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LondonEnergy Energy Centre Condition Survey

RAMBOLL

NLWA

LondonEnergy Energy Centre Condition Survey

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List of Abbreviations

AHU	Air Handling Unit
APC	Air Pollution Control
ATEX	Atmospheres Explosives (Derived from a French standard)
BAT	Best Available Technique
BAT-AEL	BAT-associated emission level
BREF	BAT Reference Document
BS	British Standard
C&I	Commercial & Industrial
CAPEX	Capital Expenditure
CFD	Computational Fluid Dynamics
CV	Calorific Value
CW	Chilled Water
DCS	Distributed Control System
DEFRA	Department for Environment, Food and Rural Affairs
DSEAR	Dangerous Substances and Explosive Atmospheres
DSCC	Dynamic Sensing Combustion System
DX	Direct Expansion
EA	Environment Agency
EfW	Energy from Waste
ELV	Emission Limit Value
EPP	Environmental Permitting Programme
ESP	Electro Static Precipitator
ETP	Effluent Treatment Plant
FGT	Flue Gas Treatment
FPP	Fuel Preparation Plant
FTIR	Fourier Transform Infra Red
HP	High Pressure
HV	High Voltage
IBA	Incinerator Bottom Ash
ID	Induced Draught
IED	Industrial Emissions Directive (2010/75/EC)
IPPC	Integrated Pollution Prevention & Control
LEL	LondonEnergy Limited
LP	Low Pressure
LTHW	Low Temperature Hot Water
MCB	Miniature Circuit Breaker
MCC	Motor Control Centre

MSW	Municipal Solid Waste
NDT	Non Destructive Testing
NLWA	North London Waste Authority
Nm^3	Normal cubic meters (at standard temp. and pressure)
O&M	Operation & Maintenance
OPEX	Operational Expenditure
P&ID	Process & Instrumentation Diagram
PAC	Pulverized Activated Carbon
PCB	Poly Chlorinated Biphenyl
PCDD/F	Poly Chlorinated Dibenzo Dioxins/Furans
PE	Poly Ethylene
PET	Poly Ethylene Terephthalate
PFA	Per Fluoro Alkoxy
PLC	Programable Logic Controller
PP	Poly Propylene
PS	Poly Styren
PTFE	Poly Tetra Fluoro Ethylene
PVC	Poly Vinyl Chloride
QAL	Quality Assurance Level (acc. EN14181)
RDF	Refuse Derived Fuel
SCADA	Supervisory Control and Data Acquisition
SCR	Selective Catalytic Reduction (of NO_x using NH_3)
SiC90	Silicon Carbide (90% content)
SNCR	Selective Non Catalytic Reduction (of NO_x using NH_3 or urea/carbamin)
T/A	Turbine Alternator
TEQ	Toxicity equivalents
TG	Turbine Generator
TOC	Total Organic Carbon
UPS	Uninterruptible Power Supply
VOC	Volatile Organic Carbon
WID	Waste Incineration Directive (2000/76)

0 Executive Summary

This technical report details the findings from the London Energy Limited (LEL) Energy from Waste (EfW) facility condition survey by a team of Ramboll EfW specialists. [redacted] The report outlines the EfW plant conditions and identifies risk and investment requirements to operate the plant through to 2025. The EfW plant commenced operations in the early 1970s. By 2025 the plant will be about 55 years old. This is beyond the typical mechanical and electrical design life of 25 years and typical civil design life of 50 years for an EfW plant.

Ramboll's survey included condition questionnaires, interviews with LEL staff, visual inspections of plant and review of historic information.

LEL provided good support to the study.

The plant was found to be well operated and generally well maintained for its age. LEL is in the process of undertaking works and investments to support operations to 2025, drawing on a number of Ramboll recommendations from [redacted].

EfW plant operations beyond 2025 is outside the scope of this condition survey report. [redacted]

The following presents a summary of the general plant assessment scope of investments/works for plant operations to 2025.

0.1 General plant assessment

This section provides a summary of conclusions on the following main areas of Ramboll's assessment:

- Waste processing
  - Waste reception and handling
  - Furnace/combustion systems
  - Boiler
  - Bottom ash, fly ash and riddlings
- Flue Gas Treatment
- Turbine/Generator/Cooling Water Plant
- Civils/structures
- Electrical
- Distributed Control Systems (DCS)
- Regulatory aspects

0.1.1 Waste Processing

Waste reception and handling

Logistics regarding weighbridges, access ramps and unloading area are considered to be good.

Dust and odour control from the bunker is considered satisfactory. No complaints have been registered from neighbours or the Environment Agency (EA).

Waste mixing is important for EfW operations because it supports the creation of a homogeneous fuel aiding more efficient and consistent plant operations. This is in terms of energy supply into the furnace for energy recovery and flue gas treatment plant operations from an emissions and consumable use perspective.

LEL's plant comprises [redacted] separate bunkers. Modern EfW plants with two or more lines tend to have single bunkers that serve all plant lines. The division of LEL's bunker into [redacted] sections makes it more difficult to ensure good waste mixing. However, waste mixing is not currently a significant issue for LEL due to the following:

- relatively large size and depths of each bunker section enables natural waste mixing
- waste/bunker management initiative have been implemented (i.e. problematic waste is distributed evenly between the [redacted] bunker sections)
- deliveries are mainly household waste, thus relatively homogeneous,
- LEL's vast experience and knowhow in its waste reception and management practices.

Waste mixing may be a challenge if significant amounts of Commercial and Industrial (C&I) waste is processed and greater mixing is required. LEL's bunker dividing walls are [redacted]. These walls cannot easily be altered to form a single bunker to enhance waste mixing.

High levels wear to waste crane grabs, wire and cables appears to have been solved with a corresponding increase in the reliability of cranes in recent years. Work has included [redacted].

LEL's waste cranes have been [redacted] operated until recently. LEL is upgrading the three waste cranes to [redacted] operation. This is expected to be completed during [redacted].

Furnace/combustion systems

Major refurbishment works were carried out on the furnaces and combustion systems on LEL's all [redacted] waste combustion units in [redacted]. This formed part of the WID upgrade and improved a vital part of the EfW facility.

The Edmonton EfW plant is equipped with roller grates. Majority of new EfW facilities are equipped with moving grate technology. Moving grates facilitate an even distribution of waste and results in combustion with better air flow distribution. The relatively low calorific value waste processed at Edmonton minimises some of the disadvantages associated with the roller grate system.

LEL achieved significant improvements to the combustion systems through the WID upgrade. The most important of those being:

- Significant reduction of CO-emissions and establishment of NOx reduction by SNCR. No melted metal deposits in riddling hoppers and riddling conveyers due to improvements to primary air system and the grate.
- Reduced jamming of the roller grates by installing a new type of grate bar.
- Improved burn out of bottom ash, but with a high moisture content introduction.

The installation and operation of the [redacted] tiles has so far required a moderate but manageable replacement. LEL intends to keep on using the [redacted] tile system based on the experience to date.

Boilers

The design of the LEL boilers is not ideal. The primary fault in boiler design is that the radiation pass is too small, causing two major problems:

- Non-conformity with the WID/IED retention time demand of 850°C/2s. However, LEL has achieved a derogation for the [redacted] requirement; and
- A very limited superheater lifetime of approximately [redacted] compared to a normal super heater lifetime of [redacted] years on new plants with similar steam parameters.

LEL has over the years carried out extensive optimisations to reach these approx. [redacted] life time of black steel super heaters. To try to further optimise the life time of the super heaters, LEL has, over a period of time, carried out test with [redacted] cladded super heater tube sections and installed complete set of [redacted] cladded super heater sections on all [redacted] boilers.

Having gained significant operational experience with [redacted] cladded super heaters, LEL assess that, based on an overall CAPEX/OPEX optimisation, that the black steel super heater configuration is preferred as compared to [redacted]. This is based on a number of different factors:

- [redacted] super heaters has revealed some problems in relation to various areas of the Inconel cladded super heater sections experiencing significant corrosion rates (caused by the very high flue gas temperatures).
- Replacement works on [redacted] super heater tubes take approx. [redacted] times longer compared to ordinary black steel tubes.
- Successful trials of improving the de-super heating control keeps a more stable steam temperature at inlet to the super heater sections which is expected to increase life time of black steel super heaters (LEL expect that [redacted] life time of black steel super heaters is possible)

Ramboll concurs with LEL's decision to switch back to black steel super heater sections, given that the detailed CAPEX/OPEX evaluation shows that black steel super heater sections are the most optimal choice. It is noted that the expected increase from [redacted] weeks life time of black steel super heaters, due to the recent improvements of de-super heating controls, will allow more flexibility in the planning of the boiler outages for black steel super heater sections as compared to how it has been historically. The lack of flexibility in the planning of boiler outages was one of the important advantages for changing to [redacted]

Ramboll would normally recommend the following design principles for EfW plant boiler design:

- Horizontal convection passes, which allow for the installation of pneumatic rapping devices. These are a much more efficient cleaning method than LEL's current online soot blowing method. As a result, horizontal convection passes experience very limited levels of blockages, thus increasing operational availability. The Edmonton EfW plant comprises vertical passes.
- Installation of a protective evaporator in front of superheaters to protect the superheater against high flue gas temperatures, which induces high temperature corrosion.
- Three vertical radiation passes to decrease flue gas temperature below [redacted] prior to entering the protective evaporator/superheater. Furthermore, a [redacted] turn in

the flue gas path between [redacted] pass provides an effective separation of coarse boiler ash. This reduces the dust load on the convection pass.

Changing the existing LEL boilers to match the above principles would require major investment. This would include altering civils/structures to make space for the new boilers. Furthermore, extensive plant outages would be required and, due to the need to increase the boiler height, planning consent would be required to implement the change.

Ramboll's evaluation of continued EfW plant operations retains the existing boilers.

Bottom Ash, Fly ash and Riddlings

After the WID upgrade LEL experienced problems with blockages in riddling conveyors. This was resolved by installing screen bars at the outlet of the riddling conveyor on all [redacted].

Extensive blockage problems experienced due to white metal deposits in riddling hoppers and conveyers has not occurred since the WID upgrade over [redacted] years ago.

LEL has bottom ash chain conveyers installed. This system results in too much moisture in bottom ash. Ramboll normally recommends the installation of bottom ash pushers. Systems comprising these do not present bottom ash moisture content problems. However, notable space requirements for bottom ash pushers make them unsuitable for installation at the Edmonton EfW plant.

Problems with the bottom ash conveying system occurred after the WID upgrade are most likely due to a better burn out and finer material in the bottom ash. The high moisture content in the bottom ash has on occasions resulted in the rejection of up to [redacted]% of the bottom ash at [redacted]. Problems appear to have been resolved by a number of initiatives. Only a minimal amount of bottom ash is now rejected by [redacted].

The solution to LEL's moisture problem in bottom ash includes a great deal of manual labour. Bottom ash is taken out in the cellar and later reloaded onto the rubber band conveyer. Subsequent needs to clean the cellar is also a relatively labour intensive operation.

0.1.2 Turbine/condenser/cooling water system

LEL's plant comprises [redacted] steam turbine generators dating back to start of operations in 1970. The plant also has a new house set steam turbine generators installed in 2015 to [redacted].

LEL is in the process of the procurement of a new house set of a larger capacity, rated at [redacted] kW. The new house set, which is also a [redacted], is expected to increase plant flexibility and its ability to realise higher annual waste processing levels.

The new house set is rated at a steam parameter of [redacted] That is somehow lower that the live steam temperatures the plant is currently operating. Ramboll advises LEL to confirm with [redacted] continuously operating at such conditions will not increase risk of damage and is does not limit the design lifetime of the equipment at critical levels.

[redacted].

Following the above event, online shaft vibration monitoring devices will be installed on al[redacted] during their survey periods.

LEL's steam turbine generators are serviced every [redacted] years. This is in line with/betters good steam turbine maintenance practice. Provided that LEL's comprehensive steam turbine maintenance and repair sequence is upheld, the turbines can support operations through to 2025.

LEL's steam turbines are operating at temperatures considerably below creep damage levels, usually [redacted]°C and above, and their risk of low cycle fatigue is considered to be low, based on the average annual start-ups. However, the machines have been on duty for almost twice their design lifetime. Ramboll recommends a remaining lifetime study of steam turbines to support more informed residual plant lifetime and investment planning.

In addition, whilst replications test conducted at the rotor in [redacted] did not reveal evidence of creep damage, Ramboll recommends expanding replications tests to include nozzle arrangements.

Frequent replacement of superheaters on the facility caused particle flows to the turbine, thus causing blade damage. Cyclone separators have been purchased and installed on all live steam lines upstream of the [redacted] turbines. No particle related turbine damage has not been observed since cyclones installation.

LEL acquired a full set of steam range isolation valves [redacted] in [redacted]. These were installed during a planned outage in[redacted].

LEL's steam headers regularly undergo Non Destructive Testing (NDT), typically between every [redacted] years. NDT tests in recent years have not revealed any significant problems. LEL's steam system operates at around [redacted]°C. This is significantly lower than the design temperature of [redacted] °C. Therefore, the risk for creep damage from thermal stresses is low.

In 2013 condensers started to show signs of fatigue and LEL experienced a number of condenser tube leaks. LEL has retubed all [redacted] condensers. This work was completed by the end [redacted]. Plant condensers are inspected every time turbines are out for an overhaul. The risk of any damage/outage attributed to condensers for operations to [redacted].

The EfW plant has a wet cooling plant comprising [redacted] cells in place to serve steam turbine cooling requirements. The wet cooling plant has been upgraded over the recent years with:

- [redacted]

The main cooling ring pipes are lined with rubber, internally and externally coated with Bitumen. This lining appears to be missing in several places. The main cooling water actuators and all piping on the cold side have been recently replaced. Hot side piping replacement is due [redacted]. Furthermore, additional sectional on the cooling circuit were installed in [redacted]. Standard maintenance is considered only necessary for the remaining plant lifetime.

The feed water system comprises [redacted] pumps on a main ring, [redacted] each boiler and [redacted] reserve. The [redacted] feedwater pumps have been replaced in [redacted] an the remaining are due to replacement during this year outage. Minimal maintenance will be required for plant operation to 2025.

0.1.3 Flue Gas Treatment (FGT)

The process combination of the FGT plant is in accordance with the EU BAT reference note (BREF). The operating status is judged as good with awareness of consumption rates of lime and Pulverised Activated Carbon (PAC).

The state of the FGT plant is generally reasonable. Systematic maintenance compensates for its outdoors location, and insufficient supports of reactors have been repaired. Some occurrences of corrosion on towers have been mended.

Given the observed corrosion, the quench towers, reactors and the supporting steelwork are now systematically inspected for corrosion and repaired before failure occurs. We recommend that this approach is maintained. The condition of the towers is continuing to deteriorate and on-going repair and maintenance is required.

LEL has installed new emissions monitoring equipment in [redacted]. This comprises [redacted] sets for each stack to provide redundancy for flue gas analysers. Installation of new emissions monitoring equipment will assist in avoiding outages.

LEL have also fitted monitors for Hydrogen Chloride (HCl) and Sulphur Dioxide (SO_2) at the FGT inlets to provide a feed forward to the lime dosing system. This helps avoid exceedances of HCl and SO_2.

0.1.4 Electrical

The electrical installation at LEL's plant is a mixture of original equipment, new equipment, and partially retrofitted equipment. The equipment is generally well maintained and comprises equipment from the 33/11kV export transformers connected to the UKPN distribution system down to DC and UPS equipment for essential and emergency supplies.

Most transformers within the plant are the [redacted] type. The [redacted] transformers are the subject of ongoing testing by an external organisation to determine the condition and estimated remaining lifespan. Transformers T1 [redacted] and A4 [redacted] have an estimated remaining lifespan of [redacted] years. Both transformers were manufactured in 1968. The remainder of the transformers have a minimum expected lifespan of [redacted] years. If those transformers follow the expected trend, this should enable operation of those units to 2025.

The main 11 kV switchboard is double busbar compound insulated with oil circuit breakers and comprises [redacted] circuits, it is now over 50 years old. LEL has signed a contract with [redacted] for the manufacture of a new 11 kV switchboard comprising [redacted].

The 3.3 kV switchgear is single busbar air insulated with air circuit breakers, also over [redacted] years old. LEL has signed a contract with [redacted] for the manufacture of [redacted] new 3.3 kV switchboards.

The low voltage switchgear including motor control centres is a mixture of original equipment and replacement equipment. The [redacted] main low voltage switchboards are located [redacted]. From an outward perspective, both switchboards are in good condition considering their age.

The cabling around the plant is neat and does not show any signs of being affected by installation work that may have taken place since the plant was built.

If any of the aforementioned transformers or low voltage switchgear was to be replaced, it would inevitably impact on the cables connected to the equipment.

0.1.5 Control and Instrumentation systems

The plant control and monitoring systems at LEL consist of a mix of equipment which have been installed and updated over the life of the plant. The main point of control and supervision is via a mix of operator workstations, control desks and control panels located in the central control room.

A [redacted] distributed control system (DCS) system is installed and is the main point of control and monitoring for the process plant. The [redacted] DCS network has a decentralised redundant structure/architecture with a number of control processors spread throughout the plant with operator workstations located in the central control room desk.

The boiler and its auxiliaries were migrated between [redacted] to the [redacted] DCS with control and supervision provided via the operator workstations located on the central control room desk. A number of boiler auxiliary package control system have local panels based on PLC's which are located within the boiler house, firing aisle and throughout the plant.

The [redacted] main turbine alternators (TA) control and supervision systems are PLC based and independent of the DCS with status and alarms transmitted to the DCS. The turbine control panels containing the governor and TA supervisory equipment are in the turbine hall next to each turbine alternator set.

Work is currently in progress on the migrating of the Effluent Treatment Plant (EFP) control and supervision to the DCS, this work is expected to be completed during [redacted].

The Fuel Gas Treatment (FGT) plant control and supervision is based on [redacted] PLC's which is networked to the DCS.

In general plant control systems have redundant power supplies or UPS systems.

Control panels are provided in the central control room for the remote operation of the 11kV and 3.3kV systems these will become obsolete and will be removed once new switchgear is installed in 2020.

In general control and instrumentation system equipment and installations are regularly inspected and replaced as condition dictates or on component failure.

0.1.6 Civils/structures

We observed no significant structural defects and saw no signs to suggest that any parts of the buildings are suffering significant structural distress.

Generally, structures are in a reasonable condition and significant repairs have recently been carried out.

There is some flaking of paintwork in some internal plant areas, but where areas are kept dry this will not lead to significant steelwork corrosion. There are areas where surface corrosion is occurring in damper environments such as the basement, the Flue Gas area and also to the Bottom Ash conveyor structure and the paintwork to these areas will require regular maintenance to prolong the life of the steel structures.

EfW plant cladding is generally showing signs of surface corrosion at numerous locations and there has been some mechanical damage. Cladding will require regular maintenance and repair to keep the buildings watertight.

Minor damage has been noted to concrete structures within the building. The side walls to the waste bunker chutes will require repair. The side walls to the basement walls and concrete floor slabs show some minor damage due to shrinkage but this is not considered to be significant. There is also some of the walls to the ash storage areas which will require repair to avoid long term damage.

The external roadways are showings signs of wear and will require maintenance. The surfacing to the ramps at the location of the joints will require repair to avoid water penetrating the ramp structure.

0.1.7 Quality Management Systems

LEL is certified according to the following standards:

- ISO 9001
- Environmental Management System 14001
- HMS 18001

LEL has systematic maintenance programmes. A print out of the task list describing all preventive maintenance activities is available at LEL. This comprehensive list includes the following information for each activity:

- short description of activity,
- the standard frequency with which each activity is to be carried out,
- number of person required for each activity,
- duration of activity etc.

Ramboll considers it important to apply such database systems in the operation and maintenance of an EfW facility. Generation of work orders from the database and keeping track of the operating history of each subcomponent/subsystem makes preventive maintenance more efficient.

0.1.8 Regulatory Aspects

Combustion related regulatory requirements- MSW treatment

Overall, considering the future regulatory matters and provided the combustion equipment, its controls and management continue to deliver emission levels for combustion related parameters that are compliant with the IED and the permit, Ramboll is of the view that:

- In the short-medium term the probability of the Environment Agency (EA) rescinding the WID derogation is [redacted]. Despite the [redacted] probability of more stringent standards arising within a period of [redacted] to 2025, it is hard to estimate whether the regulatory position will change. Therefore, in the light of a new BAT reference note being published soon, in the medium to long term, and taking into account that many large installations in urban environments already achieve emissions well below the IED emission limit values (ELVs), there is a risk that some additional expenditure may be required. This primary relates to:
  - Reducing NOx emission to limits in the order of [redacted] mg/Nm^3. The probability of this is estimated to be high.
  - Reducing NOx emissions even further, hence requiring installation of Selective Catalytic Reduction (SCR). Installation of SCR units would be costly and complicated due to severe physical site restrictions. It is assumed that the EA would take this into account and we estimate that the probability of the EA requiring SCR installation before 2025 as [redacted].

