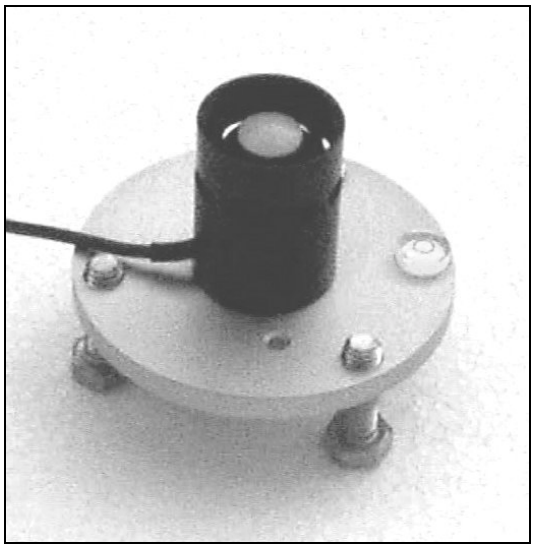
**User Manual for the**

# *Energy Sensor*

*type **ES2***



*ES2-UM-1.0*

***Delta-T Devices Ltd***

# Notices

## *Copyright*



## *CE conformity*

The sensor described in this document is a passive component as defined by the EU EMC Directive 89/336/EEC, and is not CE marked.

When used with Delta-T logging systems according to the instructions contained in this document, the sensor does not significantly affect the EMC performance when assessed under EN 50081 and EN 50082.

If the sensor is used with any other measuring equipment, it is the responsibility of the user to ensure the EMC compliance of any such measuring systems.

## *Design changes*

Delta-T Devices Ltd reserves the right to change the designs and specifications of its products at any time without prior notice.

## *User Manual Version: 1.0 April 2000*

**Delta-T Devices Ltd**
**128, Low Road, Burwell**
**CAMBRIDGE CB5 0EJ**
**U.K.**

**Tel: +44 1638 742922**
**Fax: +44 1638 743155**
**e-mail:** sales@delta-t.co.uk
WWW: http://www.delta-t.co.uk

# Contents

# Introduction

## Summary of Features

The Energy Sensor type ES2 is intended for solar energy studies in natural unobstructed daylight. Uses include measuring the incident solar radiation (in $W/m^2$) on buildings and solar collectors, for example, or as a reference for crop canopy measurements with tube solarimeters.

The Energy Sensor type ES2 is an improved version of the former sensor type ES, with the following features:

- Millivolt output with preset, standard sensitivity
- Data logger compatible
- High stability, low temperature coefficient silicon photodiodes
- Self cleaning, stay-dry diffuser with water drainage slots
- Good cosine response with infinity-error correction ring
- Screened twin core cable
- All-aluminium body with weather resistant anodising
- Internal calibration adjuster for annual recalibration
- Lower purchase and recalibration cost

The sensor can be supplied with optional levelling mounting plate, or an adapter for mounting on the top of the standard Delta-T weather station mast.

## Scope of This Manual

This manual contains the specifications and performance of the ES2 sensor, and describes its installation with Delta-T data loggers.

You will also need to refer to the appropriate Delta-T logger or Weather station manual or on-line help.

# Installation

## Unpacking

Check for any damage that may have occurred to the consignment in transit. Check that the contents of the consignment agree with the Packing List.

If any damage or shortage is apparent, notify the agents and the carriers immediately.

Make a note of the sensor(s) serial number(s), and check that the cable supplied is the length that was ordered. The serial numbers will be needed in any subsequent warranty claims, repairs or recalibration

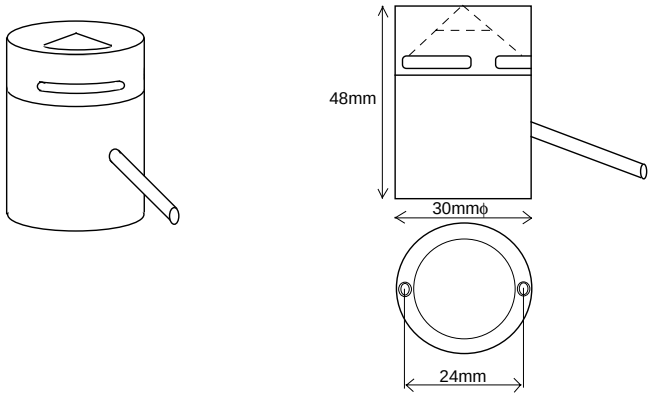
The parts supplied may include:

- ES2 sensor with cable fitted
- Levelling table or mounting bracket

Cable lengths, other than the standard 5m, that are pre-ordered will normally be fitted in unbroken lengths.

