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Electronics Design & Consultancy

Street Lighting Load Research Report

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Version 04

A report for:

ELEXON: The Supplier Volume Allocation Group (SVG) and the Unmetered Supplies User Group (UMSUG)

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Executive Summary

This report of streetlamp power consumption was commissioned by ELEXON to determine the actual power used by common types of lamp over a period of one year. Earlier field measurement results for 35 Watt SOX and 70 Watt SON lamps indicated that actual power consumption is different to those power values defined for the Charge Codes for those lamp types. Charge Codes form part of the operational data used for Settlement as governed by the Balancing and Settlement Code and defined in BCSP520 “Unmetered Supplies Registered in SMRS”.

The research brief was undertake load research on 5 different lamp/ballast combinations and provide statistical evidence on their consumption to validate the existing values and provide robust power values. Plextek have set out to monitor an ideal sample quantity of 200 for five different lamp+ballast wattages, over three geographically separate areas, recording both power consumption and power factor. Plextek approached three different local authorities and worked with their highways department to identify lamps of the target types.

This report details the planning and installation of monitoring units onto the sample street lights, and the steps taken to maintain accurate data. Plextek employed the Telensa street light monitoring system (www.telensa.com) for this exercise. A Telensa monitoring and control device called a Telecell was fitted in place of the Photoelectric Control Unit (PECU) normally present on every street light. Each Telecell communicates daily via a bi-directional radio link to one or more base stations in the survey area. The base stations in turn relay data over the 3G cellular data network back to a central server, which is part of a Central Management System (CMS). A web browser interface was used to download measurement data from the CMS database for analysis.

Measurement results from the field trial are presented in this report by county and in total for each lamp type in table form. Graphs of power measurements also allow a more detailed analysis of each lamp type to be carried out. Supporting data presented also includes plots of the variation in average power over the twelve month period, and variation in supply voltage. Over twelve months the average power generally varied by +/-1% from the year average. Comparing the power plots with the plots for supply voltage show they track in a similar manner, indicating that any seasonal variation in power is dominated by supply voltage variation.

In most cases the average power values by region for each lamp type showed fairly close agreement. In the two cases where one county was more than 5% different to the overall average, this could be attributed to the set of lamps including a different type of ballast than the other two regions.

Lamp type	**55W SOX Std**	**55W SOX LL**	**90W SOX Std**	**90W SOX LL**	**135W SOX Std**	**135W SOX LL**	**150W SON Std**	**250W SON Std**
Sample size	78	131	76	104	97	66	214	200
Measured av. W	**76.85W**	**74.33W**	**129.95W**	**121.76W**	**190.16W**	**177.73W**	**180.48W**	**301.03W**

Summary table of results, showing the five lamp types

The results are subdivided where appropriate to separate the standard (Std) magnetic ballast and low loss (LL) ballast types.

Revision History

Version	**Date**	**Description**	**Author**	**Approved by**
1	21 Oct. 2011	Draft	MDM	MTJH
2	7 Nov.	Revision additions	MDM	MTJH
3	12 Jan. 2012	Draft following detailed review	MDM	MTJH
4	25 Jan.	Corrections to draft	MDM	MTJH

Version 04	Approved by	**MTJH**

Contents

1 Project Introduction

The load ratings for street lighting defined under the Balancing and Settlement Code have historically been determined by laboratory testing of product samples, and are not necessarily representative of product performance in the field, particularly once equipment ageing is taken into consideration. This has been shown in research previously undertaken by the Electricity Association in 2002 and 2004 on the power consumption of 35W SOX and 70W SON street lamps in the field (see reports produced for ELEXON: 70W SON and 35W SOX).

ELEXON, acting on behalf of the Supplier Volume Allocation Group with support from the Unmetered Supplies User Group (UMSUG) sought to determine whether the power taken by street lamps in the field aligned with the current load ratings defined in the Charge Codes for the five lamp types. These load rating values pre-date the formation of ELEXON and require verification.

Plextek was commissioned to undertake this load research, utilising the Telensa street lighting management system. The project brief was to monitor five streetlamp types, located in three geographically separate areas, with a nominal sample quantity of 200 per lamp wattage. The lamps were to be monitored over one year to examine any seasonal variation in performance.

1.1 Lamp types/ballast combinations

Of the five lamp types specified for monitoring, two are high pressure sodium or SON type, and three are low pressure sodium or SOX type lamps. The monitoring was specified for lamps with magnetic ballasts. The SOX type lamps are used with either standard or low loss magnetic ballasts. SON lamps are normally used with one type of ballast. As a consequence, eight lamp type and ballast combinations were monitored, as in the following list:

- 55W SOX Standard ballast
- 55W SOX Low Loss ballast
- 90W SOX Standard ballast
- 90W SOX Low Loss ballast
- 135W SOX Standard ballast
- 135W SOX Low Loss ballast
- 150W SON Standard ballast
- 250W SON Standard ballast

2 Measuring Equipment

The equipment used for power measurement was sourced from Telensa Ltd (www.telensa.com). The Telensa PLANet equipment is specifically designed for the control and monitoring of street lighting. In the Telensa system, a control node or “Telecell” is attached to each lamp, replacing the Photoelectric control Unit (PECU) normally used to control the lamp switching. The Telecell contains a radio transceiver, a switching relay and a metering section calibrated to a +/-1% accuracy, equivalent to the metering equipment standard BS EN50470 class B. The Telecell power is not included in the load metering.

Upon installation, each Telecell establishes a radio link to a central base station to download a dusk/dawn switching control program which is controlled by a central photocell on the base station. More importantly for this project, every Telecell returns daily power measurement data to the base station, which in turn is stored on a remote central server.

2.1 Calibration

As a key part of manufacturing testing, the meter section in each Telensa Telecell is individually calibrated to 1% accuracy at the power levels typically used in street lighting. After calibration, the calibration is then verified by the test system. All the Telecell manufacturing test equipment is yearly calibrated by an external laboratory, traceable to national standards.

For a separate quality assurance check after the manufacturing test and verification, a 10% sample of the Telecells used in this research were connected to a 250W load for 6 hours and the Telecell meter readings compared to those of a class B accuracy regular power meter connected in the circuit. No failures were found in this process.

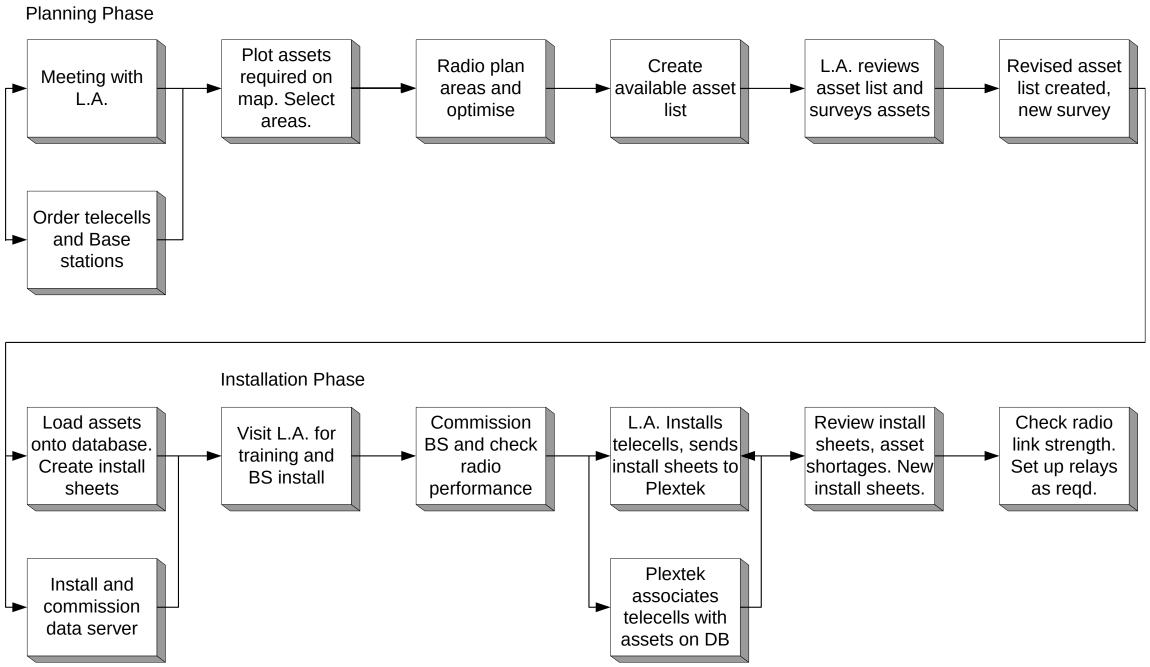
2.2 Equipment Photographs

Telecell

Lamp with Telecell and Base station

3 Methodology

3.1 Planning and Installation summary

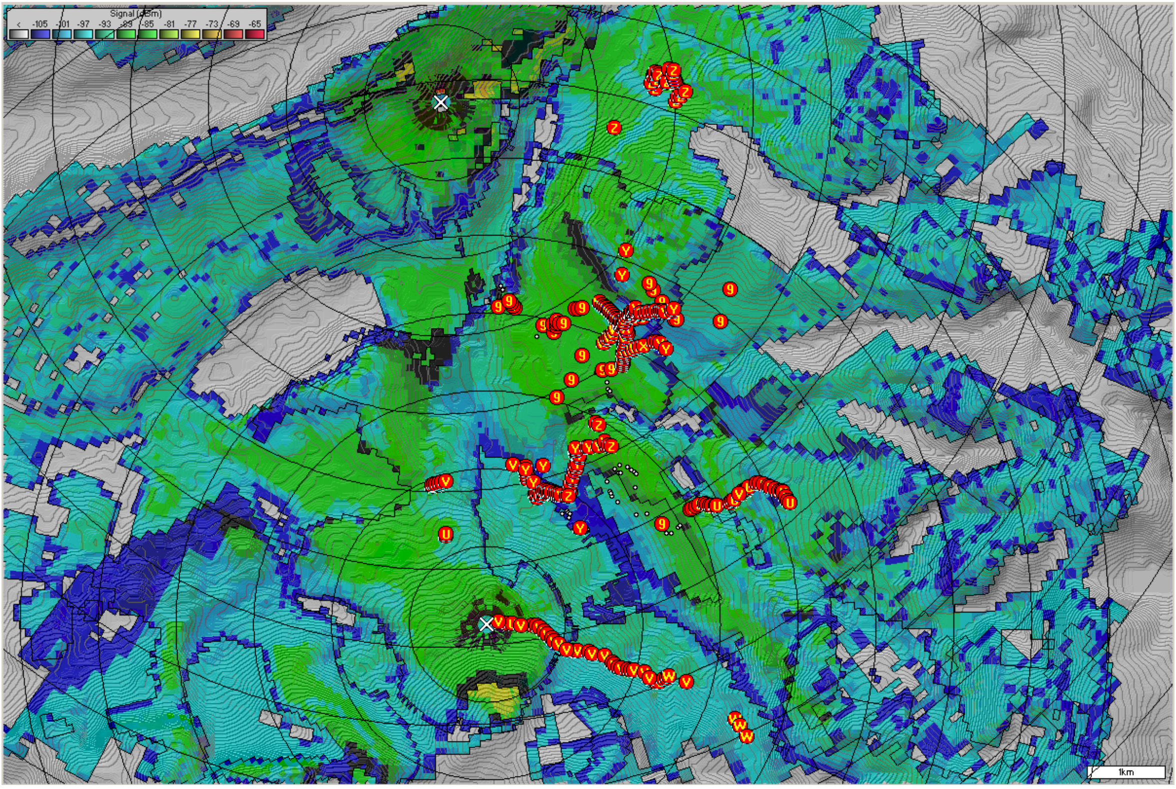


3.2 Research

Plextek approached three Local Authority highways departments in geographically separate areas who agreed to participate in the load research. The participating Authorities were Gloucestershire, Nottinghamshire and Lancashire. Each authority provided a lighting asset list with location data. The asset list was analysed using GIS software to search for concentrations of the desired lamp types. Once a suitable geographic area was identified, typically a city, then a radio planning exercise was carried out.

