# Glass has the light. Plastic has the energy savings.

# Does ETFE finally offer both?

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For a production grower, light is the currency of yield. The familiar rule of thumb — "1% more light, 1% more production" — slightly overstates the link, but only slightly: Marcelis et al. (2004), at Plant Research International Wageningen, put the real figure for tomato at 0.7–1% yield change per 1% change in light, the upper end applying in winter when light is the limiting factor.[13] A few percentage points of transmittance, then, are never trivial — which is exactly why the covering material deserves close scrutiny.

In Northern European horticulture, glass has long been the default covering material for production greenhouses for a simple reason: laboratory measurements show it transmitting approximately 91% of the visible light, whereas a conventional double-layer polyethylene PE system transmits only 75–76%. This difference is substantial and has reinforced the widespread perception that plastic coverings inevitably result in lower light transmission.

However, this perception does not withstand scrutiny under real greenhouse conditions. When double-layer ETFE with a no-drop surface treatment is evaluated on commercial greenhouse roofs over multiple years, accounting for condensation, the spectral and angular distribution of northern winter light, and the structural characteristics enabled by a lightweight covering material, the results tell a different story. Across a range of field studies, double-layer ETFE performs at least as well as conventional glass and, in direct greenhouse comparisons, often performs measurably better. Moreover, ETFE-compatible flat-arch structures provide an additional light-transmission advantage that conventional glass constructions cannot achieve, regardless of the optical performance of the covering material itself.

In the following sections, we examine the differences between glass and ETFE greenhouse coverings from two key perspectives: light transmission and energy performance.

## 1. Light transmission

### The laboratory baseline: why the question exists

The table below shows each material measured at perpendicular incidence on a clean, dry surface: the optical property of the material itself, before any real-greenhouse effect is applied.

Table 1. Laboratory visible light transmittance (perpendicular, dry, new material).

| Covering material | Lab transmittance |
|---|---|
| Low-iron AR glass (anti-reflective, 4 mm) | ~93–95% |
| ETFE clear — no-drop treatment (100 µm, single layer) | ~93–94% |
| ETFE diffuse — no-drop treatment (100 µm, single layer) | ~91–92% |
| Low-iron glass (standard Venlo, 4 mm) | ~91% |
| PE film — anti-drip treated (150 µm, single layer) | ~87% |

| | |
|---|---|
| ETFE double layer (2 × 60 µm, no-drop treatment) | ~85–88% |
| PE double layer — anti-drip treated (2 × 150 µm) | ~75–76% |

Manufacturer (supplier) data. PE double-layer value = $T_1 \times T_2$, starting value for new anti-drip treated film.

Single-layer ETFE no-drop matches the best AR glass at the top of the ranking. Double-layer ETFE, at 85–88%, sits 3–6 points below standard glass — a real gap, in dry laboratory conditions. Three factors explain why real-greenhouse measurements tell a different story.

## Condensation: why the laboratory gap closes in the field

When water vapour condenses on the inner surface of a greenhouse cover, the optical consequence depends on whether it forms discrete drops or a continuous film. A condensation drop acts as a tiny optical lens, trapping and scattering incoming radiation through total internal reflection. Pollet & Pieters (2000) measured the effect on untreated polyethylene film: condensation drops reduced PAR (Photosynthetically Active Radiation) transmittance by 23% at normal incidence[2] and by 15% for diffuse radiation,[4] compared with a dry film.

Glass should theoretically produce filmwise condensation. In practice, surface contamination and micro-irregularities cause commercial glass plates to form drops instead of a film. Pollet & Pieters (2000) measured the hemispherical PAR loss for standard glass at 8% under overcast (diffuse) sky conditions.[2] They also report negligible losses at small incidence angles and reductions of 13–15% at incidence angles of 50–65°.[2] Pollet & Pieters (2002) characterise the extreme angles: for standard glass and low-emissivity glass, reductions reach up to 18 and 21% respectively at 60° and 75° on a relative scale.[3] This integrated loss occurs precisely on cold, humid days — exactly when winter light is already the binding constraint.

Both PE anti-drip and ETFE no-drop address the condensation problem by raising the film's surface tension, forcing filmwise condensation.

> "The transmittance of the anti-drop condensation film was not affected by condensate for all angles of incidence, since the condensate spread out over the plastic surface as a film." — Pollet & Pieters (2000)[2]

For new anti-drip polymer films (ADCPE), Pollet & Pieters confirmed that:

> "The negative effect of the condensate drops on the transmittance can be eliminated by adding anti-drop agents to the plastic films, at least for newly manufactured plastic films." — Pollet & Pieters (2002)[3]

The ETFE film substrate carries a 20+ year optical warranty; the anti-drop surface coating is separately warranted for 3–7 years by the film manufacturer (longer in temperate climates; film manufacturer communication). The Pollet & Pieters measurements predate current film generations, so they should be read as a conservative lower bound for the coatings available today.

## Anti-reflective glass: the laboratory leader that doesn't translate to the field

AR-coated glass leads Table 1 at 93–95%. A thin-film coating reduces surface reflection through destructive interference. In the laboratory, where light arrives near-perpendicular, it has a clear advantage.

