

TILT · DIRECTION · SUNLIGHT

Face panels **true south at about 20°**. Anything from **15° to 25°** is within half a percent of the best.

This report sets out how much sunlight reaches this site and which tilt and direction collect the most of it over a year. It then applies the results to the three structures in the current design: the carport roof, the A-shape ground mount, and the 64 × 67 cm wedge.

SUNLIGHT ON FLAT GROUND	BEST FIXED TILT	BEST DIRECTION (AZIMUTH)	EXPECTED YIELD
≈1,795 kWh/m ² ·yr ≈4.9 kWh/m ² per day on average (irradiation)	≈20° 15–25° all within 0.5% of the best	180° S True south. Up to ±20° off costs under 1%	≈1,500 kWh/kWp·yr Near the best tilt, assuming a performance ratio of 0.80

1 · How much sun this site gets

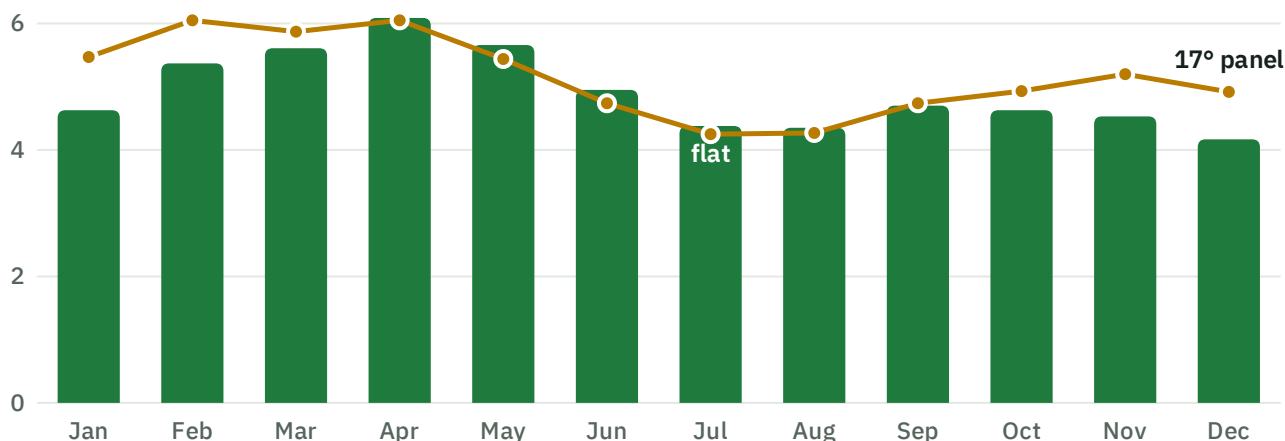
Thailand receives about 18–20 MJ/m² of solar energy per day on flat ground, which is 5.0–5.6 kWh/m². About half the country gets 18–19 MJ/m² per day.⁶⁷ For the northern region, Thai installers quote 1,680–1,780 kWh/m² per year, and specific yields of 1,350–1,450 kWh/kWp for Chiang Mai and Lamphun.⁴ A 9.5 MW ground plant in Mae Chan, Chiang Rai, was designed to produce about 15,000 MWh a year, roughly 1,580 kWh/kWp.⁸

To get a monthly profile for this exact point, I used Chiang Rai's long-term sunshine-hour records (1981–2010)² with the FAO-56 Ångström–Prescott method.³ That gives about **1,795 kWh/m² per year** on flat ground, slightly above the regional range quoted above, so treat it as the upper end. The year has three clear parts:

- **Hot dry season, Feb–May:** the sunniest months, with a peak of about 6.1 kWh/m²/day in April. Smoke haze from seasonal burning can dim these months in some years.¹⁰
- **Monsoon, Jun–Sep:** about 4 hours of sunshine a day and 300–370 mm of rain a month in July and August. Most of the light is diffuse (scattered cloud light), so tilt matters less in these months.
- **Cool dry season, Nov–Jan:** clear skies but a low sun, at 46.7° above the southern horizon at noon on 21 December. This is when tilting the panels toward the south helps most.

AVERAGE DAILY SUNLIGHT BY MONTH · KWH/M² PER DAY

■ Flat ground (horizontal) — Panel tilted 17°, facing south



From November to February the 17° panel collects 13–18% more than flat ground. From May to August it collects 2–4% less, because the sun is almost overhead. Across the year the tilted panel comes out about 5% ahead.

2 · Where the sun is at 19.85° N

This site is inside the tropics (below 23.44° latitude), so the sun passes straight overhead twice a year. For about two months in mid-year, the noon sun is slightly to the **north**. For the rest of the year, and especially in the clear cool-dry months, it is to the south. So a fixed panel should face south, but only at a moderate tilt.