3.3 Radio Planning

The local list of lamps was loaded into radio planning software which was used to determine the optimum location for one or more base stations. The base station location is determined based on a maximum distance of typically 3-4km from lamp to base station for built up areas. Once a desired base station location was determined, Google Street View was used to identify a specific lighting column on which to install the base station hardware.



Radio planning in the Burnley area showing wanted lamps in red and base stations at points "X"
Signal strength is shown on a colour gradient

3.4 Lamp sample selection

The initial lamp column data was selected on the basis of lamp type, individually switched using a NEMA type plug-in PECU. NEMA socketed columns were used for ease of replacement with a Telecell to reduce installation costs. Over 90% of lamp columns are fitted with a NEMA socket for the PECU for maintenance. The 3 pin NEMA connector uses a robust bayonet type locking action and an example is shown in the appendix.

Sets of lamps of each type were selected within good transmission range of the base station. In built up areas, this is a maximum transmission range is 3-4km, or within the turquoise areas in the radio planning map shown above. A shortlist of individual lamps by street was determined. Once the shortlist was completed, this was sent for review to the relevant highways department. Typical feedback included notes against streetlamps where access was difficult, traffic management was necessary for the work to be carried out, or that columns were due for replacement within the next year. After one or two iterations a final installation list was agreed between Plextek and the highways department.

3.5 Installation process

Installation forms with 15 lighting columns per sheet were created by Plextek (see appendix for an example) for use by contractors. The installations were subcontracted to the contractor or DLO normally used by the local authority. The individual engineers used for installation were selected by the contracts manager for their diligence. The engineers were trained to 17th edition wiring regulations and Highway Electrical Association (HEA) registered.

Plextek staff accompanied the highways department subcontractor for typically two days to train and supervise the installation. Day one was used to install the base station(s) and a small number of Telecells to confirm the radio function. Day two was used to train and shadow the Telecell installer to ensure correct installation and accurate asset logging.

For installation, each Telecell has a unique ID label, with a duplicate self adhesive ID label loosely attached to the case. The installation process involved switching off the column power, then using a Mobile Elevated Work Platform (MEWP) to access the lamp head. The lamp wattage was first checked against that expected on the install list and if it matched, the manufacturer and date code on the lamp envelope were recorded on the install sheet, as well as information where legible indicating the lamp install date. Next the existing PECU was unplugged and replaced with a Telecell.

The ballast manufacturer and type was noted, the column power switched back on, and the Telecell self test monitored. On power up, the Telecell switches on the lamp after 5 seconds, then switches off after one minute. The duplicate Telecell label was stuck on the installation list against the column ID.

3.6 Asset association

Central Management System (CMS) databases were created for each area, containing all the selected assets and all the Telecell IDs allocated to that area. The installer returned the install sheets typically every three days and assets were associated to their Telecells manually using the web based CMS interface.

3.7 Monitoring

Once assets are associated to Telecells, a daily report of each lamp’s electrical performance can be read on the CMS interface. This report includes Watt-hours (Wh), accumulated burn time, average power, voltage and power factor for that day.

In some locations where the radio link was poorer than predicted, Telecells did not report in to the base station every day. In many cases this was overcome by using the CMS interface to set up a nearby Telecell as an intermediate radio relay. Note that the Telecells maintain their meter values and the accumulated burn time (to minute intervals) internally, and an occasional break in the reporting radio link has no affect on the asset metering accuracy.

3.8 Data Reporting

At the start date and the end date of the reporting period, readings of the Watt-hour and burn-hour counters for the Telecells in each region were downloaded, plus the power factor reading for the last night.

The Mean Per Sample Apparatus Average Circuit Watts (MPSACW) per lamp for the reporting period of one month or one year was calculated as follows:

$$MPSACW = \frac{End\ Wh - Start\ Wh}{End\ Burn\ hours - Start\ Burn\ hours}$$

The calculated MPSACW for the reporting period was verified by comparing it with the spot average power value returned by the Telecell on the last night. If the figures varied by more than 5% then the data for that Telecell was examined for integrity. A typical reason for a variation would be a lamp very near end of life changing its power consumption over the reporting period.

For each lamp type, the Sample Average Watts (SAW) was determined by averaging all the MPSACW values for that lamp type. A sample precision was calculated, based on a confidence of 99%, i.e. statistically the sample precision figure is known to 99% accuracy. The method for determining sample precision is detailed in the appendix.

3.9 Monthly reporting

Plextek produced a status report for Elexon for each month of the installation and trial period. The report detailed any operational issues for that month and their resolution, as well a monthly data report. The MPSACW figures for each lamp and by county were reported, together with histograms of sample spread for MPSACW and power factor. None of the operational issues that occasionally arose affected the final determination of MPSACW figures.

3.10 Measuring equipment calibration test

At the end of the monitoring period ten randomly selected Telecells used in the monitoring trial were checked for calibration accuracy at a power factor of 1 and 0.4 (inductive) at 60W and 200W, using a class 0.2 reference standard. All the Telecell readings were found to be within 1% accuracy, the readings averaging overall at 0.1% low.

4 Final data analysis

4.1 Introduction

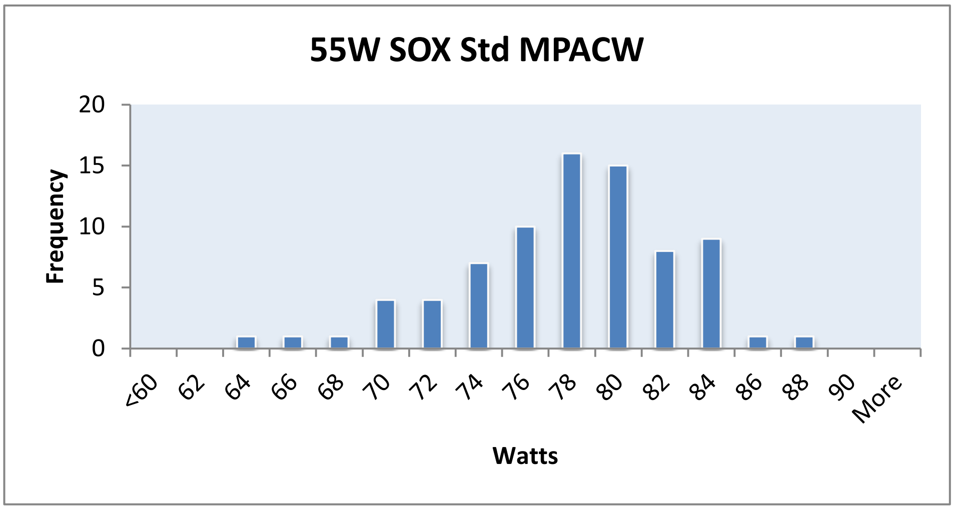
For each lamp type the Sample Average Watts (SAW) has been calculated, plus the sample precision. The sample precision is dependent on the sample size, and how close and tight the distribution of MPSACW is to a statistical normal distribution, or “bell curve”.

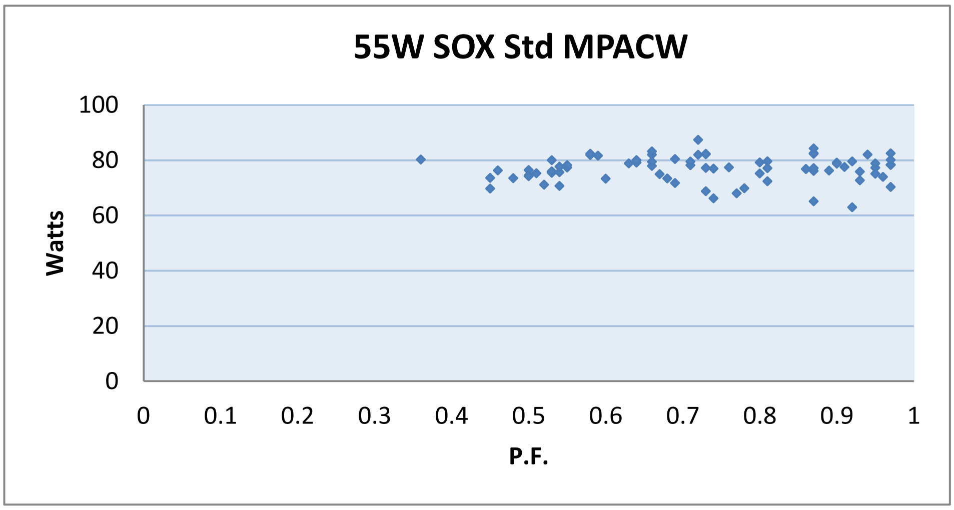
The distribution of MPSACW values is shown as a histogram with power on the horizontal axis. The scale refers to power values up to that figure. The horizontal axis is nominally scaled with the maximum value 1.5 times the minimum value.

A scatter plot illustrates the spread of MPSACW versus the absolute value of power factor for the whole sample set. Power factor is normally inductive for street lighting, but for 4% of assets a capacitive power factor was measured, but in almost all cases above 0.9. To simplify presentation, all power factor figures have been converted to an absolute (positive) value.

4.2 Results for 55W SOX with Standard ballast

Charge code 11 0055 1000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	0	47	31	78	At 99% confidence
Average MPSACW	n/a	77.00	76.63	**76.85**	1.72%





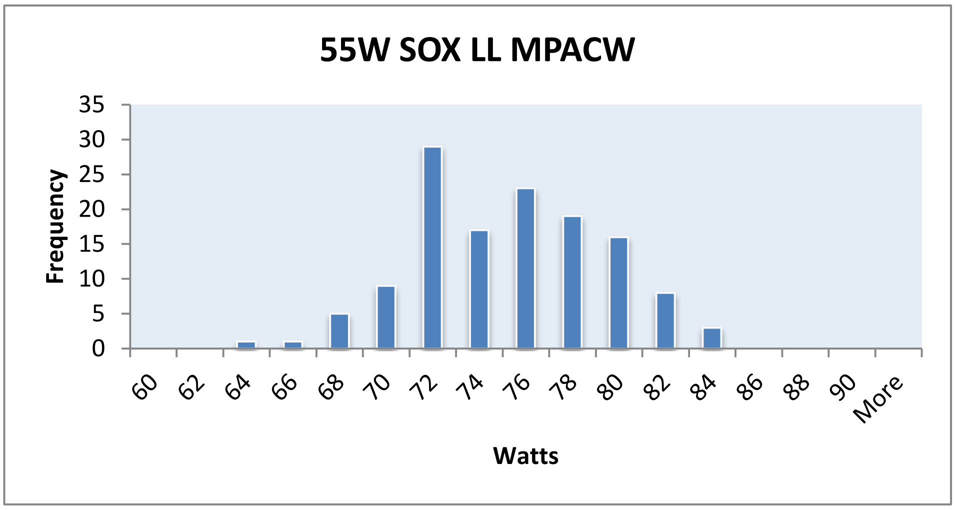
4.2.1 Observations

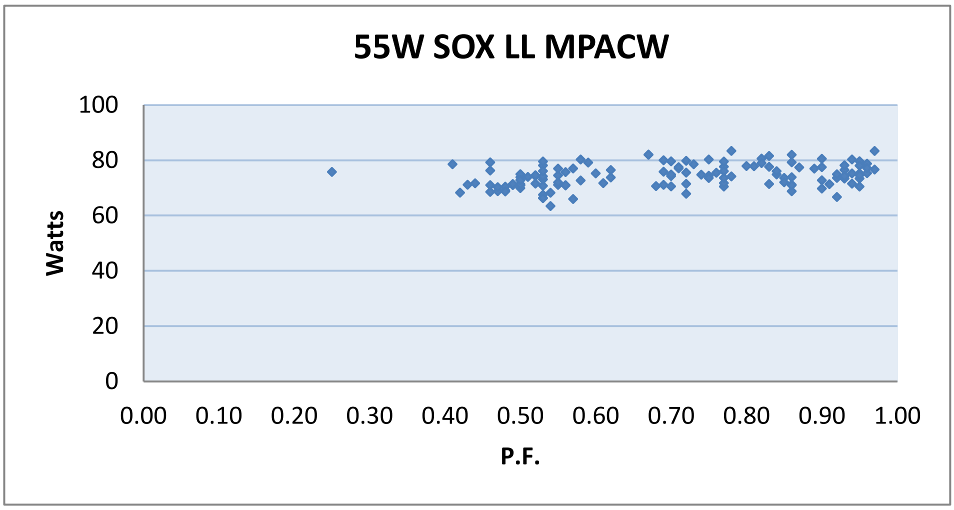
MPSACW results show an approximate normal distribution.

