08

SITE ANALYSIS · SUPPLEMENT TO THE AUTODESK FORMA STUDIES

Quarterly climate analysis – Yanbu

How the Red Sea climate at the site changes through the year, quarter by quarter – from the official station normals and 34 years of reanalysis data – and how the design answers each season.

Station normals 1991–2020 (WMO) | ERA5 reanalysis 1991–2024 | Trend projection to 2030

The year in four quarters

Temperatures and rain from the Yanbu station normals; humidity, wind, sun, comfort and the warming trend from ERA5 at the waterfront.

28.2 °C
annual mean (station)

51.0 °C
record high, July

39.5 mm
rain a year, 3–4 rain days

≈ 3,700
cooling degree days (base 18 °C)

Q1 Cool and comfortable season

JAN–MAR

29.3°	15.7°	10	80%
mean max	mean min	mm rain	comfortable hours

Outdoor season: terraces, pool decks, roof café and al fresco dining in full use; north-westerly sea breeze of 4–7 m/s in the afternoon; the first winter rain and rare flash-flood events (Jan).

DESIGN RESPONSE

- Open the roof venues and podium decks for daytime use; wind screens 40–50 % porous on the W–NW edges (Forma roof study).
- Pool and deck heating not needed; light shading is enough.
- Roof and podium drainage sized for short intense storms; falls to outlets and overflow scuppers.

Q2 Heating up – sea-breeze season

APR–JUN

38.0°	23.5°	1	27%
mean max	mean min	mm rain	comfortable hours

Mean max 38 °C; the afternoon W–WNW sea breeze is strongest (7–8 m/s at 15:00–17:00); dust and haze events; dry mornings.

DESIGN RESPONSE

- Bronze khatam screens and deep sawtooth balconies cut the west and south-west sun in the afternoon.
- Use the sea breeze: shaded west terraces and pool decks usable in the late afternoon and evening.
- Sand-trap louvres and filtration on fresh-air intakes; cooling plant moves to summer duty.

Q3 Peak heat and humidity

JUL–SEP

40.5°	27.1°	0	1%
mean max	mean min	mm rain	comfortable hours

Mean max 40.5 °C (record 51.0 °C), nights stay near 27–28 °C, humidity peaks (dew point ≈ 23 °C) – hardly any comfortable outdoor hours; peak cooling load.

DESIGN RESPONSE

- Design cooling load and plant sizing on Q3 (≈ 38 % of the yearly cooling degree days); SHGC ≤ 0.25 glazing and U ≤ 0.34 walls.
- Outdoor life moves to early morning and late evening; shaded, misted and fan-assisted terraces; indoor pool and fitness alternatives.
- Condensation control on cold surfaces and at the glazing in humid nights.

Q4 Mild, wettest quarter

OCT–DEC

33.3°	19.9°	29	51%
mean max	mean min	mm rain	comfortable hours

Mean max 33 °C falling to 30 °C by December; comfortable evenings return; most of the annual rain (≈ 29 of 39 mm) falls in Nov–Dec in a few heavy events; NE winds return.

DESIGN RESPONSE

- Outdoor season re-opens from November; terraces and roof venues in evening use.
- Storm-water drainage, basement ramp entrance trench drains and podium waterproofing checked for the Nov–Dec storms.
- Native, drought-tolerant planting re-establishes with the winter rain; TSE drip irrigation reduced.

