Hemphurd 80%
 sized 8mm
 Cement 20%

Hemp insulation
 Hemphurd 98%
 lime 2%

Hempcrete
 Hemphurd 20%
 lime
 Cement

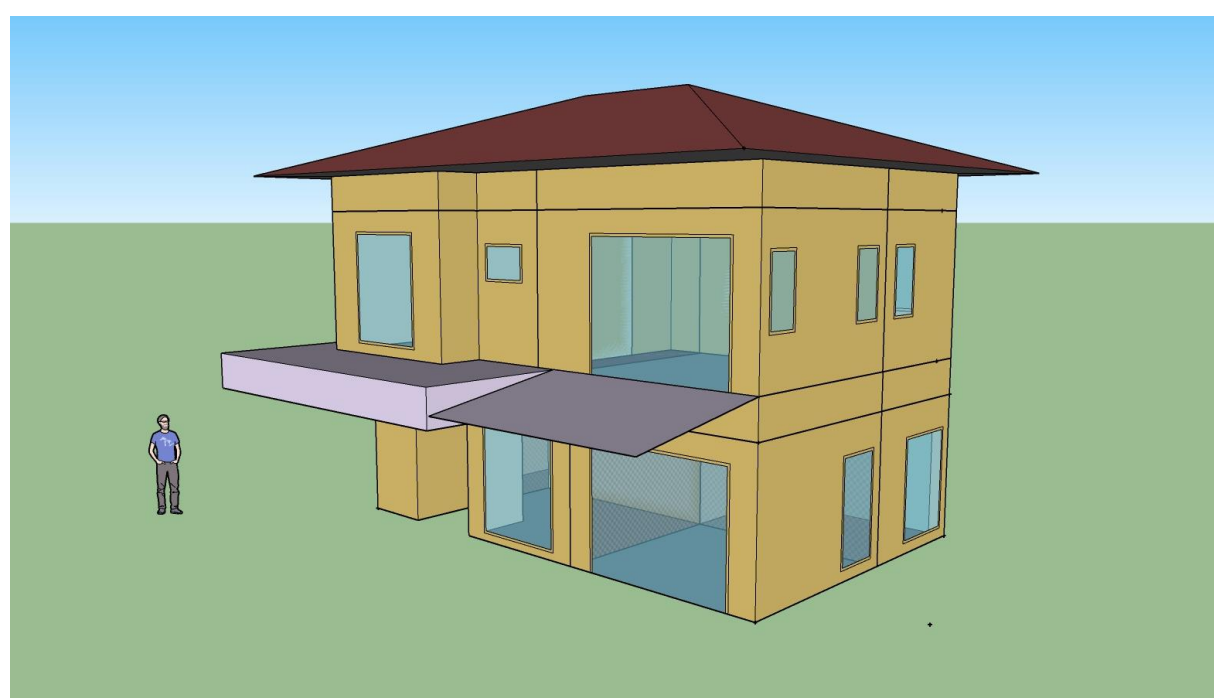
Hempcrete
 Hemphurd 10%
 Lime
 Cement



Hempcrete & Hemp lime

Hemp clay brick

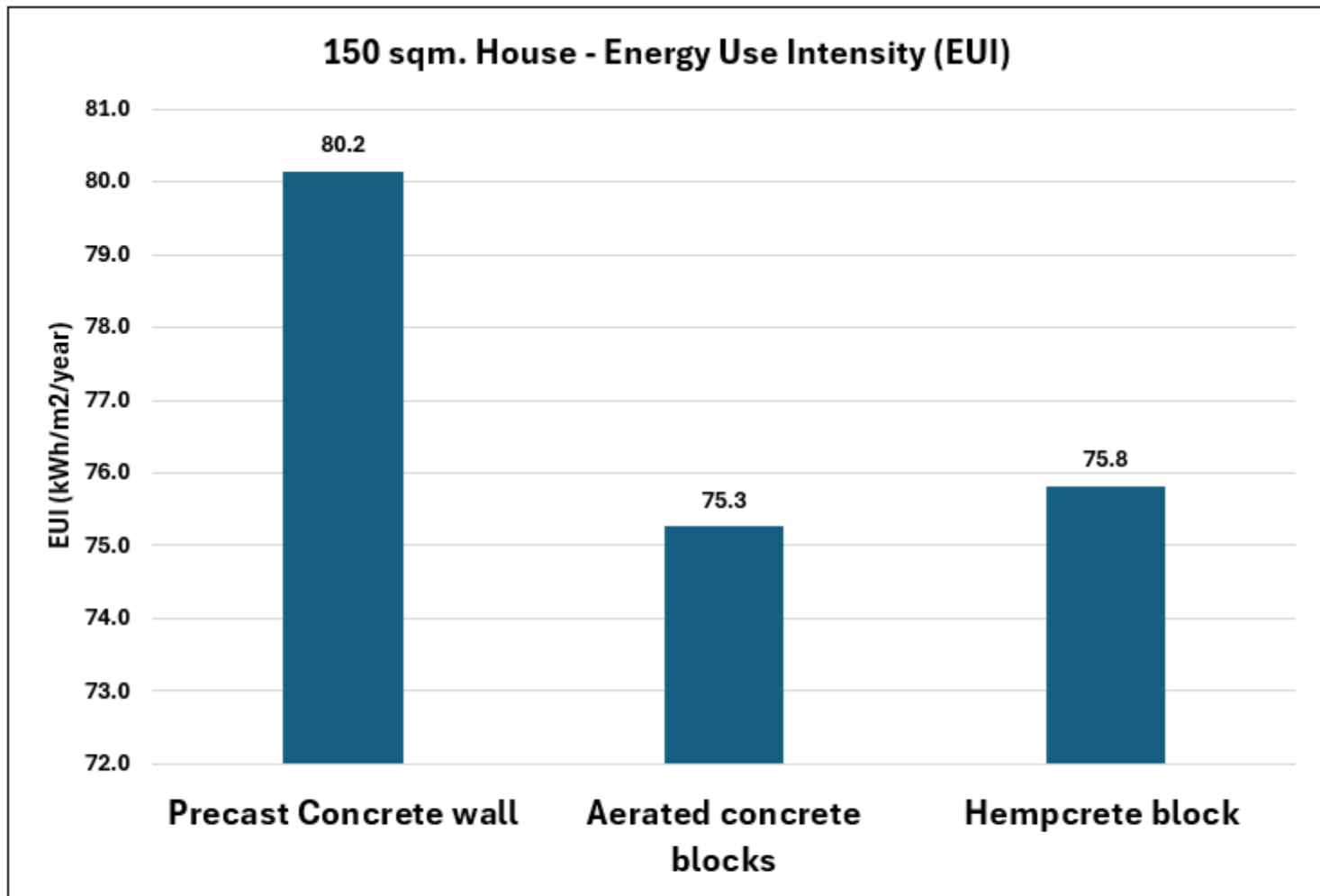
In situ Hemp



Energy Simulation using Energy Plus



Items	Type	Base case (Normal Design)	Proposed upgrade items
1	Roof insulation	No roof insulation	Fiberglass insulation 3 inch above 2nd-floor ceiling Aluminium Foil insulation under roof tile Bubble foil insulation under roof tile PU Foam 1 inch under metal sheet roof
2	Exterior Wall	Tunnel / Precast concrete	Lightweight block 10 cm. Tunnel or Precast concrete 10 cm
3	Façade shading	No Façade shading	Existing design small shading at the center of front façade
4	Glass	Clear glass 5 mm	Tinted - Ocean Green 6 mm. (กระจกเขียวตัดแสง)
5	Tree shading	No tree shading	Tree shading for front façade
6	Framing	No PU foam	PU foam inside door and window frame
7	PV for Shading	No PV	Solar rooftop (3kW) as shaded for the roof
8	Daylight Sensor	No Daylight Sensor	Day light sensor in Living and dining room
9	Exterior Lighting	Normal Lighting fixtures	Solar cell lighting for lighting at front of house (Normal operate 18.00 - 06.00)
10	Roof color	Dark color	Light roof color



150 sqm. House (120 sqm. Interior space)

Interior & Exterior Wall	Wall Thickness (m)	K-Value (W/m.°C)	Density (kg/m ³)	EUI (kWh/m ² /year)	% Saving
Precast Concrete wall	0.1	1.44	2400	80.2	-
Aerated concrete blocks	0.1	0.18	620	75.3	6.1%
Hempcrete block	0.1	0.10	1000	75.8	5.4%

SUMMARY

- Traditional house design V.S. Climate change & Urban Heat.
- Net-zero energy house (**better envelope + renewable energy**).
- Embodied carbon plays a more import role in net zero.
- Use of low-carbon materials (wood based).
- Hempcrete has a potential to reduce both embodied & operational carbon.
- More research on suitable ingredients for hempcrete blocks (**ratios of hemp hurds & binders – lime or cement to maintain strength while reducing thermal conductivity & density**)