- The need to further investigate primary means of optimising combustion to further limit CO excursions. It is estimated that there is [redacted] probability of the investigations being required, with the likelihood that the findings will result in relatively minor process optimisation rather than capital expenditure.
- Examination of start-up and shut down emissions, and associated operation protocols. LEL has produced a definition of start-up and shutdowns both in normal and emergency conditions as part of its Permit conditions. This clearly identifies when the plant is in [redacted] condition. This defines whether incidences of exceedances are reportable and on the Public Register.
- Pneumatic transport of [redacted] [redacted] [redacted] pass boiler ash to the APC silos. The probability of this is estimated to be [redacted].
- Expenditure to comply with Atmospheres Explosives (Derived from a French standard) (ATEX)/Dangerous Substances and Explosive Atmospheres (DSEAR) regulations. A risk assessment has been carried out to assess compliance and estimate the cost of any remedial work. This has concluded that only minimal remedial works are required.

FGT related regulatory requirements – MSW treatment

Overall, and considering the future regulatory matters, it is considered that:

- With emissions being low and generally compliant with the environmental permit, in the short to medium term the EA is less likely to impose any changes to the permit that will give rise to significant expenditure.
- In the longer term there is a risk of some tightening of ELVs. As noted above, [redacted] is considered the main parameter where more stringent requirements may arise.

Regulatory issues regarding emissions to water

Overall, and considering future regulatory matters, the following is concluded:

- Emissions to water are low and do not provide a significant regulatory concern. This situation is [redacted] change in the long term.
- There is a [redacted] that the EA may require discharge measurement point of the effluent plant to be moved upstream to the outlet of the effluent plant (before dilution with bleed off water from the cooling water plant). Dilution of processed effluent with relatively clean cooling water assists meeting discharge concertation limits. If this should occur, the effluent plant may have to be upgraded to improve heavy metal separation to comply with discharge limits.

Regulatory issues regarding monitoring

Overall, and considering the future regulatory matters, it is considered that:

- Current monitoring arrangements are adequate, and well managed, particularly when new, redundant emissions monitoring system are installed.
- Current EA view is that monitoring of the [redacted] flue lines at the stack rather than each of the [redacted] FGT process lines (or [redacted] furnace/boiler lines) is sufficient. This is not the interpretation in some of the other EU countries. This is therefore an area where there is a risk of policy change. This factor coupled with the potential for greater focus on avoiding start-up and shut-down it may be concluded that there is a significant likelihood that

expenditure on monitoring equipment and its operation will increase significantly in the medium term. Investment risk is estimated to be medium.

- There is a risk that additional monitoring of Poly Chlorinated Dibenzo Dioxins/Furans (PCDD/F) will give rise to alterations in start-up and shut-down protocols and adaptation to carbon injection regime and rates. Provided there are suitable disposal routes for the residue created, this is [redacted] to give rise to significant capital expenditure. However, operational costs would increase through the need for additional monitoring and modifications to start-up protocol and carbon injection. This risk is considered to be [redacted]
- Further mitigation of flue gas PCDD/F content downstream of boilers, before entering the FGT plant, could be achieved by improving burnout in the furnace. This may entail costly replacement of boilers to allow for a greater afterburning chamber fulfilling the 2 second/850 °C IED/WID requirement. The risk for imposing a requirement on reduced PCDD/F content downstream the boilers is low. If actions are required to address PCDD/F issue, more cost effective approaches such as modified carbon injection may be available. Hence, the risk of high cost solutions such as boiler replacement is considered very low.

Regulatory issues regarding change of waste type

We expect [redacted] in respect of the EA permit regulatory risks regarding the import of MSW from other Authorities. Possible political and planning related risks are not considered by Ramboll. Risk associated with treating notably increased fractions of C&I waste is rather different. The EA is of the view that this would require the following:

- Specific discussions with the EA in advance [redacted]
- An application to vary the permit [redacted]
- A phased testing programme to demonstrate that the plant can still comply with permit terms [redacted]
- Not likely to give rise to greatly changed permit conditions over and above those that would be required for MSW, provided technical barriers seen can be overcome, and capacity is appropriate to the revised waste feed
- It is only likely that waste of a similar nature to MSW would be acceptable at the plant, C&I waste from shops and offices might be acceptable, subject to testing and approval – but it is unlikely that hazardous wastes or more industrial wastes would be acceptable as these are already specifically excluded from the plant.

0.2 Scope for continued operation until 2025

0.2.1 Overall Assessment

Ramboll's assessment is that the Edmonton EfW plant is well operated and maintained for its age. We believe that with targeted investment and continued good operation and maintenance the EfW plant should be capable of operating through to 2025.

The EA is satisfied with the performance of the plant. Possible future investments driven by regulatory demands may arise between now and 2025. However, the risk of large investment requirements is considered [redacted]. Provided that the EfW plant continues its current performance, it is [redacted] the EA will withdraw LEL's derogation of the 2s at 850°C WID requirement.

0.2.2 Availability and Waste Throughput

We estimate an average operational availability of [redacted] through to 2025, provided that good operating practices are maintained, waste specification is unchanged, and that maintenance and CAPEX are as a minimum as set out below.

The above availability would support an average annual throughput of [redacted] tpa with current heat waste heat values. This corresponds to a waste combustion rate of [redacted] tonnes/hour per furnace/boiler.

Increases in waste calorific values will results in a reduction of waste throughput. This is due to mechanical and thermal processing capacity limitations. Waste composition changes may also affect plant availability.

0.2.3 CAPEX programme

We have identified a number of investment scenarios and grouped them under the following categories:

- CAPEX required to extend the plant life until 2025
- CAPEX which is potentially required for regulatory reasons

[redacted]

0.2.4 Volumes of Electricity Generation and Metal Sales

Based on our assessment of the estimated average future availability the plant can be expected to generate [redacted] MWh of electricity per annum for export to the grid and/or other consumers outside the EfW facility.

Over the recent years LEL recovered in the region of [redacted] t of metals per year. Metals recovered are sold for recycling.

0.2.5 Operation and Maintenance Costs

[redacted]

We have not assessed LEL's residue disposal costs/contracts. Residue disposal is a significant cost element for EfW plants. We recommend that NLWA also acquires residue cost information from LEL.

0.2.6 Risks

Risks which may be foreseen during the operating period, for consideration and implementation of mitigation measures, include the following:

- [redacted]
- [redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

NLWA is advised to also consider other aspects such as health and safety, securing insurances, cost of insurance and the infrastructure and service availability required to meet all its waste management commitments through to 2025.

1 Introduction

This report details Ramboll's findings from its Condition Survey of London Waste Limited's Energy from Waste (EfW) facility located in Edmonton, London. The EfW plant is also known as the LondonWaste Energy Centre. [redacted].

1.1 Objectives

The objective of this study is for Ramboll to undertake a Plant Condition Survey of the EfW plant and advise NLWA its findings in a report. The study includes describing the risks and investment requirements foreseen to support EfW plant operations through to 2025. Ramboll's survey and report also reflects new information and developments at the facility since [redacted].

The timeline considered for Ramboll's assessment is operations to 2025. Therefore, EfW plant maintenance and investment estimates reflect investment needs to 2025. A separate Ramboll report will describe risks and investment requirements for plant operations beyond 2025 to 2030.

Ramboll understands that this study will support NLWA in informing its Members on EfW plant condition, operational risks and investment requirements. The report will also support NLWA with its waste management infrastructure considerations.

This report details the following EfW plant information:

- Plant description and status
- Regulatory considerations
- Historical plant performance:
    - Plant household waste processing capacity (annual)
    - Electricity generation (annual MWh)
    - Ferrous metals recovery (% of waste and annual amount)
    - Maintenance costs (annual)
    - Incinerator Bottom Ash (IBA) production (% of waste and annual amount)
    - Air Pollution Control (APC) residues arising(% of waste and annual amount)
    - Plant consumables (annual tonnages)
- [redacted]
- Commentary on the possibility of Commercial and Industrial (C&I) waste treatment and EfW plant performance impacts

1.2 Report Structure

The structure of this report is detailed below to better aid its reading and use:

Chapter 2: A description of EfW plant areas assessed as part of our condition survey

Chapter 3: Regulatory Aspects.

Chapter 4: Historical EfW plant performance. Information on historical plant performance is presented in this section. Plant performance information presented includes:

- Mass and energy balances, considering both inputs and outputs

- Operational availability
- [redacted]
- Performance of key plant areas
- Boiler corrosion rates
- Flue Gas Treatment Plant (FGT) operations
- Steam turbine generator efficiency

Chapter 5: A number of upgrade and maintenance investments/activities have been identified and are described in this chapter. The investments proposed are based on our EfW plant survey findings and are divided into the following categories:

- [redacted]
- [redacted]

Chapter 6: Future EfW plant performance.

1.3 Site visits

Table 1-1 below provides an overview of site visits and EfW plant survey activities completed to produce this report. In addition to the inspections, the site visits also entailed discussions with LEL staff managing the operations and maintenance of the EfW plant.

EfW plant site visits were conducted in line with LEL's [redacted] boiler outage programme to aid boiler and furnace surveys and prevent condition survey impacts on LEL operations. [redacted] and Ramboll inspection of these [redacted] was not conducted as part of Ramboll's condition survey. Ramboll's condition survey does not require a visual inspection of each of the [redacted] boilers. Information provided by LEL and surveys of the three boilers inspected were sufficient to inform Ramboll's condition survey.

A range of pictures of the plant from the site inspection are presented in Appendix A.

Site Visit Ref	Boiler Inspection	Other/Additional Plant Area Inspected
Visit 1 (16th April 2019)	[redacted]	None
Visit 2 (15 & 16th May 2019)	NA	Electrical and Control & Instrumentation systems
Visit 3 (23rd May 2019)	[redacted]	Waste reception and handling, Flue gas treatment plant
Visit 4 (18th June 2019)	[redacted]	Steam turbine generators and wet cooling plant
Visit 5 (25th June 2019)	NA	Civils and Structures and Building Services

Table 1-1 Schedule of EfW plant visits and activities undertaken

1.4 Survey scope/interfaces

Ramboll's survey encompasses the entire EfW plant. A list of EfW plant interfaces regarding process water, steam and residues is provided below to clarify survey exclusions:

- The onsite IBA treatment facility operated by [redacted] excluded from the condition survey
- FGT residue off site treatment facilities are excluded from the condition survey scope.
- Treated water from the effluent plant is directed to the sewage treatment plant for further treatment. The Sewage treatment plant is excluded from the condition survey.
- Treated water is supplied from the sewage treatment plant and used as process water at the EfW plant. As stated above, the Sewage treatment plant is excluded from our condition survey.

1.5 Plant documentation

Ramboll issued a questionnaire setting out documents and information required to support its plant condition survey. The questionnaire is presented in Appendix B together with LEL and Ramboll comments. LEL's comments include the provision of information requested by Ramboll.

The following is the list of documents/information obtained by Ramboll. Electronic copies of these are presented in the respective Appendices. Information such as plant drawings and EfW plant permit, which remain unchanged, was held by Ramboll [redacted].

- [redacted]

[redacted]

[redacted] following specific key information was provided by LEL. Information for earlier periods was held on our records through the [redacted]. Information obtained is evaluated in associated sections of this report.

LEL Information Required	Period of Information
Waste processed per annum (tonnes)	[redacted]
Gross and net electricity generation (GWh)	[redacted]
Boiler hours [redacted]	[redacted]
Steam production rate (tonnes /h)	[redacted]
Consumables used by the plant per annum (tonnes): • Lime • PAC • Carbamin • HCl	[redacted]
Consumption of utilities per annum. • Townswater (m^3) • Gas (Nm^3)	[redacted]
Residue materials produced per annum (tonnes): • Bottom ash • Metals • APC residue • Waste water	[redacted]
Overall plant operational availability (%)	[redacted]
Flue gas treatment plant emissions records	[redacted]
Thickness measurements of the following boiler parts (mm): • Tube walls in the radiation pass • Tube walls at evaporator tube	[redacted]
Maintenance costs (£)	[redacted]

1.6 Disclaimer

It should be noted that:

- This report should not to be considered as a Vendors Due Diligence report.
- Ramboll gives no warranty to any party as to the accuracy, completeness, reliability or sufficiency of report contents.
- Ramboll does not owe any duty of care to any interested third parties.
- Third parties should make their own surveys, investigations and assessments, as they see fit to satisfy themselves as to the condition of the EfW plant.
- The benefit of this report may not be assigned.

2 Plant Description and Status

2.1 General Description and Main Data

LEL's EfW plant comprises [redacted] processing units. Waste is received in [redacted] sections and supplied to [redacted] grate/furnace boiler units for processing and energy recover. Flue gas from the processing units is supplied to systems comprising [redacted] treatment streams. Similarly, under normal operations, steam is supplied to [redacted] main steam turbine generator units for power generation. Flue gas treatment and the water steam cycle are further described below.

The flue gas arising from thermal treatment of waste goes through the following path and treatment phases:

- [redacted] electrostatic precipitator (ESP) units,
- [redacted] induced draft (ID) fans,
- [redacted] flue gas manifolds,
- [redacted] flue gas treatment (FGT) units,
- [redacted] booster fans,
- flue gas manifold,
- [redacted] emission monitoring stations, and
- [redacted] flue gas stack pipes.

An overview of the water steam cycle is as follows:

- [redacted] boiler units,
- [redacted] steam manifolds,
- [redacted] main turbine/condenser units,
- [redacted] turbine generator, only used as back up,
- [redacted] de-aerators, and
- [redacted] feed water pumps.

The cooling water plant serving steam turbine generator requirements comprises [redacted] cooler units and [redacted] circulation pumps.

Main EfW plant data

Table 2-1 sets out the main data for the EfW plant:

[redacted]

Each plant area in more detail in the following sections below.

2.2 Waste Reception and Handling

2.2.1 Weighbridge

All waste delivery vehicles entering and leaving the EcoPark go through weighbridges to determine the weight of waste deliveries as well as obtaining and recording other information required for statutory, commercial and operational purposes.

There are [redacted] offices: [redacted] offices is on the South of the site, there are [redacted] weighbridges by this office. The [redacted] is on the North of the site, there are three weighbridges by this office. All [redacted]. Replacements included new automated systems for the weighbridges.

2.2.2 Tipping Apron

There is an access ramp leading to and an exit ramp from the tipping hall. The tipping apron has [redacted] bays, which is more than the typical amount for a plant of this capacity [redacted]. Each bay is equipped with a hydraulic trimming door with new hydraulic panels fitted on all the doors.

Typically, new EfW plants are not built with hydraulic trimming doors to separate the tipping apron from the waste bunker. Barriers are considered to be an adequate health and safety measure for preventing trucks from driving/falling into the bunker.

The area provided for manoeuvring within the tipping apron, including the access ramps, is good.

2.2.3 Waste Bunker

The waste bunker is divided into [redacted] by concrete walls. Each bunker section is centralised around a corresponding waste hopper for feeding each of the [redacted] process lines [redacted]

Waste is mixed in the bunkers using cranes with special attention given to waste considered to have high chlorine and/or sulphur content. Efforts are made to distribute such waste into different bunker sections to reduce overall concentrations of chlorine and/or sulphur better facilitate its processing.

Waste mixing practices aiming at obtaining a homogenous fuel is important for EfW plant operations for the following reasons:

- Reducing high temperature corrosion and wear on:
  - The grate. Especially when processing waste with a high calorific value. The air cooled roller grates at LEL are more prone to high temperature corrosion than water cooled moving grates. However, LEL does not currently experience grate corrosion.
  - Unprotected walls in the radiation pass of the furnace and boiler
  - Superheaters in the boiler
- Reducing damage to the refractory and tiles caused by large fluctuations in furnace temperatures.
- Reducing risk of uncomplete combustion causing high CO concentration peaks in combustion gases when low calorific waste is processed. This is especially important since there is no longer an option for primary air pre-heating at LEL[redacted]
- Reducing HCl and SO_2 peaks in raw flue gas. The dry flue gas cleaning system at LEL is more sensitive to HCl and SO_2 peaks when compared to a wet/combined flue gas cleaning system.
- Improving energy efficiency by reducing stoking effect fluctuations, thereby reducing steam flow variations.

Based on visual inspections only, the waste in LEL's bunkers appeared satisfactorily homogenous.

Low-grade clinical waste is fed into the bunkers.

Originally, a dust filtering and odour control system was installed at the top of the bunker hall. It never functioned properly and was therefore dismantled [redacted]

The bunker is equipped with air-and-water spraying systems for dust control. This system works satisfactorily.

The bunker is equipped with water sprinklers for firefighting.

The bunker is separated from the tipping apron by the trimming doors. There is no record of odour problems or complaints.

2.2.4 Waste Cranes

The plant has [redacted] cranes originating from installation/commissioning in 1970s. Cranes are operated manually by crane drivers sitting in "a cab" below the crane with an overview of the bunker area.

LEL is [redacted]. This is expected to be completed during [redacted].

There are [redacted] grabs – [redacted] for each crane and [redacted] spare grabs.

Crane grab wear is extensive due to the fact that the bunker is divided into [redacted] by concrete walls. Wear-resistant steel alloy has been welded onto the outside of the grab arms. This has reduced wear on grab arms.

Crane cables and wires were historically replaced several times a year on each crane. This problem has been resolved through a modification to the guiding system of the cables and wires [redacted]. This modification has been implemented on all cranes.

The usual practice of mixing waste across the bunker by gradually opening the crane grab while running over the bunker is not carried out at LEL. This is because hoisting waste above the separating walls is time consuming. Waste mixing is carried out within each of the [redacted] individual bunker sections.

The waste processed at LEL is household waste, which, when compared to commercial waste, is relatively homogenous and has a relatively low calorific value with a lower chlorine and sulphur content. This makes the challenge of mixing somewhat easier.

LEL has a grab service area next to [redacted] Grabs can be lowered to ground level for maintenance.

It was noted in 2013 that LEL had exchanged crane motors and associated control system. Furthermore, crane hoist control systems were replaced in [redacted] to remove the existing imperial slip ring motors and the controlling [redacted] unit which were no longer supported by ABB.

The hoist motor was replaced with a [redacted] forced cooled induction motor with a new control panel. This incorporates an [redacted] re-generative drive and, as a backup, a standard inverter drives that acts as a hot swap in the event of a drive failure. Power consumption on the cranes has greatly reduced due to the replacement works, with a corresponding reduction in associated carbon emissions. A capital project replacing the slip ring drives on the long and cross travel motors has also been completed. Replacements use [redacted] frequency inverters for speed control.

LEL instructed [redacted] undertake Crane Reliability Surveys (CRS) on all of its [redacted] cranes in 2015. Summary reports from these surveys are presented in [redacted] Conclusions from the reports include the following:

> "*The crane is now* [redacted] *years old and still operational with relatively good reports on its reliability from the operators. Given the age, duty and environment which the crane operates in is a testament to the good level of maintenance carried out by the onsite engineering teams.*
>
> *That being said, the crane has now surpassed its design limits and the evidence gathered onsite from these CRS indicates that the crane's main mechanical components are now at a higher risk of failure and should be replaced with modern equipment to ensure the future safe and reliable operations…"*

[redacted] recommend works in [redacted], which LEL confirmed as been carried out. This includes replacement of the long travel rails of the waste cranes in [redacted]

2.2.5 Summary/conclusion

The condition of weighbridges, access ramps and tipping apron is good.

Dust and odour control for the bunker is considered satisfactory with no complaints being received.

Waste mixing is carried out by distributing problematic waste between bunker sections when unloading waste loads. Furthermore, waste mixing within each bunker section is carried out using waste cranes.

Division of the bunker into [redacted] is a disadvantage from a waste mixing point of view. The bunker structure, including the dividing walls, forms an integrated part of the load carrying structure. Therefore, it is unrealistic to consider changing this structure to create a large, single undivided bunker.

Increased wear on the grab arms due to contact with bunker dividing walls is managed by welding wear resistant steel alloy onto the outside of the grab arms.