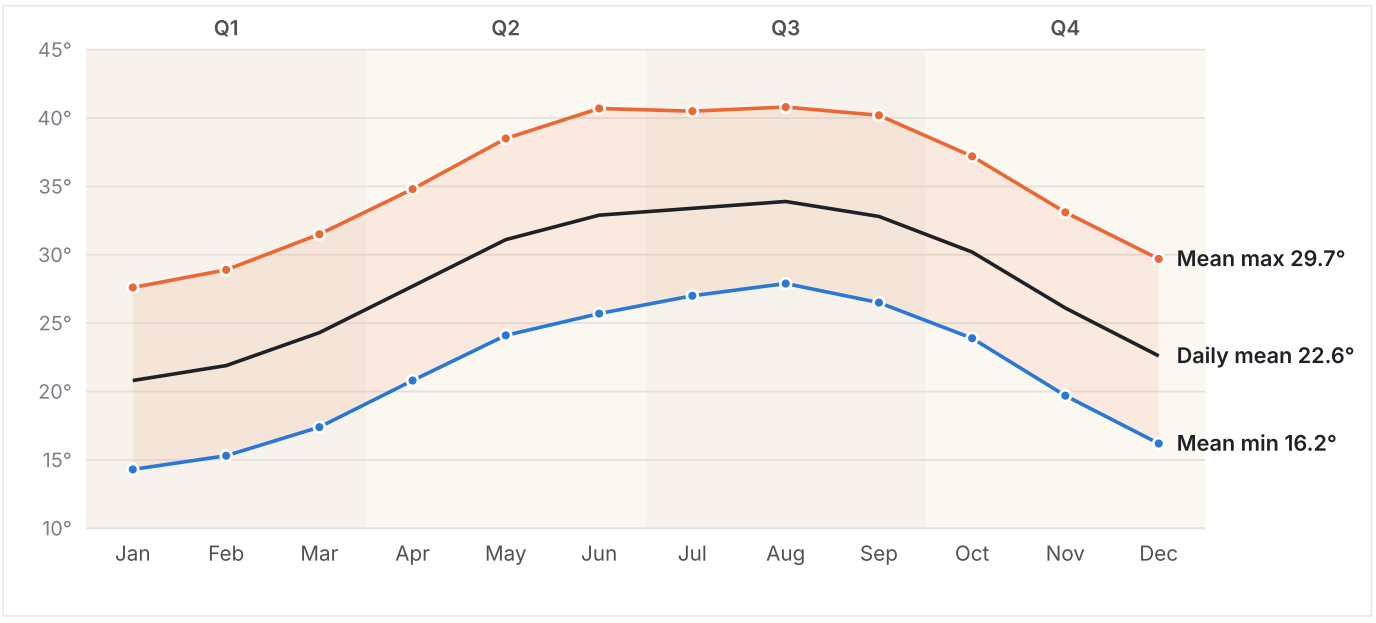
Quarterly summary

QUARTER	MEAN MAX °C	MEAN °C	MEAN MIN °C	RECORD MAX °C	RAIN MM	RH %	DEW POINT °C	WIND M/S	PREVAILING WIND (FROM)	SUN H/DAY	SOLAR KWH/M²·DAY	COOLING DEGREE DAYS	COMFORTABLE HOURS	NIGHTS ≥ 28 °C
Q1 · Jan–Mar	29.3	22.3	15.7	40.0	9.5	55	12.1	4.6	WNW, NW	10.7	5.5	392	80 %	0
Q2 · Apr–Jun	38.0	30.6	23.5	49.6	0.9	56	18.6	4.8	WNW, W	12.6	7.5	1144	27 %	20
Q3 · Jul–Sep	40.5	33.4	27.1	51.0	0.1	61	22.6	5.0	W, WNW	12.1	6.9	1414	1 %	65
Q4 · Oct–Dec	33.3	26.3	19.9	47.4	28.9	58	16.8	4.0	WNW, NW	10.5	4.9	764	51 %	4

Rain, record and mean temperatures: Yanbu station (WMO 40439), 1991–2020. Humidity, dew point, wind, sun and solar: ERA5, 1991–2020. Comfortable hours and nights ≥ 28 °C: ERA5 hourly, 2015–2024. Cooling degree days from the station monthly means.

