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# OAQ User Guide RF-LW-TOAQ

**RF-LW-TOAQ-CO2**

**RF-LW-TOAQ**

## LoRaWAN Wireless Outdoor Air Quality Monitor

- LoRa long range wireless
- Battery or externally powered
- Built in sensors and options for:

- Temperature (°C)
- Humidity (%RH)
- Barometric Pressure (Pa)
- Volatile Organic Compounds (VOC's)
- EPA Air Quality Index (AQI)
- Particles PM 1, 2.5, 4, 10
- Carbon Dioxide ($CO_2$)*
- Ozone ($O_3$)*
- One additional gas from CO, $NO_2$, $H_2S$, $SO_2$, $O_2$, Odours, HCHO (Formaldehyde)*


The OAQ Indoor Air Quality Monitor is a precision instrument which accurately measures up to ten key environmental parameters including Temperature, Relative Humidity, VOC's, Carbon Dioxide, Particulate Matter (PM1, PM 2.5, PM4 & PM10), Barometric Pressure, EPA Air Quality Index (AQI), Ozone, Formaldehyde, Carbon Monoxide, Nitrogen Dioxide, Hydrogen Sulphide, Sulphur Dioxide, Odours and Oxygen.

Readings are transmitted to the cloud using long range LoRa wireless, where the data can be displayed and analysed.
A built in USB port allows all parameters including air quality data, wireless signal strength and wireless network configuration to be viewed and set using simple menus via any USB enabled host such as a PC or Mac.

## Features

- Multiple sensor options*
- LoRa long range wireless
- Frequency Range 863-870MHz*
- Frequency Range 902-928MHz*
- Up to +18dBm Tx Power
- Built in USB port for configuration
- Battery or externally powered
- CE / FCC compliant
- RoHS compliant
- Made in the UK

*Option / model dependent

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## 1. Introduction

OAQ accurately measures up to ten key outdoor air quality parameters with class leading accuracy.

Available with temperature, relative humidity, particulate matter, $CO_2$, Ozone, $CH_2O$, CO, $NO_2$, $H_2S$, $SO_2$, $O_2$, Odours, VOC's and barometric pressure.

## 2. Configuration

LoRa devices can be configured using OTAA (Over-the-Air-Activation) or ABP (Activation-byPersonalisation).

OTAA is the most secure way to connect a device to the LoRa network. In OTAA, the device performs a Join-procedure with the network, during which a dynamic DevAddr (device address) is assigned and security keys are negotiated with the device.

ABP allows you to set the DevAddr as well as the security keys in the module. This is simpler than OTAA as there is no Join procedure, however, it is less secure than OTAA.

This guide will illustrate using OTAA as it is the most secure and flexible method.

The OTAA configuration requires the following parameters to be correctly set:

- DevEUI: End-device Identifier. It is unique for every device and is set at device manufacture.

- AppEUI / JoinEUI*: Application Identifier. Used to identify the end application.
- AppKey: Application key. Used to create the session keys.

*Note: In LoRaWAN 1.1, AppEUI was renamed to JoinEUI.

The DevEUI is always set at device manufacture and is unique. The device AppEUI and AppKey can easily be set via the USB connection if required and the process is detailed later in this document.

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## 3. Join devices to the LoRa network

Devices in wireless range and with the correct AppEUI and AppKey settings will automatically join the LoRa network when they are first powered up.


*OAQ Unit Label*

The unique **DevEUI** is printed on all devices and is also present in the QR code. The **DevEUI** can be used to identify the device once joined to the network.

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## 4. Powering the unit

### a. Powering the unit via the onboard batteries

To power the device ON, first slide the power switch to the EXT position, to disconnect the battery power input.

Insert the 4 x AA sized Lithium 3.6V batteries taking great care to insert them the correct way around. Locate the plus (+) and minus (-) signs on the battery and use the plus (+) and minus (-) guides on AA battery holders to insert the batteries in the proper direction. All four batteries face in the same direction.

Be sure to insert the minus (-) end first and remove the plus (+) end first when replacing the batteries.

Lithium batteries have very high energy capacity and a great degree of care should be exercised to ensure that all batteries are new, from the same manufacturer, installed the correct way around and are not in any way damaged. Refer to Section 13 for more details.

Check that the batteries are correctly inserted and then slide the power switch to BATT to connect the battery power to the unit.

Note that the unit can only be battery powered or externally powered. When the switch is in the BATT position, any external power source is automatically disconnected. When in the EXT position, the batteries are automatically disconnected.

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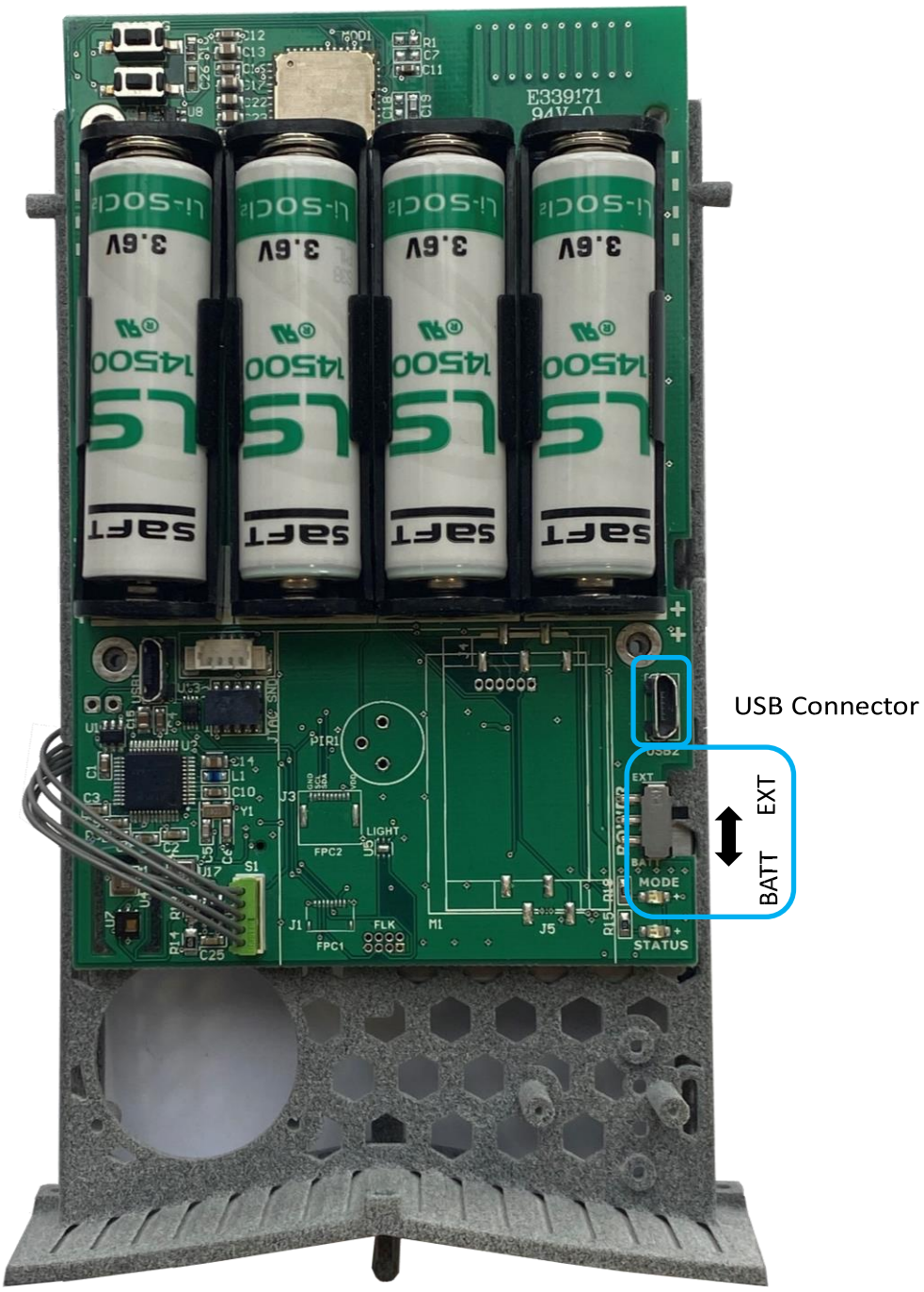