## Description of Equipment

Outline Diagram




## Mounting the Sensor

Two M4 mounting screws are provided with each sensor.

The sensor is usually mounted horizontally for most solar radiation insolation studies. The readings then give the irradiance ($kW.m^{-2}$) of a horizontal surface.

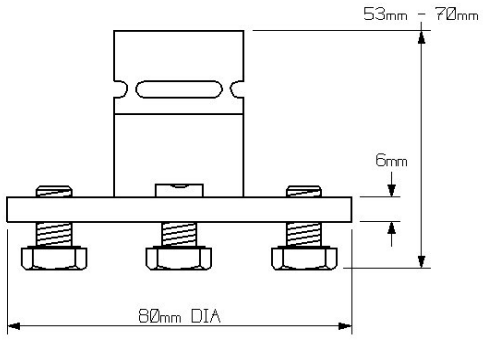
A common exception is made where the sensor is mounted on the face of a tilted solar collector panel. The readings obtained will then be the irradiance of the solar panel surface, but you must check the validity of this approach (see below: *Accuracy Limitations*).

Two standard fittings are offered, or you can easily make up your own mounting plate.

If you need to remove excess length of cable at this stage, simply cut off the excess, but allow for a sufficient length of the cable screen.

## Levelling Mount type SRLF1

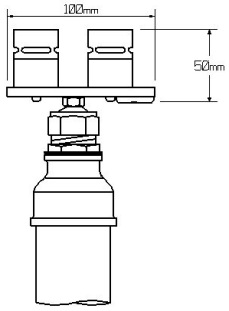
This is a freestanding platform with adjustable legs and bubble level to allow the sensor to be accurately mounted horizontally.




## M2 Mast Top Fixture

This is a mast-mounted bracket with an inverted bubble level.

The moveable ball-joint allows the sensor to be mounted horizontally even if the mast is not exactly vertical.



# Sensor Connections

## Outline Specs

| Parameter | Value |
|---|---|
| Output | 10.0 mV per $kW.m^{-2}$ |
| Resistance | 100 ohm (typical) |

## Sensor Wiring

The sensor is fitted with 5m of cable with bare wire ends as standard.

| Conductor | Function | Notes |
|---|---|---|
| Red | Signal HI | mV Signal positive |
| Blue | Signal LO | mV Signal negative |
| Screen | screen | Not connected to body of sensor |

For best electronic interference protection, the screen should be connected to the ground/frame of any measuring equipment.

If you are not using Delta-T measuring equipment etc, please refer to your equipment manufacturer's instructions.

## Cable

Up to 100m of cable can be fitted at time of ordering.

The ES2 sensor output is not sensitive to the cable length within this limit.

If you need to remove excess cable, simply cut off the excess, but allow for a sufficient length of the cable screen to make the necessary connections.

If you need to extend the cable length, simply add extra cable of similar type with a waterproof joint or junction box.

## Data Requirements

Typical common usage:

Sample the ES2 every minute; store the average every hour or half-hour.