Power Factor readings are evenly spread above 0.5. The P.F. is less than 0.85 for 65% of units.

4.3 Results for 55W SOX with Low Loss ballast

Charge code 11 0055 2000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	68	47	16	131	At 99% confidence
Average MPSACW	73.29	75.21	76.12	**74.33**	1.23%





4.3.1 Observations

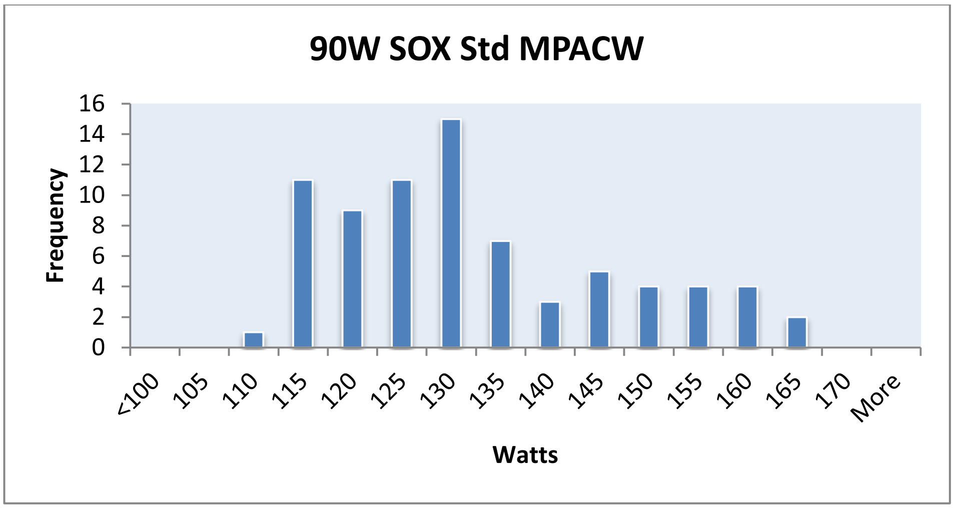
MPSACW results show a recognisable normal distribution.

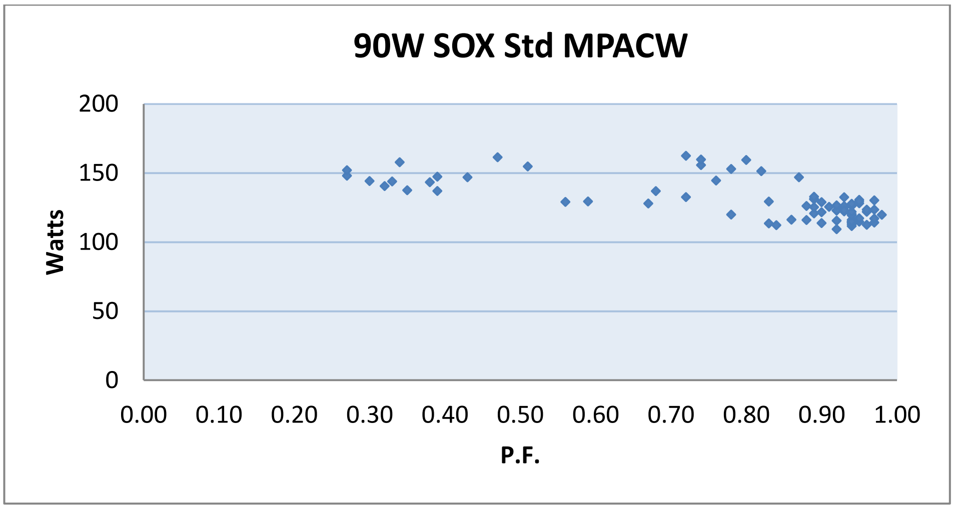
Power Factor readings are evenly spread above 0.4, but in two groupings, one around 0.5 and the other around 0.8.

The P.F. is less than 0.85 for 70% of units.

4.4 Results for 90W SOX with Standard ballast

Charge code 11 0090 1000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	23	25	28	76	At 99% confidence
Average MPSACW	147.83	121.72	122.62	**129.95**	3.24%





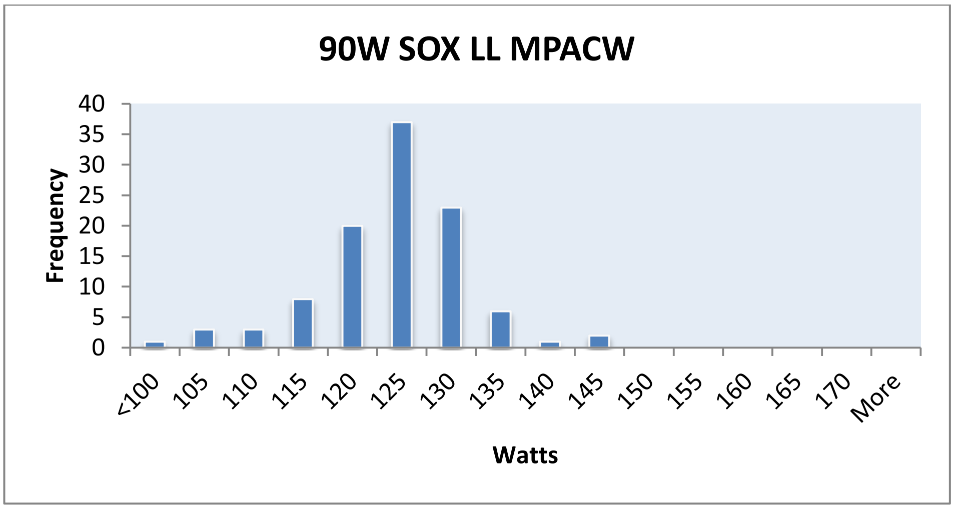
4.4.1 Observations

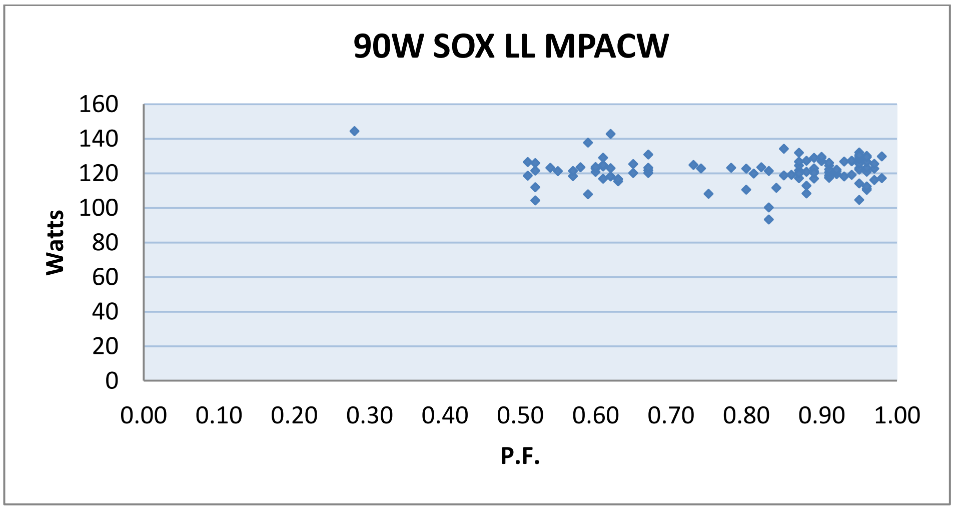
MPSACW results are not a recognisable normal distribution, with a significant extension upwards of 135W. The 19 lamps above 140W are all in Gloucestershire. Examining the installation sheets, the majority of these lamps use early ballast types manufactured by GEC and Osram which are not used in the other two areas.

Power Factor readings are grouped above 0.8 with 40% of units less than 0.85.

4.5 Results for 90W SOX with Low Loss ballast

Charge code 11 0090 2000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	47	57	0	104	At 99% confidence
Average MPSACW	120.74	122.60	n/a	**121.76**	1.61%





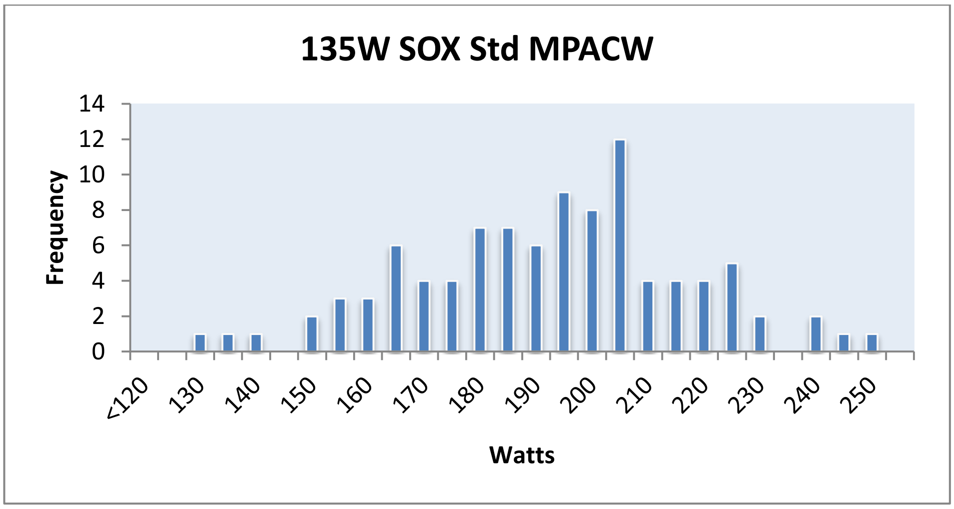
4.5.1 Observations

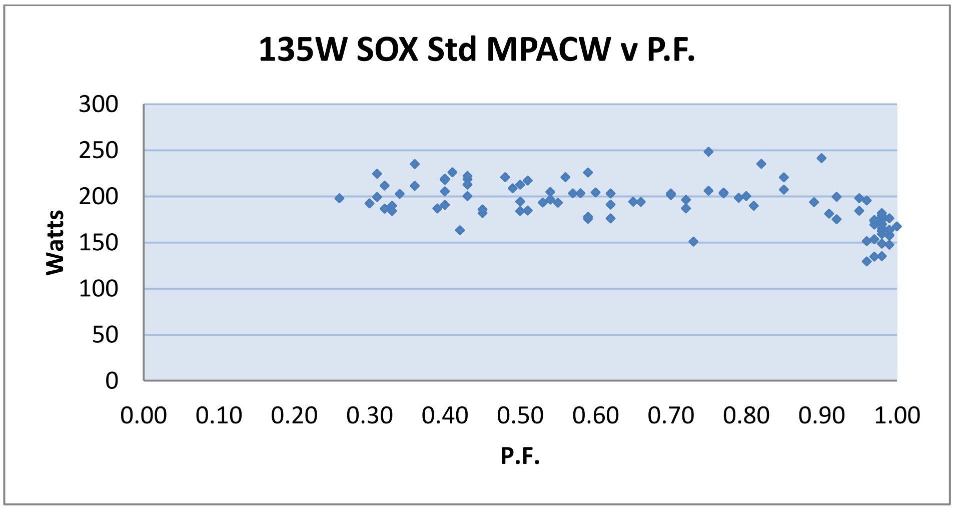
MPSACW results show a recognisable normal distribution.
Power factor readings are generally above 0.5.

