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Final Process Report: Deemed Metering of a sample of Phase I projects (delivery winter 2015/16) included in the Electricity Demand Reduction (EDR) Pilot

April 2017

Energence Ltd.

Executive Summary

The objectives of the Electricity Demand Reduction (EDR) Pilot are to examine the viability of electricity demand reduction in the Capacity Market; and to learn lessons for Government and wider stakeholders on the delivery of EDR schemes. In order to understand how accurately Measurement and Verification (M&V) documentation, particularly the Deemed Savings Calculator (DSC), reflects the actual kW savings delivered by pilot participants a sample of Phase I participants were selected to take part in the Deemed Metering project. All Phase I participants of the pilot opted to install lighting measures using a deeming approach to estimate savings. Therefore the project initially involved the installation of 350 meters at 76 sites (metering about 23,000 lamps) which allowed the electricity use to be metered. The deemed metering project provides insight as to the reliability of demand reduction, and the DSC.

Monitoring is undertaken using Metering Instrumentation Directive (MID) certified 'smart' meters. Every night these communicate the previous day's half hourly electricity consumption to the Energy Monitoring Platform (EMP) via a mobile phone network. This data harvest has been used to observe both the accuracy of applicant's claims of the peak electricity demand reduction they have to offer, and BEIS' DSC savings estimates – with a focus on lighting measures.

We found that the accuracy of the DSC varies with the lighting technology installed; in the case of High Intensity Discharge (HID) lamps the DSC was accurate, however it underestimated the actual energy demand of florescent lamps by an average of 15%. We also found that the metered outturn for most sites is not well represented by the information included in the M&V documentation provided by the participant at the application stage of the EDR pilot.

Wider lessons to be considered in future metering projects include the importance of site inspection as the only real indicator of the physical site circuitry (and therefore metering possibilities, challenges and constraints) as sites often presented differently to what might have been expected from the pilot application paperwork submitted. On large sites with complex circuits it is likely to be impractical to count the number of lights and therefore benchmarking is essential. Site specific health and safety requirement can delay meter installation and energising with implications for the collection of benchmarking data from old technology before new energy efficiency measures are installed. It is therefore worthwhile, ensuring at the application stage that these site specific requirements are explicitly detailed from the outset.

Metering data can show electricity use patterns but not necessarily allow a firm conclusion to be drawn as to why the demand reduction is observed; sometimes without site inspection it is not possible to distinguish from the metered data output whether the demand reduction is due to the energy efficiency measures or behavioral change. This could result in participants receiving funding for the installation of energy efficiency measures actually being paid for behavior change (or not) if the behavior was never to use the lights during the specified peak period in the first place. Therefore site inspection may be required to verify the patterns of use of measures before and after the change in energy efficiency technology. A reduction in demand might occur because the lights are not used as assumed at application for funding.

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1. Background to Phase I deemed metering

Participants of Phase I of the Electricity Demand Reduction (EDR) pilot were required to install agreed energy efficiency measures during 2015 so as to deliver ongoing electricity savings. Phase I EDR Pilot participants were paid for delivery of the kW savings they contracted to deliver during the winter peak hours of 2015/16 (Monday – Friday, between 16:00 and 20:00, from November to February). A sample of phase I projects were selected to participate in the deemed metering project. These projects included 76 sites across which a total of 350 meters were installed to monitor approximately 23,000 lamps. The purpose of installing the meters is to test whether the savings reported in the Deemed Savings Calculator (DSC) submitted with the Measurement and Verification (M&V) documentation by participants at the time of application, the M&V updates and Operation Verification (OV) information provided during the pilot reflect the savings observed by metering evidence. BEIS is also keen to learn wider lessons about site metering, therefore this report details the key practical metering insights from this metering project.

The selection of projects to meter was done via a sampling methodology which involved dividing all the Phase I participants' projects (all of which were lighting projects) into four groups (indoor lighting/lighting with controls; outdoor lighting/lighting with controls) and randomly sampling from each of the four subgroups. Analysis of the performance of each of these four subgroups of projects is not the focus of this report however, because site visits revealed that a number of sites were counted in the wrong subgroup based on the information supplied at application. Therefore this report instead focuses on how the metered outturn of each metered site compares to that predicted by the DSC submitted by participates for the metered sites at application.

There are a number of challenges when trying to make a meaningful comparison. The key problem in analysing sites with controls is the inevitable randomness of automation. For example some lighting circuits at a site may have basic timer controls and some proximity controls which may be triggered by weather events as well as daylight hours and movement. This makes it difficult to establish an energy use profile for these sites which can be projected onto a wider LED replacement load saving. Proximity controls (particularly in shopping centre car park stairwells) may not be triggered on a regular daily basis, but in a random way depending on peak shopping times. Some of the external lighting sites (car parks) have daylight sensitive controls which are subject to the randomness of the weather – with a cloudy afternoon in winter triggering the lights to come on earlier.

Of the 76 sites where meters were installed, there were 8 sites (approximately 10%) from which useful data for the winter peak period could not be collected. This was due to a variety of reasons including; onsite electrical problems (2 sites), vacated buildings where no data was generated (2 sites), anomalous readings (4 sites). In addition, logistical/technical reasons' prevented 1 additional site from collecting data until after the winter peak in March 2016. A further 6 sites were excluded as the applicant withdrew from the pilot, however data collected from 2 of these sites offers a valuable evidence base data for existing technologies. A further 5 sites did not progress the installation of the planned energy efficiency measures (fluorescent/LED swap). Therefore, in total this report is able to compare the metering output of 56 metered sites with the DSC estimates at EDR pilot application.

The deemed metering project involved the installation of 350 meters. 332 meters returned accurate and analysable data across 76 sites. 18 meters returned anomalous readings that were not relatable to the lamp parameters provided in the M&V plans, or could not be deciphered by comparing against known benchmark data or the Deemed Saving Calculator. Only 6 of these anomalous meters were in the 56 sites that were included in the final analysis. The other 12 were installed at sites that were either withdrawn or abandoned by the applicant, or did not progress the technology (LED) swap.