*OAQ Sensor cartridge*

Once powered ON, the device will send a Join request message to the gateway. The Status LED will blink RED as shown below whilst the Join process is taking place. Depending on factors such as signal strength, RF interference etc the Join process may take several seconds to complete.

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*Blinking Red LED – Attempting Join*

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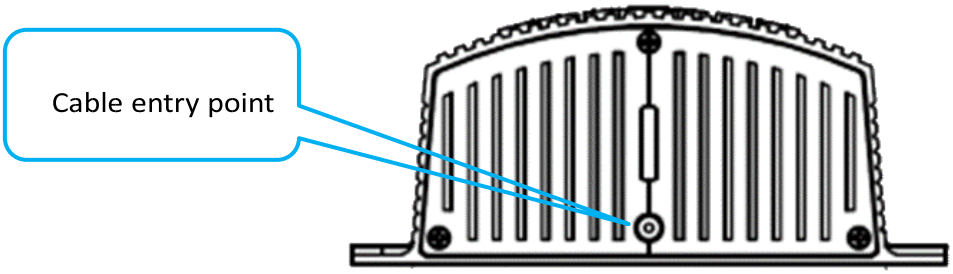
When the device has successfully joined the network the Mode LED will blink GREEN for several seconds to show that the Join has been completed. The LED's will then switch off to conserve the batteries.

### b. Powering the unit with External Power

The OAQ may be powered from an external power source if required. The unit requires 12 – 24V DC at 200mA.

To power the unit, first drill out the cable entry knockout as shown below with a 5 - 5.5mm drill. There is a moulded tongue behind the knockout to allow a cable tie to be attached to the cable to act as a strain relief.




Power is supplied to the unit via a 2 pole Molex push button connector as shown below.

The conductor size should be 18-26 AWG (1mm – 0.5mm diameter, 0.82mm CSA – 0.13mm CSA). Strip the cable to expose 5mm of conductor.

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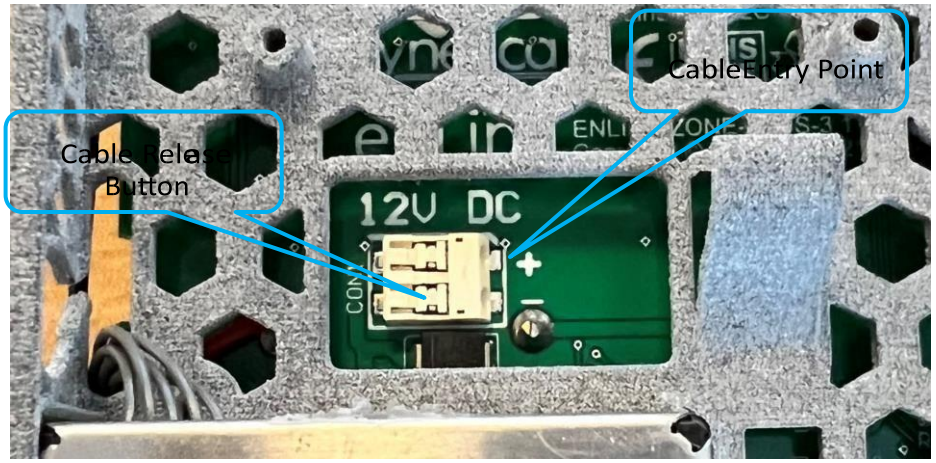
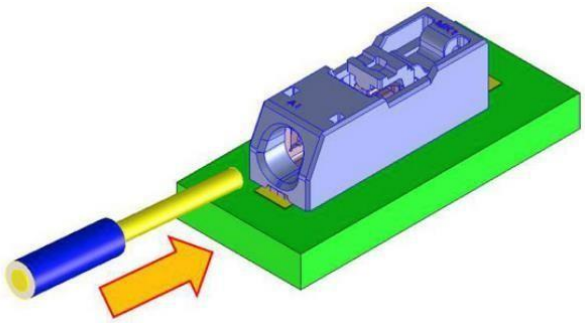



*OAQ External Power Connector*

Push the stripped end of the power cable into the connector taking great care to observe the correct polarity. The positive cable should connect to the terminal marked (+) and the negative cable to the terminal marked (-)

| |
|---|
| Wire is directly inserted and pushes open lowinsertion force gate-style terminal, which “traps” wire in place. |
| |
| Wire strip length is 5mm |



*Power Wire Insertion*

Gently pull on the cable to ensure that that it is correctly inserted. Ensure that no uninsulated cable is showing.

Once complete, move the power switch to the EXT position for external power as shown below. The unit will power up and attempt to join the LoRaWAN network.