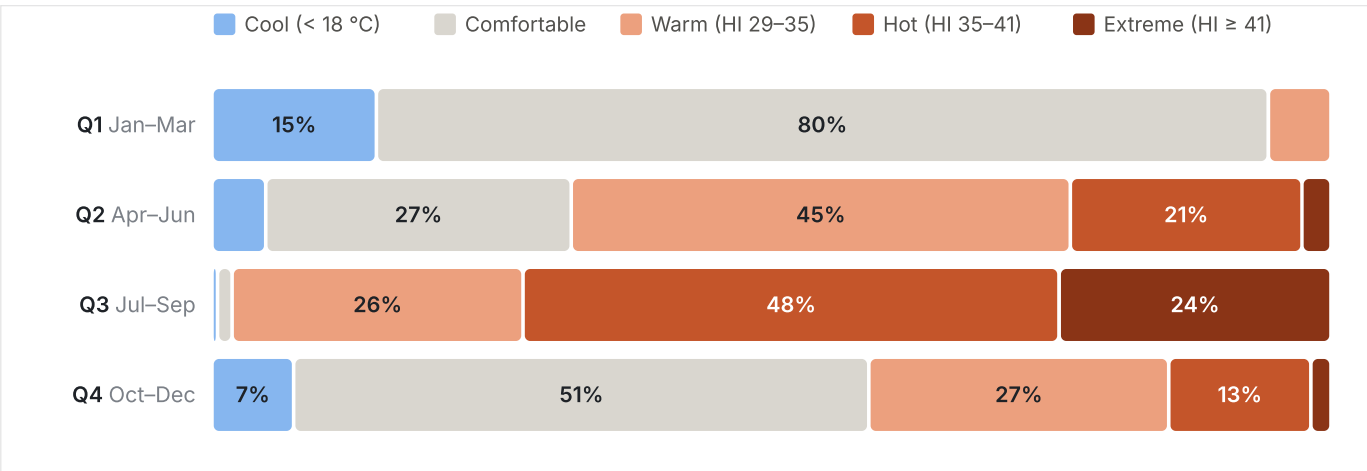
Temperature through the year

Mean daily maximum, mean and minimum by month – Yanbu station normals 1991–2020. Hover a month for the values and records.



Outdoor comfort by quarter

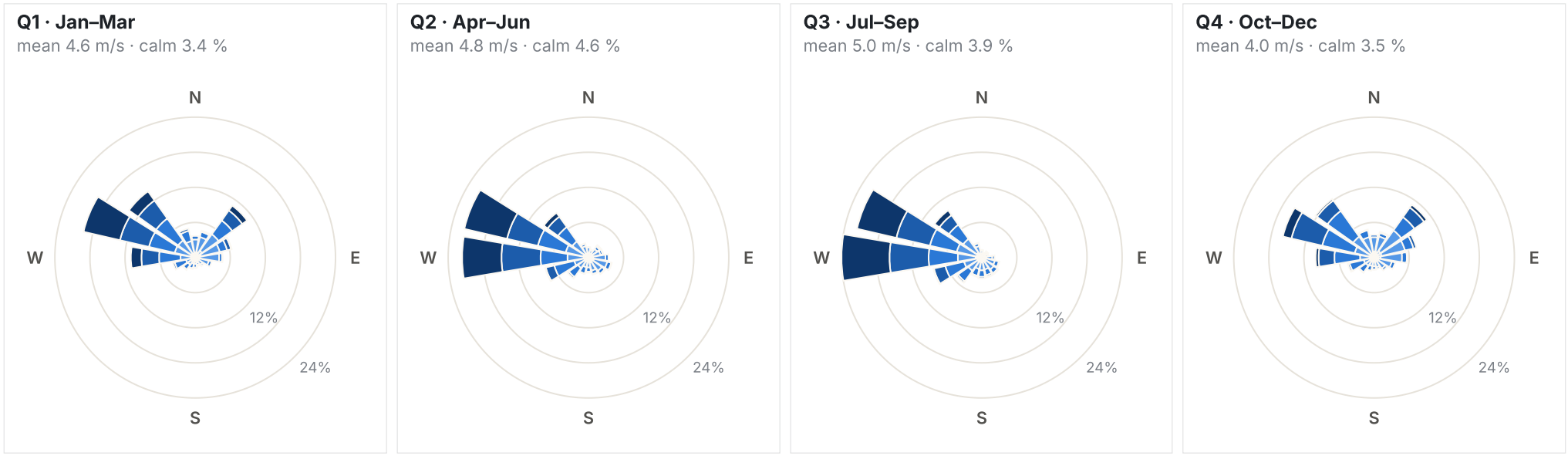
Share of all hours by heat stress (heat index from temperature and humidity), ERA5 hourly 2015–2024 at the waterfront. Q1 is the outdoor season; Q3 has almost no comfortable hours, day or night.



Evening hours (17:00–23:00) that are comfortable: Q1 93 % · Q2 20 % · Q3 0 % · Q4 48 %.

