Supplementary Appendix A — Reference Model Parameterisation and Matched-Envelope Verification

A Sequential EnergyPlus–DSSAT Framework for Assessing Energy Use, Environmental Control and Wheat Production in Vertical Farming | Journal of Biosystems Engineering | Online Resource 1

Tables A1–A3 reproduce the reference EnergyPlus and DSSAT parameter summary. Tables A4–A5 provide the verified S18–S22 matched-envelope inputs and annual energy/environmental performance. The companion Online Resources 2–3 contain the source-derived daily and annual hourly temperature/RH comparisons.

Table A1. EnergyPlus reference settings and construction records

Parameter	Recorded setting	Source / clarification
Building and model	EnergyPlus, S18 reference input deck	Source: S18 building input deck; later campaign software versions are noted in the scope statement.
External weather	Timimoun weather boundary	Timimoun outdoor weather file used as the EnergyPlus boundary condition.
Grow-room dimensions	42 × 40 × 10 m	Modelled surface geometry: floor area 1,680 m² and volume 16,800 m³.
Service-room floor area	≈131.04 m²	Service-space surface geometry, approximately 12.91 × 10.15 m.
Productive growing area	3,600 m²	Study crop-area record; this is not an EnergyPlus zone-floor value.
Multi-tier production	Five tiers; nominal growing/floor-area ratio ≈2.14	Five-tier crop-rack arrangement from the reference design record.
Reference crop-light specification	PPFD 600 µmol m^{-2} s^{-1}; 16 h d^{-1}	Prescribed biological lighting condition for the S18 reference.
LED photon efficacy	2.7 µmol J^{-1}	Reference lighting-efficiency specification used for electrical translation.
EnergyPlus lighting power	475 W m^{-2} of grow-room floor	EnergyPlus lighting object; 475 × 1,680 = 798 kW.
Lighting schedule	16 h d^{-1}: ON 10:00–24:00 and 00:00–02:00	EnergyPlus 16-hour lighting schedule.
Plant latent load	80 W m^{-2} grow-room floor	OtherEquipment plant latent input; fixed reference assumption.
Plant sensible load	+40 W m^{-2} grow-room floor	OtherEquipment plant sensible input; fixed reference assumption.
Heating / cooling setpoints	20 °C / 22 °C	Grow-room heating and cooling setpoint schedules.
Grow-room RH control setpoint	60% RH	ZoneControl:Humidistat; annual RH compliance is assessed from simulation outputs.
Infiltration	0.1 air changes per hour	EnergyPlus infiltration input object.

Parameter	Recorded setting	Source / clarification
Grow-room outdoor air	1.68 $m^3 s^{-1}$ (0.001 $m^3 s^{-1}$ per m^2)	DesignSpecification:OutdoorAir; 1.68 / 1,680 = 0.001.
HVAC configuration	PTAC with single-speed DX cooling and electric heating	ZoneHVAC:PackagedTerminalAirConditioner and related coils.
Cooling COP	3.0 (gross rated)	Coil:Cooling:DX:SingleSpeed, gross rated COP.
Supply fan	Constant-volume; autosized flow	Fan:ConstantVolume; flow is autosized.
Coil capacity / airflow	Autosized	Cooling-coil and PTAC object definitions.
Independent dehumidifier	Not identified as a separate system in this IDF	A separately modelled dedicated dehumidifier was not identified in the inspected input.
Wall construction	3 mm exterior finish; 150 mm XPS; 150 mm concrete; 20 mm interior plaster	Wall_Timimoun_VF material-layer definitions in the inspected IDF.
Roof construction	5 mm coating; 120 mm PIR; 150 mm concrete; 20 mm interior plaster	Roof timimoun material-layer definitions in the inspected IDF.
Ground-floor construction	150 mm concrete slab; 80 mm XPS	Floor Timimoun material-layer definitions in the inspected IDF.

Source: S18 EnergyPlus IDF and model material definitions. Envelope properties are reported as layer compositions and thicknesses rather than unverified overall assembly U-values.