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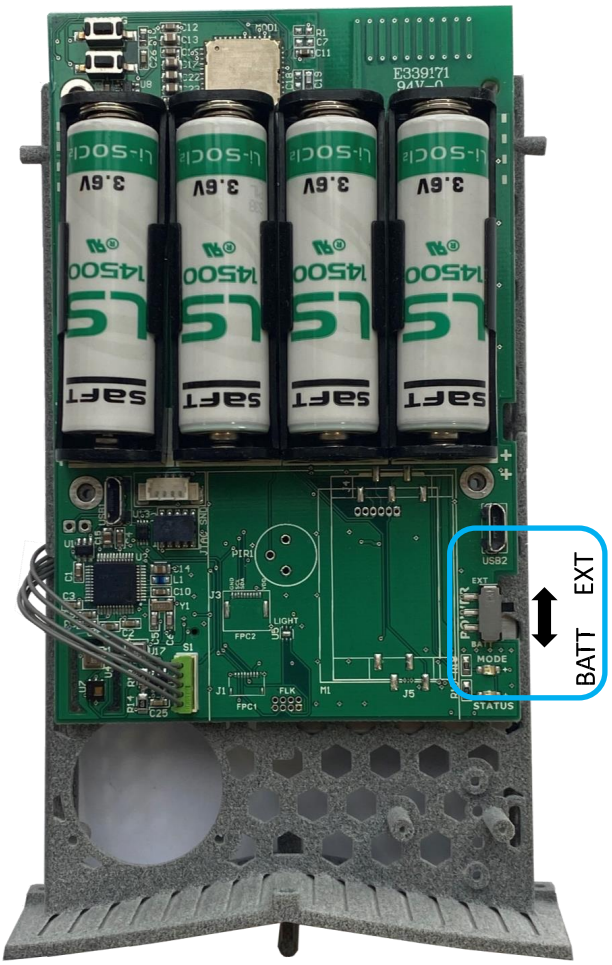
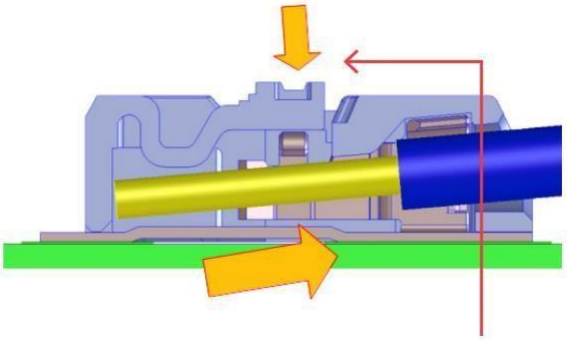



*OAQ power switch, select EXT position*

To release the cable, gently press down on the button lever, as shown below and the cable will release freely.

| |
|---|
| Button-style lever is pushed down, gatestyle terminal opens, and wire can be freely pulled out. |



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*Release Power Cables*

## 5. Setting / changing the LoRa keys

If the LoRa gateway has matching keys the join process will happen automatically once the OAQ unit is in wireless range and powered on.

The DevEUI is always set at device manufacture and is unique. The device **AppEUI** and **AppKey** can easily be set via the USB connection as detailed below.

Once the sensor cartridge is removed, connect a micro USB cable to the unit. There are two USB connectors on the OAQ, so be sure to connect to the correct USB port (USB2) as shown in the image below. The device will attach to a COM port on your PC.

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*Configuration USB Port*

Using a terminal program (e.g. Teraterm https://ttssh2.osdn.jp/) connect to the COM port used by the device.

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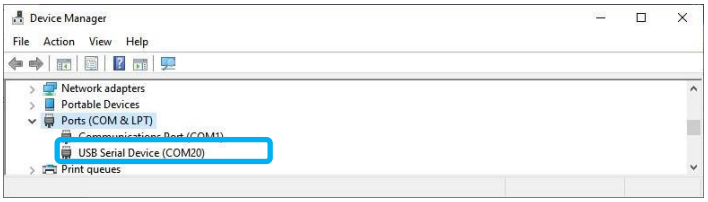
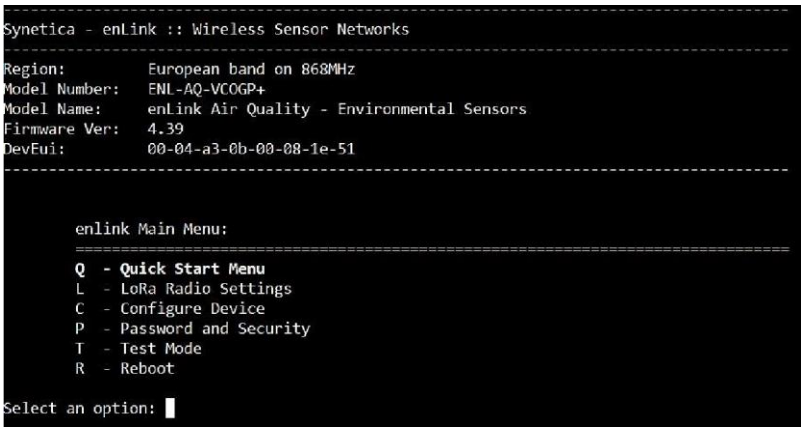
To verify which COM port is being used, check the Windows™ Device Manager (In Windows - Click the **Start** button, type **device manager** into the search box and tap **Device Manager** on the menu.) Expand the **Ports (Com & LPT)** menu as shown below.

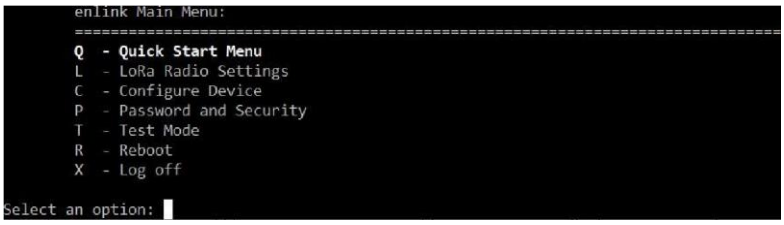



In your terminal program press the **Enter** key. An summary screen will appear as shown below. The default password is the last four digits of the displayed **DevEUI**, in the screen below this is 1e51.




*logon screen*

The screen below will show with the Main Menu options. Enter **Q** to enter the **Quick Start Menu**.




*Main Menu*

The **Quick Start Menu** contains only the parameters that normally need to be configured to setup the device and join the LoRa network.

From the **Quick Start Menu** you can change the **AppEUI** and **AppKey**.