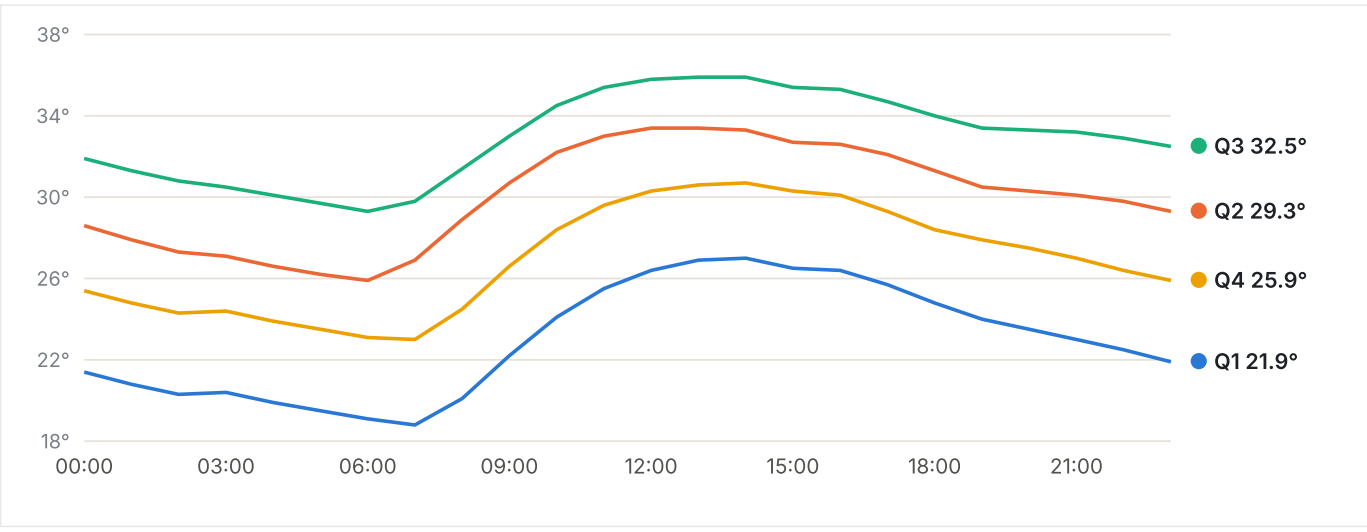
Wind by quarter

Wind roses from ERA5 hourly data 2015–2024 (10 m). The sea breeze from the W–NW dominates all year and is strongest in Q2–Q3 afternoons; NNE–NE land winds return in Q4–Q1 nights.

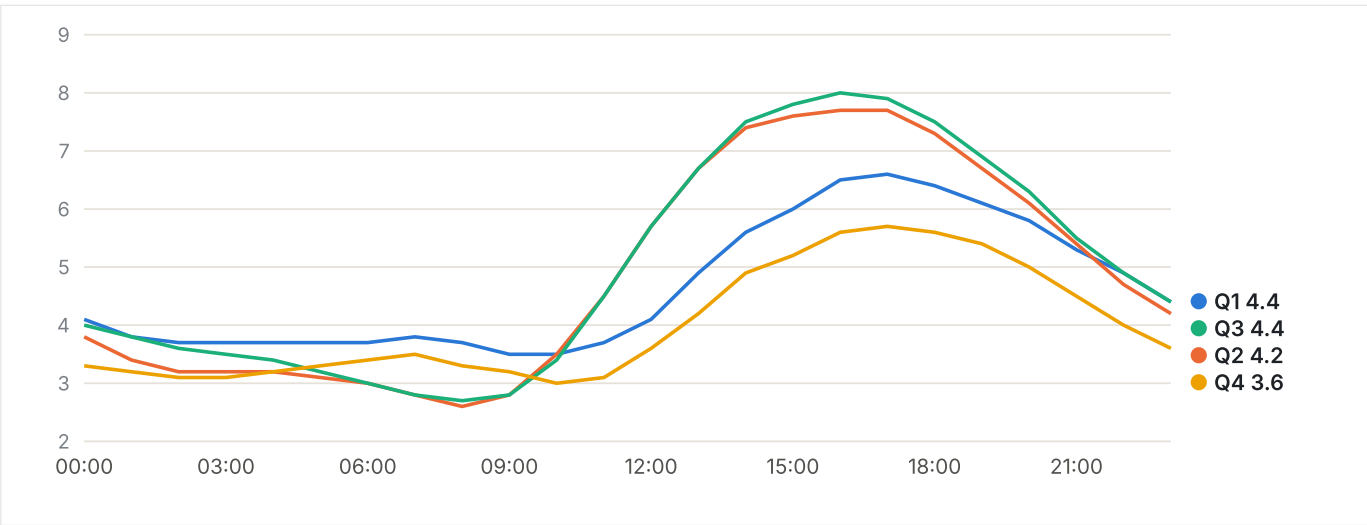


A typical day in each quarter

Average temperature by hour of the day (ERA5 hourly 2015–2024, local time).