The number of units with a P.F. of less than 0.85 is 45%.

4.6 Results for 135W SOX with Standard ballast

Charge code 11 0135 1000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	23	25	49	97	At 99% confidence
Average MPSACW	203.69	194.03	181.85	**190.16**	3.33%





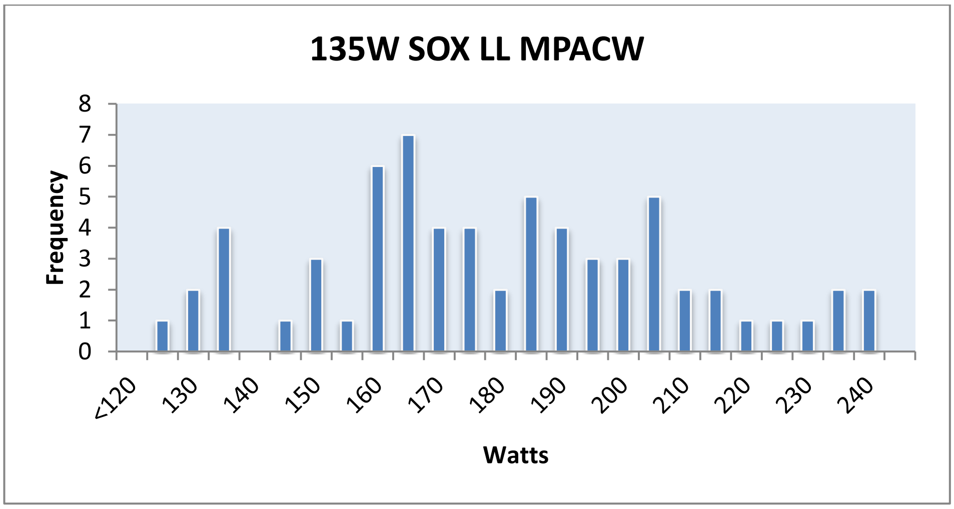
4.6.1 Observations

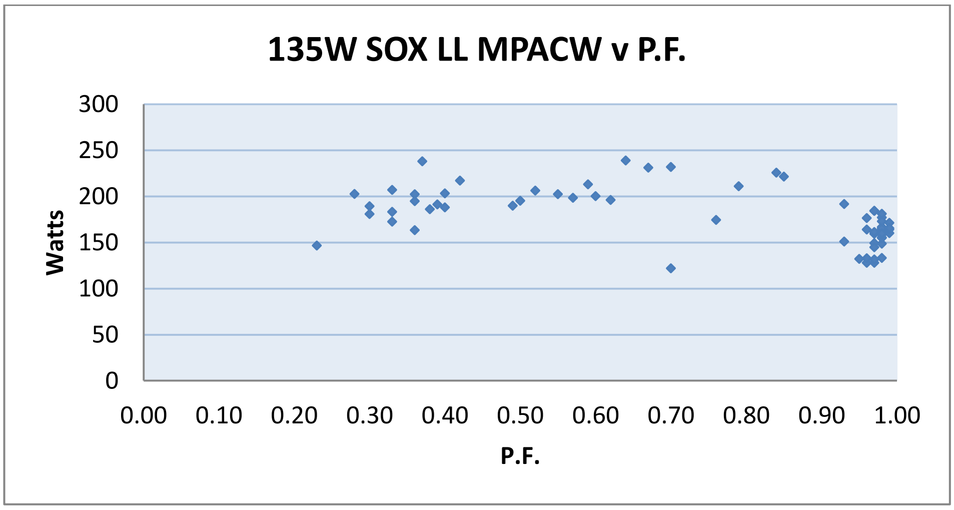
MPSACW results show a wide and offset normal distribution.
Power factor readings are widely spread above a very low value of 0.3 and there is a tight group on the far right of the scatter plot. This group of samples are predominantly from Lancashire and use a different ballast make to the other counties, accounting for the lower average figure for that county.

The P.F. is less than 0.85 for 60% of units.

4.7 Results for 135W SOX with Low Loss ballast

Charge code 11 0135 2000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	27	31	8	66	At 99% confidence
Average MPSACW	170.84	185.92	169.24	**177.73**	5.14%





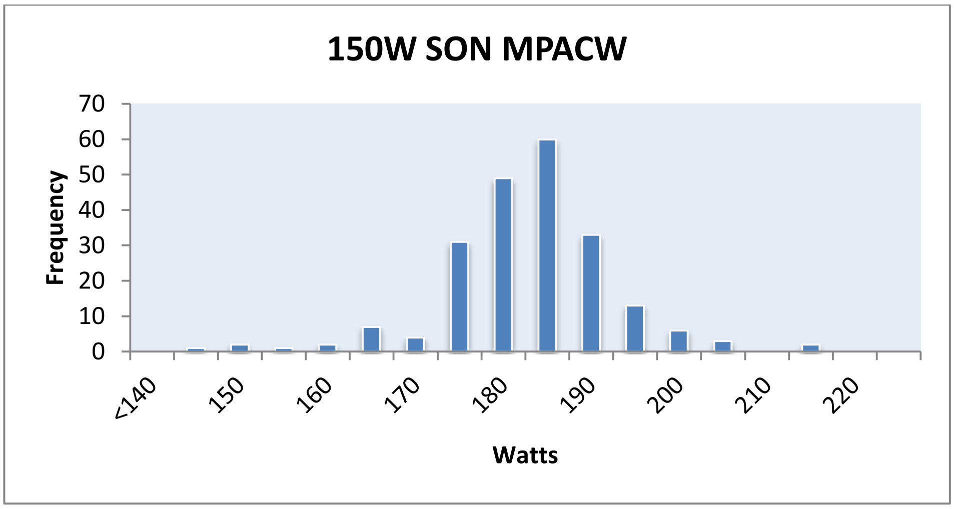
4.7.1 Observations

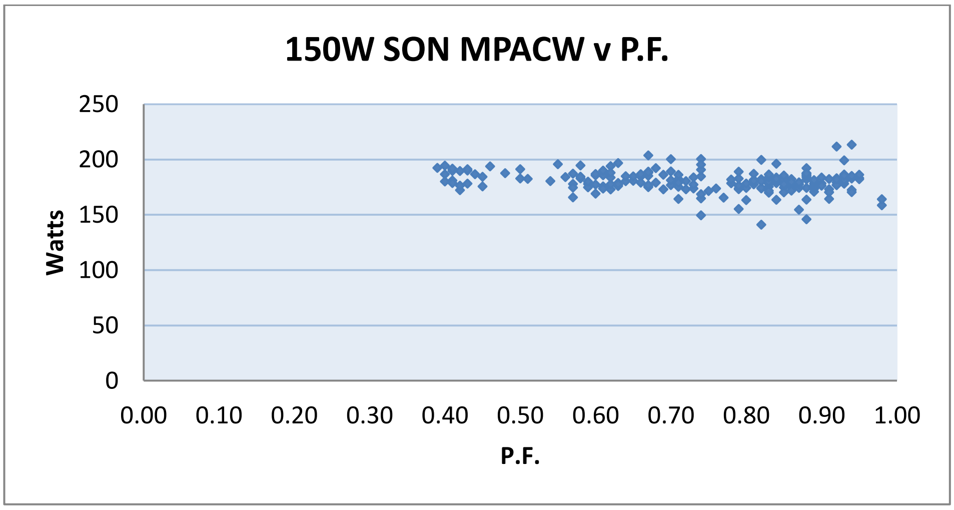
MPSACW results show a wide and offset normal distribution.
Power factor readings are widely spread above a very low value of 0.3 with a group above 0.9.
Examining the ballast information, all three areas primarily use the same three ballast manufacturers. The Nottinghamshire samples use a higher proportion of older ballast makes, plus one type not used elsewhere, and this has increased its average MPACW figure.

The P.F. is less than 0.85 for 50% of units.

4.8 Results for 150W SON with standard ballast

Charge code 14 0150 1000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	70	80	64	214	At 99% confidence
Average MPSACW	184.14	178.35	179.15	**180.48**	0.93%





4.8.1 Observations

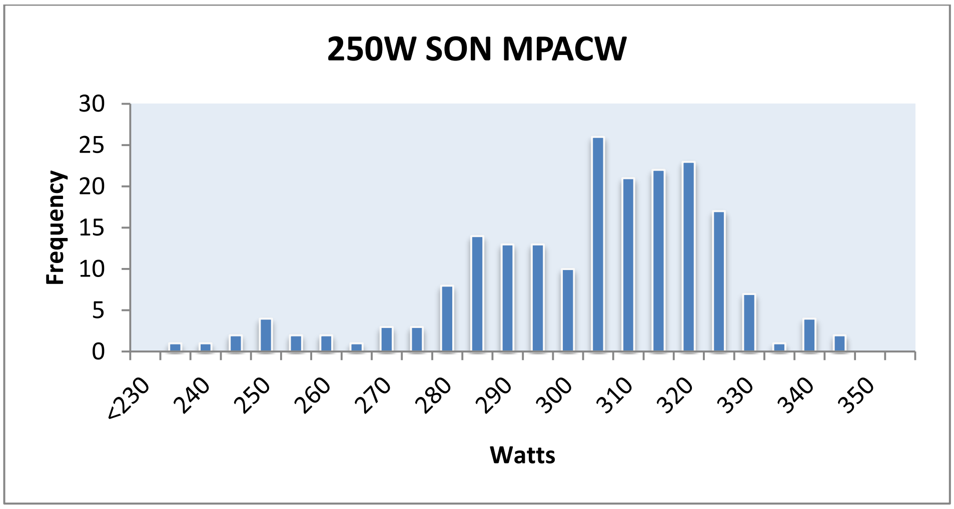
MPACW results show a recognisable normal distribution over a small range which correlates to the tight sample precision. The two samples with the highest power were double checked to confirm that no other loads were attached to these assets; however these two assets incorporate a different make of ballast to the rest of the sample assets.

