Engineering Justification Paper

Energy Management and Utility Reduction

Final Version

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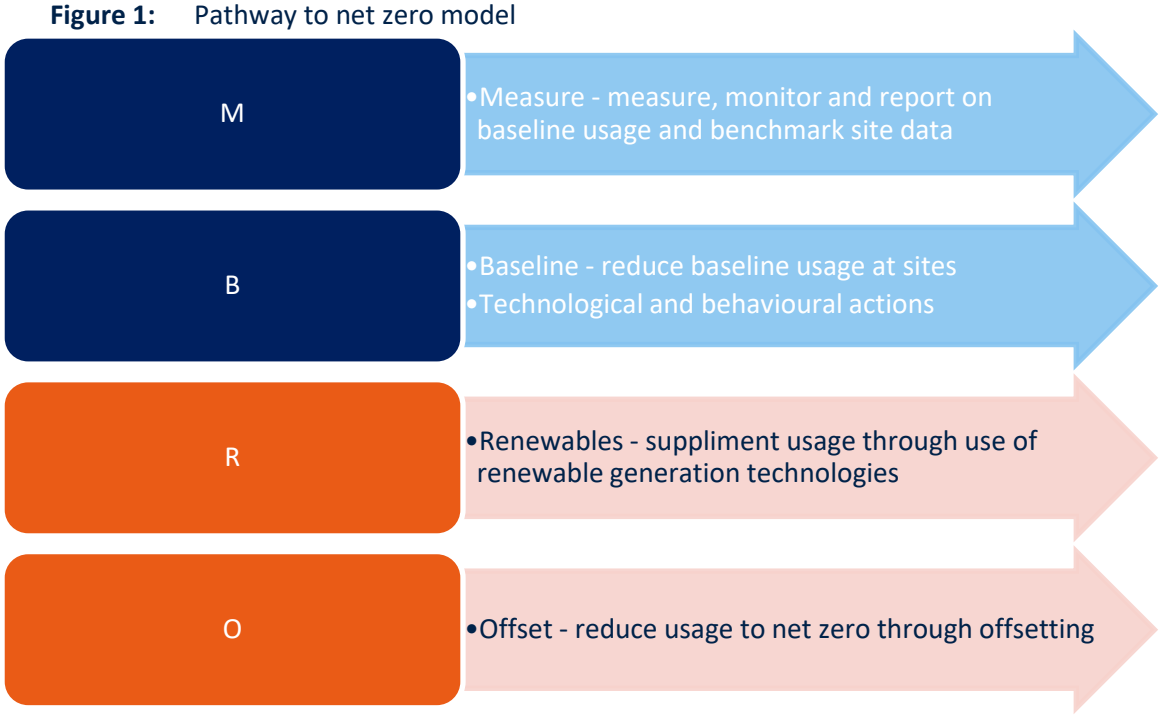
2 Introduction

This paper is for a programme of energy management and utility saving projects in support of our Environmental Action Plan (EAP) goals. To support delivery of these goals, we will be creating a "pathway to net zero" for each of our occupied premises. The basis of the pathway will follow a four-step process for each building as highlighted in **Figure 1** below:

Figure 1: Pathway to net zero model



The above pathway model highlights four key action areas to focus on in order to achieve significant savings. These action areas have been summarised below: -

Measure
Install equipment to measure and monitor baseline usage per area. Report on usage against a baseline in order to identify and target reductions. Examples of energy management equipment are Building Management Systems (BMS) or Smart Metering technologies. Installation of this type of equipment at occupied sites will accurately measure, monitor and manage energy usage.

Baseline
Identify both technological and behavioural opportunities to reduce energy usage at a site. Industry data suggests that the two highest consumers of energy in non-domestic buildings are heating (41%) and lighting (23%). This paper seeks funding to target reductions against each by installing networked BMS to monitor and control systems and reduce usage. It also seeks to implement interface control to existing Heating, Ventilation and Air Conditioning (HVAC) and a rolling programme to install new LED lighting and BMS control interfaces. Behavioural change campaigns linked to our EAP will also be undertaken in GD2 to target baseline usage reduction.

Renewables
Once baseline usage is as low as possible, supplement usage by the introduction of renewable generation technologies to supplement the site consumption (a separate paper has been submitted to cover this area – **SGN Prop 003 Renewable Energy EJP and CBA**).

Offsetting

Additional carbon offsetting must then be considered to achieve net zero.

By delivering the intervention detailed in this paper we can make a significant and cost-effective contribution in reducing SGNs Business Carbon Footprint (BCF), which will (together with the installation of renewables) bring about a 68% reduction in comparison to financial year 2018/19 and provide an ambitious move towards net zero in 2045.

3 Equipment Summary

The SGN property estate has a wide variety of building assets that are varying in age and condition, many of which are reaching or have exceeded their economic and/or technological lifecycle as well as being inefficient.

Existing Controls

Building services controls are used to perform two main functions: -

1. Switching equipment on and off
2. Adjusting the output of equipment to maintain the required operation conditions.

The existing building services control components are limited across our sites and consist mainly of simple analogue controls at system level, they are not interfaced and are basic technology. Examples include: -

- **Time switches** – simple time clocks on equipment e.g. boilers on/off at set control times
- **Thermostats** – controls which turn equipment on/off/change of mode when certain temperatures are reached.
- **Sensors** – measure a set condition to inform function e.g. LUX/PIR sensors on lighting, pressure sensors and flow rates
- **Actuators** – devices that physically operate values and dampers in response to a controlling device
- **Direct Digital Controls (DDC)** – these are slightly more intelligence and complex control systems that coordinated one or many controls e.g. Mitsubishi AG150/AE200 HVAC controls which can program timings, temperature coordination and set-back parameters

We have a number of varying simple controllers across our sites with the limited capability and complexity. These controls require on-site programming and management and are unable to coordinate with other systems with limited ability to apply an efficient overall controls programme.

The introduction of a BMS allows for the communication and coordination of all Building Services Systems in one control programme.

At present, we only have one BMS installed to monitor, control and reduce our utility consumption which is a Trend Control UK Ltd system installed at our new build premises in Epsom. The case studies presented by Trend as part of this project indicated that the introduction of a BMS could result in a lower overall energy consumption than individual controls.

Existing lighting systems are predominately fluorescent t-series fittings with no intelligent control systems. Some offices benefit from LUX and PIR sensors.