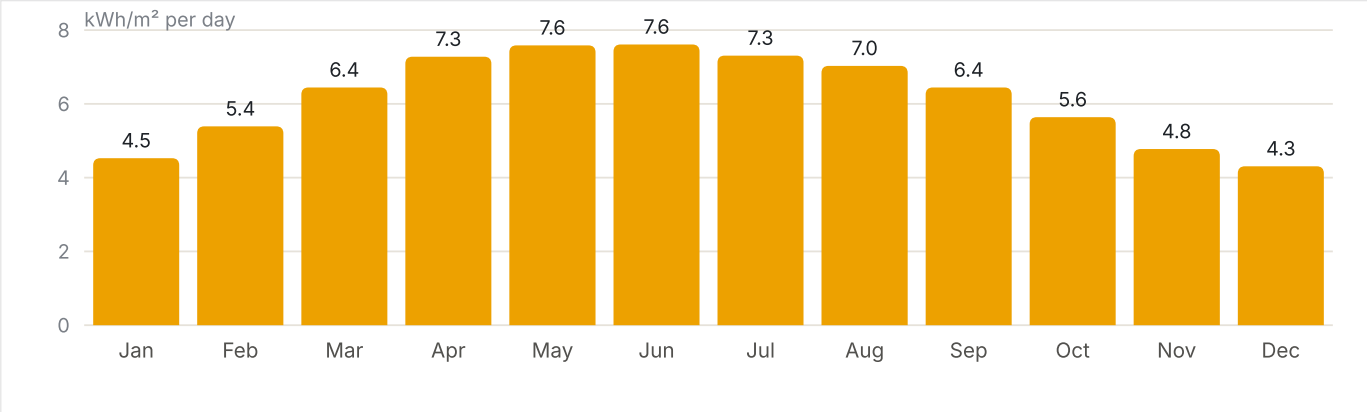
Average wind speed by hour – the afternoon sea breeze peaks at 15:00–17:00 in every quarter.



m/s at 10 m

Sun and solar energy

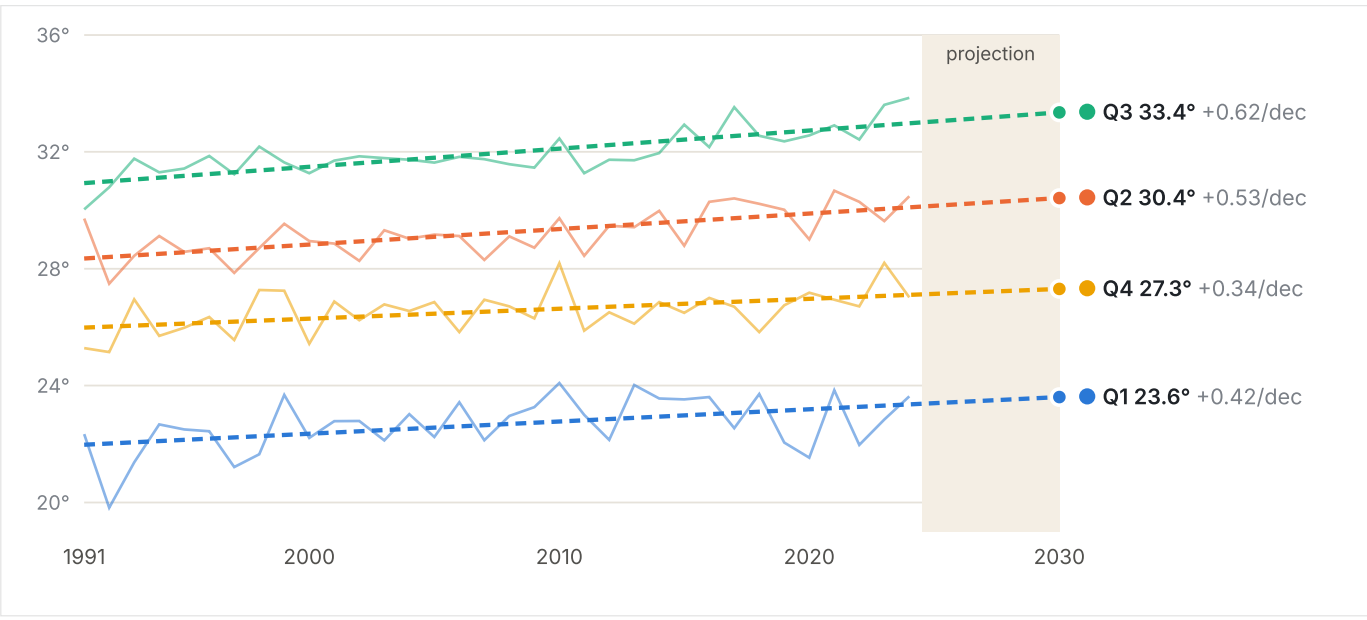
Daily global horizontal irradiation by month (ERA5 1991–2020) – the resource behind the roof PV and the PV carports. Annual ≈ 2,263 kWh/m².