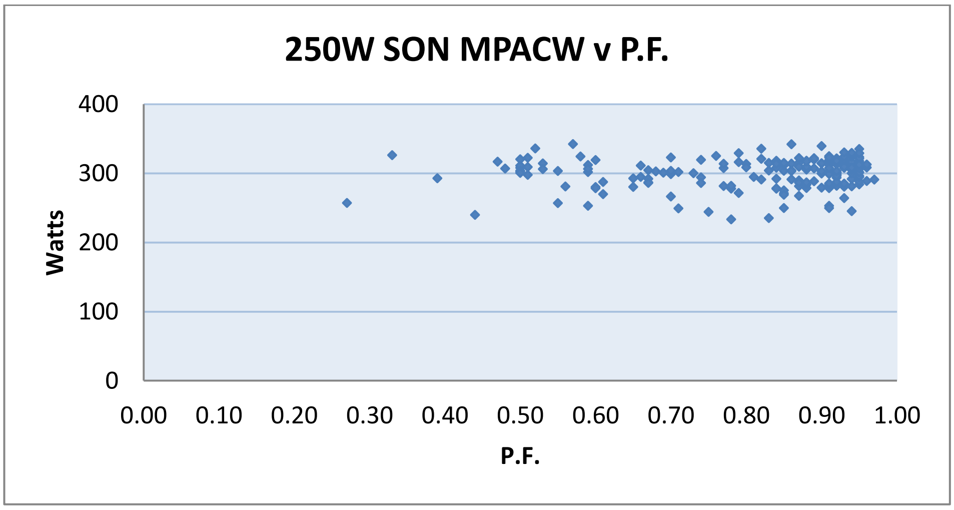
Power factor readings are evenly spread above a value of 0.4.

The P.F. is less than 0.85 for 65% of units.

4.9 Results for 250W SON with standard ballast

Charge code 14 0250 1000 100	Gloucs	Notts	Lancs	Combined	Sample Precision
Sample size	73	71	56	200	At 99% confidence
Average MPSACW	308.90	298.52	293.94	**301.03**	1.27%





4.9.1 Observations

MPSACW results show a relatively wide and offset normal distribution.

The Gloucestershire average power is higher than the other counties. The Gloucestershire assets use a relatively even mix of four different ballast makes, one of which is not used in the other areas and this contributes towards the higher average power.

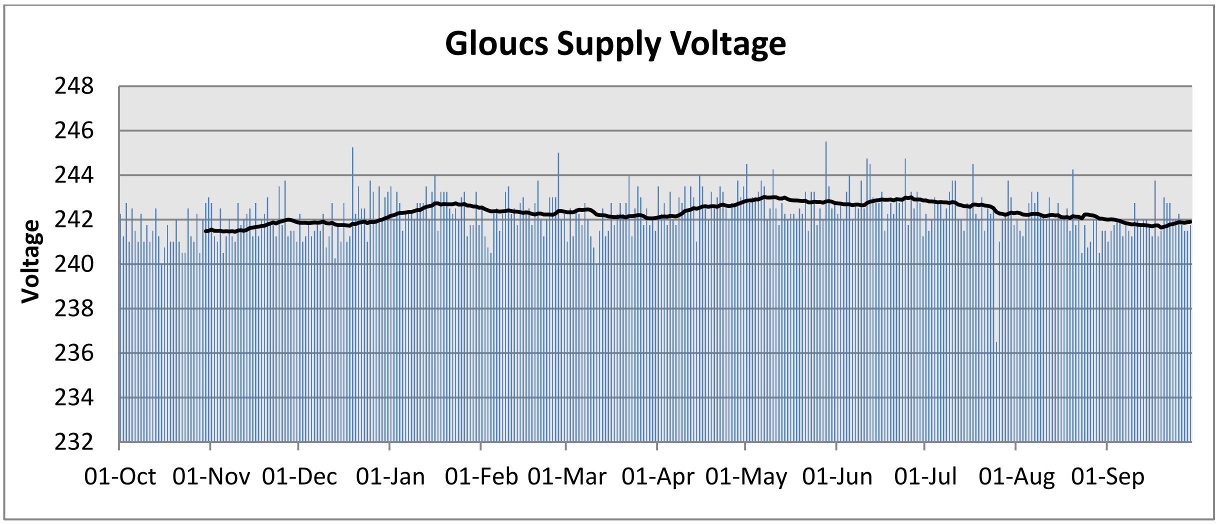
Power Factor readings are generally spread above 0.5 with a strong grouping above 0.8.
The P.F. is less than 0.85 for 40% of units.

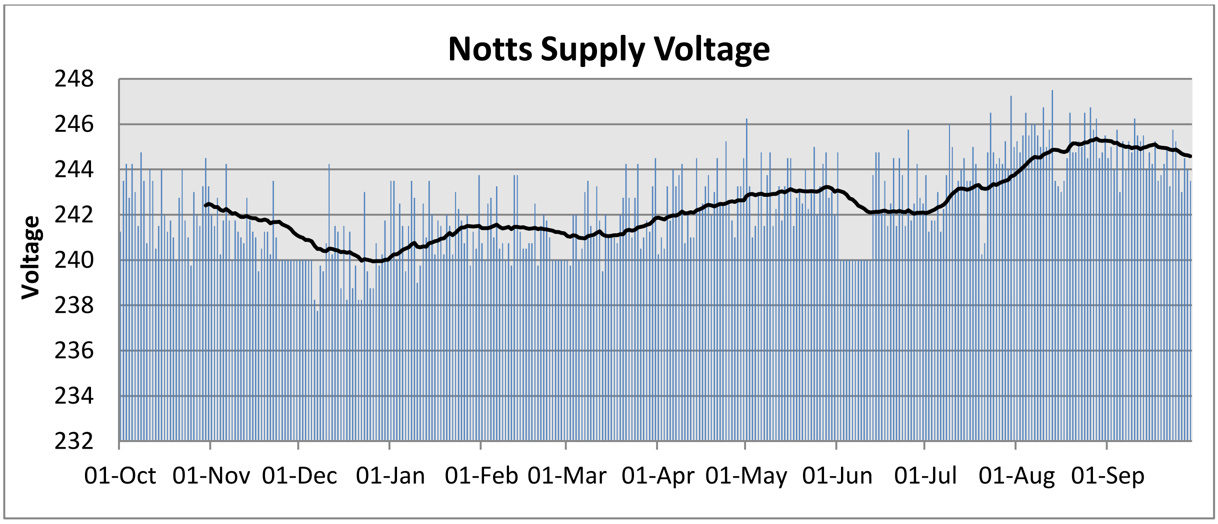
5 Analysis

5.1 Seasonal variation of supply voltage

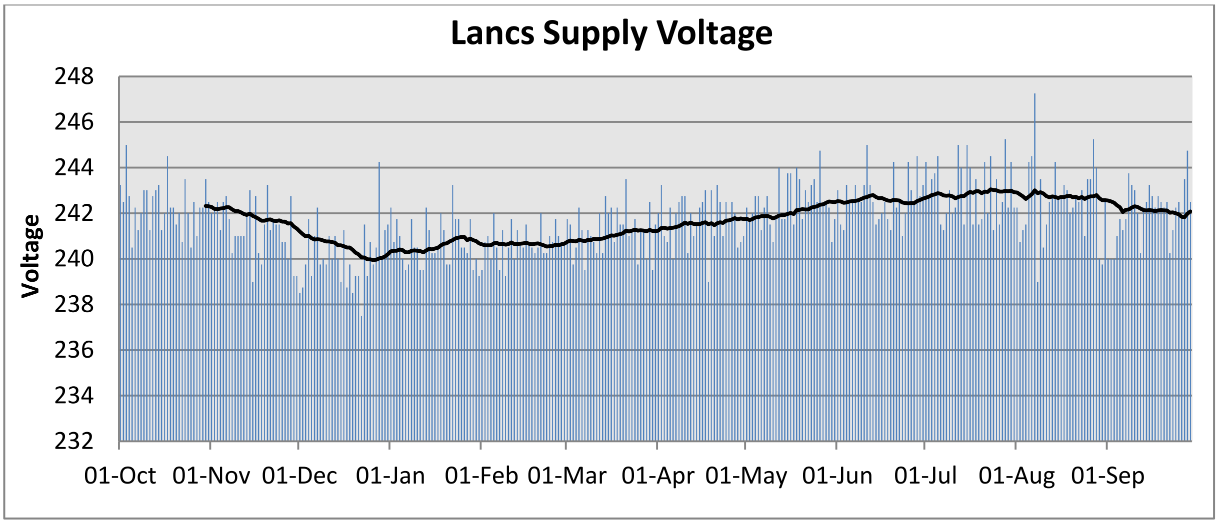
The average supply voltage for the sample lamps measured over the trial year is shown in the following graphs, by Local Authority. Each Telecell takes an average voltage reading over the last ten minutes before the lamp is switched off, and these daily readings have been averaged across all Telecells. The measurements are therefore only indicative of the supply voltage over the burn period. A 30 day moving average trend line is also included in each graph.

For all three Local Authorities the average over the year of all the daily readings is 242V.



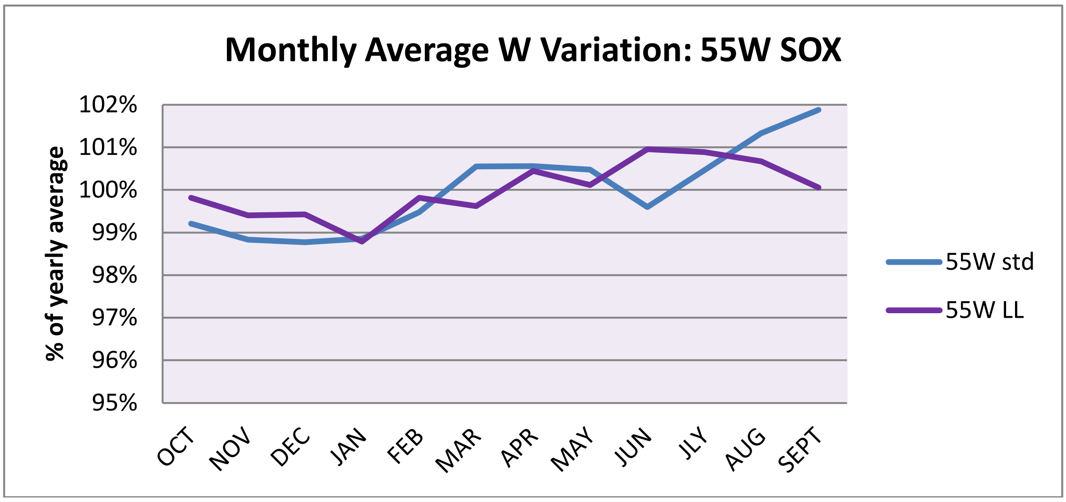


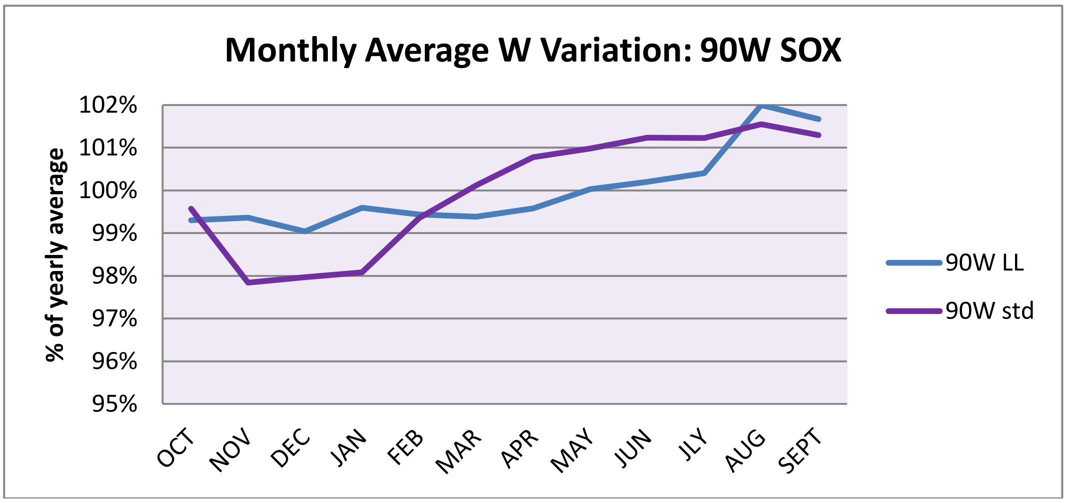
Note: for Notts that there are 3 short periods of missing daily voltage data, in December, March and June, due to loss of base station communication. 240V has been used as a default value for these periods, which can be identified as flat sections at 240V.