Therefore, 56 sites (74%) are included in the EDR evaluation recording kWh data from 240 meters monitoring 18,000 lamps. *See table 1. below.*

	Sites	Accurate meters	Anomalous meters	Total meters installed	Rejected meters	Included meters
Sites withdrawn by applicant	6	69	2	71	71	0
Sites abandoned due to anomalous data or electrical problems	9	17	10	27	27	0
Sites with no LED swap	5	6	0	6	6	0
Sites included in analysis	56	240	6	246	6	240
Totals	**76**	**332**	**18**	**350**	**110**	**240**

2. Key Findings and Insights

As of 22 November 2016, across the 56[3] site sample, 71.27% of the predicted load saving were delivered - a total kW load saving of 0.948 MW was observed compared to the predicted kW load saving of 1.146MW identified in the M&V plans submitted at application[1]. The total peak hours of operation (PHO) is 251,163. Chart 1 shows the percentage of savings identified in the original M&V plans that were delivered (as observed by metering) at each of the 56 sites over the winter peak hours of 2015/16[2]. It is interesting to note that while most (45) sites delivered less than identified in their original M&V applications[3], there were 11 sites that over delivered, in the case of site 43 by 85%.

Chart 1 (below) shows the savings for each site extrapolated by comparing the monitored data against the revised M&V plans. An explanation of Plan revision is given below.

[1] In most cases these M&V plans did not contain accurate information on the light numbers, and sometimes the light types. However, it was possible to correct this information with a combination of site surveys, and by cross checking the plans against the Deemed Saving Calculator and robust light kW load benchmarks.

[2] The peak hours kW savings are from 1 November 2015 to 29 February 2016. Savings are assessed by comparing monitored data from LED lights against M&V plan projections.

[3]Part of this discrepancy might be attributed to the consistent underestimation of fluorescent lamp loads, whereas HIDD (High Intensity Discharge) lamp load predictions were within 1% accuracy.

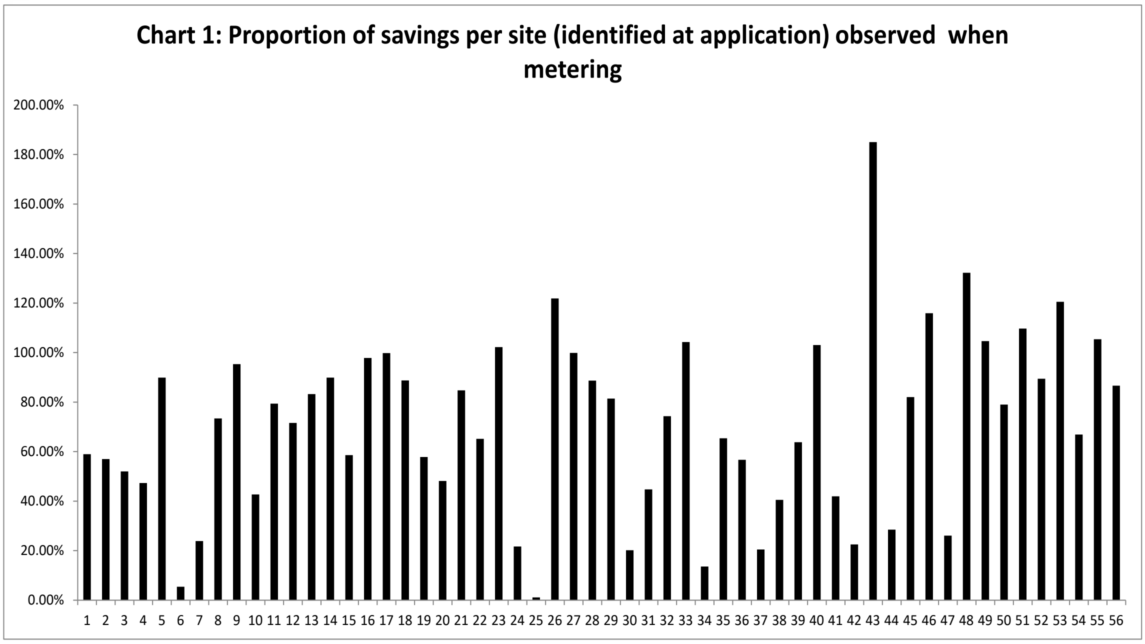
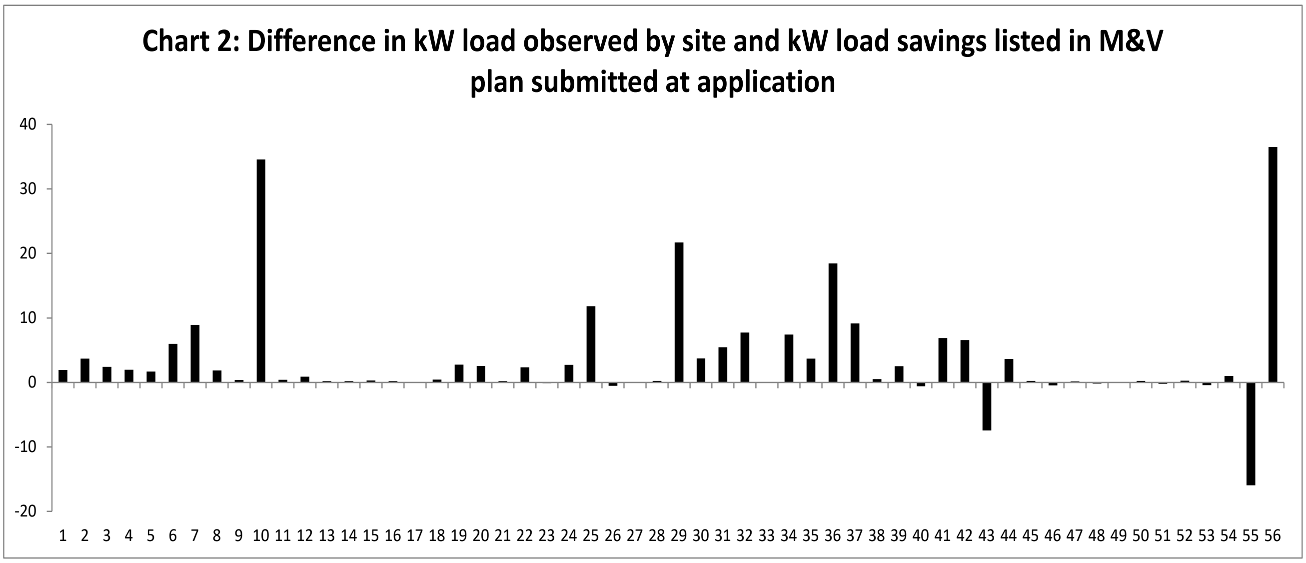