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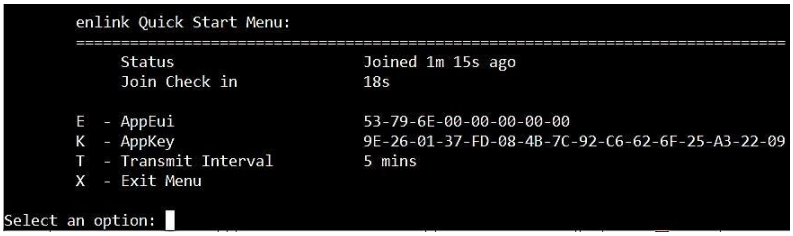
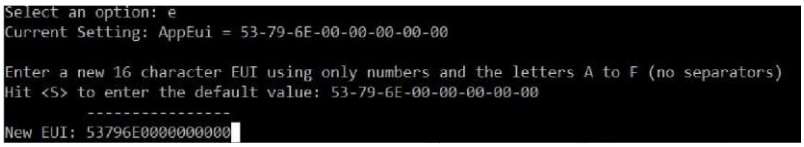


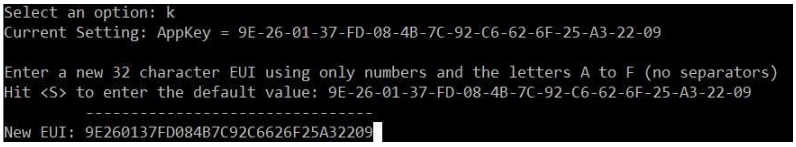

*Quick Start Settings Menu*

From the **Quick Start Settings Menu**, access the **AppEUI** setting by entering **e**. Enter the 16 character **AppEUI** using numbers and letters a to f. Do not include spaces or any other characters. Pressing **S** will enter the default **AppEUI** which you can then edit. Press **Enter** when the key is correctly entered to return to the **Quick Start Settings Menu**.




s *AppEUI setting*

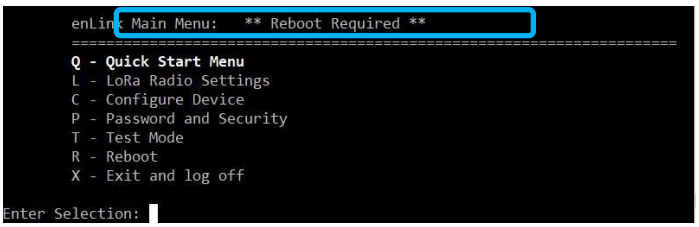
From the **Quick Start Settings Menu** access the **AppKey** setting by entering **k**. Enter the 32 character **Appkey** using numbers and letters a to f. Do not include spaces or any other characters. Pressing **S** will enter the default **AppKey** which you can then edit. Press **Enter** when the key is correctly entered to return to the **Quick Start Settings Menu**.




*AppKey setting*

Press **X** from the **Quick Start Settings Menu** to return to the enLink Main menu.

The header will show **** Reboot Required **** as shown below. The new key settings will not take effect until the device is restarted. Enter **r** to reboot followed by **OK**. The device will restart with the entered **AppEUI** and **AppKey** and attempt to join the LoRa network.




*Reboot Required notification*

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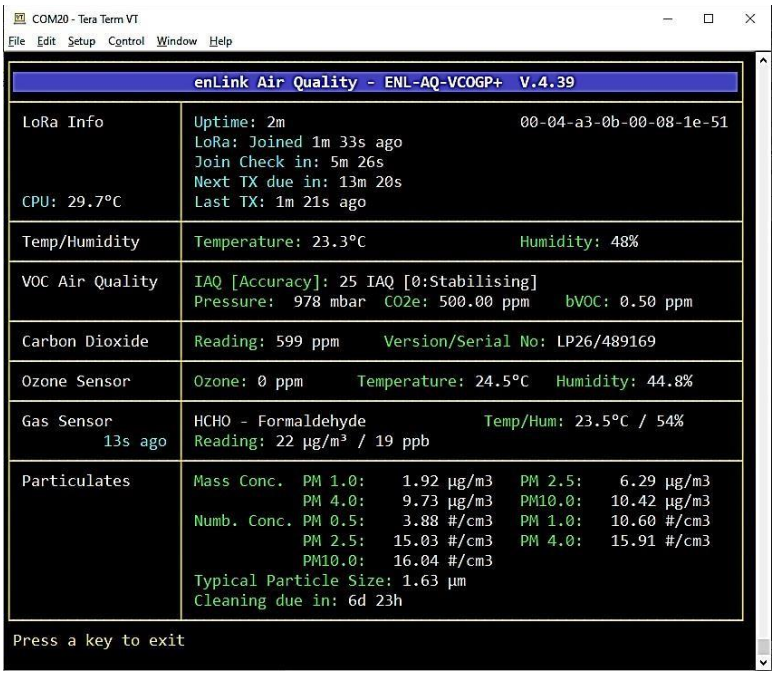
## 6. Live Menu

OAQ incorporates a live data screen which shows all readings and device status for easy data validation. To enter the Live status screen, from the **Main Menu** enter **c** for Configure Device followed by **d** for Live readings display. A screen similar to the one below will show. The sensors will vary according to the OAQ model and the installed sensors.




*Live Display*

## 7. Configuration Menu

The OAQ configuration menu allows you to view current sensor readings and also to change various functions of their behaviour such as calibration data. To enter the Configure Device menu press **c** from the main menu. A screen similar to the one below will show. The exact parameters shown will vary according to the OAQ model and sensors fitted.