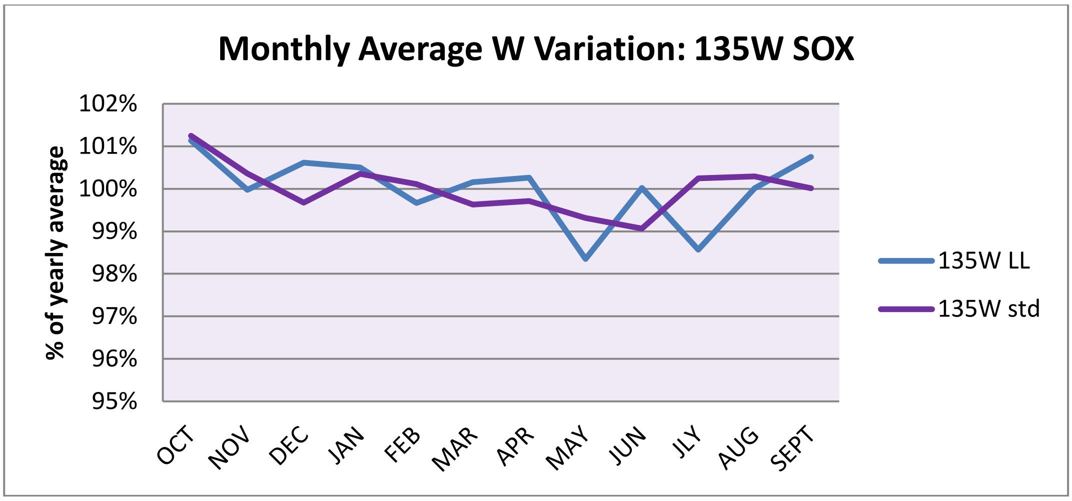


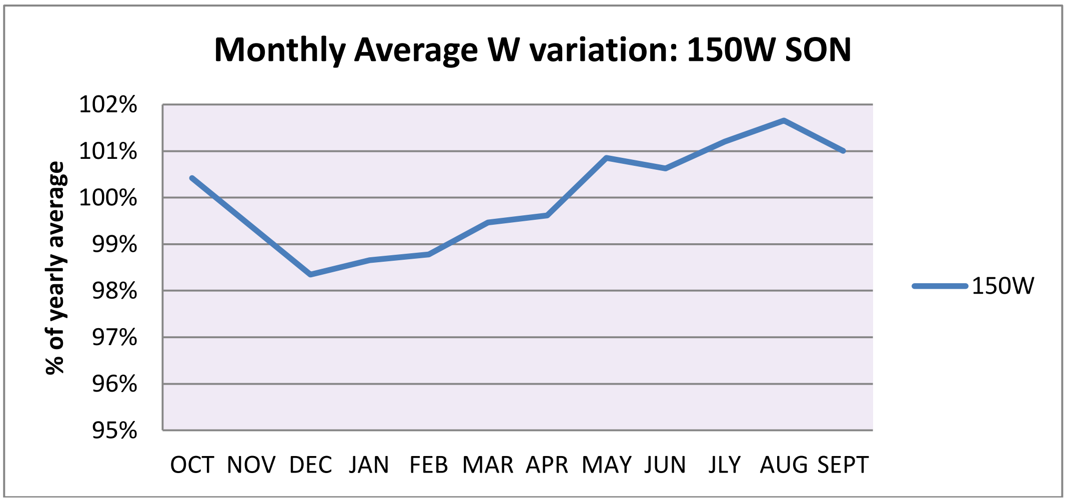
5.2 Seasonal variation in measured power

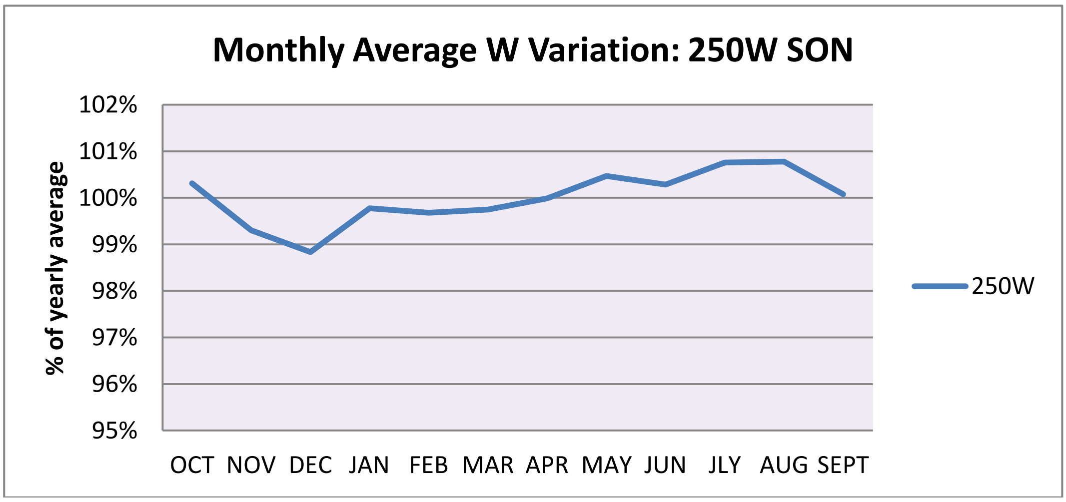
The average power calculated by month for each lamp is shown in the following graphs. The variation over the year shows some correlation to season, and in many cases does show a correlation to the varying supply voltage trend lines from the previous section.






Monthly Average W Variation: 135W SOX
% of yearly average
102%
101%
100%
99%
98%
97%
96%
95%
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JLY
AUG
SEPT
135W LL
135W std

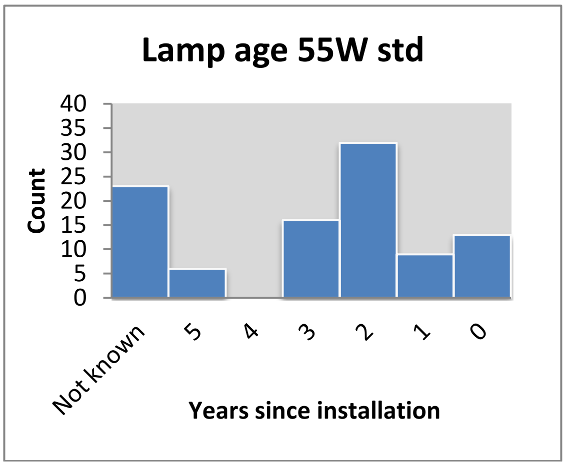

Monthly Average W variation: 150W SON
% of yearly average
102%
101%
100%
99%
98%
97%
96%
95%
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JLY
AUG
SEPT
150W

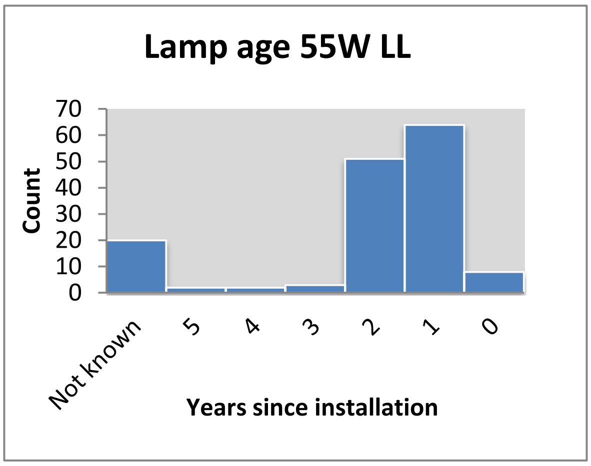

Monthly Average W Variation: 250W SON
% of yearly average
102%
101%
100%
99%
98%
97%
96%
95%
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
JLY
AUG
SEPT
250W

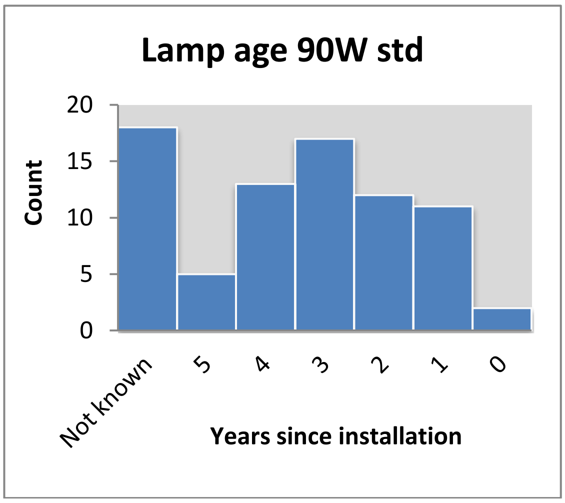
5.3 Age of sample apparatus

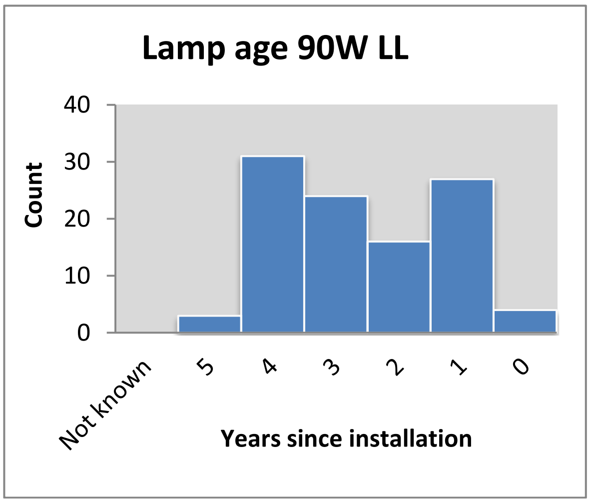
The age of each lamp type are presented in the following histograms. This information is not directly relevant to the research activities but it does provide background information on the assets being monitored.

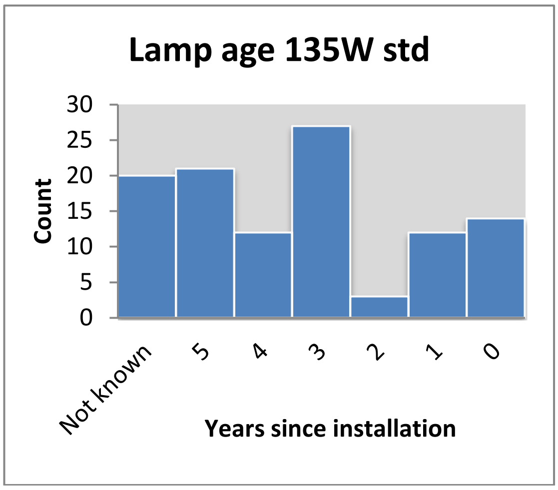
It was not possible to determine the install date for every lamp, The install date is usually recorded on a label inside the lamp fitting each time a lamp is replaced. One local authority had fewer labels in place, and in other cases the labels were illegible. Note that there was no way of knowing that all labels were valid. The unknowns are shown in the column on the left.