LEL carried out crane surveys in [redacted]. These concluded that, whilst being reliable, the cranes are beyond their design life and that mechanical components are at a higher risk of failure. The [redacted] recommend works in [redacted] which LEL confirmed as been carried out. This includes replacement of the long travel rails of the waste cranes [redacted].

Furthermore, LEL is upgrading the three waste cranes to fully automatic (unmanned) operation. This is expected to be completed [redacted].

2.3 Furnace/Combustion System

2.3.1 General

As part of an upgrade to comply with the Waste Incineration Directive (WID) major refurbishment works were carried out on the furnaces and combustion systems of the [redacted] lines in [redacted] and [redacted] The works consisted of the following for all [redacted]:

- Replacement of the entire primary air systems
- Replacement of the entire secondary air systems
- Replacement of roller grates no [redacted] scrapers and refurbishment of roller grates 6 and 7 on each line.
- Installation of water-cooled waste chutes
- Replacement of riddling conveyers

- Installation of new compressors
- Installation of SNCR
- Changing of the geometry of the combustion chamber/afterburning chamber including installation of new water cooled panel sidewalls.
- Installation of 3 gas burners on each line

In addition, the bottom ash pusher on [redacted] replaced by a bottom ash conveyor identical to the type on the [redacted] other lines.

A more detailed description of the above-mentioned works and the consequences for the operation is included in the sections below.

2.3.2 Waste Chute

The waste chutes on all [redacted] were replaced by water-cooled waste chutes as part of the WID upgrade.

During [redacted] annual outage periods the water cooled waste chutes were replaced on all [redacted] lines.

The hydraulically operated chute flaps were also replaced. These are used during start-up and shut-down to prevent tramp air from entering through the chute. During start-up and shut-down the gas burners are operated, and there is no waste below the chute flap and on the grates.

2.3.3 Waste Pusher (Feeder Ram)

The waste pusher has [redacted] cylinder. At every outage the cylinder is replaced with an overhauled cylinder fitted with new seals.

The scraper is usually replaced at every outage and rails are replaced when necessary (about every second outage).

Following the installation of the auxiliary burners/start-up burners during the WID upgrade there was an incident where the waste pusher overheated, causing the seals to be destroyed and leading to hydraulic oil leaks.

Forced cooling is now employed and the feeder ram is retracted at start-up and shut-down to avoid both overheating and hydraulic oil leakages.

During [redacted] outages the feed tables on all [redacted] were replaced.

2.3.4 Grate

The grate on each of the [redacted] process lines is a [redacted] roller grate which consists of [redacted] rollers [redacted] On modern new built EfW facilities moving grates are usually installed as they facilitate a more even distribution of the waste on the grate, which provides for a more optimal combustion process with a better air flow distribution.

The primary part of the moving grates which are installed today are water cooled and allow primary air to be distributed to optimise the combustion process without the need for air to cool the grate. Water cooling is not an option for the roller grate. Edmonton has a relatively low calorific value of the waste and an air cooled grate is not a disadvantage.

The roller grates are reversible. The objective of the WID upgrade of the grate was to reduce the tramp air, improve combustion and eliminate white metal problems in the hoppers and riddling conveyers. The WID upgrade included the following changes to the grate:

- Roller grate nos. [redacted] replaced on all [redacted] lines.
- Roller grate nos. [redacted] refurbished on all [redacted] lines.
- All scrapers positioned between the rollers were replaced [redacted].
- A new type of grate bar was used for roller grates nos. [redacted] The fastening system on the new grate bars has been altered. There are 3 holes in each of the new grate bars. Previously, breaking of a grate bar occurred which caused jamming of the grate rollers and consequently shut-down of the line. This has not occurred with the new grate bars.
- Unit [redacted] on other units, is generally exposed to limited wear. Old stockpiles grate bars in a good condition were reused on [redacted]
- The motors of all [redacted] have been equipped with frequency converters and variable gear boxes have been replaced with constant gear boxes to reduce the maintenance requirements.
- The rollers have [redacted] types of grate bars: Closing bars, sliding bar, left and right end bars. The closing bars and end bars are fastened by bolts, and welds are applied onto the top of the bolts in order to protect the bolts against hot-temperature corrosion and wear.

Prior to the WID upgrade all grate bars on [redacted] roller grates were typically replaced at every outage. The procedure for replacing the grate bars was to replace the grate bars on the hot zones of the grate with new ones. The dismantled grate bars were then moved further down the grate. The grate bars at rollers [redacted] thrown away (many bars would break during disassembly).

After the WID upgrade fair wear and tear is evident across all rollers on each process line. The most notable wear and tear is in areas of greatest combustion, particularly [redacted]

Wear on grate bars on roller [redacted] is not as significant. LEL has tried to identify differences in the quality of material and operating parameters in order to explain the difference in the wear. However, no explanation for the wear has yet been established.

The life time of the grate bars on grate roller no [redacted]. The other grate rollers are only subject to impact damage. LEL have advised that early excessive wear seems to have reduced in recent years.

Previously there were significant operational and maintenance problems related to melted metal inside the rollers [redacted] in the air gaps and particularly within the riddling hoppers and conveyors (see section below). These problems have been resolved.

The scrapers between the grate rollers are replaced at every second outage. At the first outage the scrapers are adjusted. This is done in order to have small well defined air gaps for primary air between the grate rollers and the scrapers.

The burn-out of the waste has improved significantly and is now safely below the WID requirements.

2.3.5 Primary Air System

The primary air intake is positioned [redacted]. The primary air duct is equipped with venturi flow measurement of the overall primary air flow.

Pitot flow measurement is positioned on each inlet of the [redacted] riddling hoppers.

The primary air fans are equipped with vibration monitoring, and the motors have frequency inverters controlling the speed.

The new primary air fans are bigger and have been designed to produce a higher pressure which combined with the smaller gaps in the new roller grates have improved the combustion process.

The amount of melted aluminium has reduced significantly, and a better burn-out of the bottom ash has been achieved.

LEL advised that no dust deposits that can cause vibration issues have been observed in the primary air fan. Generally during annual outage the primary air fans are cleaned and impellers are visually inspected (NDT of impellers is only carried out in case the visual inspection cause suspicion of cracks).

2.3.5.1 Primary Air Pre-heater

Originally the plant was equipped with steam driven primary air pre-heaters. These were dismantled during the WID modifications and the steam output was connected to the autoclaves for treatment of clinical waste. The autoclave plant was closed down in [redacted]. LEL now use the steam output to heat water for washing crane grabs.

In the absence of heated primary air, the auxiliary burners are used to aid combustion where required.

2.3.6 Secondary Air System

The secondary air intake is positioned [redacted] the basement floor level. The flow of the secondary air is measured by [redacted] pitot tubes – one for the front row and one for the back row of secondary air nozzles.

The secondary air nozzles at the rear nose have been moved as part of the geometry change of the combustion and afterburning chambers [redacted]

The secondary air fans are equipped with vibration monitoring and frequency inverters for speed control.

Since the WID upgrade the bearings on [redacted] secondary air fans have been replaced. This has not caused unplanned outages.

LEL advised that no dust deposits that can cause vibration issues have been observed in the primary air fan. Generally during annual outages, the secondary air fans are cleaned and impellers are visually inspected (NDT of impellers is only carried out in case the visual inspection cause suspicion of cracks).

2.3.7 Refractory

All brick/refractory work in the furnaces was renewed in connection with the WID upgrade (including removal of asbestos). Brick/refractory work is now repaired on a running basis during the annual outages.

Until [redacted] the refractory used in the furnace and boilers was gunned SiC90 with either hexmesh or ordinary refractory anchors. Hexmesh consists of Inconel hexagonals, which is built into a pattern. The advantage of Hexmesh is that it is easier to attach to the boiler wall than ordinary refractory anchors. However, the disadvantage is that the hexmesh comes off more easily than ordinary refractory anchors. The use of gunned refractory has been stable with the replacement of approximately [redacted] refractory at every shutdown.

On the left and right sidewall in the radiation pass the refractory level is up to level [redacted]

In all [redacted] boilers a tile system supplied by [redacted] has been installed in [redacted] on the side walls. The lower part of the boiler/furnace sidewalls and the front wall is still protected by gunned SiC90 refractory with either hexmesh or ordinary refractory anchors. LEL's experience with [redacted] tile system is that moderate replacement rate of the tiles is needed. Please refer also to photograph at appendix A3-1 where an example of the area where replacement of tiles has been needed.

LEL intends to keep on using the [redacted] tile system based on the experience until [redacted]. In areas where the refractory has come off LEL carries out random thickness measurements to monitor the status of the panel wall behind the refractory. Ramboll considers this an important preventive maintenance activity as this may prevent unplanned outages, especially as refractory damage normally occurs in the areas subject to the highest temperature. When a boiler tube wall located in such an area becomes unprotected due to damaged refractory the unprotected boiler wall is subject to excessive high temperature corrosion rate. If the measurements confirm that the tubes' thickness behind the refractory is satisfactory, the probability of tube leaks will be low (mitigation work during planned outage can be completed before the tube thickness becomes critical).

LEL is complying with the drying curves provided by the refractory suppliers, after outages or after the installation of new refractory. Normal heating up rate in the furnace/after burning chamber is aimed at [redacted].

[redacted]

Refractory and tiles are normally a problem area in EfW facilities due to the aggressive nature of flue gasses and flue gas temperatures fluctuations. It can be difficult to find a tile system which performs satisfactorily. The tile system needs to be tailored to the EfW plant configuration.

2.3.8 Start-up/Auxiliary Burners

Originally there were no burners installed. In [redacted] line was equipped with one start-up oil-burner positioned on the back wall of the furnace.

As part of the WID upgrade the following burners were installed on each line:

- The original start-up burner was replaced by a gas burner in the same position.
- [redacted] additional start-up/auxiliary burners were installed in the boiler above the secondary air nozzles.

The start-up burner at the bottom is equipped with a separate fan for combustion air whereas the additional [redacted] start-up/auxiliary burners have one common fan for combustion air.

[redacted].

2.3.9 Summary/Conclusion

The major refurbishment works carried out on the furnaces and combustion systems of the [redacted] as part of the WID upgrade has improved this vital part of the EfW facility.

It should be noted that modern new built EfW facilities are often equipped with moving grates. The moving grate concept facilitates an even distribution of the waste on the grate allowing a better air flow distribution. The low calorific value waste processed at the EfW plant minimises some of the disadvantages associated with the roller grate system.

LEL has achieved significant improvements in the combustion systems through the WID upgrade. The most important being:

- Significant reduction of CO and NOx emissions reduction have been achieved due to improved combustion and the use of the SNCR system. For further description of the impact on emissions and other WID compliance and other relevant regulations see Section 3.
- Removal of melted metal deposits in the riddling hoppers and riddling conveyers due to the improvements on the primary air system and the grate.
- A reduction in the jamming of the roller grates by installing a new type of grate bar.
- Improved burn out of the bottom ash, but introduction of a high moisture content in the bottom ash[redacted]

[redacted]

2.4 Boiler

2.4.1 Overall Boiler Design

[redacted] boiler has one radiation pass, a vertical pass with [redacted] superheater elements, a vertical evaporator pass and a vertical economiser pass [redacted].

Generally, it should be noted that the boilers have an inappropriate design. The primary fault in the design is that the radiation pass is too small, which causes two major problems:

- Non-conformity with the WID retention time demand of [redacted]
- Very limited superheater lifetime. However, after successfully testing inconel cladded superheaters recently, this issue has been significantly improved. See further description below.

The convection passes of the boilers are vertical. For new boilers Ramboll normally recommends horizontal convection passes, which allow for more efficient cleaning methods and thus better availability.

Generally, it should be noted that all original boiler tube walls only consist of tubes. There are no fins welded in between the tubes. However, the new membrane walls which were installed during the WID upgrade included fins.

Today, all modern new built EfW plant membrane walls are designed with fins between the tubes. This reduces the weight and cost of the boiler due to less steel necessary and normal insulation material can be used on the outside of the boiler walls rather than refractory. Furthermore, boiler tube walls without fins have the disadvantage that tramp air can enter into the boiler between the tubes - especially if the outside casing has holes or cracks.

2.4.2 Radiation Pass

The WID upgrade included changing the geometry of the combustion chamber and afterburning chambers. New water cooled panel sidewalls were installed on [redacted]. The sidewalls have a pitching of [redacted]. The fins are [redacted] Thereby the width of the fins is approximately 30 mm which is acceptable to avoid "burning off" the fins. If fins are too wide, they get very hot in the middle causing excessive high temperature corrosion rates. Even when the tube walls are covered with refractory this is important as damage to the refractory may expose the tube walls to the flue gas.

The WID upgrade has changed the temperature profile in the radiation pass which was confirmed by the CFD-analysis (carried out as part of the engineering of the WID upgrade). On the front wall there was no high temperature corrosion prior to the WID upgrade on al[redacted]. However, after the WID upgrade the corrosion rate on the front wall has increased significantly. As a consequence, the refractory area has been extended slightly in this area. In order to prevent an increase in the temperature at the inlet to the superheaters it has been decided to consider this area as a wear part where tubes are replaced regularly. The corrosion rates are further analysed in section 4.5.

Brand new tubes bursting at the top of the radiation pass screen wall [redacted] have been caused by bad circulation. In order to increase circulation and thereby prevent this type of failure, tubes in the corners of the roof in the furnace are now exposed (without refractory). No tube bursts due to bad circulation have occurred since this modification, a period of over [redacted]

Occasionally tube leaks in the roof or upper parts of the tube wall occur due to high temperature corrosion. However, this is quite rare thanks to a monitoring programme of the boiler tube thickness. Preventive replacement of the tubes is carried out based on the results (see section 4.5).

The screen walls have experienced high corrosion rates. Therefore, LEL has extended the Inconel area on the screen wall all the way up to the roof. The current status for the extent of [redacted] composite tubes on the screen wall is as follows:

[redacted]

The screen wall [redacted] co-extracted tubes and boiler [redacted] was installed/welded approximately [redacted] years ago. However, replacement of boiler 1 bottom half Sandvik composite tubes with Inconel cladded tubes in [redacted] revealed that the [redacted] tubes appeared to be still in good condition.

Based on visual inspections, the Inconel cladding appears to be in a good condition without visible pitting corrosion. LEL advised that spot check thickness measurements of [redacted] tubes as well as [redacted] cladded tubes show no loss of thickness.

LEL advised that, despite deformations of the screen walls caused by dry boiling incidents, the mounting of super heater sections have been adapted and therefore there are no plans to replace screen walls due to the deformation of the screen walls.

2.4.2.1 SNCR

The WID upgrade included installation of an SNCR system for NOx removal. The system injects Carbamin in the radiation pass of the boilers. It should be noted that 'carbamin' is the same as 'urea', that may be referred to elsewhere.

There are [redacted] positioned on the same level for injection of carbamin in each boiler. The carbamin is injected as a [redacted] solution together with water and pressurised air for atomisation.

Excess carbamin that is not used in the process of NOx-reduction or oxidised to nitrogen or nitrous oxide, N_2O, would appear in the flue gas as ammonia, NH_3, the so-called 'ammonia slippage'. In order to reduce the ammonia slippage LEL has optimised the carbamin/urea dosing. This includes an automatic dosing system controlled by the temperature in the afterburning chamber. In addition, at the outlet of the ESPs, a raw gas NOx measurement is installed which provides input to the optimisation of the carbamin dosing on each individual furnace/boiler. The ammonia and NOx measurements in the emission monitoring stations are more difficult to integrate in the optimisation system as this is an average of the NOx and ammonia flue gas concentrations in mixed flue gas from, in principle, [redacted].

[redacted]

[redacted]

Figure 2-1, Carbamin consumption per tonne waste (cf. data in table 4-3)

Generally, SNCR systems have nozzles installed at [redacted] levels in order to optimise the injection of carbamin (or ammonia water). This is to be able to inject the carbamin (or ammonia water) at the optimal flue gas temperature and thereby reduce the ammonia slippage and the carbamin consumption.

The NOx reduction is further discussed in Chapter 3 Regulatory Aspects.

2.4.3 Superheater

Typically, the flue gas temperature at the superheater inlet is between [redacted] boilers and between [redacted] when leaving the superheaters. This is significantly above Ramboll's usual recommendation of super heater inlet temperatures of [redacted] (for the steam parameters implemented at the Edmonton EfW plant). Furthermore, there are no protective pre-evaporator tube bundles installed upstream the super heaters, which is also a standard Ramboll recommendation for new WtE facilities.

The high inlet temperature to the superheaters is due to the small radiation surface in the radiation chamber. The consequence of this is a lifetime of approximately [redacted] for black steel super heater sections, which is much less compared to the [redacted] typical lifetime of superheaters in modern EfW plants.

LEL has over the years carried out extensive optimisations to reach these approx. [redacted] life time of black steel super heaters. In order to try to further optimise the life time of the super heaters, LEL has over a period of time carried out test with Inconel cladded super heater tube sections. Based on results of these tests all three superheater banks on [redacted] were replaced with Inconel overlay welded superheater banks in [redacted] replacement with full Inconel cladding on all super heater sections were carried out in 2016 and 2017.

Having gained significant operational experience with [redacted] cladded super heaters, LEL assess that based on an overall CAPEX/OPEX optimisation that the black steel super heater configuration is preferred as compared to Inconel cladding. This is based on a number of different factors:

- [redacted] super heaters has revealed some problems in relation to various areas of the Inconel cladded super heater sections experiencing significant corrosion rates (caused by the very high flue gas temperatures).

- Replacement works on [redacted] super heater tubes have an approx. [redacted] longer duration as compared to ordinary black steel tubes.

- Successful trials of improving the de-super heating control keeps a more stable steam temperature at inlet to the super heater sections which is expected to increase life time of black steel super heaters [redacted]

Ramboll concurs with LEL's decision to switch back to black steel super heater sections, given that the detailed CAPEX/OPEX evaluation shows that black steel super heater sections are the most optimal choice. It is noted that the expected increase from [redacted] life time of black steel super heaters due to the recent improvements of de-super heating controls will allow more flexibility in the planning of the boiler outages for black steel super heater sections as compared to how it has been historically. The lack of flexibility in the planning of boiler outages was one of the important advantages for changing [redacted]. This is no longer assessed to be a significant upside for the [redacted].

Historically there were problems with blockages in the superheaters. This was caused by build-up of particles in flue gas from the furnace/boiler. To avoid these blockages in year [redacted] pitching of all superheater banks for all [redacted] changed from [redacted] Since this change, there have been no blockages in the superheaters.

The superheater in each of the [redacted] of three banks. The steam from the boiler drum is flowing downwards in the outer tubes in each side of the superheater through all three banks to the bottom header which is split [redacted]. From the [redacted] parts the steam is taken out into [redacted] pipe, where de-superheating takes place to control the superheated steam temperature. Subsequently steam is directed to the middle part of the bottom header from which the steam flows upwards in the middle of the superheater through the three superheater banks and into the header.

2.4.3.1 [redacted]

A new design of the superheaters was implemented on [redacted] in order to extend the superheater lifetime. The superheater was further modified to increase pitch in mid and bottom banks in [redacted]

The "new" design still consists of three superheater sections but the steam flow direction was changed to be the same as the flue gas flow direction (co-flow). The safety valve, start-up valves and main steam shut-off valve were moved from the top of the boiler to the bottom of the boiler. This required major piping re-configuration.

In order to provide access for the installation of burners for the WID modifications it was necessary to remove the de-superheater on [redacted] The de-superheater on [redacted] never used because [redacted] smaller diameter tubes, which reduces the overall surface area and thereby the general need for water injection was reduced. However, the disadvantage of this design of the superheater is the risk of increased fluctuations in steam temperature as regulation by the de-superheater is not available.

The screen wall was also modified slightly so that the intermediate superheater headers would be positioned in line with the screen wall. The outlet header is at the bottom in place of the original intermediate header. Therefore, a bulge consisting of [redacted] the screen wall has been installed to make room for the new intermediate headers. (The top one of the two is the primary superheater outlet and the lower one is the secondary superheater inlet).

The primary result of the modified design has been that the most severe high-temperature corroded areas have been moved down towards superheater [redacted]. This is insufficient to justify the additional spend. Therefore, the modified design has not been implemented on the [redacted] other boilers.

Full Inconel cladding on all three super heater sections has also been applied [redacted]. However. based on operational experience from full [redacted] super heater sections LEL has decided to revert to the black steel super heater solution for all [redacted] (see above).

The [redacted] headers are covered with refractory in order to protect them against high temperature corrosion. The superheater final outlet headers are replaced with a refurbished header every few years.