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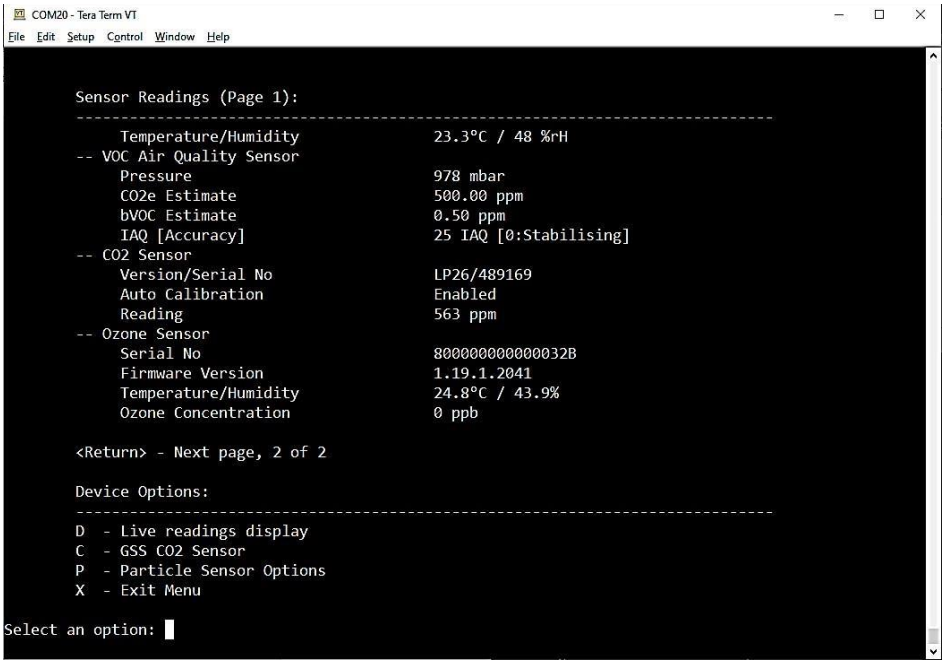
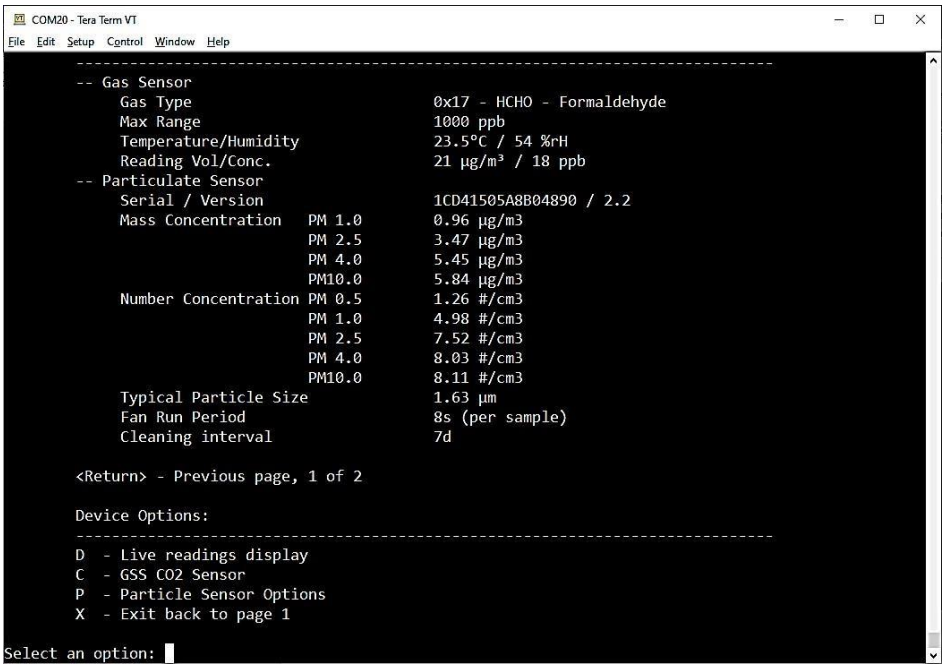



Page 1. Press the enter key to show page 2




## $CO_2$ Sensor Auto Calibration Configuration

To view and set $CO_2$ sensor calibration information, enter **c** and the screen below will show.

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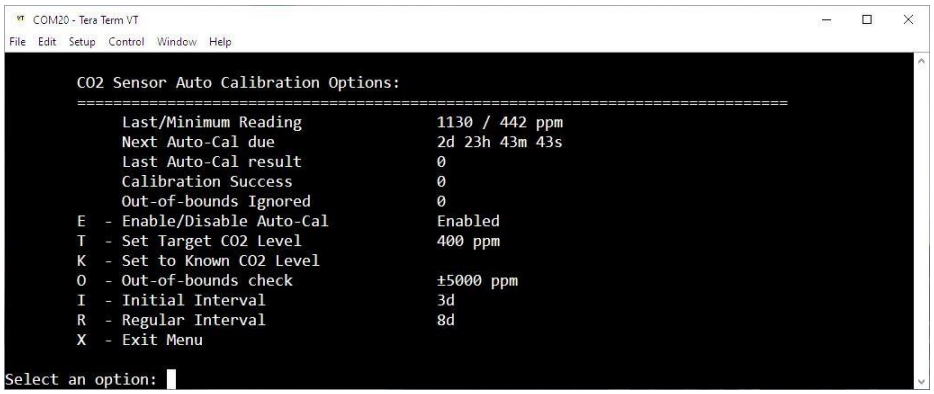


Please see the table below for information on each menu item.

| Menu Item | Description / details |
|---|---|
| Last/Minimum Reading | Shows the last $CO_2$ value read and the minimum $CO_2$ value read since the last auto calibration. |
| Next Auto-Cal due | Shows when the next autocalibration routine will occur |
| Last Auto-Cal result | Shows the value of the last auto calibration result. Used internally by the sensor. |
| Calibration Success | This shows the total number of successful auto calibrations since the device was powered up. |
| Out-of-bounds Ignored | Shows the number of times that auto calibration did not run due to the Out Of Bounds setting. |
| E - Enable/Disable Auto-Cal | Enables or disables the auto calibration routine. |
| T - Set Target CO2 Level | This is the known $CO_2$ corresponding to the minimum value the sensor has read since power-up or last calibration. It is normally 'fresh air' or the lowest level when the building is unoccupied overnight or at weekends. Typically this is 400 ~ 450 ppm. |
| K - Set to Known CO2 Level | This will re-calibrate the zero point of the sensor to a known gas concentration. The sensor should be placed in this gas concentration and allowed to stabilise.<br>This command runs in the background and will take 8 to 10 seconds to complete.<br>As an example, fresh air is typically around 400 ~ 450 ppm. |
| O - Out-of-bounds check | The Out-of-bounds value is used to ignore the calibration if the minimum value the sensor has read is not within a sensible range of the target concentration level. So, if the target concentration level is 400, the Out-of-bounds value is ±50 and the minimum reading is 451 (or more), the calibration routine is ignored. |
| I - Initial Interval | It is possible for the first auto-calibration to take place more quickly than the regular autocalibration events. This can be useful to stabilise the readings quickly after installation. |
| R - Regular Interval | This is the standard calibration interval, it is set to 8 days by default to accommodate a week long period where the minimum sensed $CO_2$ level should have fallen to background levels. |

Many of the above parameters can also be set via LoRaWAN downlink message.