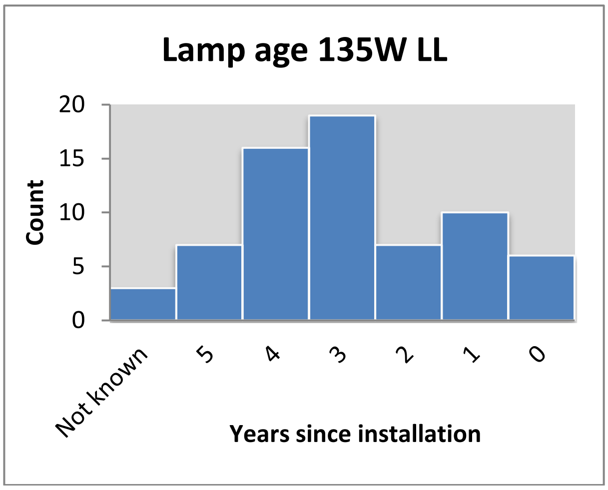

Lamp age 55W std

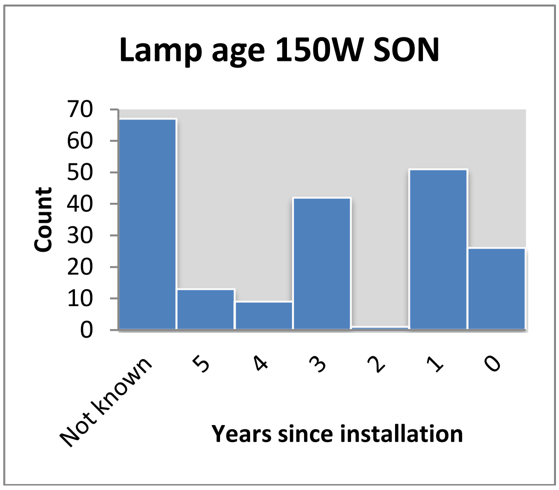

Lamp age 55W LL

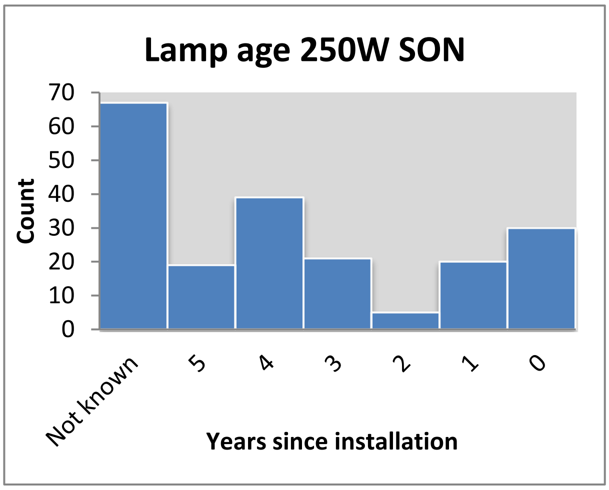

Lamp age 90W std


Lamp age 90W LL


Lamp age 135W std
Count
30
25
20
15
10
5
0
Not known
5
4
3
2
1
0
Years since installation


Lamp age 135W LL
Count
20
15
10
5
0
Not known
5
4
3
2
1
0
Years since installation


Lamp age 150W SON
Count
70
60
50
40
30
20
10
0
Not known
5
4
3
2
1
0
Years since installation

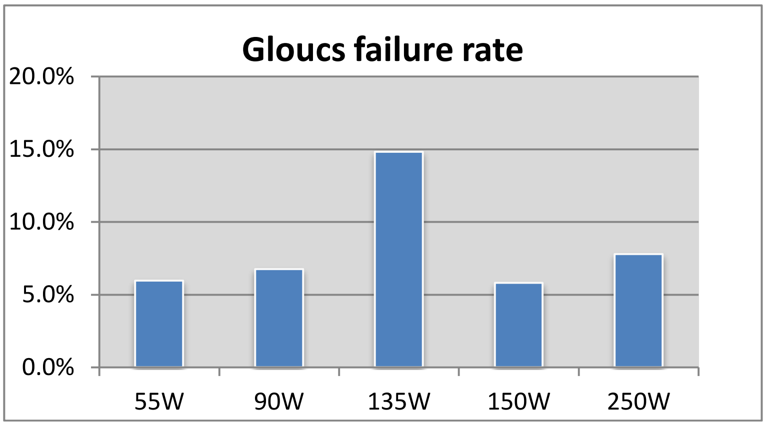

Lamp age 250W SON
Count
70
60
50
40
30
20
10
0
Not known
5
4
3
2
1
0
Years since installation

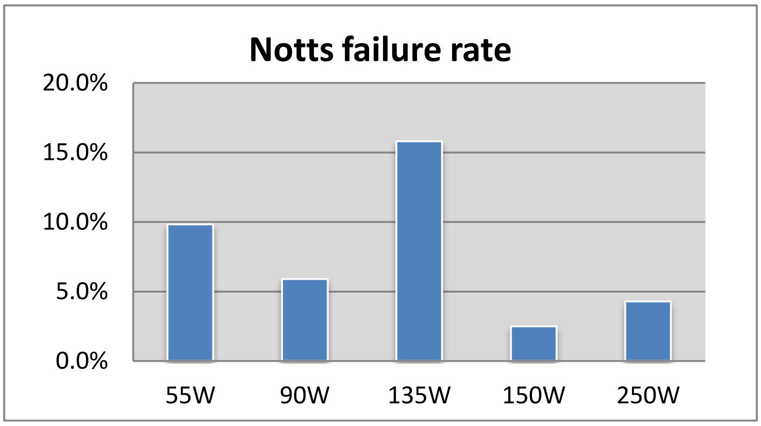
5.4 Lamp failure rate

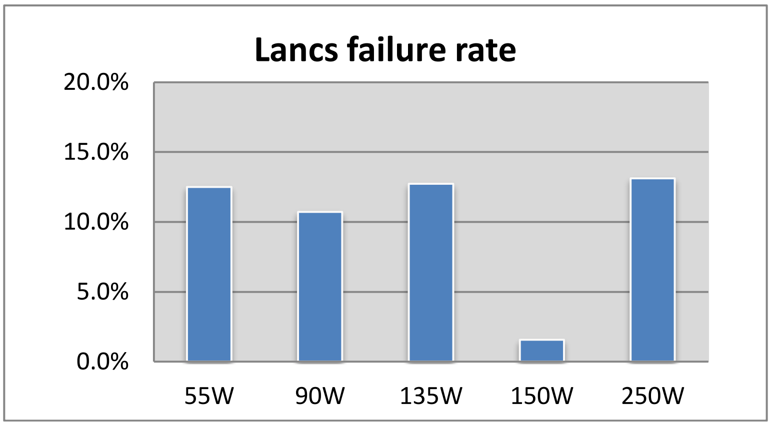
These graphs show the percentage of lamp failures in the monitored lamp sample. The failure rate will depend on the replacement policy adopted by the Local Authority and whether it is planned replacement or burn to extinction. Lamp failures have been counted for each time an old lamp expires and is replaced by a new lamp in the same column. The figures cover the 12 month monitoring period and the average time taken to replace a failed lamp was 5-6 weeks.

There should be some correlation between the failure rate and the age of installation, but this is not apparent, with the exception of the 150W SON lamps, which have the lowest failure rates and the newest installation dates.

An average lamp life is quoted as 4-5 years for street lighting (18000 hrs at 4000 hrs per year).







6 Observations and lessons learned

6.1 Ballast manufacturers

The assets monitored for this load research used ballasts with 19 different brand names. The most common makes were GEC, Thorn and Philips.

6.2 Planning issues

Some types of lamps were not available to monitor in all regions. Specifically, 55W standard ballast lamps were not available in the Gloucester area, and 90W low loss ballast lamps were not available in Lancashire. Sample quantities for each lamp could not always be split evenly across the 3 counties due to a limited availability of some lamp types.

6.3 Installation issues

During the installation phase, the installer sometimes found a different type of lamp to that on the installation sheet. On other occasions, standard ballasts were found to have been already upgraded to low loss ballasts.

Some local authority asset registers were more accurate than others. A second installation phase had to be carried out to top-up some lamp types in some areas due to asset register errors.

Some assets on the installation sheets could not be accessed due to overgrown hedges or other obstructions at the column base. A nearby asset of the same specification was used instead, and noted on the installation sheet.

For future monitoring work, we will produce the final installation phase install sheet with more assets than needed, and instruct the installer to work through the install sheet until all Telecells are used, as was done in the later phases of this project.

6.4 Monitoring issues

The biggest problem during the monitoring phase was “disappearing” assets or lost Telecells. In some cases this was caused by the theft of Telecells from the shorter columns used for 55W lamps. The majority of losses were caused by planned column replacement work on a street and the upgrade of SOX lighting to newer types. In most cases the Telecell was disposed of by the contractor along with the column.

Plextek worked with each highway authority office at the start of the project to avoid areas where planned lamp upgrades were imminent. However, some upgrades were unexpected and discovered only after the event. An extra 3% of lamps were installed at the start of the project to allow for unexpected losses such as this and in future this allowance will be increased to around 5%.

6.5 Performance of monitoring equipment

Some Telecells, particularly in Gloucester, did not report every day over the radio link due to their distance from the base station. The later installations in Notts and Lancs took account of this issue, with the radio planning tool set more conservatively to better guarantee connectivity. This approach will be continued in subsequent monitoring work.

During the monitoring phase there were occasional breaks in communication to the base stations due to interruption of the 3G wireless data connection. In some cases this caused a base station to “lock up” and it had to be manually power cycled by the local authority user. This issue has now been fixed in the base station operating software. It should be noted that the cumulative power meter readings and burn hours are held in non-volatile memory within the Telecell and so a break in communication with the base station has no affect on the reading values.

There was a failure of one Telecell in Gloucestershire early-on in the trial which was replaced.

For future work, the availability of software updates from Telensa will be monitored and any critical updates applied.

6.6 Data use and validation

In the data analysis, the data for the lost Telecells had to be discarded as it did not cover a full twelve months. In two cases where Telecells were recently lost then eleven months of data was used.

Once the final data was produced, a data validation process was carried out closely examining those individual assets with MPACW values outside the main range of data. In 14 cases where assets were identified as faulty, or could be identified as having the wrong charge code allocated, then these assets were removed from the final figures.

6.7 Future monitoring research

In future work, the lamp type under investigation should be monitored in at least 3 areas whenever possible and the sample quantity for each area should be similar. The total sample quantity should aim to give a sample precision of less than 2%, which from work to date typically means a total of between 100 and 200 units.

Within two weeks after monitoring has started, the power consumption of the sample lamps should be reviewed and compared with expected values and any asset outside a likely range should be physically revisited to either confirm or remove the sample.