Crop-model input and parameter libraries

Table A2. DSSAT CERES-Wheat reference configuration

Parameter	Recorded setting	Source / clarification
Experiment identifier	S18 — reference controlled-environment wheat case	Source: reference DSSAT experiment and simulation outputs.
Crop model	DSSAT CERES-Wheat	Process-based crop simulation.
Cultivar code / name	DFAULT / DEFAULT	Source: WHX *CULTIVARS and WHCER048.CUL row.
Linked ecotype	DFAULT	Source: WHCER048.CUL ECO# → WHCER048.ECO DFAULT row.
Cultivar parameters	P1V 5; P1D 75; P5 450	Source: WHCER048.CUL DEFAULT record.
Cultivar parameters continued	G1 30; G2 35; G3 1.0; PHINT 60	Source: WHCER048.CUL DEFAULT record.

Parameter	Recorded setting	Source / clarification
Planting / emergence density	PPOP 350; PPOE 350 plants m^{-2}	Source: reference DSSAT experiment file; S18 reference population.
Row spacing / depth	15 cm / 3 cm	Source: reference DSSAT experiment file.
Photoperiod override	EDAY = R 16 hours	Source: reference DSSAT experiment file environmental modification.
CO_2 override	ECO2 = R 380 ppm	Source: reference DSSAT experiment file; for this experiment only.
Weather-station reference	controlled-environment weather station record	Source: crop-model weather station field.
Daily crop-model radiation	15.1 MJ m^{-2} d^{-1} in S18 output	Output-confirmed for S18; not identical to PPFD/DLI expressed in photon units.
Daily crop temperature	TMAX = TMIN = 22.0 °C in S18 output	Source: reference DSSAT daily weather and summary output.
Precipitation	RAIN = 0 mm d^{-1} in indoor crop weather input	Output-confirmed for S18.
Water balance / nitrogen	WATER = Y; NITRO = N	Source: WHX simulation controls.
Irrigation management	Automatic; IMDEP 30; ITHRL 80; ITHRU 100; IR005; IRAMT 10; IREFF 1	Source: reference DSSAT experiment file automatic irrigation management record.
Crop-model output interpretation	Potential production under model assumptions	Cannot be regarded as facility-calibrated or experimentally validated wheat yield.

Source: Reference DSSAT experiment, weather and simulation outputs, together with CERES-Wheat cultivar and ecotype parameter libraries.

Table A3. Selected DFAULT wheat ecotype coefficients

Parameter	Recorded setting	Source / clarification
Phenological phase durations	P1 = 200; P2 = 200; P3 = 200; P4 = 200	Source: WHCER048.ECO, DFAULT row; degree-day/thermal units as library-defined.
Vernalisation effect	VEFF = 0.6	Source: DFAULT ecotype.

Parameter	Recorded setting	Source / clarification
PAR conversion (crop-model)	PARUE = PARU2 = 2.7 g MJ^{-1}	Crop biomass radiation-use coefficients; *not* LED photon efficacy 2.7 µmol J^{-1}.
Canopy PAR extinction	KCAN = 0.85	Source: DFAULT ecotype.
Standard canopy height	HTSTD = 100 cm	Source: DFAULT ecotype.
Root depth growth rate	RDGS = 3.0 cm per standard day	Source: DFAULT ecotype.
Standard grain N	GN%S = 3.0%	Source: DFAULT ecotype.
Other ecotype coefficients	Additional parameters in WHCER048.ECO DFAULT row	Full library row is the reproducibility source; default coefficients are not facility-specific calibration.

Cross-domain interpretation. Lighting electricity per grow-room floor area (W m^{-2}), prescribed crop photons (µmol m^{-2} s^{-1}), equivalent DSSAT radiation (MJ m^{-2} d^{-1}) and crop-model PAR-use efficiency (g MJ^{-1}) represent distinct physical quantities and are not interchangeable.

Reproducibility scope. The reference building model was originally configured in EnergyPlus 24.1, with later scenarios also evaluated using 26.1. The reference DSSAT weather representation specifies SRAD = 15.1 MJ m^{-2} d^{-1} and daily TMAX/TMIN = 22.0/22.0°C. The soil-water and automatic-irrigation representations are defined in the underlying crop model, but the complete soil hydraulic properties are not reproduced in these tables. The appendix documents the available reference parameterisation; it is not a complete executable model package.