19 May · 24 Jul

Sun directly overhead at solar noon (about 12:17 and 12:27 local time)

46.7° high, south

Noon sun on 21 December; the day is 10 h 56 min long

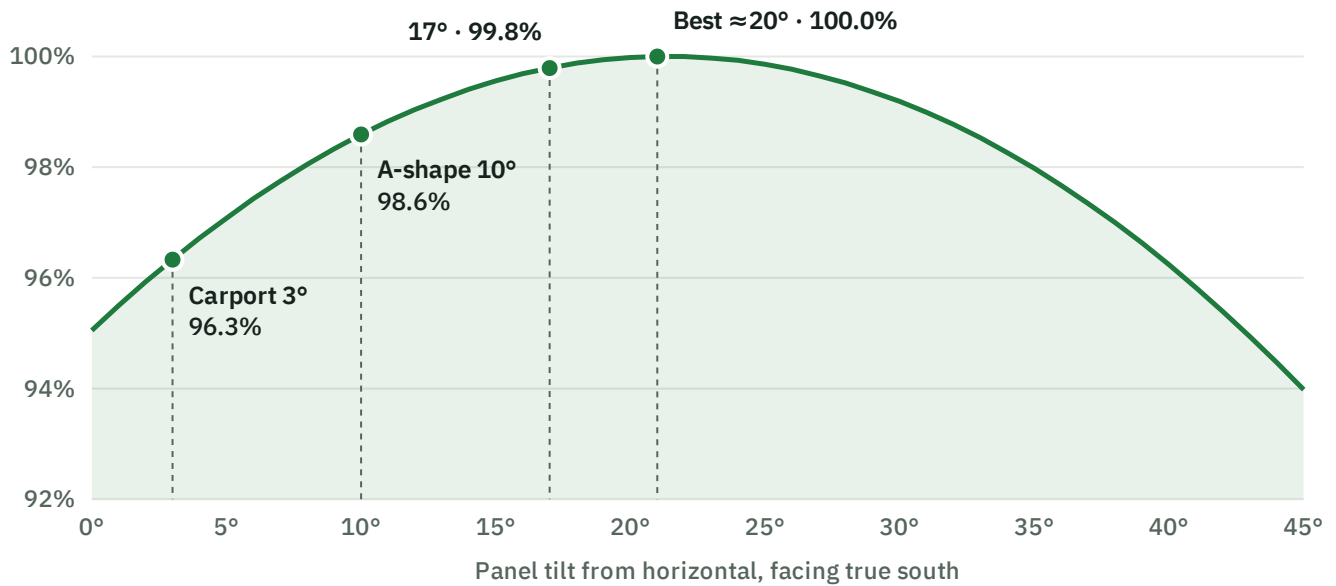
86.4° high, north

Noon sun on 21 June; the day is 13 h 20 min long

3 · Best tilt angle

A worldwide study of optimal tilt (Jacobson & Jadhav, *Solar Energy*, 2018) fitted a formula from latitude to the best tilt. At 19.85° N it gives $\approx 20.2^\circ$.¹ A Thai regional guide recommends **19° for Chiang Rai** and 18° for Chiang Mai.⁵ My site model agrees: the best is 20–22°, and the curve is very flat around the peak.

YEARLY SUNLIGHT ON THE PANEL VS TILT · SOUTH-FACING · % OF BEST



Flat panels collect 95% of the best. Every degree added between 0° and 10° gains about 0.35%, and past 15° the curve is almost level. Tilts steeper than 30° start losing again: 40° collects 96%, and the 51° triangle discussed earlier would collect about 91%.

A minimum of 10° for self-cleaning. Below about 10°, rain doesn't run off fast enough to wash away dust and pollen. Thai installers report 5–10% lower output in the dry months on near-flat arrays.⁵ Global studies also find soiling losses fall as tilt increases.¹² Jacobson & Jadhav recommend at least ±10° in the tropics for the same reason.¹ The dry season here, with farm dust and smoke, makes this more important in northern Thailand.

4 · Best direction (azimuth)

Point the panels at **true south (azimuth 180°)**. The table shows how forgiving this is. At low tilts, direction hardly matters because the panel is nearly flat. As the tilt increases, facing away from south costs more. North-facing panels lose the most, which is why the north side of an A-shape is kept at a low tilt.