2.4.4 Evaporator

The evaporator tubes bundles are positioned in a vertical pass. The tube walls – baffle wall, rear wall and side walls - at the evaporator tube bundles were replaced during the period of [redacted]

Around [redacted] evaporator tube bundles were replaced on all [redacted] boilers. Furthermore, evaporator tube bundles on [redacted] boilers were replaced in [redacted] (the boiler numbers have not been provided).

LEL has decided to replace the evaporator tube bundles on all [redacted] boilers during the planned [redacted] outages. LEL advised that this is partly due to the current age of the evaporator tube bundles (and thereby increased risk of leakages) and partly due to ash blocking problems in the narrow gaps between the evaporator tubes, which, especially in the bottom part of the evaporator bundles, cause blockages that sometimes requires shut down for manual cleaning. The new evaporator bundles are to be redesigned to allow larger distance/gaps between the tubes in the bottom part. LEL advised that the new redesign will include circulation calculation to verify the design change.

Ramboll supports LEL's decision for replacement of evaporator tube bundles, including the specified design change.

In [redacted] tube rupture occurred in the evaporator tube walls in the second pass (at the superheaters) on [redacted] an inspection access door causing a substantial water leak and thereby emptying the boiler drum. As the boiler leakage was in the second pass the fire on the grate was not extinguished fast enough to avoid dry boiling of the boiler. The boiler roof and the screenwall were damaged by this incident. The screen wall has been permanently deformed with maximum amplitude of approximately [redacted] A complete replacement of the entire screen wall with new Inconel cladded screenwall was carried [redacted].

LEL reported that the tube rupture was due to a localised failure/wear at the inspection door which was not discovered by the thickness measurements. New routines to carry out thickness measurements on these specific tube areas have been implemented on all boilers to avoid reoccurrence.

In order to avoid dry boiling LEL has installed [redacted], a water spray system in the secondary air nozzles above the grate to be able to extinguish the fire on the grate instantly.

In 2012 there was a similar dry boiling incident [redacted] During this dry boiling incident, the water spray system was not activated. LEL has now established remote control (from the control room) of the water spray system to improve its usability. For further detail on the [redacted] dry boiling incident please refer to the [redacted]

The tubes in the evaporator tube bundles which are directly exposed to steam from the soot blowers are protected against soot blower erosion by stainless steel shrouds.

2.4.5 Economiser

Reduction of the flue gas temperature was needed in connection with upgrading of the FGT system. Therefore, it was decided to replace the existing economisers with new larger economisers capable of reducing the outlet flue gas temperature to approximately [redacted]

This design change turned the economiser into an evaporating economiser. The change from hot water to a mixture of hot water and saturated steam entering the boiler drum from the economiser caused a significant volume flow increases to the boiler drum. As a result, the connection of the economiser outlet to the drum was changed; spare openings were available after a previous modification dating to the 1970's when a number of boiler bank tubes were removed because of blockages due to gas side fouling.

The vertical economisers on each of the [redacted] lines consist of [redacted], all with finned tubes.

[redacted]

The economiser has a steel plate casing and the dimension of the tubes in the economiser is [redacted]

To avoid leakages caused by soot blowers, the original design has been modified by installation of protective plates at the points where the soot blowers are turning (longer steam soot blower exposure time for these points).

In [redacted] sections on all [redacted] replaced with new economiser sections. Before this full replacement, the economisers experienced a number of leakages at the tube bends where the corrosion rates were higher than on the straight tube sections. The former economisers were approx. 17 years old at the time of replacement in[redacted]. Based on the experience of the failure mechanism of leakages at the bends of the former economisers no reoccurrence of leakages at the bends are expected for the period until 2025, which is the scope of this report. As there is good access conditions to the economiser bends it is still recommended that a few thickness measurements at the economiser bends in the bottom sections are carried out during annual outages to keep track of the corrosion rates.

2.4.6 Boiler cleaning

2.4.6.1 On-line Cleaning

On-line cleaning of the boiler is performed by soot blowing or explosion cleaning.

In each of the boilers the following soot blowers are installed:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted].

The frequency of soot blowing can be as often as once per shift depending upon differential furnace pressures and final steam temperature. The Soot blower [redacted] at the bottom of the economiser is seldom used as this area does not foul.

LEL informed Ramboll that during shut-down, visual inspections were made in the radiation pass. There was no difference observed between the fouling at the membrane walls in the area close to the soot blowers and the fouling found in areas further away. This suggests that the soot blowers are not efficient in cleaning the radiation pass.

At the outlet of the boiler bank area below the boiler drum, LEL has recently installed an additional soot blower on all [redacted]due to the tendency for build-up of compacted ash deposits in this area. The additional soot blower has solved this problem and the build-up of ash deposits in this area has significantly reduced. These new soot blowers are non-retractable i.e. they stay in the flue gas all the time. However due to the relatively low flue gas temperature in this position there are no high temperature corrosion problems. These soot blowers are designed such that steam is shut off from the soot blower's lance when the nozzles along the lance pass the drum as it rotates thus only blowing on the tubes in the gas path.

Monitoring of the pressure drop on steam to the soot blowers was implemented in [redacted] Each soot blower has different characteristics making it difficult to get reliable readings. However, the new control system in place provides more alarms and features to improve operation and reduce failure rate. This improves the possibility to ensure that the soot blower lance can be replaced before a blockage occurs, hence preventing unplanned shut down of the boiler for cleaning.

Prior to this improvement the indication of failure of a soot blower was delayed as it was usually based on the detection of an increased load on the induced draft fan due to a higher pressure drop over the blocked area in the boiler.

In total for the [redacted] boilers approximately [redacted] fail every year. The soot blower positioned in the bottom of the evaporator bank is the most critical as failure of this leads quickly to a blockage.

LEL had experienced problems with build-up of ash deposits in the ash hopper below the superheaters and the boiler bank. To mitigate this air shock blasters were mounted in the four corners of the hoppers for all [redacted]. The air shock blasters are operated on a regular basis during daily operations and have eradicated the problem of ash build up in this area.

[redacted]

Explosion cleaning of the evaporator banks is carried out every [redacted] for each boiler. The explosion cleaning is performed by the company KRR (Bang and Clean) using ethane and oxygen. There is no explosion cleaning of the economisers.

Just before the annual outage, explosion cleaning of the superheaters is carried out in order to reduce the outage time.

[redacted] conducted a trial using sonic cleaners (acoustic horn), installed in the mid bank section of the economiser. These have improved differential pressures and prevent blocking of the mid bank section. This has improved the boiler availability. Following this successful trial, sonic cleaners were installed in [redacted].

2.4.6.2 Off-line Cleaning

If required as a result of soot blower failure, the boiler is shut-down for manual cleaning of the evaporator tube bundles and the economiser banks. The duration of the shut-down is approximately [redacted] cooling down of the boiler.

The economiser banks were grit blasted with the evaporator tube bundles manually cleaned using sticks and hammers. This is no longer required due to the use of sonic cleaners.

During the annual outage, the radiation pass is cleaned by water jetting the walls, the evaporator tube bundles are cleaned by explosive cleaning and the economiser is washed.

2.4.7 Boiler Water Quality

LEL has provided descriptions of the procedures for monitoring the boiler water quality. [redacted] this has been a manual procedure. The quality of the boiler water has been monitored closely by daily sampling and analysis by chemists in LEL’s laboratory. LEL advised that analysis generally show that the boiler water quality is good. The following parameters have been tested:

- [redacted]

In 2015 LEL installed automatic water/steam sampling stations instead of the manual testing. The automatic water/steam sampling station analyses for the same parameters as listed above.

If the analysis of the boiler water is outside the acceptable limits the bleed off is increased or boiler blow down is carried out until the boiler water quality improves.

It is Ramboll's assessment that LEL's monitoring of boiler water quality provides confidence that the corrosion from the inside of the water/steam system is negligible.

2.4.8 Boiler Drum

LEL informed Ramboll that wall thickness of the boiler drums and the headers have regularly been measured and there is no sign of corrosion on the water side.

The boiler drum safety valve is the original valve on all of the [redacted] they are overhauled at every outage. The boiler drum safety valve releases at [redacted].

2.4.9 Steam System

The superheated steam outlet of each boiler is equipped with: a safety valve and [redacted] start-up [redacted]

Furthermore, the main outlet from the header has a non-return valve and an electrically actuated stop valve. There is a manual by pass around the stop valve. From the outlet header there is also a manual valve, an electrically actuated valve for steam to soot blowers and a valve for a steam pressure transmitter for the header.

The safety valves are overhauled at every outage.

LEL has furthermore overhauled all the original [redacted] valves with new valve seats. In addition LEL has purchased a full set of [redacted] safety valves as strategic spares. These spare valves were used to enable the overhaul on a rolling programme of all [redacted] boilers without affecting the availability. The replaced set is kept as a strategic spare for availability purposes.

2.4.10 Summary/Conclusion

Generally, it should be noted that the boilers have an inappropriate design. The primary fault in the design is that the radiation pass is too small, which causes two major problems:

- Non-conformity with the WID/IED retention time demand of [redacted] However, LEL has obtained a derogation for the retention time requirement (see section 3.1).

- Superheaters lifetime of approximately [redacted] is very short compared to a normal superheater lifetime of [redacted] on new plants with similar steam parameters.

LEL has over the years carried out extensive optimisations to reach these approx. [redacted] life time of black steel super heaters. In order to try to further optimize the life time of the super heaters, LEL has over a period of time carried out test with Inconel cladded super heater tube sections and installed complete set of Inconel cladded super heater sections on all [redacted] boilers.

Having gained significant operational experience with Inconel cladded super heaters, LEL assess that based on an overall CAPEX/OPEX optimization that the black steel super heater configuration is preferred as compared to Inconel cladding. This is based on a number of different factors:

- [redacted] cladded super heaters has revealed some problems in relation to various areas of the Inconel cladded super heater sections experiencing significant corrosion rates (caused by the very high flue gas temperatures).

- Replacement works on [redacted] cladded super heater tubes have an approx. [redacted] times longer duration as compared to ordinary black steel tubes.

- Successful trials of improving the de-super heating control keeps a more stable steam temperature at inlet to the super heater sections which is expected to increase life time of black steel super heaters [redacted]

Ramboll supports LEL's decision to switch back to black steel super heater sections, given that the detailed CAPEX/OPEX evaluation shows that black steel super heater sections are the most optimal choice. It is noted that the expected increase from [redacted] life time of black steel super heaters due to the recent improvements of de-super heating controls will allow more flexibility in the planning of the boiler outages for black steel super heater sections as compared to how it has been historically. The lack of flexibility in the planning of boiler outages was one of the important advantages for changing to [redacted] which is no longer assessed to be a significant upside for the Inconel solution.

Regarding the design of EfW boilers, Ramboll would normally recommend the following design principles:

- For modern new built boilers Ramboll recommends horizontal convection passes. The convection passes of the boilers in Edmonton are vertical. Horizontal convection passes allow for installation of pneumatic rapping devices which provide a more efficient cleaning method than the present LEL online cleaning method of soot blowing. Horizontal convection passes experience very limited amount of blockages and have increased operational availability.
- Installation of a protective evaporator in front of the superheaters to protect the superheater against high flue gas temperature (high temperature corrosion).
- Three vertical radiation passes in order to decrease the flue gas temperature below [redacted] prior to entering the protective evaporator/superheater. Furthermore the [redacted] turn in the flue gas path between the [redacted] pass provides an effective separation of coarse boiler ash. This reduces the dust load on the convection pass of the boiler.

However, changing the existing boiler design to integrate the principles described above would require a major investment. It would also include altering the building structure to make room for the new boilers. Furthermore, extensive outage periods for the plant would be required to complete the works and a new planning approval would need to be obtained.

Therefore, our opinion the existing boiler design should be maintained to ensure continued operation of the Edmonton EfW facility.

2.5 Bottom Ash, Fly ash and Riddlings

2.5.1 Riddling Hoppers and Conveyer

Prior to the WID upgrade the riddling hoppers as well as the riddling conveyers caused significant operational problems:

- Large quantities of melted metal deposits were regularly blocking the riddling hoppers.
- The riddling conveyers which used to be screw conveyers often jammed due to melted aluminium deposits and wires which became "bird nest" in the screw conveyers.

Cleaning the hoppers and riddling conveyers during operation used to cause health and safety concerns for the operators.

During the WID upgrade the screw conveyers were replaced by chain conveyers on all [redacted] Furthermore, the riddling hoppers were replaced with new "straight down" chute type to prevent blocking in the hoppers.

A combination of the upgrade to the primary air system described above and the grate has reduced white metal deposits in the hoppers and the riddling conveyers to a satisfactory level. As a result, the hoppers and the riddling conveyer no longer need on-line cleaning to remove white metal between annual outages.

There were some commissioning problems with the new riddling chain conveyers. Riddling deposits built up at the inlet to the quench bath which caused blockages in the chain conveyer. LEL made some smaller adjustments to the conveyer which solved the problems.

The riddling conveyers now only have very limited operational problems. For instance, occasionally, wood floats backwards from the quench bath and blocks the riddling conveyer. In autumn [redacted], screen bars were trialled at the outlet of the riddling conveyor on boiler 3 and this proved to be a success. They have now been installed on all [redacted] and which has prevented a reoccurrence of the problem.

LEL has modified the riddling conveyers on all [redacted] boilers during the [redacted] annual outages to further reduce any blockage problems.

2.5.2 Boiler Fly Ash Transport Systems

The fly ash from the superheaters and the evaporator banks is gathered in [redacted] hoppers. At the outlet of the hoppers a vibration conveyer transports the fly ash to a chute which directs the fly ash into the bottom ash quench bath. The casing of the vibration conveyers has been renewed on all 5 lines.

During the [redacted] annual outages, all plate work on hoppers underneath super heaters and evaporator banks have been replaced and trace heating has been installed on these hoppers.

No fly ash extraction is available from the economisers. The flue gas carries all the fly ash from the economiser to the ESP. LEL reported that blockages do not occur in either the bottom of the economisers or in the flue gas ducts to the ESP.

2.5.3 Bottom ash conveyer

Each boiler is equipped with a bottom ash quench bath/chain conveyer, which transports the bottom ash to a common rubber belt conveyer. There are [redacted] rubber belt conveyer systems situated in parallel – one is in use and the other is on standby. Each rubber belt conveyer system consists of [redacted] rubber belts:

- A horizontal rubber belt situated in the basement and upon which all the [redacted] eject the bottom ash.
- An inclined rubber belt transporting the bottom ash from the basement to the "bottom ash building".

During [redacted] significant repair works were carried out on all [redacted] belt conveyors due to substantial corrosion. After this refurbishment, the rubber belt conveyors were assessed as being in a reasonable state. However, maintenance of this transport system will be an ongoing activity.

During the [redacted], a complete overhaul of all quench bath internals for [redacted] has been carried out and the quench bath drives have been equipped with new inverter drives.

[redacted] a bottom ash pusher installed. However due to the limited space available this never functioned satisfactorily. During the WID-upgrade the bottom ash pusher on unit 3 was replaced with a bottom ash conveyer identical to the [redacted] other lines.

Since the WID upgrade the moisture content in the bottom ash has increased. This seems to be due to the improved combustion system resulting in the bottom ash being better burnt out producing finer material.

[redacted]

LEL appears to have resolved the problem with excessive moisture in the bottom ash [redacted] now only rejects a minimal amount of the ash for being too wet.

LEL has taken several initiatives to deal with the problem with excessive moisture in the bottom ash. These include:

- modified quench bath buckets,
- speed control of conveyors,
- quench bath levels,
- modified conveyors,
- ash storage and operational combustion conditions.

A test where the shape and size of the holes in the bottom ash chain conveyer was changed in order to improve the draining of the bottom ash has been carried out [redacted] This has subsequently been conducted on [redacted] positive results and has now been implemented on the remaining boilers.

LEL has installed chutes at the rubber belt unloading points to direct bottom ash with a higher moisture content to separate piles from where the higher moisture bottom ash is collected and gathered in receivers. These receivers are located in the basement and at the main ash bay. The bottom ash rapidly changes consistency as it drains and becomes drier within a few hours. Following this the bottom ash is loaded onto the rubber belt conveyer [redacted] or transferred directly from the ash bay and processed as normal.

Water washing/cleaning of the floor, a relatively labour intensive operation, is often needed in the basement. Following the WID upgrade minor explosions or pops occurred during handling of the bottom ash with loading machinery. These are H_2 explosions caused by the presence of aluminium as fine particles and are a regular occurrence throughout the industry when the ash moisture content becomes too high.

In order to evaluate whether the aluminium content in the boiler fly ash was the cause of the "minor explosions" a test was carried out where for a [redacted] the boiler fly ash from all the boilers wasn't mixed with bottom ash from the roller grates (the conveying systems from the boilers to the bottom ash was stopped for this period of time). However, no conclusions could be drawn based on this test – as the "minor explosions" or "pops" continued at this time of the trial.

A further objective of the test was to see if the excess moisture problem could be reduced by leaving out the boiler fly ash from the bottom ash. However, the moisture content didn't seem to be reduced on this occasion.

Overall, the initiatives taken by LEL have reduced the moisture content of the IBA. Since these initiatives have been implemented, there has been a significant reduction in the number of "pops" or "minor explosions" in the IBA.

It should be noted that there have been no incidents of "minor explosions" or "pops" of the IBA that have required an official report as an incident or a Near Miss.

2.5.4 Magnetic Separator

To separate iron from the bottom ash [redacted] separators – one for each rubber belt conveyer - are installed at the top of the bottom ash building.

The magnetic separators turn and catch the iron pieces from the bottom ash as the bottom ash leaves the belt conveyer[redacted]

The magnetic separators are generally reliable.

There exist other types of magnetic separators in the market. Overhead rubber band magnetic separators are widely used. Ballast Phoenix extracts further iron amounts from LEL's IBA by an overhead rubber band magnetic separator.

2.5.5 Summary/conclusion

Generally, the transport systems for riddling and fly ash are functioning satisfactorily.

Following the WID upgrade some initial problems occurred with blockages in the riddling conveyors. These have now been resolved. However, there were still problems with items floating from the bottom ash conveyor into the riddling conveyor and causing jamming. This has been resolved by the installation of screen bars at the outlet of the riddling conveyor [redacted]

The extensive problems with blocking due to white metal deposits in the riddling hoppers and conveyers which occurred before the WID upgrade has not occurred since this upgrade.

LEL has bottom ash chain conveyers installed. This yields high moisture content in bottom ash. Ramboll normally recommends installation of bottom ash pushers reducing moisture content in the bottom ash. However, space requirements for bottom ash pushers make them unsuitable for LEL.

The problems with the bottom ash conveying system have occurred since the WID upgrade and are probably due to a better burn out/finer material in the bottom ash. The high moisture content in the bottom ash has on occasions resulted in rejection of up to [redacted] bottom ash by [redacted] However, these problems appear to have been resolved by a number of initiatives and now only minimal amounts of bottom ash are rejected by Ballast Phoenix.

The solution to the problems requires a great deal of manual labour for handling of the bottom ash which is taken out in the basement and later reloaded onto the rubber band conveyer. Furthermore, the cleaning of the basement is also a relatively labour intensive operation.

2.6 Flue Gas Treatment

The flue gas treatment (FGT) system comprises [redacted] electrostatic precipitators from the original plant and [redacted] lines installed in [redacted].

The basis of the retrofitted FGT is a dry process in which acid gases react with hydrated lime, and the residue is taken out in a bag house filter.

All main components of the FGTs are located outdoor, directly exposed to wind, rain and mist from the cooling towers close by.

2.6.1 FGT Process

The basic process of the FGT is in accordance with the principles laid down in the EU BAT reference note on waste incineration. With a bag house filter, the emission of particles, heavy metals and PCDD/F should be well controlled. The lime process preceded by pre-conditioning by water injection fulfils the WID requirements for acid gases (HCl, SO_2 and HF). However, this type of process is commonly regarded as less efficient than processes based on wet/combined scrubbing. Furthermore, from a NO_x removal point of view, the SNCR process in place at LEL is less efficient than the more costly SCR-process.

The use of hydrated lime as basic reactant for acid gases is simple. It generates no wastewater and the installation cost is relatively low. The drawbacks are the relatively high consumption rates of reactant and it generates higher amount of solid residue than a wet scrubbing system. The dry/semi-dry FGT process is widely used in the UK. [redacted]

2.6.2 ESPs

[redacted] identical electrostatic precipitators (ESPs), one for each unit, are located outside the boiler hall, downstream of the economisers. They are from the original erection of the flue gas treatment system dating back to [redacted]

Major overhauls include:

- [redacted]

The electrostatic precipitators consist of [redacted] fields. The fly ash is transported pneumatically to the residue silos over a fairly long distance.