Matched-envelope S18–S22 scenario evidence

The paired EnergyPlus 26.1 runs were matched at the level of modelled physical inputs. A field-by-field comparison of 348 non-output-request IDF objects identified a single difference: the grow-room lighting power density. Further differences between the IDF files were additional Output: requests in S22, which do not change building physics. The two annual EnergyPlus reports provide 8,760-hour site-energy totals; the directly extracted hourly outputs provide zone-air temperature and relative humidity for the identical calendar index.

Table A4. Input controls, crop-light exposure and evidence status in the matched-envelope comparison

Input/verification quantity	S18 reference	S22 LED-efficacy case
EnergyPlus execution engine	26.1.0	26.1.0
Envelope, HVAC, plant-load inputs	Reference IDF retained	Identical to S18 IDF
Grow-room lighting power density	475 W m^{-2}	366.85 W m^{-2}
Modelled PPFD (scenario specification)	600 µmol m^{-2} s^{-1}	600 µmol m^{-2} s^{-1}
Photoperiod	16 h d^{-1}	16 h d^{-1}
LED efficacy (scenario interpretation)	2.7 µmol J^{-1}	3.5 µmol J^{-1}
DLI (specified photon exposure)	34.56 mol m^{-2} d^{-1}	34.56 mol m^{-2} d^{-1}
DSSAT-equivalent radiation (calculation)	15.12 MJ m^{-2} d^{-1}	15.12 MJ m^{-2} d^{-1}
Daily rounded TMAX/TMIN, tested days 1–72	22.0/22.0°C (all 72 days)	22.0/22.0°C (all 72 days)
Crop result provenance	S18 CERES-Wheat run	S18 crop output reused (scenario register)

Evidence classification: EnergyPlus version, physical-model equivalence and hourly temperature values were checked directly from the paired run files. PPFD, photoperiod, LED photon efficacy and DSSAT-equivalent radiation are grounded in the documented lighting scenario specifications and calculations; the DSSAT experiment files were not independently compared input by input for S22. Consequently, the inherited S18 crop output remains conditional on retention of other crop-related inputs.

Table A5. Paired annual results and conditional integrated indicators

Annual metric	S18	S22
EnergyPlus site electricity (GJ yr^{-1})	24,500.64	19,192.38
Annual site electricity (GWh yr^{-1})	6.8057	5.3312
Cooling electricity (GWh yr^{-1})	1.8669	1.5120
Lighting electricity (GWh yr^{-1})	4.6604	3.5993
Fan electricity (GWh yr^{-1})	0.2784	0.2199
Hours above 60% relative humidity	4	224
Hours outside 19.5–22.5°C	0	3
First 72 days TMAX/TMIN matching at 0.1°C	72/72	72/72
Potential annual grain output (kg yr^{-1})	9,123.18 (S18 DSSAT)	9,123.18 (inherited; conditional)
Illustrative electricity per potential grain (kWh kg^{-1})	746.0	584.4 (conditional)

The lighting-only reduction in annual site electricity was 21.7%. S18 achieved 99.954% annual RH compliance, whereas S22 achieved 97.443% against the study-specific threshold of RH ≤60% for ≥99% of the year. Although the 72-day daily TMAX and TMIN inputs agreed after rounding to 0.1°C, the full annual temperature series were not identical (annual maximum 22.37°C in S18 versus 23.99°C in S22). These results do not establish suitable operation in S22, nor validate conditional crop-output reuse throughout the year.

Data and method notes. Online Resource 2 provides the daily comparison for the first 72 annual-run days; Online Resource 3 provides 8,760 matched annual hourly crop-zone records. Hourly values were extracted from EnergyPlus results for both matched-envelope simulations, excluding sizing/design periods. The first-72-days test window is assumed to correspond to the reference crop-cycle comparison; the precise crop-calendar alignment and the complete DSSAT weather/experiment-input identity have not been independently re-audited in this package. Estimates of annual crop production assume uninterrupted consecutive 72-day cycles, without operational downtime.