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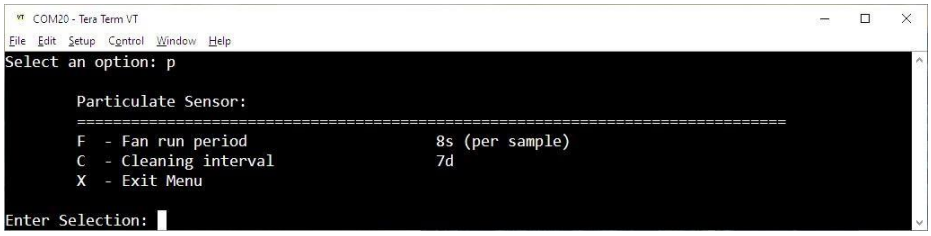
The $CO_2$ sensor needs to be exposed to fresh, clean air periodically for the auto calibration to be successful. Most occupied areas are unoccupied for some time during a week-long period, typically at night, or at the weekend and therefore the auto calibration runs every 8 days by default. Background $CO_2$ levels are typically around 400-450 ppm, if the background $CO_2$ level is known to be a different value, then this can be set in the "Set Target $CO_2$ Level" parameter

If a unit is placed in an area where the $CO_2$ level may not fall below a certain level, e.g. 450ppm, during the calibration interval then the "Out-of-bounds check" parameter can be set so that the auto calibration routine does not run. As an example, if an area is continuously occupied for a long period and the minimum $CO_2$ reading does not fall below, say 450ppm, then it is undesirable to run the autocalibration routine based on a target of 400ppm. In this case, if the "Set Target CO2 Level" is set to 400ppm and the "Out-of-bounds check" value is set to +/-50 ppm then the autocalibration routine will not run unless the minimum read value falls below 451ppm in the interval.

## 9. Particulate Matter Sensor Configuration

To view and set Particulate sensor information, enter **p** and the screen below will show.




Menu item **f** sets the particulate sensor fan run time. The default is 8 seconds and is the recommended setting for most applications. The fan run time may be extended for certain applications, however this will have an impact on the battery life of the unit.

The particulate sensor has a self-cleaning function which runs the fan at high speed to clean away any dust build up in the measurement chamber. By default, this cleaning cycle operates every 7 days but may be changed if required. Reducing the cleaning interval will have a detrimental effect on battery life.

The above parameters can also be set via LoRaWAN downlink message.

## 10. EPA Index Sensor Configuration

The OAQ has an EPA AQI sensor fitted, this is used to determine the Air Quality Index (AQI) based on nitrogen dioxide (NO2) and ozone (O3) concentrations.

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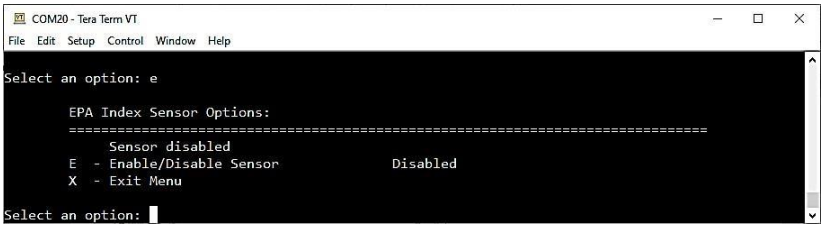
The sensor uses moderate amounts of power when in use as it utilises an integrated heater and metal-oxide chemresistor which measures the current amount of ambient ozone and nitrogen dioxide.

If the measurements are not required, then the sensor can be disabled to prolong battery life.

To view and set the EPA Index sensor parameters, enter **e** from the configuration menu and the screen below will show.



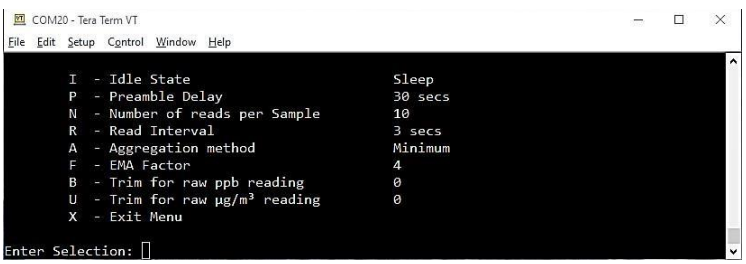

Enter **e** to toggle the sensor from enabled to disabled and confirm your selection.

## 11. Gas Sensor Configuration

The OAQ has the capability for one additional gas sensor to monitor one of the gases below:

- AQS-CO-10 Carbon Monoxide, 0 - 10 ppm
- AQS-CH2O-5 Formaldehyde, 0 - 5 ppm
- AQS-H2S-2 Hydrogen Sulphide, 0 - 2 ppm
- AQS-NO2-5 Nitrogen Dioxide, 0-5 ppm
- AQS-NO2-2 Nitrogen Dioxide, 0-2 ppm
- AQS-SO2-5 Sulphur Dioxide, 0 - 5 ppm
- AQS-ODOUR-5 Odorous gas sensor, 0 - 5 ppm

To view and set the gas sensor parameters, enter **g** from the configuration menu and the screen below will show.



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Please see the table below for information on each menu item.

| Menu Item | Description / details |
|---|---|
| I - Set Idle State | Sets the power options for the gas sensor. When the gas sensor is not actively reading, the power can be set to Off, Sleep or On.<br><br>Off mode turns the gas sensor off between measurements. This conserves maximum power, but is the least accurate as the sensor must stabilise to obtain the most accurate ppb level readings. Recommended for operation on battery power and where absolute accuracy is less important than battery life.<br><br>Sleep mode places the gas sensor processor in sleep but keeps the gas sensor analogue stage active. This balances accuracy and power consumption, when combined with a preamble delay of several seconds, good accuracy can be achieved. Recommended for external power such as solar power where good accuracy is required and more power is available than just the onboard batteries.<br><br>On mode leaves the gas sensor permanently powered. This mode uses maximum power and provides the most accurate ppb level readings. Recommended for externally powered units and where absolute accuracy is important. |
| P - Set Preamble Delay | Sets the stabilisation time prior to taking the first measurement. Longer preamble times consume more power. For good accuracy set to 15 seconds or 60 seconds for increased accuracy. |
| N - Set Number of Reads per Sample | Sets the number of readings taken per measurement. A value of 5 to 10 is recommended. |
| R - Set Read Interval | Sets the delay between readings. A value of 3 is recommended for most applications. |
| A - Set Aggregation Method | Sets the aggregation method. The readings per measurement can be aggregated as the maximum, minimum or average. Setting this to Minimum generally gives the best results at low ppb levels. Setting this to None uses the last reading taken. |
| F - Set the EMA (smoothing) Factor | To help smooth transients, the values can be averaged using an exponential moving average. The bigger the EMA factor, the greater the smoothing effect. A value of 4 gives good results in most applications. |
| B - Set trim value for ppb reading | Allows the ppb reading to be offset to align more closely with reference instruments. |
| U - Set trim value for µg/m³ reading | Allows the mass concentration reading to be offset to align more closely with reference instruments. |

All of the above parameters can also be set via LoRaWAN downlink message.