YEARLY SUNLIGHT ON THE PANEL · % OF THE BEST (20–21°, TRUE SOUTH)

Facing ↓ / tilt →	0°	3°	5°	10°	15°	17°	20°	25°	30°	40°
South 180°	95.1	96.3	97.1	98.6	99.6	99.8	100.0	99.9	99.2	96.2
SSE / SSW ±22°	95.1	96.2	96.9	98.2	99.0	99.2	99.3	99.0	98.2	95.0
SE / SW ±45°	95.1	95.9	96.4	97.3	97.6	97.6	97.4	96.7	95.5	91.7
East / West 90°	95.1	95.0	94.8	94.0	92.8	92.2	91.1	89.1	86.8	81.3
North 0°	95.1	93.6	92.5	89.5	86.0	84.5	82.0	77.7	73.0	63.0

Darker green means more sunlight. Examples: south at 10° gives 98.6%, south-east at 10° gives 97.3%, east or west at 10° gives 94.0%, and north at 10° gives 89.5%. Use true north, not the compass. Magnetic north in northern Thailand is less than about 1° from true north, so a phone compass set to "true north" is accurate enough.

5 · Applied to this installation

Carport roof, 28 panels

Current design: $\approx 3^\circ$ tilt (columns 2.30 m front, 2.50 m back), 96.3% of the best

Suggested: raise to 10° , facing south.
+2.3% sunlight, about +580 kWh a year, and the panels clean themselves in the rain.

For 10° over the 3.78 m beam span, the back column goes up from 2.50 m to about 2.97 m. The front and back columns together are then 5.27 m, which still fits in the one 6 m tube per frame, so the steel cost barely changes. The higher roof catches more wind, so the engineer must re-check the frame and footings.

A-shape, 7 south + 7 north

Current design: 10° both sides. South side 98.6%, north side 89.5%, average 94.0%

Keep 10° if cost and a small footprint come first. Making the north slope steeper loses more: at 15° it drops to 86%.

If you want the most energy instead, put all 14 panels facing south at $17\text{--}20^\circ$. That gives about +6% ($\approx +760$ kWh a year), but it needs a 16 m single-slope row and more steel, as we found when costing the options.

Wedge $64 \times 67 \times 19.8$ cm

Tilt 17.2° , 99.8% of the best

Good as it is. Face it true south. At 17° it also sheds dust and rain well.

The 51 cm high versions ($38.6\text{--}49.6^\circ$) would collect only about 91–97% of the best, and their taller frames catch more wind.

OPTION	TILT / DIRECTION	SUNLIGHT ON PANEL	ESTIMATED ENERGY PER YEAR*
Carport as designed	$3^\circ \cdot$ south	1,819 kWh/m ²	$\approx 26,500$ kWh (18.2 kWp)
Carport raised	$10^\circ \cdot$ south	1,859 kWh/m ²	$\approx 27,100$ kWh (+580)
A-shape as designed	$10^\circ \cdot$ 7 S + 7 N	1,777 kWh/m ² avg	$\approx 12,900$ kWh (9.1 kWp)
A-shape all south	$17^\circ \cdot$ south	1,881 kWh/m ²	$\approx 13,700$ kWh (+760)

*Energy = sunlight on the panel $\times$ performance ratio 0.80 $\times$ kWp. This is an estimate for comparing options. Before quoting a customer, check the absolute figures with PVGIS or Global Solar Atlas for this exact point.⁹

6 · Other things that matter on site

- **Shading beats angle.** A tree, pole or building shading part of a string in the morning or afternoon can cost more than any tilt choice. Check the horizon to the east, south and west, especially the low winter sun in the south, where it sits at 47° at noon and much lower in the morning.
- **Heat.** Hot panels produce less, losing roughly 0.3% for every $^\circ\text{C}$ they heat up. A carport and a raised A-shape are open underneath and stay cooler than panels mounted flush on a roof.
- **Cleaning.** Plan cleaning at the end of the dry season (March–April), when dust and smoke build up. Clean more often if the tilt is below 10° .
- **Keep each string on one direction.** On the A-shape, the south and north slopes should go to separate MPPT inputs, or at least separate strings, because they peak at different times.

Method and assumptions

Monthly flat-ground sunlight came from Royal Irrigation Department sunshine hours for Chiang Rai (1981–2010)², using the Ångström–Prescott formula with FAO-56 default coefficients $a = 0.25$ and $b = 0.50$.³ These monthly totals were spread over each hour with the pvlib clear-sky model (Linke turbidity 4.0) and split into direct and diffuse light (Erbs method). The light was then projected onto each tilt and direction using the Hay–Davies sky model, with ground reflectance 0.2 and an angle-of-incidence loss, all in pvlib-python.¹¹ Relative results (percentages and the best angle) are reliable. The absolute kWh depend on the sunshine-to-sunlight conversion, which gives a total slightly above published regional values⁴, so read them as the upper end. I couldn't get the PVGIS and NASA POWER data for this point from here, so running those tools is a sensible final check.

References

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