Chart 2 presents the differences between the savings identified in the original M&V plans and those metered in terms of the kW savings (rather than percentages presented in Chart 1) Sites with negative values in Chart 2 have metered savings greater than those listed in the original M&V plans for the winter peak hours of 2015/16. In comparing Charts 1 and 2 it is important to note that whilst a number of sites over/under delivered savings by a large proportion of their proposed original savings the impact in kW was relatively small, for example site 43 over delivered by 85% but this represented only of 7 kW of savings. However for other sites small differences in the proportion of savings delivered led to larger impact, for example site 55 metered kW savings 5% greater to that anticipated in their original M&V plan, resulting in an over delivery of 15 kW saving as the size of the potential savings on site was greater.



Differences in the level of delivered savings observed through the metered data and savings estimated in original M&V plans at application were identified as arising for a number of reasons, including:

- **Inaccuracies in identifying type and number of lights:** Only 1 of the 76 sites had a 100% accurate M&V plan at application that correctly identified the exact type and number of lights. The inaccuracy in each plan ranged from light number miscounts, that might be expected on large sites, to vastly overestimated lamp numbers/power demands and hours of operation.
- **Project revisions:** Eight (11%) of the sites sampled had not swapped the lights they committed to in their original M&V plans while five others appear to have only partially swapped. Others did not have the lights to swap in the first place. Project revisions meant that changes to the proposed measures were captured in updated M&V documentation and Operation Verification (OV) number. These results were closer to metered data, but are not reflected in the analysis above which only compares metered data to the original plans.
- **Overestimating hours of operation:** Some sites were found to only operated (had/have lights on) for the first half hour of the relevant four hours. Whilst daylight sensors were found to undermine the accuracy of the M&V plans that assumed savings over all four peak hours, given the lights not coming on for the first hour in November and February. Without half hourly readings it would not have been possible for this project to see that some sites were not operating for all of the relevant hours. Higher granularity (10 minute or less) would have been a distraction leading to unnecessary micro fixation on when lights came on and off.

In addition to the reasons above, the project also came across complications in comparing metered data with M&V plans: The ambition of monitoring at least 75% of a site compromised the ability to harvest accurate comparable data. Too often this target has led to multiple lights with differing wattages being recorded on a single meter circuit, leading to complicated M&V and DSC comparisons. A better approach to help those installing the meters would have been to require applicants to provide more detailed lighting circuit schematics. This would enable more focussed and accurate monitoring of known light numbers. This would be more costly for pilot participants.

Despite the frequent flaws in the submitted M&V plans, it was however possible to revise some of the plans so that meaningful analysis could be extrapolated. There were two ways that the Plans could be revised. Firstly, from the site surveys and revisits which helped to identify, with varying degrees of success, the types/numbers of lamps, their locations, hours of operation, and controls. The second method was to compare the monitored loads against the survey information available. Some of the monitored data closely matched the Deemed Savings Calculator (a good example of this was HID lights at the Newport site). This meant that it was sometimes possible to align the revised M&V Plans against a monitored load and confirm the parameters with reasonable confidence. However, it was rarely possible to confidently revise the Plans so that they were completely accurate. Despite the surveys, it was often still impossible to identify the exact parameters, so, the degree to which these revisions are accurate was often impossible to quantify. The “Projected kW savings” column in the supporting spreadsheet are taken from these revised Plans rather than those submitted by the applicants.

Although the M&V Plans could be revised, there was nevertheless, an average variance of 28.73% between the M&V plans and the monitored data. This variance is probably attributable to site behavioural factors, or the revised M&V plan still being too inaccurate.

Actual patterns of light use did not always match that predicted in the M&V plans submitted at application. The discrepancy in usage patterns from that reported at application highlights the potential advantage that metering has over a site inspector monitoring the electricity use patterns. An inspector monitoring the site load pre and post the technology swap during visits would not result in an accurate assessment of any kW load reduction. This is because inspections would have to be carried out at the exact time all the lights on the meter circuit are on, but this is often at random times for different circuits at a site. At some sites the maximum load is randomly observed across days of the week (or even month). This is particularly true for sites with daylight/proximity sensors such as car parks, stairwells, and corridors. Such circuits cannot 'just' be turned on.

An inspector simply attending a site to monitor the electrical light load once before and once after the LED swap would not identify the actual kW savings because of the random nature of when lights are on and off over an extended period. Therefore, an inspector might have to visit the site numerous times to build up a true energy use profile and so extrapolate the real kW saving. As part of this they would have to liaise with the applicant and their electrical maintenance contractor, and undertake considerable prior and post desk-top research to familiarise themselves with what is being measured and analysing the results.

Importantly, the inspector would have to be given authority over the site applicant's building facilities staff, otherwise they will not be allowed access (by the facilities staff) to the relevant areas of the building and/or electrical infrastructure. In many cases this will likely be either administratively impractical or at least administratively very time consuming, and may rule out potentially rewarding safety/ commercially/security critical sites.