# Logger Connections

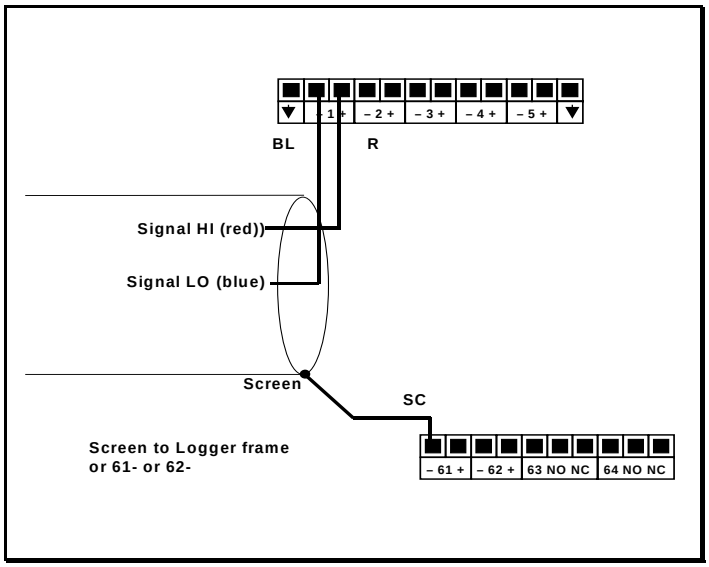
## DL2e Logger

### Use with LAC1

This diagram shows the wiring connections for the LAC1 analogue input card.

For use with other cards, please refer to DL2e Logger User Manual

### Wiring Schematic for DL2e




The example shows the ES2 sensor connected to analogue channel number 1 (for convenience) in the DL2e logger, with the following assumptions:

The LAC1 input card is used in its 15-channel (differential) mode, with the 15-30 slider set to "15".

The LAC1 card can be used in its 30-channel (single ended) mode *if* no powered sensors is used in the same configuration. See the DL2e User Manual for more details.

Note: The cable screen is connected to either channel 61- or 62-, the digital earth/frame of the DL2e, for electrical screening purposes.

### DL2e Sensor Code

When creating your DL2e logger configuration with the LS2e software, you can use the “ES2” sensor code provided. The ES2 code is included in the sensor library from Release 12 onwards.

If you have an earlier release of the LS2e software, you can download the latest version from the Delta-T web site.

Alternatively, you can create a sensor code using the correct value of conversion factor (10.0 mV per $kW.m^{-2}$).

***Warning!*** *Do not use the sensor code “ESR” for the former ES Energy Sensor. It has a different conversion factor (10.8) that will give inaccurate results if used with the ES2.*

All that remains is to choose suitable sampling and logging intervals (see *data requirements*) in your logging configuration.

## DL3000 Logger

### Wiring Connections

Full details, including example connection diagrams, are available in the application note Dtapp102.exe. This application note is available as a file supplied with the DL3000, or can be downloaded from the Delta-T web site.

### Sensor Type

Load the sensor library that comes with the above application note and select the ES2 sensor type. Select suitable sampling and logging intervals (see *data requirements*).

## Other Loggers

Any logger with a 25 or 30 mV input range channel could be used. Follow the general principles laid out above.

# Specifications

| Parameter | Notes |
|---|---|
| Photodiode | High quality Silicon Photodiode |
| Sensitivity | 10.0 mV per $kW.m^{-2}$ of solar radiation in the 300 – 3000 nm waveband |
| Accuracy | ±3% at 20°C, subject to limitations (see below) |
| Calibration traceability | Traceable to the UK National Physical Laboratory |
| Linearity | ±1% 0-2 $kW.m^{-2}$ |
| Azimuth error | ±1% over 360° |
| Stability | Typically better than ±2% per year |
| Response time | 10 µs |
| Temperature dependence | Sensitivity <0.2% / °C |
| Spectral response | Bandwidth: 400-1050 nm. See Fig 1. |
| Cosine response | Cosine corrected within ±5% up to 70°. See Fig 2. |
| Measuring limits | 0-2 $kW.m^{-2}$ |
| Internal resistance | 100 ohm typical (dark) |
| Temperature Limits | Operating range -10 to +60 °C<br>Storage range: -20 to + 100 °C |
| Cable type | Screened pair, bare wire terminations:<br>Red wire, + (photodiode anode)<br>Blue wire, - (photodiode cathode) |
| Cable length | As supplied. Maximum 100 m |
| Screen | Screen, not connected at the detector |
| Mounting | Two M4 tapped holes (24mm PCD) in base |
| Housing | Black anodised aluminium |
| Enclosure rating | IP65 |
| Size and Weight | 48 mm high x 30 mm dia. 70 g |

# Accuracy Limitations

The Energy Sensor is calibrated by comparison with a transfer standard Energy Sensor of identical construction, using simulated solar light (from a xenon arc lamp) and an integrating sphere. The light distribution is Lambertian (uniform brightness in all directions). Under these conditions, the accuracy will be within the stated ±3%.