The particle content of the flue gas downstream of the ESPs is not known. Judging from its age, the [redacted]-field configuration, and the fact that APC residues have a fairly high content of inert matter, we would expect some [redacted]

The fly ash transport systems are reported to suffer occasionally from clogging. Such incidents happen rarely and therefore do not constitute a major problem.

Trace heating of ESP hoppers is planned in [redacted]

2.6.3 ID fans downstream the ESPs

The original induced draught (ID) fans are located downstream of the ESPs. The fans ensure that the furnaces and boilers are kept under negative pressure.

Major overhauls include:

- [redacted]

The bearings of the induced draft fans are equipped with vibration monitoring. In [redacted] NDT was carried out on all large fans (ID, primary, secondary air and booster fans) to check for fatigue following a failure at another (non LEL) plant. This failure occurred when an inverter controlled fan that experienced frequent speed changes suffered fatigue failure. No signs of fatigue were found at LEL.

The general state is reported to be good.

2.6.4 Manifold

The flue gas from all [redacted] lines is led from the ID fans to the common manifold, which originally (before erection of the FGT system) led the flue gas to the stacks.

Dampers are located downstream of each ID fan at the inlet to the manifold and downstream of the manifold at the inlet to each FGT line. These can be used for independent isolation of each furnace/boiler line and each FGT line allowing maintenance work within each unit while other parts of the plant are still in operation. Another damper can separate the manifold into [redacted]. It has not been used for many years and is always open.

The manifold has not undergone any major overhauls, as stop of all furnace/boiler lines shall be necessary to allow inspection and works to be done.

The state of the manifold is reported to be reasonable. The upper cladding of the manifold has been modified to incorporate a slope to allow rain water to run off and prevent ingress of water under the cladding.

2.6.5 Dampers at FGT inlets

A quench tower is located as the first process step of the FGT system downstream of the ESPs. With [redacted] FGT systems there is the same number of quench towers. Like the other parts of the FGT system, they were commissioned in [redacted]. New dampers at all FGT lines have been installed during [redacted].

The hot flue gas [redacted] is quenched by injection of water in the upper part of the quench tower. Water evaporates in the tower, thereby cooling the gas and increasing its moisture content. The target cooling temperature of [redacted] is now achieved without clogging.

The steel casing at the bottom of the quench towers has been replaced several times due to corrosion. To prevent corrosion in this area, the bottom of the quench towers has been protected by refractory concrete. This has reportedly done away with corrosion at the bottom, and from visual inspection corrosion there was no evidence of a problem in the other parts of the quench towers. The state is now being followed by thickness measurements, which are reported not to indicate any significant rate of corrosion.

2.6.6 Reactor Towers

The quenched flue gas from the quench towers is directed to the bottom of the reactor towers where injection of fresh lime (hydrated lime, $Ca(OH)_2$), pulverised activated carbon (PAC) and recirculated residue takes place. In the towers, the lime reacts with hydrochloric acid, sulphur dioxide and hydrogen fluoride (HCl, SO_2 and HF). The PAC adsorbs mercury (Hg) and dioxin. The dosage rate of PAC is adjusted manually. The dosage of lime is adjusted automatically by HCl and SO_2 monitoring (CEMS) in the stacks. The installation of HCl monitoring and the recently installed (in 2016) SO_2 monitoring at FGT inlets have enabled feed forward control of lime dosing. In any case the inlet monitoring assists in preventing exceedances of HCl and SO_2 and enable informed decisions by easing fault identification and improving process monitoring.

Significant corrosion to all [redacted] towers has occurred. This was caused by insufficient insulation causing a cold bridge at the steel supports. [redacted]

Furthermore, the supports were somewhat inclined, probably due to insufficient strength (possibly accompanied by corrosion of the reactor) where the supports were welded on the reactor. This has now been rectified through extension of the connection area by welding on additional connecting steel.

The sheet cladding covering the insulation has given rise to problems and repair work. The original rivets have to a great extent disappeared due to corrosion, which has led to loosening of the cladding sheets. The rivets have been replaced by screws. The joints between the sheets of the original cladding are not water tight, allowing ingress of water under the sheet, which moisturises the insulation and causes corrosion on the outside of the reactor body. The outside corrosion is increased through a small content of salts (and other substances originating from the cooling water and the use of hypochlorite as a disinfectant) in the mist escaping from the cooling towers. A large share of the sheet joints have been sealed with a silicone sealant.

The towers have not been examined systematically for corrosion in the course of this inspection. From visual inspections the condition of the towers is continuing to deteriorate with on-going repair and maintenance is requirements.

LEL repair any leak as soon as possible after its discovery. Area by area cladding sheets have been fastened with screws and sealed to prevent ingress of rainwater [redacted] Furthermore, any horizontal roofing on the top of equipment has been given an inclination for water run-off.

Corrosion of the structures supporting the towers is discussed at section 2.9.

2.6.7 Bag House Filters

From the reactors, the flue gas enters the bag house filter where particles are efficiently taken out. This includes the residue generated from the reaction of hydrated lime with HCl, SO_2 and HF. The filter also separates the remaining fly ash, unreacted lime and PAC with its content of mercury and dioxin.

A redler conveyor transports the residue to a small recirculation silo where some residue was recirculated to the reactor with some taken to a pneumatic vessel for transport to the residue silo. Recirculation is no longer in use since [redacted], a more reactive lime, is used at the plant.

There have been severe problems with

- clogging of hoppers under the bag house filters,
- the redler,
- intermediate silo, and
- recirculation pipe.

These have been resolved by

- heat tracing critical equipment,
- raising the temperature in the reactor (less quench cooling),
- limiting the recirculation rate, and
- frequent visual inspection of critical areas and residue quality.

LEL reported that clogging is now under control.

Corrosion is not prevalent in the hoppers below the bag house filters and the casing of the bag house filters. Only limited corrosion repair work has been required. With regular replacement of filter bags, the state of the bag house filters is good.

Replacement of filter bags is necessary with around 5 years' interval. For FGT [redacted] replacement took place in [redacted] Replacement took place for [redacted].

Spot checks of corrosion were ongoing during the [redacted]. This consisted dismounting the cladding and insulation to allow inspection of the casing. This is justified by the outdoors location of filters, their age, the risk of ingress of water, and the history from elsewhere at the FGT plant including corroded rivets, APC residue silos and reactor towers. With the scaffolding in place, replacement of rivets with screws and sealing of joints were found necessary. These inspections from the outside were reported not to reveal any significant corrosion of the casings so far. The spot checks are planned to continue over the next year.

Thickness measurements should be included for the sake of getting a firm picture of potential corrosion from the inside (which may not be visible on the outside) and improved documentation.

2.6.8 Booster fan

The booster fans ensure that flue gas is transported through the FGT to the stack, the manifold is kept at slight negative pressure and that the flue gas flow is appropriately distributed between the [redacted] lines.

The fan motors are equipped with frequency converters. The booster fans are equipped with vibration monitoring. NDT testing has been conducted on the booster fans as discussed above in section 2.6.3.

New drives for FGT booster fans have been installed in [redacted] It is unlikely that they will need replacing again before [redacted]

Otherwise no major overhauls have been reported, and no severe problems have occurred in their lifetime.

2.6.9 Flue Gas Ducts

There are long ducts in the flue gas treatment system, particularly for the connection to the manifold and for directing the flue gas to the stack.

The condition of the manifold has not been fully assessed in recent times and the expansion joints have had temporary repairs to avoid an unplanned plant shut down. [redacted]

LEL is planning on inspecting all flue gas ducts during the full shutdown scheduled in [redacted]

2.6.10 Raw gas monitoring

The raw gas is the untreated flue gas at the boiler outlet, and, hence, it is the same gas that arrives at FGT inlets except for the particles separated by the ESPs and the effect of having [redacted] connected to a common duct upstream the FGT inlet.

Oxygen and CO monitors are installed downstream of all [redacted] for furnace control. CO-monitors were replaced in 2016.

One separate monitor is used for raw flue gas analysis downstream of the ESPs. The analyser usually samples from the [redacted] lines in sequence, e.g.[redacted]. It analyses the gas for NO_x and O_2.

Its use is mainly to follow the SNCR NO_x removal process on each line, as the emission monitoring system only monitor emissions the [redacted] stacks, only, not from individual furnaces/boiler lines.

Hydrochloric acid and Sulphur Dioxide analysers on FGT Inlets were installed in [redacted], respectively.

2.6.11 Emission monitoring station

In the emission monitoring station flue gas samples from both stacks are analysed. The flue gas emission is analysed for O_2, HCl, SO_2, NO_x, HF, CO, TOC, NH_3 and H_2O. The configuration of [redacted] means that each set of measurements represent [redacted] stack, [redacted] FGT lines and, in principle, [redacted].

The emission monitoring is under severe pressure as any outage [redacted] is reported as a non-compliance, counting against the 60 hours annual allowance for exceedances.

Replacement of existing Continuous Emission Monitoring (CEMS) units at stack emission point on both stacks was undertaken in 2016. [redacted] redundant [redacted] of CEMS are now installed to ensure availability.

2.6.12 Stack Ducting

Clean flue gas is collected in pairs from each of the [redacted] and discharged through [redacted] stack pipes (northern and southern, respectively).

The stack is approx. [redacted] and was designed to disperse much higher emission concentrations than currently achieved. Therefore, our immediate assessment (with reservations, having made no modelling calculations) is that dispersion should not be a problem.

The stack pipes have been found to be damaged where lagging has fallen off. Lagging is held in place with steel bands which have corroded and broken, allowing this to occur.

The corrosion damage had allowed two large holes to form (one was approximately [redacted] which have been repaired. The following works were undertaken in [redacted]

- flue pipe hole repair,
- flue pipe thickness testing,
- re-fixing the lagging,
- painting,
- lightning conductors and
- drainage.

LEL is planning to inspect all stack gas ducts during the full shutdown scheduled in 2020.

2.6.13 Transport systems for FGT residues

Originally the fly ash from the ESPs was transported by screw conveyers to the bottom ash conveyer and mixed with the bottom ash. Due to the high level of heavy metals in ESP ash, this transport system was replaced in August [redacted] Instead a pneumatic transport system was installed which conveys the ESP fly ash to the FGT-residue silos. It is mixed with FGT residue from the bag house filters.

2.6.14 Silos for FGT residues

There are [redacted] silos. Discharge takes place as powder directly into bulk lorries.

The silos suffered severe corrosion and were replaced in [redacted]

2.6.15 Summary/Conclusion

The FGT process is in line with modern principles laid down in the EU BAT reference note (BREF). The operating status is considered as good with awareness of the high consumption rates of lime and PAC.

The state of the FGT is generally reasonable. Systematic maintenance takes care of insufficient cladding for the outdoors equipment, and inadequate supports for the reactors have been repaired. Some occurrences of corrosion on the towers have been mended.

Considering the corrosion rates observed, the quench towers, reactors, bag house filters and the supporting steelwork are now systematically inspected and preventatively repaired before failure occurs. [redacted]

LEL has procured new emissions monitoring equipment. A double set for each stack provides redundancy for the flue gas analysers and reduce the risk of outages.

LEL has also fitted monitors for HCl and SO_2 at the FGT inlets to provide a feed forward to the lime dosing system to help avoid exceedances of HCl and SO_2.

2.7 Turbine, Condenser and Cooling Water Plant

2.7.1 Steam System

LEL's steam system is illustrated in Figure 2-1. The system comprises a ring incorporating [redacted] steam receivers in the boiler house and [redacted] in the turbine hall. Following the installation of the new house set, the steam lines to the [redacted] have been linked to enable the new house set to be supplied from either side of the ring main and reduce steam velocity through pipework.

In the plant manual, the ring is described as: "*Ring sectioning valves allow plant isolating valves to be maintained and allow <u>double</u> valve isolation of major items of plant, although isolation of a section of the ring may isolate simultaneously either* [redacted] *boilers or* [redacted] *main turbines. Should a header or receiver require to be maintained it can be isolated without affecting the steam supply to the dump condenser or either house set*"

Further on the plant manual states that the steam flow shall not exceed [redacted] which might be the case in the event that the ring is isolated (corresponds to approximately 4 lines in operation).

LEL states, that due to this loss in capacity and under normal conditions, it does not operate a policy of individually isolating single valves or headers in the system.

[redacted]

In its [redacted]3 condition survey report Ramboll highlighted poor condition of main section and ring isolation valves, proposing their replacement or refurbishment.

LEL acquired a full set of steam range isolation valves [redacted]. These were installed during a planned outage in [redacted]. The replacement plan is illustrated in the following Figure 2-2. The works address Ramboll's concerns raised in [redacted], proving LEL with more operational flexibility. This included an enhanced ability to isolate plant areas for works or servicing.

[redacted]

LEL undertakes NDT inspections in accordance with pressure regulations. Inspections have not identified any issues.

Steam main line replication testing was conducted in [redacted] This confirmed NDT findings, and indicating that no creep damage was evident.

LEL's boiler and live steam system is designed for [redacted]. However, the plant has been operating at about [redacted] Usually system and material lifetime can be prolonged for [redacted] °C of reduction in operating temperatures from the design temperature. This correlation indicates a much-prolonged lifetime for LEL's steam system.

Given that steam system operating temperatures at Edmonton are notably below design temperatures, Ramboll does not foresee the need for extensive replica testing. We believe that steam system availability can be maintained as long as the existing NDT and replica testing programme is continued.

Our assessment is based on the pre-condition that the steam system is designed for the stated temperatures of [redacted] Ramboll has previously recommended a material identification test to confirm this.

On WPS prepared for the replacement valves installation in [redacted] material is identified as [redacted]. Both materials are not susceptible for creep damage at the current operating levels. Precious replica testing did not reveal any damage/cracks. The risk levels can be therefore confirmed.

Frequent replacement of superheaters on the facility caused particle flows to the turbine, thus causing blade damage. Cyclone separators have been purchased and installed on all live steam lines upstream of the [redacted] main turbines. The cyclones are intended as protection against the risk of further damage from particles in live steam, thus reducing turbine damage risks considerably. Feedback from interviews held with facility personnel is that cyclones operate effectively, and particle related turbine damage has not been observed since cyclones installation.

2.7.2 Turbines

Steam is fed to [redacted] directly driven steam turbines, each coupled with a generator, rated at [redacted]. The make of main turbines is Associated Electrical Industries (AEI), which is now part of Alstom, a recognised steam turbine generator and other industrial equipment supplier.

[redacted]

The [redacted] bleed was used to supply steam to autoclaves. This bleed was originally designed to supply steam for air pre-heating, but the air pre-heaters have since been dismantled - see also 2.3.5.1. The autoclaves are also no longer in place. Steam from the bleed is now used to heat water for crane grab washing and for the calorifier.

The second bleed supplies steam to the de-aerator. LEL intends to operate deaerators at [redacted] However, there are periods where lower condensate temperatures, in the range of [redacted] are observed. This is primarily due to limited turbine bleed capacity for supporting [redacted] deaerators.

The third bleed supplies steam to a feed water pre-heater. Steam supplied is at an approximate temperature of [redacted]

LEL originally had [redacted] gear driven 'house' turbo-generators, each rated at [redacted] Following major damage to these turbines, the house sets were replaced in 2013 by a single house turbine rated at [redacted]. The house set was supplied by [redacted] The house set is only operated when one of the [redacted] main sets is not available.

The [redacted] tripped when it was brought into service in [redacted] This is in line with modern standard steam turbine design and is an appropriate health and safety measure. The turbine trip experienced can arise at old or new plants, whether an entirely new plant or a turbine is retrofitted or supplied into an operational plant. Steam turbines are designed with a range of trip mechanisms as industry practice.

LEL is in the process of the procurement of a new house set of a larger capacity, rated at [redacted] Physical and process tie-ins will be identical with the currently installed house set. The new house set is expected to increase plant flexibility and ability to realise higher waste processing levels.

LEL's main steam turbines are designed for steam supply at [redacted]. However, due to excessive high temperature corrosion rates at boiler superheater banks, steam temperature was reduced in the late-1990s to approx. [redacted] Operational temperatures are in the order of [redacted] due to reduced superheater surface areas, refractory on the elements and boiler fouling.

The new house set is rated at a steam parameter of [redacted] That is somehow lower that the live steam temperatures the plant is currently operating. Th house set is designed to withstand variations in the live steam parameters according to applicable norms. Ramboll advises LEL to confirm with the supplier of the new house set that continuous operation at such condition will not increase risk of damage and is does not limit the design lifetime of the equipment at critical levels.

[redacted] a steel stake being driven into the ground to support metal formwork penetrated a [redacted] cable resulting in a loss of electrical supply to part of the plant. This cable strike, and the failure of the electrical protection to isolate the fault, resulted in a sequence of events which led to the subsequent damage to Turbo-Alternator 2 (TA2).

As a consequence of the incident the turbine shaft had moved 7mm towards the generator and bended the axle. Turbine blades in stages [redacted] have been also severely damaged as also both bearings.

[redacted]

On aftermath of this event and as Ramboll has previously recommended, shaft online vibration monitoring devices will be installed on all [redacted] their survey periods starting with [redacted] will have it installed in [redacted] respectively.

[redacted] coupling to generator has been also damaged after a generator incident had its coupling bolts replaced and is subject to coupling face remedial works upon next [redacted]

[redacted], repair work on the turbines is conducted by [redacted] new specialist steam turbine servicing company. LEL steam turbine servicing activities include a large refurbishment/overhaul of each main turbine every [redacted] years. This is in line with/betters good steam turbine maintenance practice.

[redacted]

- [redacted]
- [redacted]

We note that LEL's scope of turbine servicing/overhauls is very comprehensive. Activities include inspection and repairs of the steam turbine and valves, steam condensers - including ejectors, oil systems including oil coolers – oil purifier – condenser –oil tank and de-superheater condenser.

Following Ramboll's recommendation, functional checks of safety valves for turbine drains and bleed lines were performed in [redacted].

It has been observed that scope of overhaul has been slightly limited based the records from [redacted] outage. Safety valve tests have not been repeated in 2017 and rotor replica has not been performed.

[redacted]

[redacted]

[redacted]

LEL's main turbines are almost over 45 years old. Securing spare parts for these turbines can be difficult. Therefore, most turbine parts must be 'reverse engineered'. To date, LEL has not experienced this as being a problem and holds critical spare parts on site.

Changing live steam inlet conditions from [redacted] has an adverse effect on the steam quality at turbine exhaust/rear blades. According to WEIR Turbines some erosion was observed in the low-pressure end of the turbine. However, no noticeable further erosion has been observed since.

It should be noted that stress cracks in the casing of LEL turbines have been observed. LEL reported that these stress cracks have been regularly monitored over the past 20 years and no growth has been noted. LEL suggests that these cracks originate from poor welding during turbine manufacture. The stress cracks noted are not considered to constitute a risk.

In [redacted] one of the main turbines [redacted] was exposed to an oil fire. This is understood to be as a result of leaking lubrication oil from the front bearing pedestal penetrating turbine insulation. The steam turbine underwent major repair and was brought back into operation in [redacted]. LEL has carried out short-and long-term maintenance to prevent the same failure on the remaining three main turbines and no such incidents have occurred [redacted]

[redacted] has incorporated air seal sealing in the bearing pedestals and installation of additional CO_2 firefighting equipment as part of its measures to avoid oil fires.

During a planned over speed test in [redacted]) was exposed to bearing damage. This is believed to be due to failures in the lubrication oil pressure switches that control operation of the electrically driven lubrication oil pumps.

Following the incident, intervals of oil pressure switches has been re-evaluated and oil pressure switches are now maintained every [redacted].

The hydraulic controllers for steam control valves on all [redacted] have undergone major maintenance for better regulating with newly installed electronic control and synchronization units.

LEL has completed a programme of upgrading mechanical internals on [redacted] on each turbine. All steam turbines have had improved/modified governor valves fitted in addition to the new governor control system.

In its [redacted] condition survey report Ramboll recommended the replacement of all ring nozzles as substantial repairs had been undertaken in [redacted] by major overhauls in [redacted] risk is now considered considerably lower after the installation of the steam cyclones and the fact that minor repairs are carried out under the revenue budget every [redacted] years. A replacement nozzle ring was fitted to [redacted].