3. Deemed Saving Calculator (DSC)

The DSC provides an estimate of the kW electricity savings resulting from the installation of electricity demand reduction measures, by providing technology benchmarks against which to compare the installed energy efficiency measures[4]. Deemed Savings are pre-determined, validated estimates of energy and peak demand savings attributable to energy efficiency measures in a particular type of application. Estimation approaches such as the DSC may be used instead of monitoring energy and peak demand savings through activities such as metering, provided that the submitted M&V plans are accurate. A DSC is of no use unless it is aligned to an accurate M&V Plan.

The measures included in the Phase I metering project included various types of fluorescent and High Intensity Discharge (HID) lighting. There were also eight known sites with halogen and 2D fluorescent lights which were not included in the DSC or appeared on the M&V plans. These technologies should be added to the DSC. Only LED lights were used (at all sites) as replacements. The deemed savings calculator[5] provided to EDR pilot participants seemed to perform best for High Intensity Discharge (HID) lamps. For High Intensity Discharge (HID) lamps the DSC was found to be within 1% accuracy (see below), however it underestimated the energy demand of florescent lamps by an average of 15% (varying from 10% to 30%). The DSC relied on the accuracy of the lamp count in the M&V plans, an

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[4] Only lighting projects came forward in Phase I of the EDR pilot therefore only the lighting DSC was tested in this Deemed Metering project.

[5] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/449307/Appendix_A_-_Deemed_Measure_Overviews_and_Data_Calculations_v1_0.pdf DSC manual see pp 20 -25 for information on the formula used in the DSC.

accuracy which at large complex and safety/commercially/security critical sites may inevitably be challenging to report accurately, and so undermine the accuracy of the calculations.

There were several sites which validated the DSC figures:

HID lights: One large site undertook bench tests which showed that 400W HID lamps pulled a 460W load. This matched the DSC to within 1% – which validates the calculator for these powered lamps, and provided a helpful benchmark for many other sites.

There were several other sites with 80-90% accurate and in many cases revised M&V plans (and which were supported by JBrand site surveys) and robust data, that also validated the DSC.

Fluorescent lights: 18 (64%) of the sites were similar in performance to each other, though there were 10 sites (36%) where the monitored data made it difficult to validate the DSC. Monitoring at the 18 sites showed that the DSC is accurate for T8 Fluorescents, but for certain locations and other types of fluorescents there seemed to be a general underestimate of loads.

Incandescent lights: There are only two meters which seem to have dedicated incandescent lights and so it is difficult to assess the accuracy of the DSC/M&V plans. These incandescent light loads appear to be twice that of fluorescent lamps.

LED (replacement) lamps: These lamps were mostly accurate to within 15% accuracy of the DSC with an increasing accuracy the lower the wattage.

More than 75% of sites were more complicated than anticipated, including challenges from antiquated wiring and distribution boards. This compromised the ability of the DSC to predict the demand from each circuit as they often had multiple parameters (several lamp types and different wattages per circuit), which were often controlled in different ways. In these cases it was only possible to estimate by cross-referencing the M&V plans against known benchmark sites and the DSC. However there were enough meters in enough sites (approx 42) to allow us to confidently draw conclusions. When controls (daylight/proximity) are used it becomes difficult to accurately assess those lights. Examination of some car park lights shows that the automation of the (mainly daylight) sensors creates a randomness to the data. For example a cloudy day skews the collated daily figures. This is also true of lights in car parking stairwells which often have proximity sensors. Also occupier behavioural patterns add randomness to the results. Patterns in the data produced at some sites when combined with web research revealed the reason for apparent random behaviour. This included buildings only being occupied /active on certain days.

Despite this randomness in some sites, the majority were non control and so it was possible to validate the DSC figures across a number of the sites with accurate enough survey results.

Procedure for identifying the light numbers and kW loads using a benchmark

In order to extrapolate meaningful analysis from the EDR pilot, it was necessary to revise the M&V Plans submitted by the applicants. A recurring problem with the submitted M&V Plans was the inaccurate assessment of the lamp numbers and their respective energy demand. However, it was possible to resolve this problem in many cases and revise the Plans, though, as previously mentioned, it is impossible to quantify the accuracy the revisions. Where lamp numbers were not confidently identified the procedure below was followed.

On smaller individual sites it is more likely that the participant is easily able to count and correctly identify the correct number of light fittings that are in place at their premises. However for larger or more complex sites counting the correct number of lights was not practical or feasible. Therefore a benchmarking method is used to calculate an approximation of the number of lights. The number of lamps per meter circuit is calculated using a benchmark kW load per lamp and the maximum kW load.

The benchmark is determined using the data from the last day when all half hour readings over the 24 hour period are available for existing lamp operation to determine the existing hourly light kW loads. For each half hour period the average maximum kWh for the existing lights is multiplied by 2 to give the kW load. The number of lamps on a meter circuit is given by dividing the kW load by the benchmark kW load per lamp[6]. After identifying the last day that the existing lights were in operation and the first day that the replacement lights were in operation[7], identify a half hour trigger threshold. This threshold is likely to be set between 60% and 70% depending on the visual analysis of the meter/ lamp profile. The trigger threshold will determine the percentage of a half hour period's kWh use will designate that particular half hour period (on the corresponding day the previous year) as being active (lights on) and in so doing allocate an existing technology (lamp) kWh use for assessing the annual kWh savings. An anomaly filter set to a kWh figure just above the robust maximum kWh for any half hour period over the entire monitored period. Using extrapolated existing lamp baseline, delete any day that has zero or negligible readings, then take an average of each of the peak half hours and then each of the relevant peak hours. The difference between a combined four hour average and the four hourly averages then the EMP will display a disparity between the deemed and monitored figures. The EMP is providing an evidence base on the potential savings delivered by LEDs. The distortions simply reveal that a site has unexpected controls or that the occupants have changed their behaviour patterns by switching off lights at different times. When assessing peak load to calculate light numbers make sure that the controls are at "None" in the DSC to get full load figure, otherwise the controls weighting will skew the figure.