The transfer standard Energy Sensor itself is calibrated by comparison with a standard glass dome thermopile pyranometer in “natural daylight” conditions. These conditions correspond to the average summer time daylight experienced at sea level in the U.K. (a temperate climate, latitude 52° N). In these conditions, the accuracy of daily integrals of insolation will be typically within ±5%.

The validity of the calibration of the Energy Sensor is good only when the spectral characteristic of the light being measured is similar to these conditions. Light with a different spectral characteristic may introduce some degree of error.

This approach is necessary because the photodiode spectral response (400 – 1050 nm) covers only about 70% of the energy in the full solar spectrum (300 – 3000 nm). All simple photodiode sensors suffer from this constraint, but the consequences of it are not always fully explained to the user.

The following general information is offered. Please contact Delta-T if you need special advice or guidance on these matters.

## Conditions to Avoid or Validate

The daylight spectrum depends on the solar spectrum, and to some extent on many other atmospheric factors: for example, the degree of cloud cover, the season, the time of day, the amount of dust, water vapour and aerosol contaminants, and also the altitude.

The following situations should be avoided:

1. Artificial lighting, especially lights with a peaky non-solar spectral distribution, or with a high frequency oscillation component (>> 50 Hz) in the light level.
2. Situations where there is a strong component of reflected light. Note that this could occur with sensors mounted on the face of tilted solar collectors.
3. Measurements within a crop. The vegetation changes the spectral composition of the light below the crop canopy.

The following situations should be validated:

1. Sensors installed at altitudes of greater than a few hundred meters.
2. Situations where there is long term, heavy, atmospheric pollution.

## Method of Validation

You should compare the output of your ES2 with a standard glass dome thermopile pyranometer installed at the actual measurement site.

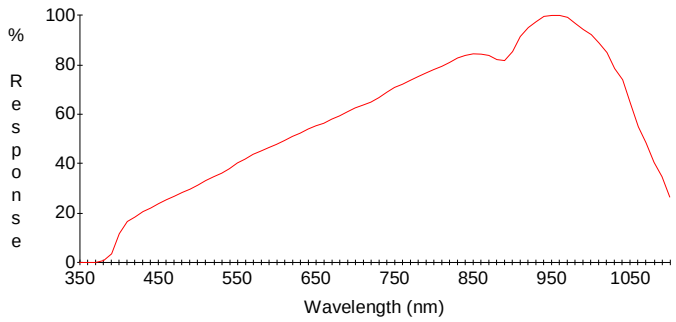
Take measurements of both sensors over a number of days. Compare the daily integrals obtained ($MJ.m^{-2}$) each day. If a constant factor is found, you can apply this as a correction factor to the results obtained from your ES2.

If the factor varies widely (say > ±10%) from day to day under different atmospheric or weather conditions, the ES2 is not suitable for this application.

# Spectral Response

### *Figure 1*

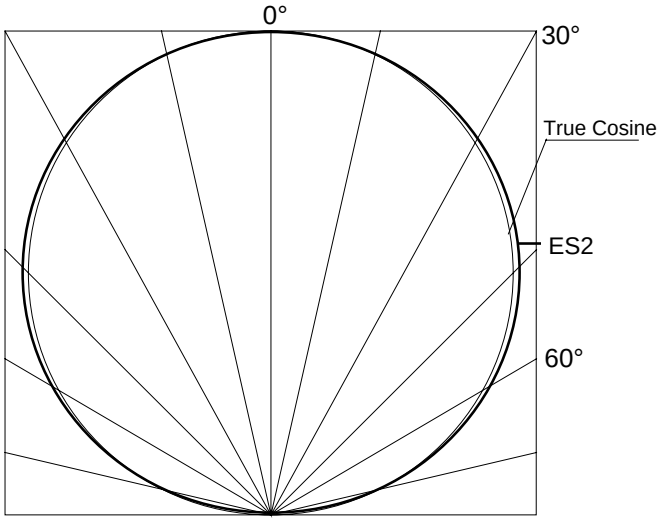
Relative Spectral Response




# Cosine Response

### *Figure 2*

Cosine correction within ±5% up to 70° incidence.