Tantau et al. (2012) measured what happens on a real roof:

> "In the laboratory, the PAR transmittance of a new antireflection coated glass was higher than that of an uncoated glass. When the respective specimens were mounted on a greenhouse roof this difference could not be found." — Tantau et al. (2012)[5]

The explanation is straightforward: in Northern European winters, solar radiation arrives predominantly as diffuse light — scattered from every direction simultaneously. AR coatings are optimised for near-perpendicular incidence; under diffuse radiation conditions they offer no advantage. Weathering and cleaning cycles complete the process, and the laboratory lead disappears entirely in the field.[5]

The no-drop treatment on ETFE works through wetting chemistry, which is angle-independent. It performs identically under diffuse winter light and direct summer sun.

## The structure: 6 additional percentage points independent of the covering

Beyond the material itself, a greenhouse transmits only the light its structure does not block. This is where the flat arch has a straightforward, measurable advantage.

Glass weighs approximately 10 kg/m². The Venlo structure designed to support it across its standard span assigns roughly 11% of roof area to structural elements. A double-layer plastic film weighs a fraction of that; the flat arch, designed around plastic film, uses 5–7% of roof area for structure, depending on the configuration.[10] That difference of roughly 4–6 percentage points translates directly into usable light entering the greenhouse.

Kempkes, Swinkels & Hemming (2018) quantified the difficulty of recovering this kind of light loss in a Venlo structure: gaining 10% more PAR required a combination of many simultaneous engineering measures applied together.[11] The flat arch begins with a structural advantage that requires no engineering at all — it is simply the consequence of a lighter covering.

## What field measurements show: a range, both ends favourable

Two independent studies place bounds on the real-world performance of double-layer ETFE relative to glass.

**The conservative baseline — Tantau et al. (2012).** A five-year outdoor study with 20 covering materials mounted on a real greenhouse roof in Hannover (52.4°N). In field conditions, double-layer ETFE lands in the group Tantau et al. (2012) describe as:

> "It is remarkable that double layer systems such as PMMA Alltop and ETFE double are as efficient as conventional glazing materials, offering the possibility of energy saving without PAR transmittance losses." — Tantau et al. (2012)[5]

This is the floor: in real Northern European conditions, double ETFE performs at least as well as conventional float glass.

**The measured greenhouse result — CTIFL, Grisey et al. (2014).** Within CTIFL's five-year "Serre capteur d'énergie" project near Nîmes in France, a double-wall F-Clean® ETFE greenhouse — anti-drip ETFE, clear 100 µm outer layer and diffuse 60 µm inner layer — was compared against a glass control, both built on identical 960 m² Venlo structures. The peer-reviewed result: the ETFE greenhouse showed 6 to 8% more light transmission than the glasshouse, measured with pyranometers.[6] The project's French technical synthesis reports the conservative seasonal figure: on average over the winter period, +5% transmittance relative to the glass control.[6b] This is a direct greenhouse-to-greenhouse measurement integrating all real-world effects simultaneously, and because the structures were identical, it isolates the covering material itself.

> "This greenhouse has 6 to 8% more light transmission than the glasshouse (measured with pyrometers) and a better insulation." — Grisey et al. (2014)[6]

The two results describe different experimental conditions and different measurement approaches. Tantau et al. measured PAR transmittance (photosynthetically active radiation, 400–700 nm) while the CTIFL focused on the visible light transmission. Both are legitimate metrics for evaluating greenhouse performance, but they are not directly interchangeable.

What neither study includes is the structural advantage of the flat arch — which applies regardless of the material performance, because only Venlo structures were tested for these field experiments.

### Diffuse light: a yield bonus on top of the quantity argument

Beyond total light quantity, the angular distribution of incoming radiation affects crop production. Diffuse light — arriving from multiple directions simultaneously — penetrates deeper into the canopy, reduces photoinhibition in upper leaves, and increases photosynthesis in lower ones.

Dueck et al. (2012) at WUR Bleiswijk demonstrated the effect directly, comparing diffuse glass (haze 45–71%) against standard glass at identical total PAR: +7–9% tomato production by June, +8–11% by year end, with heavier fruit.[8] Holsteens et al. (2020) confirmed a +2.8% annual yield gain with low-haze diffuse glass at standard tomato density (3.33 stems/m²).[9]

ETFE diffuse film, at 60% Hortiscatter factor — the specification used in WUR's own ETFE greenhouse at Bleiswijk[7] — falls precisely in the haze range that produced those results. The yield benefit applies to any diffusing covering in this range, glass or film, on high-irradiance days when PAR exceeds crop saturation.