The following are example downlink messages to set the gas sensor to operate in the following mode:

- Idle State – Sleep

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- Preamble Delay– 60 Seconds
- Number of Reads per Sample – 10 Reads
- Read Interval – 3 Seconds
- Aggregation Method – Minimum
- EMA (smoothing) Factor – 4

Set Idle State – Sleep (0x01)
Downlink message is: A5 02 2D 01

Set Preamble Delay– 60 Seconds (0x3C)
Downlink message is: A5 02 2E 3C

Set Number of Reads per Sample – 10 Reads (0x0A)

Downlink message is: A5 02 2F 0A

Set Read Interval – 3 Seconds (0x03)

Downlink message is: A5 02 30 03

Set Aggregation Method – 1 Minimum (0x01)

Downlink message is: A5 02 31 01

Set the EMA (smoothing) Factor – 4 (0x04)

Downlink message is: A5 02 32 04

Reboot
Downlink message is: A5 01 FF

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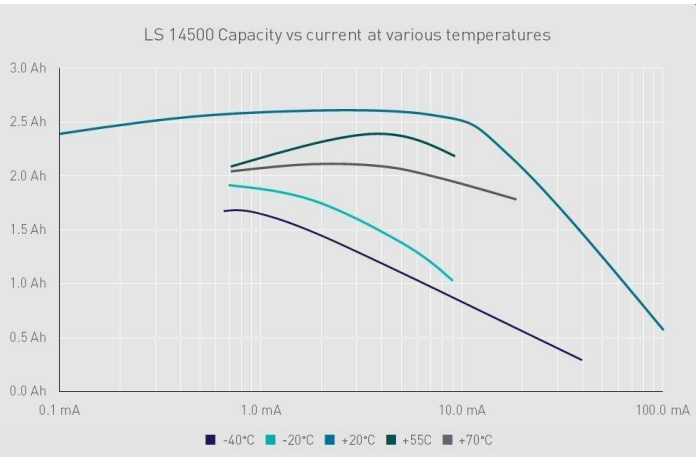
## Power Considerations

The OAQ can be powered with 4 x 3.6V Lithium-Thionyl chloride (Li-$SOCl_2$) AA sized batteries or via external power (12 - 24V DC @ 200mA or greater).

OAQ can be specified with many environmental sensor options including laser scattering particle matter sensor and a variety of gas sensors. These sensors consume considerable power while actively sensing and therefore, to prolong battery life, the sampling interval should be set to the longest period practical for the application. Sampling / transmission intervals of 30 minutes or less place additional strain on the batteries, limiting their capacity and should be avoided when operating on battery power. If frequent sampling is required, then external power should be applied to the unit.

Where the OAQ unit is fitted with a gas sensor, please refer to the recommendations regarding power consumption in section 11.

Battery capacity is dependent on ambient temperatures and this should be considered when estimating battery life. Low temperatures slow down electrochemical reactions significantly and increase the internal resistance of the batteries. High temperatures increase the battery selfdischarge. The chart below illustrates the effect of temperature on the available battery capacity.




*Battery capacity vs current at various temperatures for SAFT LS14500 batteries.*

Battery life is also highly dependent on the LoRa spreading factor used. Higher spreading factors result in longer active times for the radio transceivers and shorter battery life. Positioning devices in closer proximity to a gateway will generally result in lower spreading factors, shorter time on air and much lower transmit power.

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## Battery Installation / Replacement

For battery power, OAQ devices use 4 x SAFT LS14500 or EVE ER14505 AA size 3.6 Volt Lithium Thionyl Chloride (Li-$SOCl_2$) batteries (non-rechargeable) or direct equivalent.

No other batteries are approved for use in the device.

Lithium Thionyl Chloride batteries have very high energy capacity and must be used and handled with care observing the guidance below.

WARNING

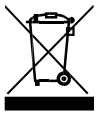
Risk of death or serious injury from explosion or fire.

- Keep out of sight and reach of children.
- Fire, explosion and burn hazard - do not recharge, short circuit, crush, disassemble, incinerate.
- Due to the high terminal voltage (3.6V), they are not suitable as direct replacements for other battery technologies in the same can sizes.
- When not in use the Batteries must be stored in a non-Hazardous Area.
- Do not change batteries in an explosive gas atmosphere.
- When installing batteries, do not snag the battery terminal on the clip or the battery may be damaged. Do not apply excessive force.
- Do not drop. Dropping the battery may cause damage. If a battery is dropped, do not install the dropped battery into the unit. Dispose of dropped battery promptly per local regulations or per the battery manufacturer's recommendations.

### Guidance

- Always install the batteries correctly as per instructions taking great care to observe the battery polarity.
- Ensure that the contact points are clean and conductive.
- All batteries must be the same model from the same manufacturer.
- Do not mix old and new batteries or batteries from different manufacturers.
- Do not heat or attempt to recharge the battery.
- Do not dispose of in a fire.
- Only install approved batteries: SAFT LS14500 or EVE ER14505 Lithium Thionyl Chloride AA Battery 3.6 Volt, or direct equivalent.

### Safe disposal



- Please recycle responsibly, a wide range of schemes are available.
- Do not dispose of in normal waste or in a fire.

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## OAQ Mounting Details

The OAQ should be fixed to a building wall which faces away from the sun, which is on the north side in the northern hemisphere (or south facing in the southern hemisphere). They should not be exposed to direct sunlight. The units are best placed in the middle of the building at least 3m above the ground and away from any exhaust ducts or flues.

Mounting guidelines for OAQ Units:

- Do not expose to direct sunlight.
- Do not mount on facades with a lot of ascending heat.
- Do not attach to walls in front of a chimney.
- Do not mount on eaves or a balcony.
- Do not place over windows.
- Do no mount over ventilation shafts.
- Do not paint over sensors.

- Mount sensors in an accessible location to allow easy inspection and maintenance.