LEL's steam turbines are operating at temperatures considerably below creep damage levels, usually [redacted] and above. In addition, LEL advised that each steam turbine does not have more than [redacted] year. Therefore, risk of low cycle fatigue is considered to be low. The pattern of LEL start-ups has not been analysed. However, steam turbine has been on duty for almost twice their design lifetime. Thus, whilst there are neither indications of creep damage nor a notable risk of crack propagation, Ramboll recommends a remaining lifetime study of steam turbines to support more informed residual plant lifetime and investment planning.

In addition, whilst replications test conducted at the rotor in [redacted] did not reveal evidence of creep damage Ramboll recommends expanding replications tests to include nozzle arrangements.

LEL has advised that trip testing witnessed by the Insurance Surveyor of all the turbines is carried out annually. Ramboll also recommends that LEL examines and tests the entire trip matrix for the turbines and the alternators to verify that all trip signals are handled correctly, and that the instrumentation is in good operation condition and is tested and calibrated regularly according to a maintenance plan.

Further descriptions of the upgrades detailed above are presented in [redacted]

2.7.3 Condensers

LEL steam turbine condensers operate under a vacuum pressure, generated by the steam fed air ejectors. Condensing pressure is defined by the plants cooling water system. Condensers tubes are made of brass. A number of thickness measurements are performed on these during each refurbishment. LEL had reported that during the 20 years prior to [redacted] a couple of condensers had been re-tubed.

In [redacted] condensers started to show signs of fatigue and LEL experienced a number of condenser tube leaks. LEL has retubed all [redacted] condensers. This work was completed by the end of [redacted].

Plant condensers are inspected every time turbines are out for an overhaul. During a recent outage condenser laminating have was observed and rectified. [redacted] had also its water box stitched. The risk of any damage/outage attributed to condensers for operations to 2025 is considered low.

Ramboll observed from control room screenshots at the time of site visit that poor vacuum is experienced on all condensers. Poor vacuum can be attributed to many factors. Given the fact that the poor vacuum is experience on all condensers, a consistent problem such as leakages or poor ejectors function may be the reasoning. Cooling capacity constraints are also responsible for the poor vacuum - relatively high cooling water temperature, but it cannot justify the increase in temperature difference between steam condensing temperature (as this is calculated from the condensing pressure) and cooling water outlet temperature that has been observed.

As a first step, Ramboll recommends the conduction of leakage/air tightness test at condenser when not in service. Based on the outcome of the test additional tests and/or rectifiable works can follow.

A "dump condenser" was installed to introduce some flexibility in the system, e.g. when all turbines are running at full load. The dump condenser worked like a flash tank where part of the steam was condensed and pumped back into the condensate system, and the remaining steam (now at atmospheric pressure) was 'dumped' or evacuated above the roof of the turbine building

In [redacted] the dump condenser was out of service and required repair. LEL had advised that it had not been repaired as it was considered to be of little value, diverting much needed cooling water from the main turbine and condensate losses were too great, hence being unable to keep up with demand and putting remaining plant at risk.

As of today, the plant does not have a dump condensing capacity for continuous operation (turbine bypass station and dump condenser). Ramboll previously recommended a new dump condenser to be installed. The dump condensing capacity shall make it possible to have one of the [redacted] main turbines out of operation and still run the [redacted] at maximum capacity. LEL's new house set will now provide such flexibility and thus precludes the need for a dump condenser.

2.7.4 Cooling Water Plant

The cooling water plant is designed in much the same way as the steam system. Both the supply and return piping to the [redacted] cooling towers are of the ring type, with sectioning valves in between all towers [redacted]

The cooling water pumps are operated at constant speed, whereas cooling tower fans can be operated at two speeds (full and half). Fans motors drive through new helical gearboxes to the fans.

Water for use in the cooling water plant is abstracted from a culvert containing treated secondary sewage water from Deephams sewage treatment plant (STP).

Cooling water is saturated with oxygen at [redacted] which increases risk of corrosion.

Pipes in the following heat exchangers in the water cooling system are made of brass to prevent corrosion:

- [redacted] condensers
- [redacted] coolers for alternators
- [redacted] exchangers for lubrication oil for the [redacted]

The main cooling ring pipes are lined with rubber, internally and externally coated with Bitumen. This lining appears to be missing in several places, and the auxiliary cooling circuit connected to the main cooling circuit is not rubber-lined.

In circa [redacted] a visual inspection of an isolated underground section of the cooling water circuit was performed and some thickness measurements were carried out where the internal protective lining had broken down. LEL was of the view that quite a lot of the rubber lining was missing. However, thickness measurements revealed no significant signs of corrosion.

LEL believes that most of the missing rubber lining fell off more than 25 years ago. At that time LEL often experienced problems with the nozzles of the cooling tower blocking up. Since then strainers/filters have been installed and the problem is no longer experienced. Today strainers only contain very limited amounts of small rubber bits, thus no corrosion in shells in the strainers of the cooling water system.

LEL reports leaks in the main cooling water pipes have been experienced in spots where external protection was cracked and broken down, thus rain water had entered cracks and corroded the pipe from outside. In LEL's opinion these repairs have been relatively easy to undertake. LEL estimates that a leak occurs in the system once a year.

Alternators are only indirectly cooled by cooling water. The cooling water heat exchanger is located below the alternator and no damage has occurred to the alternator where leakages have occurred. The internal brass piping of the heat exchanger has been replaced and equipment detecting water leakages in these heat exchangers has been installed on all [redacted] main air coolers.

The main cooling water actuators and all piping on the cold side have been recently replaced [redacted] Hot side piping replacement is due during this year's outage.

The [redacted] pumps for the cooling water system are made of cast iron. These pumps are refurbished/maintained regularly as part of plant O&M schedule. LEL has not experienced problems with their operation or maintenance.

An automated pH regulation doses approximately [redacted] in the cooling water system to adjust pH and protect the condensers against calcium phosphate deposits.

Chlorine has always been added to cooling water to reduce biological activity and avoid legionella health risks. This process was replaced by Sodium Hypochlorite in [redacted].

New packed beds were installed on all [redacted] cooling towers in [redacted]. Packed beds are expected to be replaced once again during the plant's lifetime. This is considered as a part the plant's OPEX. Drift eliminator were renewed in three cells in [redacted] with the remaining cells completed in [redacted]. Air inlet screens were replaced on all [redacted] towers in [redacted]. Major timber replacements works were completed on towers [redacted]. New fan gearboxes were installed in [redacted] fan blades have been replaced in the recent years.

LEL is currently carrying out surveys to improve plant cooling capability, which is historically an issue at hot days during the summer months. Among others upgrade of water spraying nozzle and change of fan blades pitch, pack cleaning or installation of intermediate diffuser.

2.7.5 Feed Water Pumps

The feed water system comprises [redacted] on a main ring, one for each boiler and one as reserve. The [redacted] pumps were replaced in [redacted] and the remained are due to be replaced in [redacted]. Minimal maintenance will be required for plant operation to 2025.

All feed water pumps feed water to a common header. In the event of electrical failure, motors for the pumps are all supplied from different sources, thus reducing complete failure risks. In the event of a complete electrical failure there is a potential risk of being unable to supply water into boilers because no steam driven pumps are installed. LEL states that this has only occurred once in over 40 years. This risk is considered minimal. It is noted that some new built EfW plants also don't have steam driven feed water pumps.

All boiler feed pump motors were upgraded to [redacted].

2.7.6 Oil System

Each turbine/generator set has its own oil system. A water separator and centrifuge has been installed to remove any particles from oil. Oil systems are inspected and repaired as part of the turbine overhaul performed every [redacted]

2.7.7 Summary/Conclusion

The condition of the turbine has been described in [redacted] company maintaining the equipment[1] "*It is of our opinion that providing that the repair and inspection sequence is kept up - there should be no problem to meet another 10-12 years and beyond - however due to the condition of some of the blading, some rows may have to be changed.*"

Ramboll has not been made aware of anything in [redacted] which would indicate otherwise. The same level and sequence of repair should be kept. The following upgrade/refurbishment have been undertaken or planned in the near future:

- [redacted] Condensers have been retubed
- [redacted] Cooling units have been refurbished. Works include:
  - New timber
  - New packing beds
  - New fans gearboxes

[1] Roy Goodge, who is Business development Engineer at Weir Services

- Steam cyclones installed to steam lines
- New sectioning/isolation valves for the Steam/headers
- Establishing online vibration monitoring system on all 4 main turbines
- New actuator of main cooling water lines
- New cooling water actuators and piping
- New feedwater pumps

One main turbine [redacted] was exposed to an oil fire in [redacted], where lubrication oil leaking from the front bearing pedestal apparently penetrated the insulation of the turbine. To avoid oil fires from happening again LEL incorporated air seals in the bearing pedestals and installed CO_2 firefighting equipment on all main turbines.

During a planned over speed test in [redacted] one main turbine [redacted] was exposed to bearing damage. Following this incident, intervals of oil pressure switches has been re-evaluated and oil pressure switches are now maintained every [redacted] as part of main turbine overhauls.

Hydraulic controllers for steam control valves on all [redacted] turbines have undergone major maintenance to better regulate them with newly installed electronic control and synchronization units.

LEL has completed a programme of upgrading mechanical internals on [redacted] valves on each turbine. All turbines have had the improved/modified governor valves fitted together with new governor control systems.

LEL's steam turbines are operating at temperatures considerably below creep damage levels, usually [redacted] and above. In addition, LEL advised that each steam turbine does not have more than [redacted] per year. Therefore, risk of low cycle fatigue is considered to be low. The pattern of LEL start-ups has not been analysed. However, steam turbine has been on duty for almost twice their design lifetime. Thus, whilst there are neither indications of creep damage nor a notable risk of crack propagation, Ramboll recommends a remaining lifetime study of steam turbines to support more informed residual plant lifetime and investment planning.

In addition, whilst replications test conducted at the rotor in [redacted] did not revealed evidence of creep damage, Ramboll recommends expanding replications tests to include nozzle arrangements.

Ramboll recommends that LEL continue to monitor the cooling circuit carefully - especially when most of the rubber lining is missing, which in most circumstances may lead to increased corrosion rates. This will also help ensure that repair works are undertaken in good time. These tests can be undertaken during full plant shutdown later this year.

LEL is in the process of the procurement of a new house set of a larger capacity, rated [redacted] kW. The new house set is expected to increase plant flexibility and ability to realise higher waste processing levels minimising the necessity for a dump condensing capacity.

[redacted]

2.8 Auxiliary Systems

2.8.1 Hydraulic Stations

There are a number of different hydraulic stations which are described in the sections below.

2.8.1.1 Hydraulic units for activation of feeding pusher

There are [redacted] process lines. All units are placed in the boiler hall behind the furnaces. One unit comprises a constant speed electric motor joined together through a coupling with the hydraulic pump. It has an electrically driven fan for cooling of the oil to protect against excessive oil temperatures. The electrical boards are placed on the wall behind the hydraulic packs.

The feeding chute comprises one piston (Ram) covering the width of the grate which is moved by a double-action hydraulic cylinder. The movement of the pusher may be regulated by means of an installed flow valve, which makes the feeding speed adaptable to the variations in the calorific value of the waste and the load required at any time. The pushers are operated from the control room. The [redacted] units have been manufactured by a local supplier and it uses Vickers' valves.

One of the units has a reserve pump, which is common for the [redacted] feeding pushers. The reserve unit is also placed in the boiler hall behind the furnaces. There are no reserve valves on this unit. All units are functional and seem to be very well maintained (they are all overhauled annually).

2.8.1.2 Hydraulic unit for activation of water-cooled feeding chute damper (below the feeding hopper)

There is one complete unit common for the [redacted] and it is placed in the boiler hall behind the furnaces, next to one of the feeding pusher units. One unit comprises [redacted] constant speed electric motors and is connected by a coupling with [redacted] pumps.

[redacted] on the hydraulic pack is a reserve pump. The control board has been built onto the hydraulic pack, and the pump can be operated directly from this board or alternatively from the control room.

The shut-off damper, which rotates through about [redacted], is activated by [redacted] cylinders mounted on the [redacted] sides of the chute. The hydraulic aggregate is functional and seems to be very well maintained (they are all overhauled annually). Normally the furnaces are operated with an open damper and the water-cooled chute is full of waste. The damper is connected to the safety system so that it closes automatically if incidents occur which require the feeding of waste to cease.

2.8.1.3 Hydraulic units for activation of trim doors in front of waste pits

There are [redacted] hydraulic units, common for the service of [redacted] moveable safety doors designed to prevent lorries from sliding down the feeding ramps leading to the waste bunker in the reception hall. The units are placed under the feeding ramps. [redacted] comprises constant speed electric motors and is connected through a coupling with the hydraulic pumps. Pressure accumulators ensure that the hydraulic pressure is always present in case of pump failure.

There are a [redacted] of which [redacted] reserve pumps.

All trim doors can be operated at the feeding ramps in the reception hall and from the control panel in the basement, by the trim doors.

The hydraulic units/power packs and corresponding control panels were all replaced in [redacted] are functional and seem to be very well maintained. The hydraulic system is very complex and will most likely require a good deal of attention and maintenance.

2.8.2 Compressed Air Plant

2.8.2.1 Air pressure system for supply of flue gas treatment

The FGT plant has three [redacted] screw compressors to replace those damaged in a fire in 2015, [redacted] air dryer with a refrigerant dryer was also renewed at the same time plus an older desiccant dried which is generally only used as a backup.

[redacted] compressors installed in [redacted] supply the De-noxification plant through a refrigerant dryer and station air to the Boiler and Turbine houses and also through desiccant dryers to the instrument air systems. This system has been supplemented by a [redacted] screw compressor in the place of an old [redacted] reciprocating compressor. There are also [redacted] old [redacted] reciprocating compressors which operate at a lower pressure for an emergency backup if required.

The precipitator fly ash is transported away using a dense phase conveying system. This system has [redacted] dedicated [redacted] screw compressors

The effluent treatment plant has its own system supplying compressed air using [redacted] compressors via a refrigerant dryer to the plant

2.8.2.2 Air Pressure System for Supply of Effluent Plant

Two complete compressor systems for the production of dry and clean instrument air have been installed for the activation of valves and miscellaneous measuring equipment on the effluent plant, which filters all waste water at the EfW plant before it is discharged to the public sewers.

A joint drying and filtering system, including a buffer tank for the dried, compressed air has been installed. Compressors, drying facilities, compressed air tanks and control panels have been supplied by [redacted] Each compressor is built into a separate silencer cassette and each has its own control panel, accessible from the front cover of the cassette. The entire equipment is placed in a common room in the same building as the water purifying plant.

The screw compressors and the plant supplies dried air at a pressure of [redacted]. The plant has been designed with a reserve capacity. All compressors and associated equipment are functional and appeared to be in a good condition.

2.8.2.3 Air pressure system for fly ash transportation

[redacted] compressor systems have been installed for the production of dry compressed air used for transportation of the segregated fly ash and residues. Fly ash from the electro static filters and residue from filter bags is transported to [redacted] silos, from where it is emptied into road tankers for disposal off site.

The air is further used for the activation of various valves, measuring and control equipment at the flue gas plant.

The [redacted] units are each connected to a complete and uniform drying and filtering system with buffer tanks for the dried, compressed air. The [redacted] air systems are connected in parallel on the transportation pipeline system and are redundant. Compressors, drying system, compressed air tanks as well as control and electrical panels have been supplied by [redacted] Each compressor is built into a separate silencer cassette. The entire system of compressors, drying system, compressed air tanks as well as control and electrical panels is placed in a building section of the boiler hall at ground level.

The screw compressors and the plant supplies dried air at a pressure of [redacted] The plant has been designed with a reserve capacity. All compressors and associated equipment are functional and appeared to be in good condition.

2.8.2.4 Operational compressed air

Two complete compressor plants [redacted] furnace-boiler lines as well as the turbines, steam and feed-water instrument air system. Both compressors are connected to the joint cooling and drying facilities. The DeNox systems on the [redacted] boilers are connected to the high pressure system (without pressure reduction). A specific buffer tank of approximately [redacted] been installed, containing dry and clean air for the supply of all DeNox systems. After the compressors, a pressure reduction station and a buffer tank of approximately [redacted] been installed, distributing the air to the remaining consumers at the plant. The two compressed air systems are redundant and have been connected in parallel to a common pipe section from where the air is distributed to the two buffer tank systems. Compressors, cooling and drying systems, reduction and control panels have been supplied by [redacted]. Each compressor is built into a separate silencer cassette and is controlled from the control panels placed on the front cover of the cassettes. The entire system of compressors and control and electrical panels is placed in the boiler hall in the basement next to the cooling water pumps, placed under the turbine hall. The screw compressors and the plant supply dried air at a pressure of [redacted] plant has been designed with a reserve capacity. All compressors and associated equipment appear to be in a good condition.

2.8.2.5 Standby compressed air system

In the turbine basement, 3[redacted] have been installed, intended for the production of dry and clean compressed air servicing the boiler and turbine installations. The piston compressors have been supplied by [redacted] and were installed mid to late 1[redacted]One of these was replaced with [redacted] compressor in [redacted] compressed air systems are on stand-by and attached to the compressed air network for the newly installed compressed air system, supplying the compressed air to, boiler and turbine systems. The three compressed air systems are in a good condition and fully functional.

2.8.3 Make Up Water Plant

The make-up water plant was installed approximately in [redacted]. It consists of [redacted] each consisting of a mixed bed, anion and cation. While [redacted]system is in operation the other system is regenerating. [redacted]

At times, the make-up water plant capacity is not sufficient and it is then necessary to purchase demin water. Consumption of demin water is increased by a number of small steam leaks throughout the plant and steam is lost in the turbine drain system, although the loss has been reduced with a new drain manifold installations. Further work on the system is recommended – even though it requires all turbines to be out of operation because these pipes are all interconnected with no shut-off valves to isolate systems.

It is estimated by LEL [redacted] be adequate for handling this emergency situation without purchasing supplementary demin water.

LEL has purchased its own demin tanker to provide additional storage capacity. This should help the plant to cope with some potential steam/water leaks, emergency scenarios and temporary breakdowns of the demin plant.

However, recently there has been an incident of demin water shortage where the complete plant needed to shut down due to demin water shortage. The incident was caused by failure of town's main water supply and also supply failure of backup tanker truck where external demin water supply from other facility was not available. To have a more robust supply of demin water, LEL has [redacted] installed and commissioned a make-up water pre-treatment plant (an RO-plant). This is supplied with cleaned water from the near-by sewage treatment facility. In addition to provide cost savings as compared to town's main water consumption this also provides additional reliability/robustness of the system where a cut off in towns main water supply will not impact the production of make-up water. However, there has been some commissioning issues with this new pre-treatment/RO-plant, which LEL is addressing by installation of inverters on the pump motors and actuators with soft open/close functions. [redacted]

2.8.4 Effluent Plant

On site there is an effluent plant [redacted] which treats the following waste water streams:

- Waste water from the fuel preparation plant
- Waste water from [redacted]
- Waste water from bottom ash quench bath
- Water from washing

Bleed from the cooling water plant is mixed with the outlet from the effluent plant. The measurement point is after mixing with bleed water from the cooling water system. LEL advised that all discharge is below the environmental permit limits.

Surface water drains go to the interceptor pit before being pumped into the ditch on the east side of site. Drainage from FGT area goes via boiler house sump to ETP.

Previously all boiler internals were washed causing significant amounts of heavy metals to be directed to the effluent plant. The amount of heavy metals to the effluent plant has been reduced significantly due to other cleaning methods being applied (the explosion cleaning in the boiler banks). Water washing of the economisers still takes place. Therefore, the purpose of the effluent plant is now primarily removal of solids from the effluent. However, the ETP is designed to removal heavy metals if required to, with its flocculation process.

The following chemicals are dosed in the effluent plant, if needed:

- Polyelectrolyte
- Lime
- HCl

For the time being, only neutralisation with HCl is used.

The effluent plant has undergone several changes and we consider it now to be working satisfactorily.

However, an I&C (Instrumentation and Controls) upgrade of the effluent treatment plant has been ongoing throughout [redacted] is a quite comprehensive upgrade of the I&C system for the effluent treatment plant.

The quantity of water discharged to sewer through the ETP has been reduced significantly now that greater use of recycled water is made in the cooling water system.

2.8.5 Hoisting Equipment

The turbine hall is equipped with a traverse overhead crane with a lifting capacity of [redacted] with an auxiliary hook of [redacted]

In the boiler building there is no traverse overhead crane. However, in the tipping apron there are [redacted] hoisting beams with associated hoisting equipment.