The way to accurately assess the existing loads during the winter peak period is to project the LED load profile onto the monitored LED load (as for estimating the annual kWh savings). The November to February LED half-hour loads are downloaded and then the percentage of the known maximum load is calculated and then projected onto the known max (all lamps on) existing load (taken from a half-hour reading). For each meter and for each of the half hours of the winter peak; between 4pm and 8pm on winter peak days 2015/16, the maximum LED load for each half hour is identified, the percentage of the max load is calculated and so too is the maximum existing load. Half hourly average loads for all of the winter peak days (for each of the peak half hours) are calculated and the average loads of each half hour are averaged again to get an hourly average load for each hour and then averaged again to get a winter peak average over the four hours. Where there is more than one type of light on a meter circuit, it is sometimes possible to identify how each light type is performing by splitting the total load into the relevant percentages. Using either/or a DSC/other site benchmark the percentage of the total load is divided by the DSC (or other) per lamp benchmark kW load. This will give an approximate estimate of lamp numbers, and if they match the M&V plan and site survey then it is reasonable to assume that the performance analysis is correct enough. Table 1 provides an example.

[6] This is adjusted to an even number, if necessary, to give a non-fractional number of LED replacements.
[7] Sometime the LED swap process can take several days.

Table 1: Estimating existing loads where there is no monitored pre-swap data percentage of max replacement load projected onto previous year load

	2015		
	Day A	Day B	Day C
Max kW load (all lights on- constant)	5 kW	5 kW	5 kW
Replacement light monitored loads	3kW	4kW	3kW
% of constant max load (5kW)	60%	80%	60%
Projected on to 2014	2014		
Max kW load (all lights on- constant)	15kW	15kW	15kW
Existing lights (from DSC) kW load projections	9kW	12kW	9kW

Where there is more than one type of light on a meter circuit it is sometimes possible to identify how each light type is performing by splitting the total load into the relevant percentages. This is done using a DSC or other site benchmark the percentage of the total load is divided by DSC (or other) per lamp benchmark kW load. This will give an approximate estimate of lamp numbers and if they match the M&V plan and site survey then performance is correct enough.

Light parameters and benchmarking

The light parameters should match the fields in the DSC:

- Lamp numbers
- Lamp wattage (per lamp)
- Lamp type
- Location
- Controls (sensors)
- Number of (peak days) of monitoring
- Which daily peak hours are monitored

The lamp location, controls used, and peak days and hours are taken from the M&V plan. Identifying the lamp types, wattage and numbers is at times complicated (and sometimes not possible). Even if the M&V plan is accurate, this can only be confirmed by cross checking against the site survey, the DSC, and the monitored data using one or more techniques.

Prior to inputting light parameter figures into the site calculation sheets, and then into the EMP parameter fields, the monitored data is visually inspected to see if there are any obvious anomalous spikes or unexpected readings. These are usually caused when lighting circuits are interfered with, grid fluctuations, and can sometimes result from SIM card data processing software glitches. These spikes can be removed from the core PHP database that drives the graphing program, though the original reading is stored in a separate database for further investigation if required.

Table 2 provides an example of one seemingly basic site was a car park that consisted of 25 x 400watt HID lamps. This information is recorded in a spreadsheet during the site survey and cross-checked later as part of the manual data interrogation – which then showed that this limited number of lamps were within 8% of the DSC. This information is extrapolated from a combination of the M&V plan and by cross-checking against benchmark sites and DSC.

Table 2: Example of a final light parameter spreadsheet:

14169507	Lights	Location	Controls	Hours	Days	Lamps	Lamp (W)
Parameter 1	HID> 200W - Electromagnetic	Oth - External	Presence & daylight on-off	4	83	25	400

14169507	Lights	Location	Controls	Hours	Days	Lamps	Lamp (W)
Parameter 1	LED Lightsource	Oth - External	Presence & daylight on-off	4	83	25	100

Pre-swap date:	13-Sep	Max (existing) kWh (HH period):	6.24
Post-swap date:	16-Sep	Max (existing) kW load:	12.48
		kW per lamp:	0.499
		DSC/Tata benchmark:	0.460
		Variance:	7.85%

4. Meter installation (includes specification and maintenance)

Site inspections

Part of the process of attempting to improve the accuracy of the submitted M&V Plans was to undertake site surveys (at all sites). The survey information was then fed into the revised M&V Plans against which the monitored data was compared. These onsite surveys were essential to establish an evidence base. Understanding of the physical circuit is achieved by cross checking M&V plans against the site surveys and benchmark data. The plans are likely compiled centrally by the organisation's facilities department rather than at a local site level where there may be a more accurate knowledge base. Furthermore, electrical circuits in commercial premises are often changed and so it is very possible that a centrally held schematic/lamp count may well not reflect the on-site reality. To resolve this problem it was essential for the meter installation contractor (JBrand) to undertake a site survey in an attempt to clarify what the light types, wattages, and numbers were. However, it was almost impossible to identify 100% of the parameters. Identifying exact lamp numbers is more complicated than simply counting them, because a particular lighting circuit might supply several locations in a building (including main office space, corridor, kitchens and toilets). Turning all the lights on and then shutting off power to the circuit to see which lights have gone out is rarely possible for safety reasons – particularly at large and complex sites.

The larger site surveys were completed by a team of 2 engineers over a day, whilst the smaller sites were covered by a single engineer at two sites per day.

Identifying lamp wattages was often impossible, especially in the large sites, as it would require erecting a scaffolding tower, unscrewing the luminaire cover to inspect the bulb itself. Where this was done the result was often contrary to the M&V plan provided by the applicant at the time of application. However, all these site surveys did provided enough information about enough sites to ensure that the metering undertaken delivered coherent results once the parameter findings were compared against the monitored data and/or the DSC.