4 Problem Statement

Why are we doing this work and what happens if we do nothing?
The introduction of technological advancement and management of our energy consumption will bring operational cost savings through utility reduction to our office accommodation and ensure we are heading in a positive direction to achieving net zero carbon naturality.

Failure to implement interventions through energy management technologies shall mean that costs savings cannot be realised, and the company carbon neutral vision cannot be achieved. Therefore, operational costs shall continue at current levels.

What is the outcome that we want to achieve?
We aim to drive efficiency and costs savings to our real estate operational expenditure on utilities. To achieve this, we seek investment to improve the technological infrastructure to drive down usage. The installation of the energy management systems can be used to reduce our ongoing energy costs and carbon footprint.

How will we understand if the spend has been successful?
Successful delivery of the proposed programme would result in a year on year baseline reduction in site energy consumption in-line with the projected saving of an overall reduction of 12% through the introduction of BMS and up to an average of 48% saving on lighting utility costs and associated costs of carbon. These savings will be demonstrable through management information reports provided by the BMS and per project post-delivery analysis.

4.1 Narrative Real-Life Example of Problem

The total electrical energy consumption for financial year 2018/19 was 6,013,465KWh which is expected to continue at current levels in GD2.

Models provided by Carbon Trust have suggested that a reduction of 56.4% in building utilities by 2030/31 is required to meet net zero targets. This will not be achievable without technological interventions through energy management and renewables - see **Appendix A.**

The following example is based on a costed proposal from Trend for a BMS and LED lighting installation at Walton Park, Hampshire. The model suggests that this technological intervention could save up to 23% of carbon emissions.

Walton Park – Cosham, Hampshire

- Current annual electricity consumption – 1,568,717Kwh
- Utility costs (based on £0.16/KWh) - £251k
- CO2 generated (DEFRA conversion factor @0.2556 Kg CO2e) = 400.1 tonnes CO2

Installation of Large Site BMS and LED Lighting install

- Large site BMS install - £49,392
- LED lighting install based on £49/m2 Large Site - £220.3k
- Utility reductions for BMS (based on 12% saving) – 188,246kWh
- Cost reduction for BMS (based on £0.16/KWh) - £30.12k
- Carbon reduction (DEFRA conversion) – 48 tonnes CO2
- Utility reduction for LED (based on lighting @23% of utility use and average 48.75% reduction) – 175,982KWh
- Cost reduction for LED (based on £0.16/KWh) - £28.14k
- Carbon reduction for LED (DEFRA conversion) – 44.5 tonnes CO2
- **Projected site carbon emissions reduction – 23.13%**

Details of our occupied site energy consumption for financial year 2018/19 is available in **Appendix D**.

4.2 Spend Boundaries

The focus of this paper is to highlight a programme fund to explore technological opportunities in Energy Management and Utility Reduction at our occupied sites.

Projected avoided costs focus on direct utility reduction and cost of carbon avoidance in support of the proposed EAP.

Approximate costs for installation have been modelled on a costed real-life example by Chartwell Controls Ltd who are an approved installer of Trend, one of the world's leading Building Energy Management Systems manufacturers.

What is in Scope?

This programme proposes the installation of appropriate energy management technologies to reduce our energy consumption and carbon emissions by monitoring and controlling our utility usage. The scope of works include the procurement of equipment, project and planning fees, installation/modifications and maintenance.

What is out of Scope

The programme does not cover repairs, upgrades or replacements to plant and infrastructure which are not linked to the installation of such technologies above.

5 Probability of Failure

A current failure mode is our inability to control energy usage within our occupied sites. Without energy management technology intervention, we are unable to influence the required reductions in utility usage and carbon emissions. This would result in a failure to meet our targets stated in the EAP – **Appendix 003.**

5.1 Probability of Failure Data Assurance

Our assumption is that there will be a steady state of failure of our existing t-series lighting assets at 200 failures per annum, it is assumed in the model that failure rates will increase between 20-40% when assets exceed their technological asset life. The data provided by SSE Enterprise suggests that the introduction of LED lighting could reduce the steady state of failures by up to 20%.

It is also assumed that our utility usage would continue at the current levels benchmarked from our financial year 2018/19 data.

6 Consequence of Failure

There are currently limited energy management assets installed across our sites, should the 'do nothing' option be adopted, the consequence of not having a pathway to a carbon neutral property portfolio would lead to utility use remaining at current levels as well as: -

- Failure to meet business carbon footprint reductions, science-based targets and net zero emissions
- Increasing costs from grid electricity and battery supply
- Increasing operational and fuel costs
- Supply issues for lithium batteries as resource scarcity increases
- Potential issues with grid reliability as pressure on the grid rises
- Fall in reputation as customers and stakeholders see other companies achieving net zero

The above would also result in a failure to achieve the stated goals and ambitions laid out in the EAP.

7 Options Considered

All options being considered are for new assets. The only intervention mode that is relevant is **Build new** (installation of new assets). All other intervention are not considered in this paper.

The options considered within **SGN Prop 004 Energy Management and Utility Reduction CBA** are: -

1. Do Nothing
2. Installation of new assets at large sites only
3. Installation of new assets at large and medium sites only
4. Installation of new assets at all sites (large, medium and small)

The equipment to be installed as part of this programme is broken into two areas: -

1. Building Management Systems (BMS)
2. LED Lighting Installation and BMS controls

Building Management Systems (BMS)

BMS are a networked computer-based control system installed in buildings that control and monitor the key mechanical, electrical and public health systems in the most cost-efficient way whilst removing waste energy usage. Additional benefits are outlined below: -

- Switches plant and equipment on and off on a programmes schedule
- Optimises plant operation and services to meet occupancy and demand needs
- Monitors status of plant and environmental conditions reducing unrequired runtime
- Allows remote access, control and monitoring via an online interface/smart device
- Provide analysis of real time energy monitoring against a baseline
- Removes waste energy use and associated costs

The programme is based on SPONS price book data and validated by a sample price check submitted by Trend. The representative install sample for a BMS is based on the following: -

- Head End – Main control unit which monitors control parameters and applies instruction.
- Primary Network – Means of communication between head end and controllers (Cat6e cabling).
- Main Plant Controller – Control for interface with main plant (e.g. Air Handling Units / AC Controllers).
- Control Enclosure – Enclosure located in plant room to house head end and main controllers.
- Lighting Controllers – Interface units to control LED controllers
- HVAC Controllers – Interface units to stand alone AC systems.
- Energy Meters – Utility meters to enable utility monitoring.