# Certification

## CE Conformity

The Manufacturer of the ES2 Energy Sensor certifies the following statement:

“Following the provision of the EMC & LV directives the above product can be treated as a passive component. However the product has been designed to ensure that the radiated immunity is maximised

The product was tested and passed the fast transient and electrostatic discharge test as detailed in the standards IEC801-2 & IEC 801-4.”

## Manufacturing Conformity

The Manufacturer of the ES2 Energy Sensor certifies the following statement:

“The product complies with the Manufacturer’s written specification and has been calibrated in accordance with test procedures.”

This is a certificate of type, and means that the product, at the time of supply, will perform in accordance with the specifications given in this User Manual.

## Individual Calibration Certificate

An individual Manufacturer’s Calibration Certificate can be provided (at extra cost) for an ES2 Energy Sensor, provided this is specified at the time of ordering or recalibration.

The certificate identifies the specific sensor by serial number, and lists the traceable calibration standards and equipment used to calibrate it. A spectral response graph can also be included.

# Maintenance

# Routine Maintenance

The performance of all light sensors is directly dependent on the transparency of the diffuser. You must keep it clean. From time to time you should wipe it with a damp cloth to remove any dust or dirt deposits. For difficult deposits, use a toothbrush and water, and then wipe it dry.

# Recalibration

Recalibration every year is recommended, or sooner if there is any reason to doubt the calibration accuracy.

## By Delta-T

Return the unit to Delta-T.

The unit will be tested and recalibrated. An individual calibration certificate will be issued, and a spectral response graph can be provided in addition, if requested. You must specify this with your order.

## User Recalibration

For the convenience of users who wish to avoid returning sensors to Delta-T, we have provided a sensitivity adjuster in the ES2.

***Warning!*** *Please note that this process is entirely at the user's own risk. Delta-T can take no responsibility for the subsequent accuracy or performance of the sensor.*

By removing the circlip and cover in the base of the ES2 you can access a trimmer potentiometer that changes the sensitivity of the output.

You will need a certified reference pyranometer (preferably a glass dome, thermopile instrument) for comparison.

1. Compare the outputs of the two units when they are exposed to identical daylight conditions at the actual measurement site.
2. Now adjust the sensitivity of the ES2 by an appropriate amount to bring it back to the standard value of 10.0 mV per $kW.m^{-2}$.

If the adjustment is more than a few % of the output this may indicate a serious change in the sensor characteristics. We recommend you do not use the sensor, and contact Delta-T for advice.

## Changing the calibration

If you have reset the calibration to a new value to allow for altitude or other effects (see *Accuracy Limitations*), you should retain your calibration standards and methods and re-use them at appropriate intervals. Do not return the units to Delta-T, otherwise they will be reset to our standard.

# Storage

Apart from the storage temperature limitations (see Specifications), there are no special requirements.

# Warranty and Service

## Terms and Conditions of Sale

Our Conditions of Sale (ref: COND: 1/00) set out Delta-T's legal obligations on these matters. The following paragraphs summarise Delta-T's position but reference should always be made to the exact terms of our Conditions of Sale, which will prevail over the following explanation.

Delta-T warrants that the goods will be free from defects arising out of the materials used or poor workmanship for a period of **twelve months** from the date of delivery.

Delta-T shall be under no liability in respect of any defect arising from fair wear and tear, and the warranty does not cover damage through misuse or inexpert servicing, or other circumstances beyond our control.

If the buyer experiences problems with the goods they shall notify Delta-T (or Delta-T's local agent) as soon as they become aware of such problem.

Delta-T may rectify the problem by supplying faulty parts free of charge, or by repairing the goods free of charge at Delta-T's premises in the UK, during the warranty period,

If Delta-T requires that goods under warranty be returned to them from overseas for repair, Delta-T shall not be liable for the cost of carriage or for customs clearance in respect of such goods. However, we much prefer to have such returns discussed with us in advance, and we may, at our discretion, waive these charges.