Accurate site/meter evaluation requires the monitored data to be compared against:

a) The M&V plan
b) A site survey
c) The Deemed Saving Calculator

If the monitored data matches these three components of the process reasonably closely, then the results will reinforce (some elements of) the DSC, whilst highlighting the inadequacies of the M&V plan approach, and the alternative idea of a (not) simple one off pre-post technology swap monitoring visit by an inspector.

Meter specification

All sites (excluding the street lighting) used 3-phase smart meters (Elster A1140 or Iskra MT382). These are the two main industry standard smart meters and were supplied depending on availability from the importers. Lead times for these meters varied depending on demand and manufacturing / logistic schedules. Using 3-phase meters maximized the number of lighting circuits that could be monitored per meter because a current transformer clamp can be positioned around three different lighting circuits each of which is running off the three phases. Sometimes it is only necessary to use two of the three available phases.

The meter must be programmed to match the CT clamp rating; this was most commonly 100/5A, though for larger loads it was 200/5A.

The street lighting required a much smaller sized meter because of the limited space available in the base of the lamp post. A 10cm x 5cm DIN rail meter was installed (inline of the lighting supply) with the DIN rail securely attached to the inside of the lamp post base. The meter had a GPRS modem plugged into it.

Meter installation (process and issues) and energising

Meter installation ahead of installation of energy efficiency measures was undertaken so as to collect baseline data. This was possible in all bar 13 cases (excluding the abandoned sites). Many sites proved more complex than the application information suggested and in some cases was wrong or incomplete. Applicants were not asked to provide sufficiently detailed site specific information at application which included information about the site health and safety requirements. These requirements proved to have significant implications for meter installation at a number of sites. Some work required specialist sub-contractors to do work. Site shut down or power down was necessary for some sites to energise meters and this caused inconvenience for pilot participants as these power downs needed to the scheduled around business need. Installation at some sites required a number of unexpected fixes including installing boxes to accommodate the meters. Once energised each meter had the data feed remotely checked and validated.

In some cases the meters were energized via a separate supply (rather than the monitored lighting circuit) because the meter needed to be live (in order to transmit its readings) in the middle of the night when the lights themselves may be switched off via a separate time or fireman's switch controlled distribution board. This is done by wiring the meter to a separate distribution board (5 amp) fuse. This also gives the meter a voltage measurement in order to make accurate power (energy) recordings.

Installation time depends on the site specific complexity. Approximately 30% of meter installations were relatively straight forward and were completed within 4 hours, with 45% taking up to 8 hours, with the remaining 25% meters taking more than a day. The main reasons for installation taking an unexpectedly long time was antiquated wiring and consumer units/fuse boards or restricted working time due to onsite occupier operations.

There were some instances (5%) where meters could be installed but not energised until a later date (in three cases a week later and in four cases over a month later) because of onsite occupier electrical works or employee activity or security issues. The time spent resolving these issues could be minimised if applicants provided wiring schematic and/or operation schedules. Some sites required secure meter enclosures. Mostly these were standard meter boxes, but at some sites a new meter enclosure had to be fabricated.

Metered data transfer (to the EMP)

Telemetry for the daily transfer of the metered data (kW hour readings collected at half-hourly intervals) is through General Packet Radio Service (GPRS) 2G mobile broadband service providers. To reduce the chances of telemetry failure due to poor coverage by a provider in a particular area roaming SIM cards that locked onto the strongest provider were used to facilitate data transmission. Despite this there were 7 sites where one or more of the meters required the installation of small (25cm) booster aerials. Which solved some of the transmission problems, but some sites have stubbornly poor reception and so continued to struggle.

All meters were successfully brought online, though subsequently 16 went offline for various site specific reasons (not to do with the meters themselves). There were a 7 meters that transmitted data only intermittently ranging from once every few days to only once a month. There is no clear reason for this. Site revisits by JBrand revealed a mix of reasons including meters being in a signal dead spot, power circuits being switched off, or telemetry inhibited by metal objects being placed adjacent to meters.

The street light aerials had to be positioned at the top of the lamp post to ensure a clear line of sight to mobile phone transmitters. This is because the power output of the small modems could not penetrate the metal base of the lamp posts.

Six meters went inexplicably offline for a while and came back online. Site electrical maintenance works or accidental/unexpected power shutdowns may account for this. Three meters went offline because the building was vacated or because of major renovation.

Four meters could be contacted online and reported good signals (during working hours), however failed to download half hourly profiles each night. Investigation (via site visits and phone) showed that this was because the occupants were turning off the site electricity (or specific metered circuits) at night via a fireman’s switch as part of their end of day close procedure. This meant the meters were asleep when they should be uploading their data in the middle of the night (it is technically difficult to reprogram meters to change their upload times). This problem was rectified at two of the four locations by adding a separate ‘always on’ power supply to power the modem in these meters, although this solution was not possible at the remaining two sites as it would have meant interfering with the neighbours electrical system. However, the overall number of meters that were unable to transmit regular data was around 5%.

Site revisits

Twenty sites were revisited during the installation period of autumn/ early winter 2015 to investigate 28 meters (some sites had more than one meter which needed attention). 2 sites required more than one revisit. Most revisits were prompted either by meters going offline (or becoming intermittent), receipt of anomalous data or to gather additional information about light parameters. Overall of the 28 meters revisited, 58% (16) of revisits resulted in metered data transmission being restored, 25% (7) data transmission was not possible; 14% (4) of meters were installed at sites which were found to no longer be occupied by the participant while for the remainder (13%) data transmission could not be fixed). For 17% (5) of the revisits light configuration was confirmed.

In one case the applicant had some major electrical works done by their own contractor, which resulted in the EDR pilot meter being pulled out and disposed of. A new meter was installed.

5. Energy Monitoring Platform (EMP)

Generic smart metering technology was used to meter electricity demand at each site. The harvested data from each meter was organised through a customised commercial web-platform, known as the Energy Monitoring Platform (EMP).