LED Lighting Installation and BMS controls

Lighting systems will be upgraded to high efficiency LED systems with lux and presence sensing technology which will be interfaced back to the BMS. The lighting system controls will apply timed schedules, to ensure that lighting is turned off during non-operational hours, it will be linked to lux sensors within the offices which will reduce/turn off the lighting power depending on average ambient light and will be linked to PIR controls, so will only be on during operational hours if presence is detected.

The programme is based on representative quoted prices for three sites (large, medium and a small), which proposed the installation of the following system: -

- IQ LED Luminaires – 400x400 drop in LED replacements for traditional tubed luminaires
- IQ LED Emergency Luminaires – 400x400 drop in replacements for emergency light luminaires

- CHAL 200 Down Lights – Replacement of downlights in corridors/toilets/welfare areas
- BETA2 Surface Mounted Luminaires – 400x400 surface mounted LEDs for hard ceiling installation
- BETA2 Surface Mounted Emergency – 400x400 surface mounted emergency LEDs for hard ceilings
- IQ Surf LED Strip Light – LED strip light for workshops, stores and non-office areas
- IQ Surf LED Emergency Strip Light – LED emergency strip light for workshops, stores, non-offices
- R2L2 External LED Light – Replacement external bulkhead lights
- Area Floor Pro & Emergency – External LED lamppost lights for external areas and car parks

The equipment highlighted in this paper will be installed at occupied sites – see **Appendix B**, based on size categories listed in **Table 1** below.

Table 1: Occupied site size categorisation

Type of site	Site Size	No of sites
Large	>=2250m2	5
Medium	<=2249m2	9
Small	<=400m2	30

The list of occupied sites and net internal areas, to which this programme is applies, is outlined in **Appendix C.**

7.2 Do Nothing (Baseline)

The option of doing nothing shall expose SGN to an inability to reduce our carbon footprint as energy will continue to be consumed at current levels. The consequence of not having a pathway to net zero approach shall affect our corporate and environmental responsibility which could be damaging to our business and customers. Energy efficiency savings would still be realised on a lesser scale through our end of life capital asset replacement programme, but this would not achieve the required savings stated in our EAP plan. This option is also not in line with our customer and stakeholder environmental expectations of a high ambition target for energy efficiency initiatives.

7.3 Install new assets

Installation of BMS technology and associated controls and LED lighting with smart controls was considered as an intervention to directly reduce our carbon footprint and energy consumption. These systems will be used to monitor and control our current utility consumption of heating, cooling and lighting. It will also yield cost reductions through the indirect cost of carbon tax.

The option is also in-line with our customer and stakeholder expectations of a high ambition target in relation to our EAP goals.

A summary of new installation options considered is detailed in **Table 2** below.

Table 2: Installation options

Options	No of sites
Installation of BMS technology and associated controls and LED lighting with smart controls at large sites only	5
Installation of BMS technology and associated controls and LED lighting with smart controls at large and medium sites only	14
Installation of BMS technology and associated controls and LED lighting with smart controls at all sites – large, medium and small	44

The perceived benefits of this option is the avoided costs detailed in **Table 3** below.

Table 3: Avoided costs

Cost Area	Description	Perceived Value £m
Utility cost reduction BMS	Utility saving projections through installation of effective BMS system from Trend case studies. Projected savings at lower end at 12%.	0.429
Utility cost reduction LED	Utility cost savings based on an average wattage reduction of sampled site luminaires at 48.75% of lighting utility use. Lighting utility use projected at 23% of total site consumption, based on CIBSE Guide M.	0.401
Carbon cost reduction BMS	Cost of carbon reduction based on projected KWh reductions from BMS install. DEFRA conversion factor applied. Cost of non-traded carbon taken from CBA template – fixed time series data 2019 price.	0.049
Carbon cost reduction LED	Cost of carbon reduction based on projected KWh reductions from LED install. DEFRA conversion factor applied. Cost of non-traded carbon taken from CBA template – fixed time series data 2019 price.	0.118
Reactive Electrical Maintenance Saving (Lighting)	Cost avoidance through a conservative projection of a 20% reduction of reactive maintenance cost through re-lamping of traditional fittings verses LED.	0.037

Options that were not considered within CBA are: -

- Pre-emptively repair
- Replace on failure

7.4 Options Technical Summary Table

A technical summary of all options is detailed in **Table 4** below.

Table 4: Technical summary

Option	First Year of Spend	Final Year of Spend	Volume of Interventions	Equipment / Investment Design Life	Total Cost £m
Do Nothing - baseline	2022	2022	0	0	5.40
Installation of new assets at large sites only	2022	2022	5	16yrs	5.62
Installation of new assets at large and medium sites only	2022	2022	14	16yrs	6.15
Installation of new assets at all sites – large, medium and small	2022	2022	44	16yrs	6.88

NOTE: The total costs shown are absolute costs relative to the baseline.

7.5 Options Cost Summary Table

A cost summary table that provides a breakdown for each option is detailed in **Table 5** below. Each option has allowed for equipment, civils and engineering costs. **Table 6** provides an annual cost breakdown for GD2.

Table 5: Cost summary

Option	Cost Breakdown £m	Total Cost £m
Do Nothing - baseline	Utility spend at current levels • Large @ 3,654,707 KW/h x 16p per KW/h per annum • Medium @ 811,969 KW/h x 16p per KW/h per annum • Small @ 1,546,789 KW/h x 16p per KW/h per annum	5.40
Installation of new assets at large sites only	Installation of BMS • Large @ £49,392 per site x 5 = 0.25 LED lighting • Large @ £49 per m2 x 4496 x 3 sites = 0.66	0.91
Installation of new assets at large and medium sites only	Installation of BMS • Large @ £49,392 per site x 5 = 0.25 • Medium @ £38,696 per site x 9 = 0.35 LED lighting • Large @ £49 per m2 x 4496 x 3 sites = 0.66 • Medium @ £49 per m2 x 948 x 8 sites = 0.37	1.62
Installation of new assets at all sites – large, medium and small	Installation of BMS • Large @ £49,392 per site x 5 = 0.25 • Medium @ £38,696 per site x 9 = 0.35 • Small @ £28,000 per site x 30 = 0.84 LED lighting • Large @ £49 per m2 x 4496 x 3 sites = 0.66 • Medium @ £49 per m2 x 948 x 8 sites = 0.37 • Small @ £49 per m2 x 168 x 30 sites = 0.25	2.71

NOTE: Number of sites differs for LED lighting due to existing LED installation

Table 6: GD2 cost breakdown

Options	2021/22 £m	2022/23 £m	2023/24 £m	2024/25 £m	2025/26 £m	Total £m
Do Nothing – baseline	1.08	1.08	1.08	1.08	1.08	5.40
Installation of new assets at large sites only	0.91	-	-	-	-	0.91
Installation of new assets at large and medium sites only	1.62	-	-	-	-	1.62
Installation of new assets at all sites – large, medium and small	2.71	-	-	-	-	2.71

8 Business Case Outline and Discussion

Our energy consultants have clearly stated the need to reduce utility consumption across our property portfolio in order to facilitate the required reduction levels to achieve our EAP goals. Therefore, the do-nothing option is deemed not acceptable.