> Sunshine: 10.3–13.0 hours a day; direct sunshine on about 95 % of daylight hours (ERA5). Forma: 9+ hours of direct sun on the site and roofs on 21 June; sunset always over the sea (azimuth 242°–293°).

Prediction – the warming trend to 2030

Quarterly mean temperature 1991–2024 (ERA5, thin lines), linear trend (dashed) and the value projected for 2030, the first years of operation. Hover a point for the year.



QUARTER	WARMING °C / DECADE (1991–2024)	MEAN MAX °C: NORMAL → 2030	MEAN °C: NORMAL → 2030	MEAN MIN °C: NORMAL → 2030	MEAN MAX 2050 (TREND)	NIGHTS ≥ 28 °C: 1991–2020 → 2015–24 → 2030
Q1 · Jan–Mar	+0.42 ± 0.15	29.3 → **30.9**	22.3 → **23.4**	15.7 → **16.4**	32.1	0 → 0 → **0**
Q2 · Apr–Jun	+0.53 ± 0.10	38.0 → **39.6**	30.6 → **31.9**	23.5 → **24.6**	41.0	10 → 20 → **24**
Q3 · Jul–Sep	+0.62 ± 0.09	40.5 → **42.1**	33.4 → **34.9**	27.1 → **28.8**	43.4	40 → 65 → **77**
Q4 · Oct–Dec	+0.34 ± 0.11	33.3 → **34.7**	26.3 → **27.1**	19.9 → **20.6**	35.7	2 → 4 → **4**

Method: least-squares linear trend of each quarter's ERA5 mean, maximum and minimum temperature, 1991–2024 (± one standard error). The 2030 values add that trend to the 1991–2020 station normals (centred on 2005). This is a statistical extrapolation of the observed trend, not a climate-model scenario.

How it fits the Forma site analysis

STUDY	AUTODESK FORMA (PRESENTATION P. 17–23)	CLIMATE DATA (THIS PAGE)	AGREEMENT
Sun	9+ hours of direct sun on site and roofs, 21 June	13.0 h sunshine a day in June; solar peak 7.6 kWh/m²·day	✓ consistent
Sunset	Azimuth 242° (Dec) to 293° (Jun), always over the sea	Afternoon solar gain on the west facade in every quarter	✓ consistent
Wind direction	Roof terraces exposed to the W–NW breeze	WSW–NW = 43–64 % of hours, strongest Q2–Q3	✓ consistent
Wind comfort	NEN 8100 / Lawson: 0 % uncomfortable at grade	Mean 4–5 m/s; ≥ 8 m/s only 3–16 % of hours, from the W–NW, in the afternoon	✓ consistent – screens on the W–NW roof edges
Solar resource	≈ 2,000 kWh/m²·yr on the roofs	≈ 2,263 kWh/m²·yr horizontal	✓ consistent

Sources and data

- **Yanbu station (WMO 40439)** – climate normals 1991–2020, World Meteorological Organization; humidity Deutscher Wetterdienst (as published in the Yanbu climate table on Wikipedia).
- **ERA5 reanalysis** – ECMWF / Copernicus Climate Change Service, via the Open-Meteo historical weather API; grid cell 24.01 °N 38.18 °E (2 m), next to the site: 12,419 daily records 1991–2024 and 87,672 hourly records 2015–2024. The grid cell is partly over the sea, so its afternoon maxima run 2–5 °C below the airport station – it represents the waterfront exposure; the station is the official temperature reference.
- **Autodesk Forma** site studies – sun hours, shadows, daylight, pedestrian wind comfort (NEN 8100 / Lawson), solar – RC presentation REV09 pages 17–23.