The EMP was originally developed to monitor and enforce Local Planning Authority renewable/low-carbon energy planning policies, underpinned by the Planning and Energy Act 2008, (the so called 'Merton Rule'), and has been in active commercial operation for over five years. A bespoke dashboard was tailor made in consultation with BEIS for the deemed metering project. The EMP has a flexible custom data/graphing tool that allows the metered data to be displayed and downloaded (for manual investigation).

A virtual "Birth Certificate" was created for each site on the EMP. The birth certificate holds key information such as address and light parameters (type and numbers). The monitored data is processed every 24 hours (each night) and fed into each site birth certificate's dashboard. The meters at each site are listed on that site dashboard and these can be selected to access the data from that particular meter. Data is analysed for the relevant peak hour period each weekday and for the number of days of operation during the winter peak period (as specified by the applicant in the M&V plan). The data is also processed 24/7/365 and the yearly kW hour savings calculated.

Parameter calculations

The parameter calculations use the type, number, location, and operating hours of the existing and replacement lights. These parameters are used by the DSC to estimate the load savings. These parameter figures are factored into the data analysis undertaken by the EMP. This is done by embedding the DSC into the EMP. The "Meter Settings" tab in the site's Birth Certificate is an exact replica of the DSC. The DSC/EMP kW saving targets are then compared against the incoming monitored data and the results displayed on the self-explanatory dashboards.

Comparison between kW used before the light replacement and after the light replacement is possible enabling the data to be assessed for the two defined periods without the distortion that different instalment periods would present.

In order to estimate the running 24/7/365 kWh savings, each day's half-hour profile is imprinted onto the corresponding day of the previous year, and scales up to the (known) existing lamp kW hours. The LED load is then deducted from this projected half-hour kWh total to get the kWh saving.

A threshold trigger ("threshold") is set to determine what constitutes a half-hour period. This threshold is set according to the nature of the meter profile – low kW loads may require a higher threshold due to the sensitivity to grid fluctuations and other anomalous readings.

The kWh "Anomaly filter limit" is set to just above the highest (reliable) kWh reading for a half-hour period, with the aim of slicing out any anomalous spikes from the combined totals.

The specific peak hours of light use (according to the M&V plan) are selected.
There is also an "Exclude" check box for meters that need their (anomalous) data redacting from the collated totals. This is used for meters/sites that are redacted from the pilot due to the applicant withdrawing the site, wildly anomalous data, or abandoned premises.

Once the existing monitored data sheets have been downloaded and the hourly peak loads identified, they are manually typed into the "Monitored existing usage" Excel cells. Quality assurance for this process comes from a visual cross-check against the calculation sheets, and from the data collection automated data analysis processes which would flag up any anomalous readings resulting from a manual data input mistake. These provide the comparison point for the deemed loads (in the Parameter calculations).

Graphs can be generated to provide easy visualization of when demand reduction has been delivered. However site specific knowledge is needed to interpret any observed demand reduction so as not to mistake changes in patterns of use with demand reduction from installed energy efficiency measures. The technology (lamp) swap point can be seen as a 'cliff edge' of energy demand in the chart. It is interesting to note that this cliff edge is not always visible when looking at the daily totals because in many cases the daily load reflects changing demand over the seasons. In these cases the cliff edge can only be observed using half-hour graphing. The graphing also reveals that the technology swap sometimes happens over an extended period.

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6. Lessons Learnt

Lesson learnt for any future Deemed Metering Projects

Due to the timing of the meter installation process, the only available information for the meter installers to use was that provided at the application stage of the pilot. Therefore although there was an M&V update provided by pilot participants at a later stage in the pilot process this information was not used in the analysis conducted in this report. Therefore when comparing the information supplied at application in the DSC with metering observations it is important to account for the challenges presented when using the early M&V information including:

1. **Site inspections are recommended for all sites in advance of meter installation as the site specifications supplied at application did not always reveal all physical site specific electrical complexities.** Site circuit plans on complex sites were found to be misleading. Indeed the majority of sites were more complicated than could be anticipated from the M&V documentation submitted at application. Some sites were particularly challenging, with antiquated wiring and distribution boards. This compromised the ability of the DSC to predict the demand from each circuit as complex circuits often had multiple parameters (several lamp types and different wattages per circuit), which were often controlled in different ways. Sites with really old equipment can present meter installation complications, which cannot be anticipated from the details supplied at application.
2. **Relying on the M&V plan submitted at application to install meters proved to be distracting, and highly complicating for contractors**. Equally the DSC, while useful as a comparison between the nameplate power of lights and the monitored demand, only helps to determine the count of lamps where the DSC actually matches a bench test value. For florescent lamps where it did not match, and did not match by seemingly random degrees, it is only of practical use when supported by specific site analysis.
3. **On inspection it was evident that some of the sites have obviously not installed the energy efficiency measures (lighting) committed to in the original M&V plan**, while others appear to have only partially swapped. Others clearly did not have the lights to swap in the first place. Some other sites only operate (had/have lights on) for the first half hour of the relevant four-hour winter peak period. Daylight sensors undermined the accuracy of the M&V plans that identified all four peak hours with the lights not coming on for the first hour in November and February. This shows that the existing (and retained) daylight sensitive control systems were working, but because the applicant maintained that the lights would be on during that first hour then they were overestimating the kW saving at each site offered to the EDR pilot. The discrepancies observed are likely to have been covered off in the updated M&V plan which the pilot participant submitted later in the pilot process.
4. **Site specific operation patterns were important to measure use.** These patterns of use were not necessarily reflected in the application documentation submitted to the pilot. Therefore in order to make sense of the electricity use data coming from the metered sites it was often important to have site specific knowledge gained from either a site visit or other sources (e.g. internet search). Some large sites had areas which were only active during some of the key winter peak hours over the winter peak months. Other sites were not in operation during the key winter peak hours on some days of the week. Varying patterns of use are further

complicated when lighting is linked to the automation of proximity sensors in offices, stairwells, and car parks.

5. **Half hourly data readings are a sufficient frequency of measure.**. Higher granularity of data reporting (10 minutes or less) would have been a distraction leading to unnecessary micro fixation on when lights came on and off. Half hourly readings made it possible to see the light usage at each site.