Following a number of consultative workshops facilitated by our Health, Safety and Environment team, the pathway to net zero model was produced for SGN. This model highlighted the introduction of appropriate energy management technologies as an essential requirement to achieve the meaningful reductions stated in our science-based targets and EAP.

A desktop study of energy management opportunities was carried out which reviewed a number of options taking into consideration our estate, installation viability and costs.

BMS and LED lighting technologies were deemed the most economically and technologically advantageous options. These options were then selected for further investigation.

A number of costed examples were provided for sample sites, the outputs of which were used in the cost model and **SGN Prop 004 Energy Management and Utility Reduction CBA**. The preferred option to install at large and medium sites was the most cost-efficient option that return sufficient reductions stated in our EAP.

8.1 Key Business Case Drivers Description

A summary of key business drivers for all **Build New** options are set out below in **Table 7**. **Table 8** provides a detailed summary of the CBA results.

Table 7: Key business drivers

Option	Description of Option	Key Business Case Drivers
1	Do nothing - baseline	• Accept as-is and continue to pay the utility bills for the estate • Failure to meet EAP targets
2	Installation of new assets at large sites only	• Reduced electricity and gas usage and resulting carbon footprint to meet EAP/science-based targets; • Improved work environment for staff; • Reduced maintenance requirements and resulting mileage; Improvement in our sustainability strategy and likelihood of meeting our reduction targets.
3	Installation of new assets at large and medium sites only	• Reduced electricity and gas usage and resulting carbon footprint to meet EAP/science-based targets; • Improved work environment for staff; • Reduced maintenance requirements and resulting mileage; • Improvement in our sustainability strategy and likelihood of meeting our reduction targets. • The cost of installation set against the savings in the most economically advantageous.
4	Installation of new assets at all sites –	• Reduced electricity and gas usage and resulting carbon footprint to meet EAP/science-based targets; • Improved work environment for staff;

	large, medium and small	• Reduced maintenance requirements and resulting mileage; • Improvement in our sustainability strategy and likelihood of meeting our reduction targets; • The core cost of installation for BMS far outweighs the benefits of savings on the smaller sites.

Table 8: Summary of CBA results

NPVs based on Payback Periods (absolute, £m)								
Option No.	Description of Option	Preferred Option (Y/N)	Total Forecast Expenditure £m	Total NPV £m	2030 £m	2035 £m	2040 £m	2050 £m
Baseline	Do Nothing / Do minimum	N	-5.40	-31.41	-6.96	-10.78	-14.48	-21.12
1	Option 1 Absolute NPV	N	-5.62	-29.17	-6.77	-10.17	-13.80	-19.73
2	Option 2 Absolute NPV	Y	-6.16	-29.64	-7.12	-10.45	-14.29	-20.13
3	Option 3 Absolute NPV	N	-6.88	-29.79	-7.51	-10.67	-14.77	-20.34
1	Option 1 NPV relative to Baseline	N	-5.62	-29.17	0.18	0.61	0.68	1.39
2	Option 2 NPV Relative to Baseline	Y	-6.16	-29.64	-0.16	0.33	0.19	1.00
3	Option 3 NPV Relative to Baseline	N	-6.88	-29.79	-0.56	0.11	-0.29	0.78

8.2 Business Case Summary

A summary table with the selected headline business case metrics is provided in **Table 9** to enable a high-level comparison of the options.

Table 9: Business case metrics

	Installation of new assets at large sites only	Installation of new assets at large and medium sites only	Installation of new assets at all sites – large, medium and small
GD2 Capex (£m)	0.91	1.62	2.71
Number of Interventions	5	14	44
Carbon Savings ktCO2e (GD2)	1084.2	1325.1	1783.9
Carbon Savings ktCO2e /yr	216.8	265.0	356.8
Carbon Emission Savings (35yr PV, £m)	0.00	0.00	0.0
Other Environmental Savings (35yr PV, £m)	0.60	0.73	0.99
Safety Benefits (35yr PV, £m)	0.00	0.00	0.0
Other Benefits (35yr PV, £m)	0.00	0.00	0.0
Direct Costs (35yr PV, £m)	0.98	0.36	-0.2
NPV (35yr PV, £m)	1.58	1.10	0.8
High Carbon Scenario			
Carbon Emission Savings (35yr PV, £m)	0.00	0.00	0.0
High Carbon NPV (35yr PV, £m)	1.58	1.10	0.8

9 Preferred Option Scope and Project Plan

9.1 Preferred option

The preferred GD2 option is **Build New**, installation of BMS technology and associated controls and LED lighting with smart controls at large and medium sites only. The total costs of this option is **£1.62m**.

9.2 Asset Health Spend Profile

The spend profile for GD2 is detailed in **Table 10** below. The costs are gross including efficiencies.

Table 10: GD2 spend profile

Asset Health Spend Profile						
Preferred option	2021/22 £m	2022/23 £m	2023/24 £m	2024/25 £m	2025/26 £m	Post GD2 £m
Installation of new assets at large and medium sites only	1.62	0	0	0	0	4.88

9.3 Investment Risk Discussion

The results from the CBA are detailed in **Tables 11-14** below.

Table 11: Risk Matrix

Risk Description	**Impact**	**Likelihood**	**Mitigation / Controls**
Resource availability for installs	Medium	<=20%	Use of Trend - Industry leading supplier with network of partner installers
Business Impact of LED change over	Medium	>20% & <=40%	Site installs will be undertaken as standalone projects. Stakeholder engagement and out of hours working where needed.
Failure to meet EAP targets	Medium	>80% & <=100%	Failure to undertake the preferred option will result in failure to meet stated EAP targets.