2.8.6 Storage Tanks

Just outside the turbine and boiler buildings close to the flue gas cleaning the following storage tanks are positioned:

- Carbamin
- HCl
- H2SO4
- Demin water A and B [redacted]
- A caustic (sodium hydroxide) tank [redacted]

The sodium hydroxide tank, hydrochloric acid tank and sulphuric acid tanks [redacted]

2.8.7 Summary/Conclusions

There are three hydraulic systems at Edmonton:

- Systems for activation of feeding pushers
- Systems for activation of water cooled feeding chute dampers
- Systems for activation of trim doors in front of waste pits

Generally, all these hydraulic systems seem to be well maintained.

For each of the following compressed air consumers a dedicated compressed air system exists:

- Supply of FGT
- Supply of effluent plant
- Supply of transportation system for fly ash transportation
- Supply of grate, boiler and turbine installation

All the compressed air systems seem to be in a good condition.

In certain situations, the make-up water plant capacity is not sufficient and it is then necessary to purchase demin water (especially when boiler tube leaks occur). A tanker has been purchased by LEL to provide storage capacity helping to mitigate the lack of capacity.

However, recently there has been an incident of demin water shortage where the complete plant needed to shut down due to demin water shortage. The incident was caused by failure of town's main water supply and also supply failure of backup tanker truck where external demin water supply from other facility was not available. To have a more robust supply of demin water, LEL has in [redacted] installed and commissioned a make-up water pre-treatment plant (an RO-plant). This is supplied with cleaned water from the near-by sewage treatment facility. In addition to provide cost savings as compared to town's main water consumption this also provides additional reliability/robustness of the system where a cut off in towns main water supply will not impact the production of make-up water. However, there has been some commissioning issues with this new pre-treatment/RO-plant, which LEL is addressing by installation of inverters on the pump motors and actuators with soft open/close functions. Furthermore, LEL is planning to replace the existing demin water storage tanks with larger tanks

The purpose of the effluent plant is now primarily removal of solids from the effluent – as only very limited amounts of heavy metals are present in the effluent. However, the ETP is designed to treat heavy metals if required, through its flocculation process. The effluent plant has undergone several changes and we consider that it is now working satisfactorily.

At new facilities, Ramboll normally recommends to install overhead transverse cranes in the boiler hall and in the turbine hall for service. The turbine hall is equipped with overhead transverse cranes for service, but in the boiler hall this is not an option at LEL due to lack of space above the boilers.

2.9 Civils and Structures

The findings below are based on a visual inspection of the readily accessible parts of the EfW plant/site. No intrusive inspections of structural elements were carried out and no samples were taken. Foul, surface, and process drainage was not inspected.

The following elements were visually inspected:

- Access and Egress Ramp
- Tipping Hall Structure
- Workshop, stores and offices
- Turbine Hall
- Flue Gas Treatment plant steelwork including Electro Static Precipitators and Reaction Towers Cooling Towers
- Concrete Shield to double flues
- Waste Bunkers
- Bottom Ash Storage
- Boiler Hall
- Roads and Paving

2.9.1 Access and Egress Ramp Structure

Access to and egress from the elevated tipping hall is via ramps to the north and south of the reception hall.

The ramp structures are elevated and appear to be constructed of a series of precast concrete beams to support the deck spanning onto insitu concrete "T" piers with a precast concrete parapet as shown in [redacted]

There are concrete wing walls at the base of the ramp within which a switch room is located.

Drawings of the ramp show that it is constructed as a series of piers supported by piled foundations supporting precast beams.

2.9.2 Access and Egress Ramp Condition

The ramp structures were repaired in [redacted] an impressed current cathodic protection system was installed to protect the structure for a design life of 25 years.

The specification documents for the repair ask for the support piers, abutment and ramp walls, beams at expansion joints, entrance ramp and parapet, exit ramp and parapet and infill to the soffit of the ramps to be repaired and inspected.

It can be seen on site that the piers and abutment walls have been sprayed with a repair concrete and the [redacted] has been installed. A sign has also been fixed to a pier to say that the structure contains embedded cathodic protection equipment and drilling into the structure is prohibited. The system will require regular testing to ensure that the a.c. power remains on and the [redacted] units are operational as recommended by the installers to make sure that the system remains effective.

There is some fine crazing to the sprayed concrete on the piers as can be seen in photograph A8 02. These were highlighted because of damp from recent rainfall tracking on the concrete.

There is staining as a result of water leaking at the location of a joint in the parapet panels on the lower west side of the egress ramp [redacted]

There is a small area of spalling to the corner of a parapet panel as seen in photograph A8 04 and there are small areas of cracking with staining to the bottom of some of the parapet walls as [redacted]

The sealant between some of the joints to the parapet walls is beginning to break down and de-bond [redacted]

There was no access available onto the ramps because they were in use by vehicles but when viewed from the bottom of the ramps, the wearing surface appears to be generally in a satisfactory condition but when viewed from the tipping hall roof there appears to be cracks at the location of the movement joints [redacted]

2.9.3 Tipping Hall Structure

The tipping hall has a felted flat roof supported on purlins spanning between beams that span the width of the hall from the concrete bunkers on the west side to columns within the external wall on the east side.

There is a suspended ceiling above the roadway which conceals the roof structure over this area.

There are [redacted] into the bunker on the west side that are flanked by insitu concrete wing walls and there are masonry infill panels within the concrete frame structure on the east side.

The floor has a bituminous surfacing over precast concrete floor planks that can be seen from the workshops below.

We were unable to gain access to the south side because the tipping hall was in use.

2.9.4 Tipping Hall Condition

There is some slight mechanical damage to the fins of the bunker that appears to be due to vehicular impact.

The bituminous floor surfacing appears to be in a reasonable condition.

The felted roof appears to be in a reasonable condition with only small areas of standing water [redacted].

2.9.5 Waste Bunker

The waste bunker is of reinforced concrete construction dived into [redacted] bays by internal reinforced concrete cross walls. Above the bunker, there are masonry infill panels between concrete columns separating the bunker area from both the boiler hall and the tipping hall. Above the concrete structure there are steel columns supporting a steel framed roof structure. There is glazing at high level above the tipping hall roof level. The external wall to the south side comprises steel cladding supported on steel angle side rails spanning between steel columns.

2.9.6 Waste Bunker Condition

Dust and detritus cover the structure and cladding. However, the structure appears to be in a satisfactory condition with surface corrosion only and we saw no obvious signs of any significant structural defects.

There is a broken glazing panel at [redacted]

2.9.7 Workshop, stores and Office Structure

The workshop and offices are located below the tipping hall.

The workshop area is predominately open plan with offices that are subdivided into small spaces. There are stores located to the west of the workshop. These stores are immediately below the waste chutes.

The ceiling is the floor of the tipping hall above and is constructed of precast concrete planks spanning east to west and supported on a reinforced concrete frame.

An overhead crane is supported on a steel runway beam which is supported from corbels from the main reinforced concrete columns.

The walls are generally made of brickwork which is built into the reinforced concrete frame.

The floor is of concrete construction and over approximately [redacted] the floor area is covered with timber floor tiles.

To the east of the offices is an elevated walkway with an upstand concrete perimeter wall. This walkway is accessed from the offices and by concrete staircases at both the northern and southern ends. The surface of the walkway is finished in asphalt.

2.9.8 Workshop, stores and office condition

We observed no signs to suggest that the building is suffering significant structural distress.

We observed some minor cracking in the ground floor slab which appears to be due to normal shrinkage.

2.9.9 Turbine Hall Structure

The turbine hall is located to the south of the boiler house and part of its northern wall is shared with the boiler house.

It is a steel framed building over a deep concrete basement. The superstructure comprises a steel frame with castellated steel roof beams supporting a flat steel decked roof with vertical glazed roof lights protruding above the general roof level.

The external walls comprise steel cladding supported off side rails spanning onto the primary steel structure. To the south of the turbine hall are switch rooms and transformers which are divided from the hall by a brickwork wall and the northern party wall comprises a concrete encased steel frame with infill brickwork panels.

The ground floor is partly of precast concrete construction with a tiled finish supported by steel beams spanning over the basement. Other areas comprise durbar plate or open mesh steel flooring on steel beams.

The basement comprises reinforced concrete walls and a reinforced concrete floor.

2.9.10 Turbine Hall Condition

We observed no significant structural damage within the turbine hall, but there is slight cracking within the concrete surrounds to the large openings within the ground floor [redacted] also slight shrinkage cracking to the concrete encasement to the party wall steel structure. The pattern of cracking suggests that these are caused by natural shrinkage of concrete and are not considered to be structurally significant.

There are a number of localised areas of salt staining to the walls of the basement. This staining appears to be as a result of water ingress through the basement wall which has occurred over a number of years [redacted]. The leakage appears to be ongoing and is probably dependent upon the climatic conditions, but it appears as if it is being managed.

2.9.11 Flue Gas Treatment Plant Structure

The flue gas treatment (FGT) plant is supported on an exposed structural steel frame comprising beams supported on columns with diagonal bracing providing lateral stability.

The structure is on [redacted] with steel staircases providing access between the levels. The floor is generally open mesh flooring with durbar plate to the top level.

The plant in a number of areas is enclosed by metal sheet cladding. With the exception of the area above the bag filter, the internal of these structures was not inspected.

The FGT plant is situated to the west of the boiler hall with the cooling towers located to the west of the FGT plant area.

2.9.12 Flue Gas Treatment Plant Condition

There is surface corrosion to much of the upper structure. however, generally this does not appear to have penetrated the structure or caused significant loss of section. Occasional beams are beginning to delaminate [redacted] and these should be cleaned and repainted to avoid further deterioration. The web of a column is also corroding below the point where it appears that a section of drainage pipe is missing. This should be rectified by cleaning and repainting the steelwork and replacing the missing section of pipe.

There are holes within the web of a beam forming part of a pipe support structure. The holes appear to be the result of corrosion and the web has been repainted as shown in photograph A8 22. The pipe is spanning over the structure and hence the section may not be carrying significant loading. however, the structural capacity of the beam has been reduced and this should be considered, should there be any alterations or additions required in the area.

The durbar plate walkway at the top level has not been painted and hence is covered with surface rust. To avoid deterioration, this should be cleaned and painted.

The enclosed area above the bag filter is dry and we observed only slight surface corrosion to the steelwork.

2.9.13 Cooling Towers Structure

The cooling tower building is clad with glass reinforced plastic cladding and has a timber frame structure supported on a reinforced concrete reservoir. The flat roof of the cooling tower building is timber and has [redacted] the towers.

2.9.14 Cooling Tower Condition
We were unable to inspect the timber frame, but we observed no evidence to suggest that it is suffering significant distress. We understand from LEL That the timbers are replaced every few years.

There is slight local cracking to the walls of the reinforced concrete pit surrounding the structure and there are signs that there has been some leaking. LEL advised that the cracks were sealed last year and the leaking has stopped.

There is some surface corrosion to the external steel walkways spanning over the pits [redacted]

2.9.15 Concrete shield
The reinforced concrete shield to the double flues was viewed externally from ground level only with limited visibility but it appears to be in a reasonable condition. From ground level it appears that repairs have been carried out to the upper levels.

2.9.16 Bottom Ash Storage
The bottom ash storage bunker is located to the north of the main building and adjoins the vehicle workshop structure on its eastern side. A steel conveyor structure carries the ash from the boiler hall to the bunker.

The bunker is constructed of reinforced concrete walls with a dividing wall to separate the ash and residual metals.

Above the bunker there is a steel structure clad with corrugated metal cladding.

The conveyor protrudes from a concrete tunnel rising from the north end of the boiler hall of the main building and is supported on a steel structure covered with metal cladding.

2.9.17 Bottom Ash Storage condition
There are gouge marks and scrape marks within the walls of the bunker as a result of vehicular impact and a steel protective plate is peeling away from the end of the wall on the north side, again probably as a result of vehicular impact, [redacted]

The metal cladding above the concrete bunker is in poor condition, covered in rust and some sections have broken away [redacted]

We were unable to gain access to the building because it was in use during our visit, but exposed sections of the steel structure appear to be in a reasonable condition with some surface corrosion.

The cladding to the conveyor structure is in a good condition but the paintwork to the conveyor structure is failing allowing surface corrosion to begin on the steelwork and steel plates [redacted]

2.9.18 Boiler Hall Structure
The boiler hall is attached to the west side of the waste bunker area. The flat roof over this area comprises profiled steel decking supported by a structural steel frame.

The wall construction varies and generally comprises profiled steel sheet cladding supported by a structural steel frame with glazing at high level. Some elevations comprise fair faced brickwork supported by a concrete encased steel frame [redacted]. Horizontal wind trusses support the secondary elevational posts.

The boiler hall is approximately [redacted] has a substantial basement area with an approximated [redacted] The walls of the basement are of in-situ concrete construction and suspended floors are concrete supported on a steel frame.

The boiler is self-supporting and top hung from a steel frame that with the exception of the foundation is independent of the building.

Work was being carried out on [redacted] our visit and so we were unable to access this area.

2.9.19 Boiler Hall Condition

We observed no obvious deviation from line or level to the main structural elements of the boiler hall structure.

Much of the paintwork is deteriorating and peeling away from structural steelwork at roof level with some surface corrosion of the steelwork taking place [redacted].

Much of the steelwork within the basement area is also exhibiting a breakdown of the paintwork resulting in the onset of surface corrosion [redacted]

The concrete basement floor was wet during our visit as a result of washing down and there is saturated ash pooling in some areas. In various areas, the surface of the concrete has worn exposing the aggregate. The bottom of columns seems to have been repainted a few years ago but fresh surface corrosion is breaking through particularly near the floor level [redacted].

2.9.20 External Cladding Condition.

Cladding is generally showing signs of some surface corrosion and there are a number of areas where the cladding has suffered from local mechanical damage.

The cladding to the bottom ash storage and metals recovery area is in a particularly poor condition. There are holes within the cladding around the large louvre to the boiler hall as can be seen in photograph A8 35 and sections of cladding to the workshop have been replaced with chipboard boarding. Other panels here are also loose, [redacted].

2.9.21 Roads and paving

Generally, the external areas are in reasonable condition for its age but there are areas where water is ponding and there are some areas where local damage and local settlement has occurred [redacted]

2.9.22 Summary/conclusion

Generally, the structures are in a reasonable condition. We observed no significant structural defects and saw no signs to suggest that any parts of the buildings are suffering significant structural distress.

There is some flaking of paintwork in numerous areas internally but where the areas are kept dry this will not lead to significant steelwork corrosion. There are areas where surface corrosion is occurring in damper environments such as the basement areas, the FGT area and also to the Bottom Ash conveyor structure and the paintwork to these areas will require regular maintenance to prolong the life of the steel structures.

Cladding is generally showing signs of surface corrosion at several locations and there has been some mechanical damage. Cladding will require regular maintenance and repair to keep the buildings watertight.

Minor damage has been noted to concrete structures within the building. The side walls to the basement walls and concrete floor slabs show some minor damage due to shrinkage, but this is not considered to be significant. There is also some of the walls to the ash storage areas which will require repair to avoid long term damage.

The external roadways are showings signs of wear and will require maintenance. The surfacing to the ramps at the location of the joints will require repair to avoid water penetrating the ramp structure.

[redacted]

2.10 Mechanical and electrical building services systems

The findings of this report are based on visual assessments of LEL's EfW building. Intrusive inspections were not possible and testing of systems has not been carried out. Recent inspection and testing reports made available to Ramboll have also been referred to.

Ramboll's findings from mechanical and electrical services systems condition survey are presented below.

2.10.1 Mechanical services systems

2.10.1.1 Domestic hot and cold water services

Cold water systems

The incoming cold water services serve a variety of outlets and cold water storage tanks directly. The admin block appears to be served by a single cold water storage tank within the roof space. This feeds outlets such as WC wash basins, showers and kitchenette facilities by gravity. The main building is provided with a new potable water storage tank in the upper bunker level to serve WC's, wash basins and showers. The incoming water supply also serves process water storage tanks and feed an expansion tank for the hot water/ Low Temperature Hot Water (LTHW) calorifier within the turbine hall.

The Legionella report shows that in general regular cleaning and maintenance of cold water storage tanks has not been carried out. Regular cleaning and maintenance should be a priority, to ensure safe water supplies are provided to the outlets.

Hot water systems

Hot water is generated by a Steam to LTHW heat exchanger located within the basement of the turbine hall. This is system is in poor condition and is beyond its serviceable lifespan. This circulates LTHW to coils within a number of hot water storage tanks. During the visit we were not able to locate all of the hot water storage tanks to assess their condition. However, a single hot water cylinder was located within the admin building which serves wash basins, kitchenette and showers. This was supplied by an electrical immersion heater. The cylinder and electrical supply appeared in good condition and should last a further 10 years if maintained correctly. Scale and corrosion within the cylinders and heat exchangers could not be determined and a further intrusive survey would inform on the condition. Consideration should be given to replacing these with instantaneous hot water heaters or smaller electrical storage calorifiers, in order to provide a further 10-15 years' service and to reduce energy losses inherent in the current hot water system.

Legionella

A Legionella risk assessment was been carried out in November 2017 by Nemco Utilities Limited. The report recommends a large number of remedial actions to be carried out in order to reduce the risk of infection. These include appropriate management of the water systems by regular flushing and cleaning along with installation improvement notices, such as the reduction of storage capacity, increasing ventilation for cold water storage tanks and increased hot water system installation. Hot water calorifiers were also noted to be storing water below the recommended 60°C. Consideration should be given to replacing these with instantaneous hot water heaters or electrical storage calorifiers, in order to provide a safe water supply, a further 10-15 years' service and to reduce energy losses inherent in the current hot water system

<u>Pipework</u>

2.10.1.2 Heating and cooling systems
A variety of heating systems have been employed within the building as follows.

<u>Admin block</u>

The entrance area has a large glazed façade with high floor to ceiling heights. Heating here is by 2 Dimplex electrical fan convectors above the inner entrance doors. These appear to be relatively new and may give a further 8-10 years of service if maintained correctly. It should also be noted that the heating capacity is in the order of 2kW each and may be insufficient for the space. Consideration may be given to providing additional heating/cooling to serve this space. The reception area has underfloor heating.

<u>Office accommodation and ancillary spaces</u>

These rooms are provided with DX split heat pump systems consisting of an internal wall mounted or ceiling mounted indoor unit with an associated outdoor condenser. Each room has a remote controller to provide control over time schedules temperature set points and fan speed. The units are a mixture of Sanyo and Fujitsu and contain R410A refrigerant and have been installed over the recent years. Air source heat pumps such as these deliver a high coefficient of performance and thereby a reduced parasitic load on the generation plant. The installation should provide for continued service for a further 10 years with regular maintenance and F-Gas checks. There is a maintenance contract in place currently with Adcock Engineering to ensure that this takes place. F-gas certificates show that regular leak testing in accordance with the regulations is taking place.

<u>Tipping Hall, bunker hall, boiler hall and turbine hall</u>

No heating systems installed. Heating is not considered to be required in these areas.

<u>HV/MV/LV switch rooms</u>

Each room has been provided with an array of electrical radiant panels at high level for frost protection purposes. These appear to have been part of the original installation during the late 1960's. It could not be established during the survey if the units are functional. However, typical lifespans are in the order of 8-10 years only. Replacement of these with low level oil filled electrical tube frost protection heaters would provide for a cost effective solution with minimal disruption, providing for 10-15 Years of service.

<u>Workshop and stores area</u>

There are hot water fan assisted heaters and warm air from a dedicated air handling unit installed in the workshop and stores area.

Control room

The main control room is provided with LTHW radiators fed by a steam to LTHW calorifier within the basement of the turbine hall. The radiators within the control room appear to be around 5-10 years old and are in good condition. These are provided with local thermostatic valves to control the heat output to the space.

In addition to the radiators there are 6 ceiling mounted cassette cooling only DX split air conditioning units, which both indoor units and condenser units appear to be in fair condition, with perhaps another 5-8 years serviceable life.

Ground floor laboratory

The ground floor laboratory contains a single ceiling mounted cassette heat pump unit and condenser providing heating and cooling for the space. This appears to be about 10 years old and could provide a further 5 years of service if properly maintained and cleaned.

LTHW heating plant

The LTHW plant consists of a single small shell and tube steam to LTHW heat exchanger, LTHW circulation pumps, hot water circulation pumps and pipework. The heat exchanger, pipework, valves and insulation appear to be an original installation, whilst the circulation pumps are a recent replacement. The unit has been sized originally to provide heating to the whole of the building including the hot water systems and air handling units. This is now only supplying a small radiator circuit, the work shop ventilation system and hot water to some wash basin and the laboratory outlets.