Delta-T shall not be liable to supply products free of charge or repair any goods where the products or goods in question have been discontinued or have become obsolete, although Delta-T will endeavour to remedy the buyer's problem.

Delta-T shall not be liable to the buyer for any consequential loss, damage or compensation whatsoever (whether caused by the negligence of the Delta-T, our employees or agents or otherwise) which arise from the supply of the goods and/or services, or their use or resale by the buyer.

Delta-T shall not be liable to the buyer by reason of any delay or failure to perform our obligations in relation to the goods and/or services, if the delay or failure was due to any cause beyond the Delta-T's reasonable control.

## Service and Spares

Users in countries that have a Delta-T Agent or Technical Representative should contact them in the first instance.

Spare parts for our own instruments can be supplied from our works. These can normally be despatched within a few working days of receiving an order.

Spare parts and accessories for sensors or other products not manufactured by Delta-T, may have to be obtained from our supplier, and a certain amount of additional delay is inevitable.

No goods or equipment should be returned to Delta-T without first obtaining the agreement of Delta-T or our agent.

On receipt at Delta-T, the goods will be inspected and the user informed of the likely cost and delay. We normally expect to complete repairs within a few working days of receiving the equipment. However, if the equipment has to be forwarded to our original supplier for specialist repairs or recalibration, additional delays of a few weeks may be expected.

# Troubleshooting

## Technical Support

Technical Support is available on Delta-T products and systems. Users in countries that have a Delta-T Agent or Technical Representative should contact them in the first instance.

Technical Support questions received by Delta-T will be handled by our Tech Support team. Your initial enquiry will be acknowledged immediately with a “T number” and an estimate of time for a detailed reply (normally 2-3 working days). Make sure to quote our T number subsequently so that we can easily trace any earlier correspondence.

In your enquiry, always quote instrument serial numbers, software version numbers, and the approximate date and source of purchase where these are relevant.

### Contact details:

Tech Support Team
Delta-T Devices Ltd
128 Low Road, Burwell, Cambridge CB5 0EJ, U.K.
email: tech.support@delta-t.co.uk
Web site: www.delta-t.co.uk
Tel: +44 (0) 1638 742922
Fax: +44 (0) 1638 743155

# Problems

## No mV Output

Carry out a continuity check.

Disconnect the sensor from any measuring equipment. Shield the sensor from any light. Measure the resistance between the red and blue wires. It should be typically 100 ohm.

If it is short circuit, open circuit, or variable, inspect the cable for damage, and repair it. Also inspect inside the body of the sensor, but do not turn the adjuster.

## Noisy Readings

If the continuity check above is satisfactory, check the connections to your measuring equipment. An intermittent, or high resistance, contact to the terminals of the logger or meter can cause noisy readings.

## Small Negative Output

In some conditions overnight the sensor can produce a small negative voltage instead of reading exactly zero. This is not a fault condition, and it can be ignored.

# Glossary

# Terms and Units

These terms apply to Quantum and Energy sensors

## Cosine Corrected

Refers to a sensor that is designed to have a cosine response.

## Cosine Response

A sensor with a true cosine response gives an output that is proportional to the cosine of the angle of incidence of the ray of light. The angle of incidence is the angle between a perpendicular to the sensor surface and the ray of light.

## Daily Integral

This is commonly used for crop studies. It is the integral with respect to time (typically one day) of the energy or quantum flux.

## Energy Flux

The flux of energy is expressed in watts per metre squared ($W.m^{-2}$).

Daily Integral units for energy flux are typically: mega joules per metre squared ($MJ.m^{-2}$)

## Irradiance

The flux of quanta or energy incident on unit surface area.

## PAR

Photosynthetically Active Radiation is defined as radiation within the (visible) band 400-700 nm. It can be expressed in terms of the quantum flux or the energy flux.

## Quantum Flux

The flux of quanta of PAR radiation is expressed in micromoles per metre squared per second ($\mu mol.m^{-2}.s^{-1}$).

The term photon is occasionally used instead of PAR quantum.

A mole of quanta is an amount of substance ($6.022 \times 10^{23}$ quanta: Avogadro's constant).

Daily Integral units for quantum flux are typically: $mol.m^{-2}$