Table 12: Capex sensitivity

	Low	Mid	High
GD2 Capex (£m)	1.21	1.62	2.43
Number of Interventions	14.00	14.00	14.00
Carbon Savings ktCO2e (GD2)	1325.07	1325.07	1325.07
Carbon Savings ktCO2e /yr	265.01	265.01	265.01
Carbon Emission Savings (35yr PV, £m)	0.00	0	0.00
Other Environmental Savings (35yr PV, £m)	1.35	0.73	-2.09
Safety Benefits (35yr PV, £m)	0.00	0.00	0.00
Other Benefits (35yr PV, £m)	0.00	0.00	0.00
Direct Costs (35yr PV, £m)	3.46	0.36	-12.23
NPV (35yr PV, £m)	4.81	1.10	-14.32

Project payback has not been carried out as part of this analysis due to the effect of the Spackman approach. For a cash-flow traditional project payback period please see scenario 4 of our Capitalisation Sensitivity table.

Table 13: Sensitivity assumptions

Spend Area	Scenario	Justification
Capex	High	Assumed 50% increase in costs and materials
	Mid	No change on original baseline.
	Low	Assumed 25% decrease in costs and materials
Opex	High	Assumed 50% increase in costs and materials
	Mid	No change on original baseline.
	Low	Assumed 25% decrease in costs and materials
Environmental Cost	High	Assumed 50% increase in utility and carbon costs
	Mid	No change on original baseline.
	Low	Assumed 25% decrease in utility and carbon costs

Capitalisation Sensitivity

Consumers fund our Totex in two ways – opex is charged immediately though bills (fast money – no capitalisation) and Capex / Repex is funded by bills over 45 years (slow money – 100% capitalisation). The amount deferred over 45 years represents the capitalisation rate. Traditionally in 'project' CBA's the cashflows are shown as they are incurred (with the investment up front which essentially is a zero-capitalisation rate). Therefore, we have developed scenarios that reflect both ways of looking at the investment – from a consumer and a 'project'.

The scenarios are summarised as follows: -

- Scenario 1 - we have used the blended average of 65%, used in previous iterations of this analysis.

- Scenario 2 - we have represented the Capex and Opex blend for the two networks, as per guidance.
- Scenario 3 - addresses our concerns on capitalisation rates whereby Repex and Capex spend is deferred (100% capitalisation rate) and Opex is paid for upfront (0% capitalisation rate).
- Scenario 4 - this reflects the payback period in 'project' / cash-flow terms and provides a project payback.

We have taken a view of the NPV in each of the scenarios, with the exception of scenario 4, at the 20, 35 and 45-year points, to demonstrate the effect of Capitalisation Rate on this value.

Table 14: Capitalisation rate sensitivity results

Scenario	**1**	**2 SGN**	**3**	**4**
Capex (%)	65	41	100	0
Opex (%)	65	41	0	0
Repex (%)	100	100	100	0
Output				
NPV (20yr PV, £m)	0.23	0.27	0.18	
NPV (35yr PV, £m)	1.05	1.10	0.99	
NPV (45yr PV, £m)	1.63	1.72	1.50	
Payback	11.00	11.00	14.00	11.00

10 List of Acronyms and Reference Documentation

10.1 Acronyms

Acronym	Description
PPM	Planned preventative maintenance
RRM	Routine reactive maintenance
HVAC	Heating, ventilation, air conditioning
CIBSE	Chartered institute of building service engineers
CBA	Cost benefit analysis
BCM	Business continuity management
EAP	Environmental Action Plan
BMS	Building Management System
LED	Light Emitting Diode
LUX	Unit of measure for light levels
PIR	Passive Infrared
AC	Air Conditioning
KWh	Kilowatt Hour – unit of measure for electricity
DEFRA	Department for Environment, Food and Rural Affairs
CO2	Carbon Dioxide Emissions

10.2 Reference Documentation

Acronym	Description
CIBSE Guides (Guide M)	Management Engineering and Management
SPONS	Architects and Builders Price Book 144th Edition (2019)
SPONS	Mechanical and Electrical Services Price Book 50th Edition (2019)
RICS	BCIS Building Maintenance Price Book 39th Edition (2019)
BSRIA BG1 / 2008	Illustrated Guide to Renewable Technologies

Appendix A - Carbon Trust Emission Reductions

Summary emission reductions – location based

Emission source		2020/21	2030/31	2050/51
Shrinkage		-10.0%	-36.7%	-68.7%
Buildings		-14.5%	-56.4%	-92.6%
Light vehicles (cars)	WTW	-8.0%	-34.2%	-68.9%
Commercial vehicles (vans)	WTW	-4.8%	-16.4%	-34.1%

Appendix B - Sample Equipment

IQ®422 Controller

Overview

The IQ®422 series of intelligent controllers is designed for localised intelligent control of distributed plant. The complement of 6 universal inputs and 6 analogue voltage outputs make the product ideally suited to small-medium sized applications as well as advanced unitary control. Full compatibility with the Trend IQ® system enables the IQ®422 to integrate the local environmental needs with the main building energy management system, optimising both comfort and running costs.

Key Features

- Ethernet 10/100 Mbps main network with TCP/IP protocol
- Trend current loop LAN option
- Delivers BACnet over IP and is certified as a BACnet Building Controllers (B-BC) at revision 15.
- 3 vCNC connections
- Small footprint with DIN rail mounting
- RS232 and USB local supervisor ports
- Soft addressing
- Embedded XML Web Services as standard

Key Benefits

- **Reduced panel size**
  Trend's smallest ever physical footprint for a 6UI/6AO controller. With its small footprint and vertical connector block extraction the IQ®422 is ideally suited to confined space applications
- **Reduced installation time**
  The IQ®422 has soft configurable inputs and addressing with automatic baud rate selection. This greatly reduces engineering and commissioning time thereby reducing the cost of install
- **Superior IT integration**
  The IQ®422 has an open system support and integration option that allows integration with IT infrastructure. A new Java free style web interface facilitates the use of mobile devices, such as smartphones and tablets
- **Cost effective means of controlling small distributed applications**
  With fully programmable 6UI/6AO the IQ®422 can provide intelligent control of a wide variety of plant. Perfect for small to mid sized applications with the power to support advanced control applications including remote web supervision with graphical representation and control adjustments

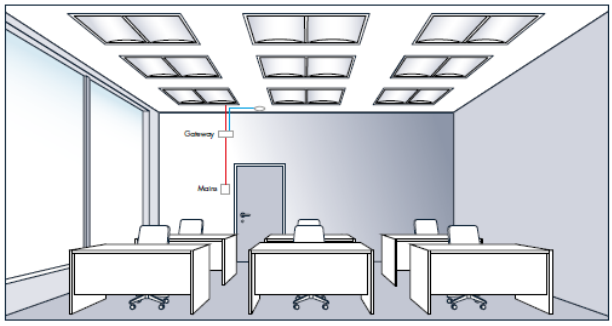
TREND

Intelligent lighting controls

As no two spaces are the same, IQ Wave offers controls which adapt to your needs.