7 Appendices

7.1 Glossary of terms

Ballast	A magnetic ballast is a wire wound component with an iron core that is connected to a lamp to limit the current taken from the mains supply. • Standard ballasts are generally older than other ballast types and sometimes incorporate the lamp ignition function. • Low loss ballasts use a different core design with better magnetic grade iron to reduce the amount of power wasted as heat within the ballast. • Electronic ballasts are a more recent development and are primarily an active electronic circuit that delivers an optimum current and voltage to the lamp. Lamps with electronic ballasts were not monitored in this load research
BSCP	Balance and Settlement Code Procedure. – The industry recognised procedure for settling payments for unmetered supply devices.
Charge Code	A charge code is used in the BSCP to look up the circuit watts associated with unmetered equipment to calculate power consumption.
CMS	Central Management System. – A monitoring and control system used for the management of street lighting and related electrical assets.
GIS	Geographic Information System. – A computer based system utilising digitised map and terrain data.
MPSACW	Mean Per Sample Average Circuit Watts. – The average power figure calculated for each lamp in the sample.
NEMA	North-American Electrical Manufacturers Association. – The standards body originally responsible for defining the connector format used on most PECUs.
PECU	Photo Electric Control Unit. - The dawn/dusk sensing device used to control a street light.
PF	Power Factor – The ratio of Real Power divided by Apparent Power in an electrical circuit. For a reactive circuit such as a lamp plus ballast the power factor will be less than 1.0, as the AC current and voltage waveforms are not in phase. A higher current is required to obtain the Real Power in the circuit which can lead to overheating and inefficiencies in the distribution network. Lamp power factor is normally corrected by including a capacitor across the circuit, but as capacitors age this correction becomes less effective. An average power factor of >0.85 over a population of assets is generally accepted as desirable.
SAW	Sample Average Watts. – The average of all the MPSACW values for one lamp type.
SOX lamp	A low pressure sodium vapour lamp distinctive for its monochromatic orange colour.
SON lamp	A high pressure sodium vapour lamp better at colour rendering, with a pink-orange or golden hue.

7.2 Determination of sample precision

The Variance of the valid Sample value of MPSACW is calculated as follows:

Sample Variance (SV) = $(n\sum MPSACW^2 - (\sum MPSACW)^2) / n(n-1)$

(a) Calculate the Sample’s Standard Error as follows:

Standard Error (SE) = Square Root of (SV/n)

(b) Calculate the t-value of the Student's t-distribution as a function of the probability (0.01) and the degrees of freedom (n-1).

E.G. T-Value = The inverse of the Students T-distribution (0.01,14) = 2.976849

(c) Calculate the 99% Confidence Interval in the mean estimate of demand as follows:

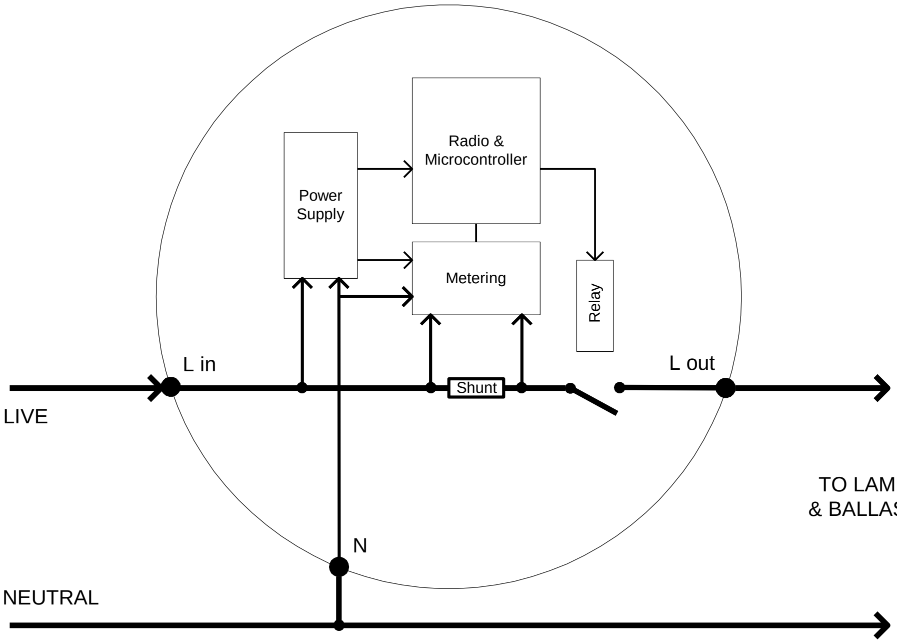
99% Confidence Interval in Watts (CIW)= t-value x SE

(d) Express the confidence intervals as a percentage of the mean estimate of demand as follows:

99% Confidence Interval (CI) = CIW/SAW *100

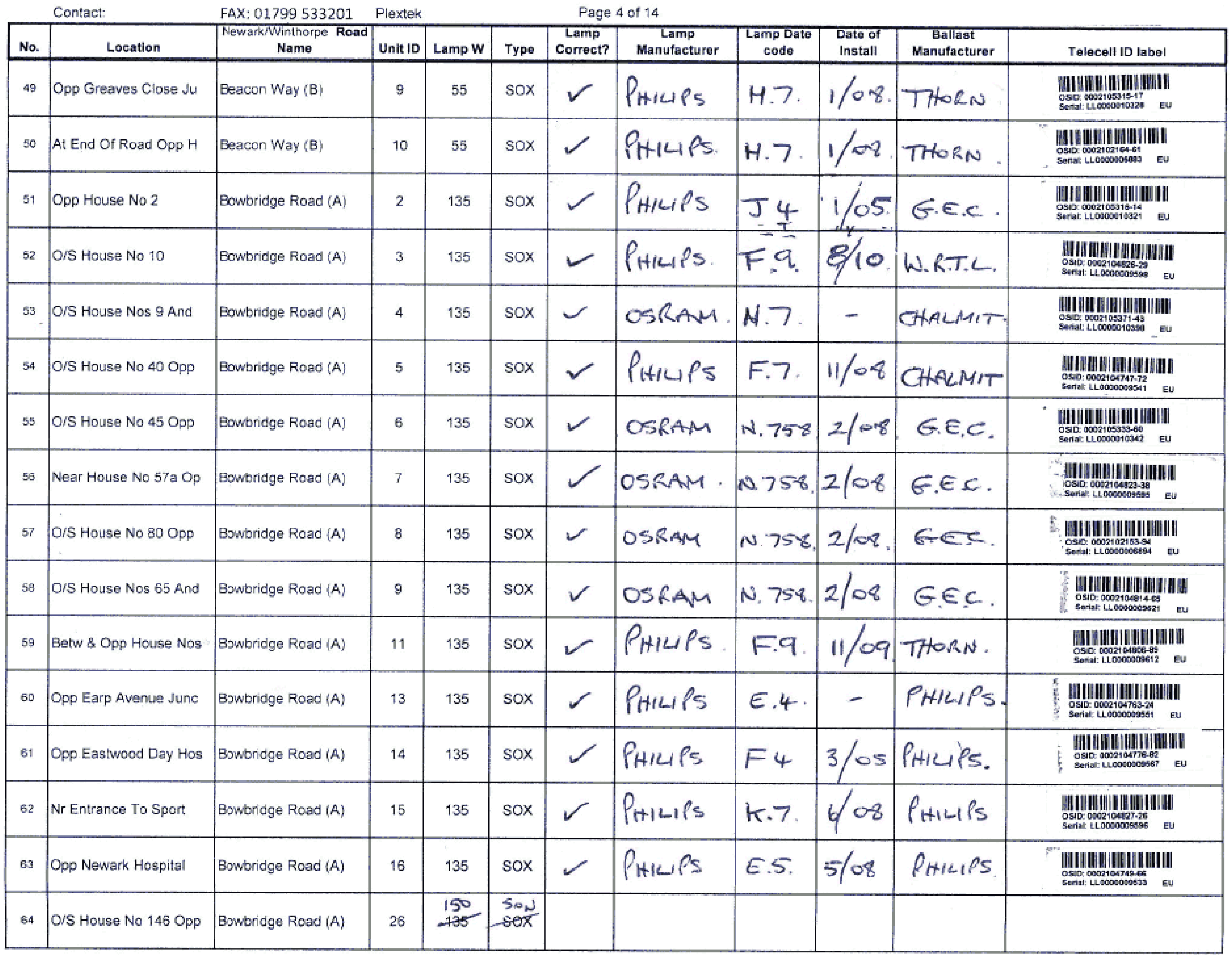
e.g. the results can be expressed as SAW +/- CI = 181.45 Watts + or - 8.2%

7.3 Measuring equipment - Telecell circuit



7.4 NEMA Connector

7.5 Example installation form



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No.	Location	Newark/Winthorpe Road Name	Unit ID	Lamp W	Type	Lamp Correct?	Lamp Manufacturer	Lamp Date code	Date of Install	Ballast Manufacturer	Telecell ID label
49	Opp Greaves Close Ju	Beacon Way (B)	9	55	SOX	✓	PHILIPS	H.7.	1/08.	THORN	OSID: 0002105315-17 Serial: LL0000010328 EU
50	At End Of Road Opp H	Beacon Way (B)	10	55	SOX	✓	PHILIPS.	H.7.	1/08	THORN.	OSID: 0002102164-61 Serial: LL0000006083 EU
51	Opp House No 2	Bowbridge Road (A)	2	135	SOX	✓	PHILIPS	J 4	1/05.	G.E.C.	OSID: 0002105316-14 Serial: LL0000010321 EU
52	O/S House No 10	Bowbridge Road (A)	3	135	SOX	✓	PHILIPS.	F.9.	8/10	W.R.T.L.	OSID: 0002104826-29 Serial: LL0000009598 EU
53	O/S House Nos 9 And	Bowbridge Road (A)	4	135	SOX	✓	OSRAM.	N.7.	-	CHALMIT.	OSID: 0002105371-43 Serial: LL0000010390 EU
54	O/S House No 40 Opp	Bowbridge Road (A)	5	135	SOX	✓	PHILIPS	F.7.	11/08	CHALMIT	OSID: 0002104747-72 Serial: LL0000009541 EU
55	O/S House No 45 Opp	Bowbridge Road (A)	6	135	SOX	✓	OSRAM	N.758	2/08	G.E.C.	OSID: 0002105333-60 Serial: LL0000010342 EU
56	Near House No 57a Op	Bowbridge Road (A)	7	135	SOX	✓	OSRAM.	N.758.	2/08	G.E.C.	OSID: 0002104823-38 Serial: LL0000009595 EU
57	O/S House No 80 Opp	Bowbridge Road (A)	8	135	SOX	✓	OSRAM	N.758.	2/08.	G.E.C.	OSID: 0002102153-94 Serial: LL0000006894 EU
58	O/S House Nos 65 And	Bowbridge Road (A)	9	135	SOX	✓	OSRAM	N.758.	2/08	G.E.C.	OSID: 0002104814-63 Serial: LL0000009621 EU
59	Betw & Opp House Nos	Bowbridge Road (A)	11	135	SOX	✓	PHILIPS.	F.9.	11/09	THORN.	OSID: 0002104806-89 Serial: LL0000009612 EU
60	Opp Earp Avenue Junc	Bowbridge Road (A)	13	135	SOX	✓	PHILIPS	E.4.	-	PHILIPS.	OSID: 0002104763-24 Serial: LL0000009551 EU
61	Opp Eastwood Day Hos	Bowbridge Road (A)	14	135	SOX	✓	PHILIPS	F4	3/05	PHILIPS.	OSID: 0002104776-82 Serial: LL0000009567 EU
62	Nr Entrance To Sport	Bowbridge Road (A)	15	135	SOX	✓	PHILIPS	K.7.	6/08	PHILIPS	OSID: 0002104827-26 Serial: LL0000009596 EU
63	Opp Newark Hospital	Bowbridge Road (A)	16	135	SOX	✓	PHILIPS	E.5.	5/08	PHILIPS	OSID: 0002104749-66 Serial: LL0000009533 EU
64	O/S House No 146 Opp	Bowbridge Road (A)	26	150 ~~135~~	SON ~~SOX~~						