6. **Benchmarking is essential**. On large sites with complex circuits it is likely to be impractical to count the number of lights and therefore benchmarking is essential.

7. **Site specific health and safety requirements can delay meter installation and the energizing process -** However more major problems were found when installation engineers arrived to find they could not install meters without attendance from the sites engineers or that the site's security protocols would not allow the standard operation of smart meters. In both cases issues arose as to who should pay the additional cost of these processes. This issue also highlights an inevitable problem of using an inspector to monitor pre and post technology swap in place of actually metering. As with other installation and administrative issues these situations could be avoided if applicants submitted detailed site electrical operation information and wiring schematics as part of their M&V plans.

8. **The person who is responsible for the electrical running of a site may not have been fully briefed or have bought into the metering committed to by the official signing the pilot participant agreement.** This issue can mainly be resolved on the ground between engineers.

9. **Some of the participants in the deemed metering project have expressed interest in further metering**. The cost burden of the metering is proportionate to the size and nature of the site. Put simply it is costs vs the number of lights on a circuit. The more lights (or whatever technology) on a circuit the metering cost is a lower proportion. Despite these on-costs, six applicants have expressed interest in wider energy metering for their portfolios. This illustrates the increasing importance that companies attach to monitoring and how they might be prepared to factor it into their ongoing operational costs.

10. **An inspector monitoring the site load pre and post the technology swap during two one off visits would not result in an accurate assessment of any kW load reduction.** Such inspections would have to be done at the exact time that all the lights on the meter circuit were on, and this is often at random times for different circuits at a site. At some sites the maximum load is randomly observed across days of the week (or even month). This is particularly true for sites with daylight/proximity sensors such as car parks, stairwells, and corridors. Such circuits cannot 'just' be turned on. An inspector would have to attend the site twice (pre/post) at very specific times and with a precise understanding of the light parameters (types and wattages), and the occupants behavioural profile/use of lighting. Importantly/critically the inspector would have to be given authority over occupants facility teams, which would rule out a large number of potentially rewarding safety/ commercially/security critical sites.

The costs associated with deeming and physically inspecting are likely to be considerably more than simply installing a smart meter and automatically remote monitoring. (Monitoring need only be for two years to ensure a complete annual cycle).

Lessons learnt for Future EDR policy

11. **M&V plans submitted at the application stage all required significant revision.** M&V plans submitted at application for most sites required updates which were supplied to the EDR pilot team at BEIS after the meter installation process was undertaken. The revised plans updated simple light number miscounts – which might be expected on large sites, vastly overestimated lamp numbers/ power demands and hours of operation. Revised M&V plans represented the applicants' savings commitment. .
12. **Deemed Savings Calculator (DSC) provided technology benchmarks as a means of assessing light numbers and types, DSC accuracy varied with the technology type**. The vast majority of lamp types found in the pilot were various types of fluorescent and High Intensity Discharge (HID) lamps. For HID lamps the DSC was accurate, however it underestimated the actual energy demand of florescent lamps by an average of 15%. As the DSC relied on an accurate lamp count in the M&V plan, for large complex sites or sites with strict safety, security or commercially sensitive site where it was not possible to count the lamp numbers the DSC was of limited use. There were also quite a lot of halogen and 2D fluorescent lights which were not included in the DSC or appeared on the M&V plans. Only LED lights were used (at all sites) as replacements.

13. **The Deemed Metering Project monitoring has provided a robust evidence base on the electrical loads of fluorescent and HID lights.** This evidence validates the Deemed Saving Calculator. It is therefore possible to project a time period (B) profile (after the LED lamp swap) back onto the corresponding period (A) of the previous year - using the DSC as a benchmark for the existing lamp loads. The saving is calculated by subtracting B from A. The ability to estimate these savings reinforces the rationale for requiring future monitoring (in conjunction with improved M&V plans) of EDR sites. In so doing BEIS will be able to confirm the volume of the technology swap and validate the resulting savings.

14. **As long as the lamp type and wattage is known, the number of lights can be calculated from the monitored power demand.** This does not however mitigate issues with complex and challenging sites, which it is suggested should either not be deemed or given a considerable additional installation time/cost allowance, together with authority to interfere with and interrogate the site in question's electrical circuits. Alternatively these sites could come under a simple before and after metering protocol.

    The DSC may also be victim to the different voltages experienced at different points in local grids. Florescent lamps especially are known to become less efficient at higher voltages. It may be useful for future refinements of the DSC to record site voltage and whether voltage optimisation equipment has been installed (or have voltage optimisation as a prerequisite). The aim to monitor at least 75% of a site compromised the ability to harvest accurate comparable data. Multiple lights with differing wattages were but should not be recorded on a single meter circuit, leading to complicated M&V and DSC comparison.

15. **Suggestions for improving M&V plans.** It may be possible to improve the M&V plan approach so that deeming is more accurate. This would however involve an increase in the amount of information that is required at application. The key requirements would be for the applicant to provide the following:

    a) Accurate wiring diagrams for each site identifying what types and numbers of lamps (or whatever technology) are on each circuit.

    b) Evidence of these lamp configurations through an electrician report and/or photos of the lamps and distribution boards.

    c) Details of the replacement lamps (or whatever technology) including make and model etc.

    d) Evidence of the replacement technology being fitted – through receipts, work schedules, installation contracts, and photos etc.

    e) Details of any control systems (proximity/daylight etc) and likely times of operation.

    f) Details of any planned changes to building layout, circuit configuration, or activity usage.

    g) Explanation of any onsite activity (such as shift working), or occupant activity (such as night time shutdowns) that might noticeably affect the electrical use profile of the site.

It should be understood that even with these improvements, there will inevitably be discrepancies between the plans and the onsite reality. Onsite automation and behavioural variables will contradict the plans and therefore compromise the load reduction projections. That said, adopting these measures will be a significant improvement on the current M&V plan structure.