IQ Wave offers three lighting control solutions:

Refurbishment dimming solution



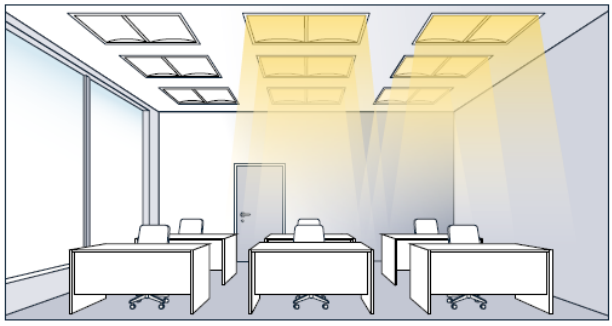
What do you need?
IQ Wave R2M + Refurbishment kit

Benefits?
- Dimming with no additional rewiring

Features:
- Dual sensor delivers presence/absence detection and active daylight dimming
- 10 luminaires per gateway
- Control via remote or sensor

Energy saving potential
Daylight dimming: 70%
Presence/absence detection: 40%

Active daylight dimming



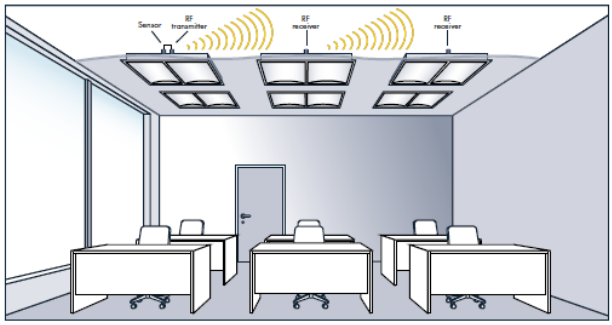
What do you need?
IQ Wave HFSX with integrated dual sensor (HFSX, see configuration guide page 15)

Benefits?
- Adjust light level according to the amount of daylight in the workspace to increase energy savings

Features:
- Active daylight dimming and presence/absence detection via integrated sensor
- 5 luminaires per group
- Control via remote

Energy saving potential
Daylight dimming: 70%
Presence/absence detection: 40%

Wireless communication



What do you need?
IQ Wave MWS RF as master luminaire, IQ Wave RF as slave luminaire (MWS RF sensor + transmitter, RF transmitter see configuration guide page 15)

Benefits?
- Flexibility in zone creation
- Easy commissioning with dip switch

Features:
- Presence/absence detection
- Up to 32 groups
- 99 products per master

Energy saving potential
Presence/absence detection: 40%
Lighting zones: 36%

Appendix C - List of occupied sites

List of Occupied Sites		
Site	**Size in m2**	**Site Size Level**
Walton Park	10,450	Large Sites
Ashford	4,038	Large Sites
Horley	3,046	Large Sites
St Mary Cray	2,513	Large Sites
Edinburgh	2,432	Large Sites
Epsom	1,956	Medium Sites
Aldershot	632	Medium Sites
Provan	2,018	Medium Sites
Paisley	1,020	Medium Sites
Glasgow	717	Medium Sites
Segensworth	795	Medium Sites
Bramshill	411	Medium Sites
Burgess Hill	553	Medium Sites
Redhill	431	Medium Sites
Dumfries	267	Small Sites
Horsham	357	Small Sites
Dunfermline	359	Small Sites
Gillingham	388	Small Sites
Oban	146	Small Sites
Thurso	144	Small Sites
Wick	143	Small Sites
Reading	144	Small Sites
Stornoway	93	Small Sites
Inverness	131	Small Sites
Basingstoke	102	Small Sites
Bexhill	31	Small Sites
Campbeltown	353	Small Sites
Galashiels	172	Small Sites
Incholm	171	Small Sites
Kilmarnock	375	Small Sites
Broadstairs	256	Small Sites
Braishfield	45	Small Sites
Milton Keynes	179	Small Sites
Whyteleaf	124	Small Sites
Croydon TN	63	Small Sites

Chichester	31	Small Sites
Dorking	90	Small Sites
Kennington DI	72	Small Sites
Farningham	130	Small Sites
Hardwick	51	Small Sites
Marsh Gibbon	53	Small Sites
Coatbridge	399	Small Sites
Shorne	108	Small Sites
Tatsfield	70	Small Sites