The CTIFL comparison provides the crop-level confirmation. The F-Clean® greenhouse — whose 60 µm inner layer is precisely such a diffuse film — produced an extra tomato yield over the glass control: 10% in the peer-reviewed account,[6] 5 to 9% in the project's French synthesis (higher mean fruit weight and fruit load), with the project's economic calculations conservatively retaining 5%.[6b]

> "No difference was observed in the crop. An extra yield of 10% was measured." — Grisey et al. (2014)[6]

## 2. Energy performance

### The thermal case: measured, simulated, and validated

The insulation advantage of a double-wall cover comes from the enclosed air layer between the two films, not from the films themselves. U-values measured by TNO Delft to EN-ISO 12567-1:[1]

| Covering material | U-value (W/m²·K) | vs 4 mm float glass |
|---|---|---|
| Double PE | 3.4 | −36% |
| Double ETFE | 4.0 | −25% |
| 4 mm float glass (reference) | 5.3 | — |
| Single PE or ETFE (single layer) | >6.0 | worse than glass |

Single-layer configurations perform worse thermally than glass and are not a relevant comparison. For double-layer systems, the air layer provides the insulation: double PE and double ETFE reach similar U-values for this reason, despite their different optical properties.

## Operational savings: simulation and regulatory validation

Hortinergy simulation (Agrithermic, 2022), full tomato cycle at Nantes (47.3°N), gas heating at 95% efficiency, against a glass Venlo with thermal screen:[10]

| Configuration | Annual energy | vs reference |
|---|---|---|
| Glass Venlo 4mm + thermal screen (reference) | 284 kWh/m²/yr | — |
| Double PE flat arch — no screen | 248 kWh/m²/yr | −13% |
| Double PE flat arch + thermal screen | 204 kWh/m²/yr | −28% |

Without any screen at all, the flat arch already saves 13% versus a glass Venlo that has one. Adding a screen reaches 28%. The simulation used PE film parameters; double ETFE (U-value 4.0 vs 3.4 W/m²K) saves marginally less, but in the same order of magnitude. Nantes is milder than the Netherlands — colder northern winters amplify the gap.

The CTIFL reference trial measured a 20% energy saving for the double-wall F-Clean® ETFE greenhouse over the glass control, both equipped with thermal screens.[6b] That field figure should be read with one caveat: the ETFE greenhouse tested was slightly less airtight than the glass one, which likely introduces a small upward bias in its measured consumption. The thermal case in this article therefore rests on the Hortinergy simulation rather than on that single field measurement — Hortinergy being a greenhouse energy-modelling tool recognised in the sector, and the same engine on which ADEME based its own validation. In 2023, France's ADEME regulatory programme and ATEE validated a 30% energy saving figure for double-wall plastic greenhouses in a certification sheet co-authored by CTIFL, Astredhor, Agrithermic, Filclair and Richel.[12] A figure that determines public fund allocation undergoes regulatory scrutiny before approval.

> "F-Clean® is an interesting material in energy savings and extra yield but the main question is the lifespan and the guarantee of the plastic. If it is necessary to change the double cover after 10 years, the return on investment is 6 years." — Grisey et al. (2014)[6]

In practical terms: at typical Dutch heated vegetable greenhouse consumption of around 340 kWh/m²/year (CBS Statline, 2023)[14], a 28–30% reduction saves 95–100 kWh/m²/year. For a 7-hectare project at current Northern European gas prices, that exceeds €200,000 per year — a margin that rising gas costs only widen. As real-world evidence of ETFE's longevity, CTIFL reports that the ETFE cover on its experimental greenhouse at Balandran has required no replacement since it was installed in 2009.

What has also changed is the commercial context. The end of the cheap-gas era that made insulation optional; the completion of engineering work that makes ETFE compatible with production-scale flat arch systems; and the emergence of Chinese ETFE film manufacturers that have introduced genuine price competition in a previously closed market. The combination that once seemed reserved for showcase projects — ETFE performance at a viable commercial price — is now accessible.

Filclair has completed the engineering integration required to offer ETFE as a standard option across its flat arch greenhouse range. The structure is validated. The thermal and light performance data is published and peer-reviewed. The supply chain is in place. The question that remains is a commercial one.

## The case, in four points

→ **Light — material:** In real Northern European conditions, double ETFE performs at worst as well as conventional float glass (Tantau, 2012: "as efficient as conventional glazing") and, in CTIFL's direct greenhouse comparison on identical Venlo structures, 6–8% better (Grisey et al., 2014; +5% on the winter average). Glass itself loses an average of 8% PAR to condensation under real greenhouse conditions (Pollet & Pieters, 2000). ETFE no-drop coating loses none (Pollet & Pieters, 2002; Tantau, 2012).

→ **Light — structure:** The flat arch uses 5–7% of roof area for structure; the Venlo uses 11%. Roughly 4–6 additional percentage points of transparent roof, automatically, as a direct consequence of a lighter covering. This gain applies whichever end of the material performance range is relevant.

→ **Energy:** Double ETFE: −25% heat loss vs float glass (TNO certified, EN-ISO 12567-1). −28% annual energy in simulation (Hortinergy, 2022). 30% validated by ADEME (2023). The insulation comes from the enclosed air layer between the films.

→ **Durability:** ETFE film substrate: 20+ year optical stability. No-drop surface coating: warranted 3–7 years by the film manufacturer. More durable than PE anti-drip, whose effect is limited in time through surfactant migration (Pieters et al., 1997)[4b]. Tantau: no degradation detected over five years.

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