The OAQ should be fixed to a wall or bracket using number 8 pan head screws. (4.2mm thread and 8.2mm pan head).

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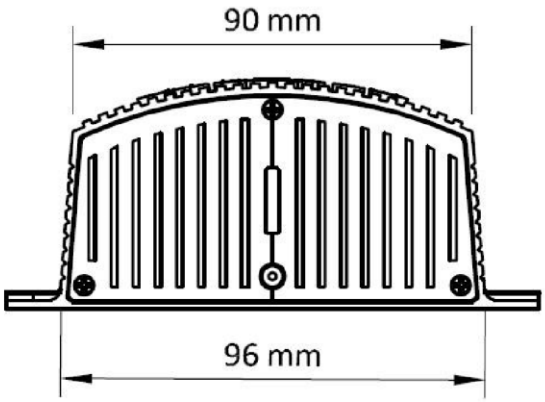


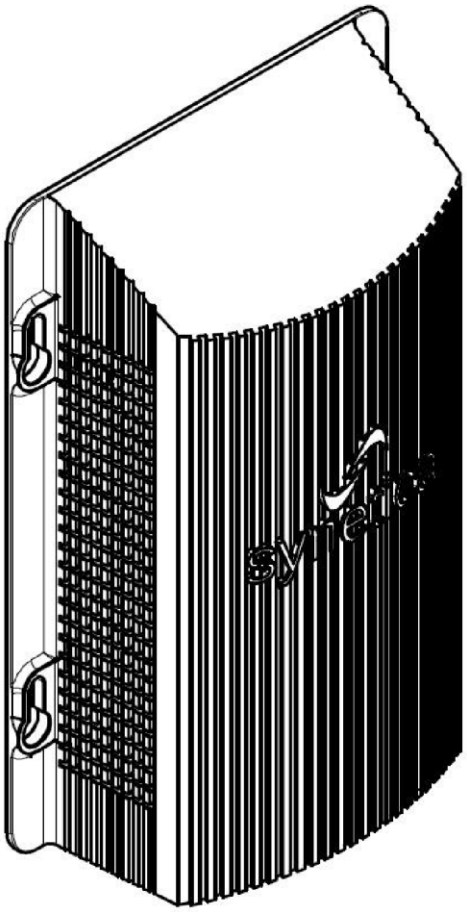

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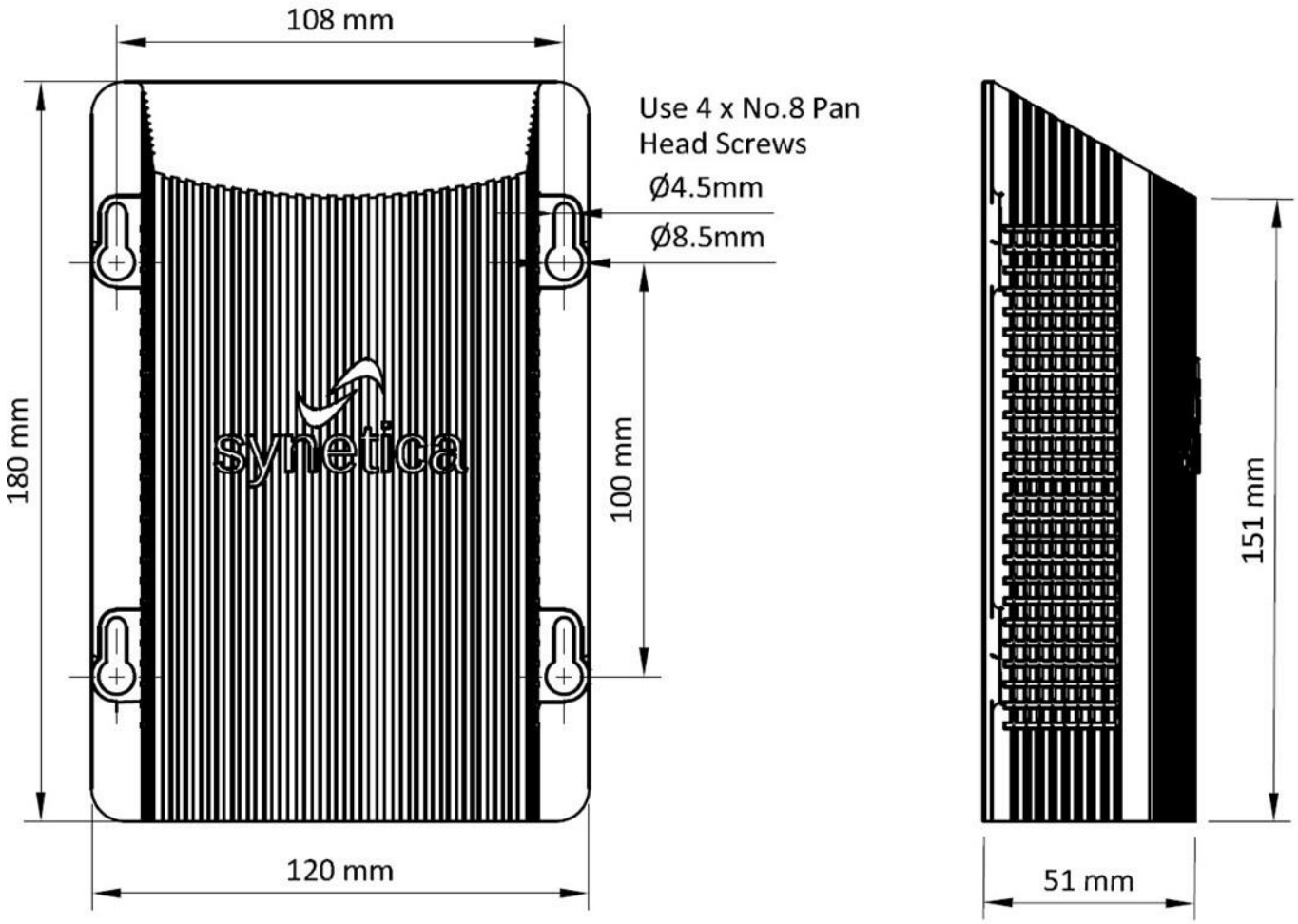


Fix the screws to the wall or bracket using suitable pan head screws and then slide the OAQ onto the screws.

Weight (without batteries): 180g

Weight (with batteries): 250g

**WEEE Directive:**
At the end of the products useful life please dispose as per the local regulations.
Do not dispose of with normal household waste.
Do not burn.