Appendix D - Occupied Site Utility Data 2018/19

S00845650190009083446 3	Large	Southern	2 LEESONS HILL, ORPINGTON KENT, BR5 2TN	38,811	54,219	31,118	33,705	80	0	0	0	0	0	0	588	158521
S00845009120001019958 1	Small	Southern	270 KENNINGTON LANE, THE OVAL KENNINGTON, LONDON, SE11 5SG	8,328	7,182	6,261	5,894	6,334	6,190	9,506	11,153	11,291	12,923	9,890	9,509	104461
S00845501180003534358 8	Large	Scotland	313 BLOCHAIRN RD, GLASGOW, G21 2RX	27,694	24,030	21,301	20,786	23,218	23,736	24,919	25,971	29,860	34,064	28,446	31,170	315195
S00845500171200295284 7	Small	Scotland	33 HARBOUR RD, INVERNESS, IV1 1UA	2,138	1,685	825	581	600	455	402	1,144	4,745	3,944	3,634	3,175	23328
S00845453200002736799 8	Small	Southern	4,5 & 6 SITE, KENAVON DRIVE, READING, RG6 1AZ	3,049	1,636	1,023	804	1,051	2,454	3,693	5,022	5,985	6,414	5,870	5,247	42248
S00845500180003530593 6	Medium	Scotland	95 KILBIRNIE STREET, GLASGOW, G5 8JD	24,205	25,147	23,975	24,916	25,461	24,492	27,361	25,305	23,800	24,850	23,835	25,739	299086
S00845550190002842885 0	Medium	Southern	COMPRESSOR STATION, HOOLEY LANE, REDHILL, RH1 6DG	2,910	608	329	1,058	2,258	2,429	3,694	-1,772	0	0	0	0	11514
S01801001116000001694 12	Small	Southern	COMPUND UNIT 1, GALLEY FARM, A5/A6 BLETCHLEY, MILTON KEYNES, MK1 1AA	0	0	1,501	0	0	1,776	0	0	1,158	0	0	1,756	6191
S03801127200001765585 0	Small	Southern	DANESHILL INDUSTRIAL ESTATE, ARMSTRONG RD, BASINGSTOKE HAMPSHIRE, RG24 8NU	0	0	4,253	99	0	7,119	0	0	4,698	0	0	25,399	41568
S03801127200005414034 3	Large	Southern	EX DE LA RUE BUILDING, WALTON RD, PORTSMOUTH, PO6 1TJ	0	1,516	0	1,334	0	0	1,500	0	0	1,533	0	0	5883
S00845550190000542454 8	Small	Southern	FACTORY LANE HOLDER STATION, CROYDON, CR0 3RL	4,390	2,662	1,740	1,472	1,662	2,324	3,740	5,177	5,969	6,952	5,596	5,466	47150
S00845500180005060836 0	Small	Scotland	GALAFOOT, GALASHIELS SELKIRKSHIRE, TD1 3HH	2,892	1,823	926	981	1,170	1,216	1,801	3,338	5,582	4,911	4,229	4,025	32894
S00845550190007062364 0	Small	Southern	GAS HOLDER STATION, STATION RD, DORKING SURREY, RH4 1HJ	1,133	579	244	337	289	383	884	1,252	1,840	2,721	2,836	2,868	15366
S00845500170005229704 1	Small	Scotland	GAS PLANT, LOCHAVULLIN INDUSTRIAL ESTATE, OBAN ARGYLL, PA34 4PL	4,635	3,729	3,267	3,430	3,885	3,575	5,203	5,801	6,267	6,072	5,091	5,247	56202
S00845550190009142288 0	Small	Southern	GILLINGHAM HOLDER STATION, PIER RD, GILLINGHAM KENT, ME7 1TZ	8,218	4,808	3,903	4,245	4,453	4,583	7,391	10,160	11,516	14,134	10,420	9,172	93003
S03801127200001846711 7	Small	Southern	HOLDER STATION, TERMINUS RD, CHICHESTER WEST SUSSEX, PO19 8TX	18,365	0	0	296	0	0	1,549	0	1,434	0	0	0	21644
S00845500180006061050 6	Large	Scotland	INCHCOLM HOUSE, 11 WEST SHORE RD, EDINBURGH, EH5 1RH	3,645	2,865	2,317	2,954	2,487	2,323	2,985	4,398	5,721	6,261	5,544	5,124	46624
S00845453200005452586 5	Large	Southern	INTAKE 1 DEPOT, WALTON RD, FARLINGTON, PORTSMOUTH, PO6 1TJ	45,558	44,843	45,816	51,399	49,624	45,763	49,958	48,966	50,315	57,151	47,810	50,377	587580
S00845453200005452592 6	Large	Southern	INTAKE 2 DEPOT, WALTON RD, FARLINGTON, PORTSMOUTH, PO6 1TJ	78,495	76,246	73,637	82,428	78,435	72,849	81,593	80,658	84,617	93,914	80,888	91,494	975254
S00845500180006078830 4	Medium	Scotland	LINWOOD, PAISLEY,RENFREWSHIRE,PA3 3BW	13,893	11,755	10,827	9,468	10,379	10,440	12,869	14,200	16,200	17,485	14,868	15,331	157715
S04639351171251648 1 250	Small	Scotland	LIQUIFIED NAT GAS PLANT, JANETSTOWN, THURSO CAITHNESS, KW14 7XF	0	4,768	4,165	3,887	3,970	4,237	4,090	5,007	5,542	7,056	7,870	7,897	58489
S00845500171248124 2 106	Small	Scotland	LIQUIFIELD NAT GAS PLANT, MILTON, WICK CAITHNESS, KW1 5SR (KW1 5XY)	4,833	4,713	4,017	3,776	3,527	4,366	5,690	6,005	7,523	6,860	5,418	5,406	62134
S00845500171279382600 0	Small	Scotland	NEW GAS PLANT, SANDWICK RD, STORNOWAY ISLE OF LEWIS, HS1 2SL	5,673	5,274	4,599	4,831	4,886	4,700	6,363	7,675	8,822	9,532	7,448	7,872	77675
S00845400200002741139 8	Medium	Southern	North Cloase, Aldershot Hampshire, Gu12 4DF	0	0	0	0	0	0	0	0	0	0	0	0	0
S00845453200002741139 8	Medium	Southern	NORTH CLOSE, ALDERSHOT, GU12 4DF	10,425	8,974	7,975	8,271	7,908	7,770	9,225	12,437	13,535	14,569	18,254	18,065	137408
S00845550190007080039 0	Small	Southern	OFFICES GASHOLDER STATION, BLATCHFORD RD, HORSHAM WEST SUSSEX, RH13 5QR	3,888	3,768	3,468	3,908	3,935	3,471	3,982	3,894	3,858	4,563	3,770	3,989	46494
S00845500180006028922 7	Large	Scotland	PLOT 10, AXIS BUSINESS CENTRE, NEWBRIDGE, EDINBURGH, EH28 8SP	36,371	37,273	40,464	37,281	36,810	33,982	37,792	39,979	43,127	46,042	39,816	40,725	469662
S00845550190002742693 1	Large	Southern	SGN DEPOT, UNIT 7, WOTTON RD, ASHFORD KENT, TN23 6JS	19,364	18,142	16,285	20,432	19,705	16,946	18,040	19,032	21,975	27,433	23,650	22,125	243129
S03801150170005147123 0	Small	Scotland	SGN Ltd UNIT 3, 22B LONGMAN DRIVE, INVERNESS, IV1 1SU	0	0	3,231	0	0	2,449	0	0	3,077	0	0	10,604	19361
S03801202180002945809 0	Small	Scotland	SGN PORTACABIN, NR TINWALD DOWNS RD, DOWNSWAY IND EST HEATHHALL, DUMFRIES, DG1 3QL	21,977	0	0	11,806	0	4,513	0	0	11,906	0	0	23,716	73918
S00845550190007068566 5	Small	Southern	SGN TATSFIELD AGI, BEDDLESTEAD LANE, TATSFIELD, WESTERHAM KENT, TN16 2AZ	16,693	10,351	2,869	2,038	2,360	3,430	9,851	25,116	30,624	32,132	28,530	29,399	193393
S06845550190007068566 5	Small	Southern	SGN TATSFIELD AGI, BEDDLESTEAD LANE, TATSFIELD, WESTERHAM KENT, TN16 2AZ	0	0	0	0	0	0	0	0	0	0	0	0	0
S04815120190002413899 0	Small	Southern	SGN THE OLD CLAY PI, LOWER HIGHAM RD, SHORNE, GRAVESEND KENT, DA12 3DP	0	1,401	0	627	741	0	0	1,384	0	0	0	0	4153
S00845550190009166718 3	Small	Southern	SGN THE OLD CLAY PI, LOWER HIGHAM RD, SHORNE, GRAVESEND KENT, DA12 3DP	0	0	0	0	0	0	0	0	4,537	0	4,599	0	9136.1
S03801201180003512150 9	Small	Scotland	SGN, BURNBANK STREET, COATBRIDGE LANARKSHIRE, ML5 2AY	68,760	0	0	28,537	0	0	25,403	0	0	24,099	0	0	146799
S00845500180003523870 3	Small	Scotland	SGN, BURNSIDE STREET, KILMARNOCK AYRSHIRE, KA1 4EU	6,528	2,965	2,156	1,093	1,003	811	2,093	2,731	3,668	3,931	4,402	5,038	36419
S03801320190002032614 0	Small	Southern	SGN, GLYNE GAP, HASTINGS RD, BEXHILL-ON-SEA EAST SUSSEX, TN40 2PU	0	758	0	206	428	0	0	750	0	0	700	0	2842
S03801201180005361661 0	Small	Scotland	SGN, GRANGE RD, DUNFERMLINE FIFE, KY11 3DG	0	4,589	3,570	546	0	2,846	0	0	3,423	0	0	4,044	19018
S05801400180003521615 1	Small	Scotland	SGN, GRANGE RD, DUNFERMLINE FIFE, KY11 3DG	0	0	0	0	0	0	0	0	0	0	0	0	0
S00845280180003521615 1	Small	Scotland	SGN, GRANGE RD, DUNFERMLINE FIFE, KY11 3DG	144	148	144	148	148	144	149	144	148	148	134	148	1747
S00845500180005430146 6	Small	Scotland	SGN, GRANGE RD, DUNFERMLINE FIFE, KY11 3DG	4,025	3,126	3,195	2,808	3,089	2,953	3,722	4,283	5,134	5,496	4,011	4,252	46094
S00845550190001242804 0	Large	Southern	ST LAWRENCE HOUSE, STATION RD, HORLEY SURREY, RH6 9HJ	68,126	70,351	72,104	78,718	71,360	63,282	65,948	66,982	67,153	74,294	63,174	68,572	830064
S00845453200005459531 0	Small	Southern	THE GAS INSTALLATION, BUNNEY LANE, BRAISHFIELD, ROMSEY HAMPSHIRE, SO51 0PG	20,425	15,726	13,222	13,602	14,846	13,711	16,875	19,520	22,264	25,437	24,439	23,825	223892
S03801320190006105626 0	Large	Southern	TRANSCO N/S NO 2, LESSONS HILL, ORPINGTON KENT, BR5 2TN	0	0	0	2,829	15,022	0	0	2,307	0	0	0	2,637	22795
S03801127200001399534 3	Medium	Southern	UN R14, 6 BRUNEL WAY, FAREHAM HAMPSHIRE, PO15 5TX	21,845	0	0	17,796	0	0	10,701	0	0	16,863	0	0	67205
S03801320190007034355 0	Small	Southern	UNIT 20 LAMBS BUSINESS PARK, TILBURSTOW HILL RD, SOUTH GODSTONE, GODSTONE SURREY, RH9 8LJ	952	0	266	10,759	-10,109	236	301	0	519	472	1,041	1,711	6148
S03802320190007034356 9	Small	Southern	UNIT 21 LAMBS BUSINESS PARK, TILBURSTOW HILL RD, SOUTH GODSTONE, GODSTONE SURREY, RH9 8LJ	676	0	497	7,952	-6,526	457	534	0	628	869	924	1,896	7907
S00845550190009148207 2	Medium	Southern	UNIT 21D, ROY RICHMOND WAY, EPSOM, SURREY, KT19 9BA	7,464	7,678	7,387	8,550	8,607	8,254	9,044	8,480	8,176	9,311	8,299	8,624	99874
S00845550190004538441 5	Medium	Southern	Unit 4, Albert Drive, Burgess Hill, RH15 9YZ	3,092	2,992	2,863	2,946	3,076	2,944	3,462	3,783	3,473	4,042	3,303	3,191	39167
S00845550190004600059 7	Small	Southern	WHYTELEAFE HOLDER STATION RD, GODSTONE RD, WHYTELEAFE SURREY, CR3 0EG	1,999	1,403	1,218	1,306	1,076	965	1,691	2,525	2,711	2,740	2,195	2,018	21847
S03801320190009165815 1	Small	Southern	Unit 1, 7 Lysander Close, Pysons Road Industrial Estate, Broadstairs Kent CT10 2YJ	0	0	0	0	400	0	1,650	0	0	0	3,218	0	5268
Total kWh Large				**318,064**	**329,485**	**303,042**	**331,866**	**296,741**	**258,881**	**282,735**	**288,293**	**302,768**	**340,692**	**289,328**	**312,812**	**3,654,707**
Total kWh Medium				**83,834**	**57,154**	**53,356**	**73,005**	**57,689**	**56,329**	**76,356**	**62,433**	**65,184**	**87,120**	**68,559**	**70,950**	**811,969**
Total kWh Small				**209,721**	**83,094**	**70,560**	**115,969**	**43,218**	**79,364**	**116,563**	**122,081**	**174,869**	**181,406**	**146,265**	**203,679**	**1,546,789**
Total kWh				**611,619**	**469,733**	**426,958**	**520,840**	**397,648**	**394,574**	**475,654**	**472,807**	**542,821**	**609,218**	**504,152**	**587,441**	**6,013,465**