The majority of this equipment has lasted far beyond is maintainable life expectancy of 20-25 years. This is showing signs of considerable wear and leakage, with ad-hoc repairs evident. Further maintenance and replacement parts may not be economical. Pipework insulation is generally in a poor condition throughout, and remedial works will be required to replace and repair this should the LTHW system be retained.

This equipment could be de-commissioned and the installation of DX split heat pump systems in the admin block could be extended to the control room. This would provide for a low cost, low energy and with minimal disruption during installation. Hot water calorifiers served by the LTHW could be replaced. For ease of replacement and to provide a low cost, short term solution, this could be replaced by instantaneous hot water heaters or electrical storage calorifiers.

2.10.1.3 Ventilation

Office accommodation and ancillary spaces

An original hot and cold duct air conditioning system provided heating and cooling along with fresh air to each of the office spaces, has been de-commissioned and replaced with DX split air conditioning units as described in an earlier section.

The consequence of the de-commissioning of the ventilation system is that there is now no means of mechanically ventilating the office spaces. There are access doors from each room to the adjacent balcony, which serve as a means of purge ventilation. This approach appears to be satisfactory to the occupants currently and there does not seem to be a problem with odours. The current solution does not comply with building regulations. However, this cannot be applied retrospectively on a building of this age.

WC's and shower facilities are considered to not have adequate ventilation. Systems in place are via small opening windows and in some cases none at all. It is recommended that local extraction fans are provided here to reduce odours and condensation, in line with the requirements of Part F of the building regulations.

The ventilation for the reception area requires consideration. There is a section of circular spiral wound ductwork with 4 no. diffusers along its length, fixed beneath the reception presentation screen. However, further investigation proves that this duct is not connected to any fan or air handling equipment at all. Thus, this provides no function. If required, a small mechanical supply air handling unit with Carbon filtration could be provided to serve the space with filtered fresh air.

Tipping Hall, bunker hall, boiler hall and turbine hall

These areas are naturally ventilated via louvered facades. These appear to provide adequate ventilation.

HV/LV switch rooms

Ventilation is provided to these rooms via natural in/exfiltration and 1 or 2 600x600 grilles (dependent on room size) at high level to the external façade. The grilles are in fair condition and should provide sufficient life span to last a further 15-20 years. These areas are not normally occupied and heat gains from equipment do not appear to be high. Ventilation has proved to be adequate throughout the life of the building and should continue to do so. Any upgrades or additions to switch gear should be reviewed for heat gain. Dust ingress in not apparent and all areas appear to be well kept.

Control room

Control room is air conditioned with a DX split to provide both heating and cooling.

Workshop and stores area

The workshops are provided with a tempered ducted supply and extract mechanical ventilation system. A dedicated supply air fan and LTHW heating coil provides warm air to the workshop via high level supply ducts on one side of the room. Air is extracted via high level ductwork and return air fan. A bypass duct between the [redacted] fans between the air intake and return ducts allows return air to recirculate to the room.

The installation is original and has been well maintained. The expected maintainable life span is approximately 20 years for a system such as this. Therefore, the current system is due for replacement. LEL may consider a replacement Air Handling Unit (AHU) with thermal wheel. This would provide 20 + years' service.

At the soffit of the large workshop area there is a new extract system with new extract fan and new ductwork providing extract from the floor above. However, during the survey the duty of this system could not be established.

It should be noted that the equipment such as lathes, pillar drills and welding booths should be provided with local extract in accordance with HSE recommendations and risk assessments. The workshop does not appear to currently contain local extract ventilation systems for these activities.

Laboratory

The ground floor laboratory contains 2 fume cupboards and an extract hood. Although 1 is currently not operational both have recent commissioning stickers to show these are both operating to the required velocity at the sash. There is no reason to believe these will not provide a further 5-10 years' service if properly maintained and repaired. The supply air to the units was not operational and a survey of the plant room indicates that the supply fans are de-commissioned and beyond repair. Further investigation into the commissioning report is required.

2.10.1.4 Fire suppression systems

Fire suppression systems considered in this report extend to the fire sprinkler/ deluge systems and gaseous suppression systems.

A fire suppression inspection and testing report has been requested. However, LEL has not yet been able to provide one. During the survey it was noticed that the gaseous fire suppression systems within the HV/LV rooms had inspection signatures dated to 2016, and none for the subsequent 3 years.

2.10.1.5 Conclusion and recommendations

The Fire suppression systems should be investigated and verified as compliant with the building insurers.

The steam to LTHW heat exchanger, associated LTHW systems and the workshop ventilation system are beyond their economically serviceable life span. Hot water heating systems which are also served by the LTHW systems may also be past reasonable maintainable service and have been identified as a potential legionella risk, with possible excessive scale.

To provide a viable solution to maintain service it is suggested that the existing equipment could be de-commissioned, and the Installation of DX split heat pump systems could be extended to the control room and other areas heated by the LTHW system. Hot water calorifiers served by the LTHW could be replaced by instantaneous hot water heaters or electrical storage calorifiers. A Packaged AHU with a heat pump heating and cooling coil could replace the existing and aged workshop ventilation system. Additional ventilation upgrades to serve the workshop equipment base on a risk assessed approach should also be considered.

2.10.2 Electrical services systems

2.10.2.1 General

The electrical section of this report provides an overview of the electrical systems (in relation to building/building services) installed within the facility and includes recommendations for remedial works or replacement equipment.

The provision of statutory periodic testing and inspection reports of the existing electrical systems could not be made available during the site visit. We would recommend that the results of these tests are reviewed as this would further inform this study and the likely longevity of the systems before failure.

2.10.2.2 Electrical distribution systems

The supplies to electrical building services are derived from the main turbine generators via a variety of [redacted] distribution panels located around the facility. All main switchboards are HRC fuse type serving local distribution boards for final circuits. The main switchboards themselves were installed circa 1970 with final distribution equipment ranging from original 1970 loose switchgear arrangements to modern MCB distribution boards. Cabling for submains supplies are predominantly PVC/SWA/PVC but some PILC cabling is present.

The electrical distribution system is in functional order but is aged and in certain cases appears to be obsolete type equipment.

Modifications have been undertaken throughout the facilities lifetime to solve immediate supply requirements and up to date record drawings are not present. PILC cabling will be aged and has been known to suffer failure if disturbed.

Where local distribution boards are original loose gear assemblies, some are showing signs of deterioration around the enclosures. We would expect that this deterioration may also be present internally within the enclosures, but this could not be confirmed as a visual non-intrusive survey was only carried out.

There is also fused distribution equipment and switched isolators within the tipping hall area which appeared to be in very poor condition. It could not be confirmed if this equipment has been de-commissioned.

2.10.2.3 Small Power Systems

Small power systems are served from local fused and MCB distribution boards.

Small power accessories in the admin building are white plastic type devices and are either flush mounted or within PVC dado trunking around the perimeter of the room.

Accessories in the main plant areas are either metalclad outlets or industrial type socket outlets for maintenance type activities.

Electrical supplies to mechanical plant are either via local fused connection units or switched rotary isolators.

Small power systems appear to have been modified over the lifetime of the building but some of the systems appear to be original.

The small power system appears to be functional with no reported issues.

2.10.2.4 Lighting, emergency lighting and external lighting installation

Lighting solutions within the facility are varied as would be expected. Typical solutions have been implemented throughout such as modular recessed to offices, high-bay type discharge lighting to halls and ingress protected fluorescent luminaires to smaller process areas.

Lighting control in the main process areas is manual and automatic lighting control within the admin type areas.

In general, the lighting is functional with minimal failures, but older installations will prove difficult to source spares etc. if failures occur.

Emergency lighting is predominantly provided by central battery systems although some self-contained type lighting is present to offices etc. Inverters and batteries are located within electrical switch-rooms and the batteries are recorded as being replaced within the last 10 years.

Evidence of phased replacement where areas have been refurbished is present but areas such as the turbine hall appear to have minimal coverage to central areas as emergency lighting is wall mounted and obscured by plant. Where slave luminaires have been replaced advantage has been taken of modern LED based luminaires which reduce load on the battery system.

It appears that the emergency lighting system is tested at the central battery or by simulating an mains failure. Emergency lighting test key switches or an automatic emergency lighting testing system were not observed during the survey.

External lighting is provided by column and building mounted lanterns and floodlights. The installation appears suitably extensive, relatively modern and although the inspection was carried out in daylight, it is reported to be functional. It was not clear how this system is controlled but it is assumed via photocell and time clock arrangement.

2.10.2.5 Fire detection alarm and alarm

A site wide fire detection and alarm system is present with the head end located in the control room and repeater panel within the office block. The system is an analogue addressable system and comprise of call points, automatic fire detection and air sampling systems (main turbine hall).

Smoke detection is provided within the circulation spaces of the admin areas. Void detection has also been provided within this area of the admin building as remote indicator devices were observed within the corridors. Fire detection is not provided within the rooms of the admin building which is an observation and does not mean that the system is non-compliant, we recommend that this is reviewed further.

Flame detection type devices are also provided within the turbine hall and appear to be providing coverage of the main turbine plant.

The boiler hall appears to have provision of a wireless fire alarm annunciation system. Automatic fire detection in the boiler hall was not observed during the site visit.

The system appears to be functional but there were two error codes being reported by the repeater panel in the main reception at the time of inspection. One of the faults being an issue with a detector in the Turbine Hall.

The fire alarm annunciation is via electronic sounders and flashing beacons in specific areas. We did not test the audibility of the system but would assume that the system is in working order and suitable alarm audibility is provided.

There was some evidence of poorly placed detectors (on wall mounted brackets in switch-rooms) and a lack of automatic detection in some workshop areas. This is not necessarily non-compliant with regulations, but we recommend further investigation e.g. fire risk assessment updated in line with the Regulatory Reform (Fire safety) Order 2015.

2.10.2.6 Structured cabling installations

A site wide data/communications network is provided with fibre backbone and twisted pair copper distribution layer cabling.

A structured cabling system is also present which generally [redacted].

Wi-Fi routers are also provided to specific areas which appears to be a recent installation.

A series of emergency telephones are also included around all areas which we understand link back to the main control desk.

Access could not be gained to the main server room, but we would assume that the system is in good working order as there were no reported issues.

2.10.2.7 Closed Circuit Television (CCTV) System

CCTV is provided to monitor process throughout the installation and record external access routes. All cameras are relayed to the main control room. All installations appear to be in good working condition, modern dome and fixed cameras were in evidence and no adverse observations were made.

2.10.2.8 Electronic access control

Electronic door access control is also provided on specific doors to restrict access to secure areas.

The system generally consists of a proximity reader on the non-secure side and a green emergency break glass and push to exit button on the secure side of the door. The locking devices appear to be magnetic locking type devices.

The system appears to be recent and in working order.

2.10.2.9 Lightning Protection

A lightning protection system is provided for the building.

The system consists of a bare copper air termination network clipped direct to the roof of the building which is connected to a series of down conductors that terminate in earth electrodes in the ground.

The earth electrodes are complete with access lids flush within the ground and we assume that there is a test point to enable testing of the system.

The system appears to be in a working order with no further adverse observations.

2.10.2.10Conclusion and recommendations

The majority of the electrical distribution systems are beyond their design service life but remain functional. Incidences of cable/distribution failures could be expected to increase in the coming years, especially where services are disturbed. There are no major factors indicating system wide failure, however obsolescence of equipment will prove costly should local failures occur.

Emergency lighting systems should be fully functionally tested and resultant coverage checked. Where systems are proven to be ineffective new emergency lighting schemes to provide safe egress should be provided.

Fire alarm system should be reviewed, and automatic detection added to areas where high fire risk is present. We also recommend that fire alarm audibility tests are carried out and visual alarm devices are added to supplement the alarm sounder system especially within areas with a high background noise such as the turbine hall.

We also recommend that physical electrical testing and inspection are carried out on the main electrical LV distribution system which would enable a predictive maintenance regime is adopted prior to a system failure.

Please see the following (non-exhaustive) list of electrical testing and inspection documentation that we assume are available but were not provided during the survey:

- Periodic testing & inspection.
- Emergency lighting.
- Fire alarm.
- Lightning protection.

2.11 Electrical

2.11.1 General

The electrical installation is a mixture of original equipment, new equipment, and partially retrofitted equipment. The rooms in which switchgear is installed are kept clean and locked where appropriate.

The equipment is generally well maintained and comprises equipment from the [redacted] export transformers connected to the UKPN distribution system down to DC and UPS equipment for essential and emergency supplies.

2.11.2 Transformers

The majority of transformers within the plant are the oil filled type. The oil filled transformers are the subject of ongoing testing by an external organisation to determine the condition and estimated remaining lifespan.

The most recent transformer assessment provided an estimated number of years to the operational end of life of each tested transformer.

The report states that [redacted] transformers, [redacted] have an estimated remaining lifespan of seven years. Both transformers were manufactured in 1968.

[redacted] is an export transformer of Ferranti manufacture rated at [redacted] and connected to the UKPN network [redacted] The construction of the ERF will require the support from the existing plant for a period of time, this will require both [redacted] to be disconnected from the UKPN system and re-connected to the ERF electrical infrastructure. If [redacted] followed the expected trend, it would need to be taken out of service in 2026. This would therefore only allow half of the output of the existing plant to be utilised to support the ERF. From an operational perspective, this constraint needs to be addressed and a decision made on its acceptability.

Transformer A4 supplies the Cooling and Residual Plant switchboard A4 and is [redacted]. As with [redacted] followed the expected trend, it would need to be taken out of service in [redacted] supplies distribution equipment in the cooling plant, intake pumphouse, effluent treatment plant, and residual plant boards. This distribution equipment is also supplied by switchboard B4 which would appear to provide sufficient redundancy to those items. There are some items however such as a fuseboard and a compressor which would be without a supply. [redacted] the criticality of this with respect to continued operation during the support to the ERF would need to be considered.

The remainder of the transformers have a minimum expected lifespan of [redacted]. If those transformers follow the expected trend, this should enable operation of those units to 2025 or even 2030.

2.11.3 11 kV switchgear

The main 11 kV switchboard is double busbar compound insulated with oil circuit breakers and comprises twenty-one circuits. The switchboard is [redacted] and is now 50 years old. The fact that the switchboard is still in operation having never been de-energised is testament to the build quality of the equipment and the maintenance regime afforded by the O&M staff during the lifetime of the switchboard. However, it should be noted that O&M staff have indicated that the compound insulation has been leaking.

An incident in the past when one of the 11 kV circuit breakers did not close properly highlighted the potential for failure. Incomplete closure of one of the oil circuit breakers would create high temperature arcs within the oil thus detonating the oil. The resulting explosion would lead to catastrophic failure of the switchboard. The 11 kV switchboard is one of the most critical items of equipment within the plant such that failure of the switchboard would result in a total loss of electrical supply to the plant and therefore total plant shutdown.

LEL has signed a contract with [redacted] for the manufacture of a new 11 kV switchboard comprising [redacted].

The FGT plant is supplied through a [redacted] 11 kV switchboard with [redacted] type vacuum circuit breakers. The switchboard was installed in [redacted] and comprises [redacted] circuits. O&M staff have not raised any concerns regarding the operation of this equipment. Although the switchgear is approaching the latter stages of what would generally be considered its' operational lifespan, refurbished circuit breakers are available as is retrofitting replacement circuit breakers for this model of circuit breaker, this should therefore ensure its continued operation for the remaining operational life of the EfW plant.

It should be noted that the switchgear rooms are kept clean and free from debris.

2.11.4 3.3 kV switchgear

The 3.3 kV switchgear is single busbar air insulated with air circuit breakers. The switchboard is the [redacted] model of switchgear manufactured by [redacted], and as with the 11kV switchboard is now 50 years old.

The connection arrangement of the 3.3kV switchboards is such that failure of one of the switchboards would result in reduced operational flexibility as the boiler feed pumps and circulating water pumps are supplied from the 3.3kV equipment.

The 3.3 kV switchgear provides supplies to the majority of the plant auxiliary equipment. Each of the [redacted] 3.3 kV switchboards is interconnected with the other thereby providing an element of redundancy should the incoming supply to one of the boards fail.

LEL has signed a contract with [redacted] for the manufacture of [redacted] new 3.3 kV switchboards.

2.11.5 Low voltage switchgear

The low voltage switchgear including motor control centres is a mixture of original equipment and replacement equipment. The [redacted] main low voltage switchboards are located in [redacted] lower. These [redacted] switchboards contain circuit breakers and provide supplies to a number of switchboards.

In [redacted] air circuit breakers of [redacted] have been removed due to failure or a lack of parts for maintenance. Operations staff indicated that due to the fact that the circuit breakers are 50 years old, it is no longer possible for them to be replaced. At the time of manufacture of these circuit breakers, it was common for the arc chutes to be manufactured from asbestos. It is not clear whether the circuit breakers within these [redacted] switchboards contain asbestos.

As with the switchboard in [redacted] a circuit breaker has been removed as it is no longer operational. The rating of the circuit breaker is not known, however it is likely to be of a similar rating to those removed from the switchboard in [redacted]

It can be seen from the photographs in the [redacted] in which the switchgear is located is clean and free from obstruction. The fact that the switchboards supply other distribution equipment and that they both have circuit breakers that are no longer operational could result in reduced availability of the equipment that is supplied from these switchboards. To ensure the sections of the plant continue to operate until the planned decommissioning, a philosophy should be developed for these [redacted] switchboards.

This philosophy could potentially involve either of the following:

a. Replace both switchboards, thus ensuring support from the manufacturer until the plant is decommissioned.
b. On the basis that both switchboards are of the same manufacture and age, the equipment within the switchboards should be interchangeable. This would potentially allow one of the switchboards to be replaced with the equipment from that switchboard being used as spares for the other switchboard.

From an outward perspective, both switchboards are in good condition considering their age. With respect to alternative b above, the decision on which switchboard to replace would need to be taken in consultation with operations staff, this decision would need to consider:

- The switchboard that requires the most maintenance.
- The switchboard that would provide the most spares.

If the circuit breaker arc chutes do contain asbestos, replacing both switchboards may be considered the preferred option.

This switchboard is manually operated as it only contains isolators, which are manually operated devices. Operations staff did not advise of any problems with any of these switchboards.

As with the other rooms containing switchgear, the room is clean and free from obstruction. The switchgear is well maintained and on the basis that operations staff advised that retrofitting of isolators, if required should not be problematic, this type of switchboard should be able to remain in service for the remaining life of the plant unless a problem arose with any of the switchboards that necessitated replacement.

2.11.6 Cabling

The cabling around the plant is neat and does not show any signs of being affected by installation work that may have taken place since the plant was built.

If any of the aforementioned transformers or low voltage switchgear was to be replaced, it would inevitably impact on the cables connected to the equipment.

The replacement of the 11 kV and 3.3 kV switchgear may impact on the cables associated with all equipment connected to the switchboards. This impact is being addressed as part of the switchgear installation.

It is not clear what effect replacing one of the main low voltage switchboards would have on the connected cables. The condition and type of cable would form part of the assessment process. With this in mind, a cost should be considered for replacement of the low voltage cables associated with the replacement of a low voltage switchboard. This cost would include for the removal of existing cables to allow space for the replacement cables.

2.11.7 Summary

The electrical installation at LEL's plant is a mixture of original equipment, new equipment, and partially retrofitted equipment. The equipment is generally well maintained and comprises equipment from the [redacted]/11kV export transformers connected to the UKPN distribution system down to DC and UPS equipment for essential and emergency supplies.

The majority of transformers within the plant are the oil filled type. The oil filled transformers are the subject of ongoing testing by an external organisation to determine the condition and estimated remaining lifespan. [redacted] have an estimated remaining lifespan of seven years. Both transformers were manufactured in 1968. The remainder of the transformers have a minimum expected lifespan of eleven years. If those transformers follow the expected trend, this should enable operation of those units to 2025 or even 2030.

The main 11 kV switchboard is double busbar compound insulated with oil circuit breakers and comprises twenty-one circuits, it is now over 50 years old. LEL has signed a contract with [redacted] for the manufacture of a new 11 kV switchboard comprising [redacted].

The 3.3 kV switchgear is single busbar air insulated with air circuit breakers, also over 50 years old. LEL has signed a contract with [redacted] for the manufacture of [redacted] new 3.3 kV switchboards.

The low voltage switchgear including motor control centres is a mixture of original equipment and replacement equipment. The [redacted] main low voltage switchboards are located in [redacted] switchboards contain circuit breakers and provide supplies to a number of switchboards. From an outward perspective, both switchboards are in good condition considering their age.

The cabling around the plant is neat and does not show any signs of being affected by installation work that may have taken place since the plant was built.

If any of the aforementioned transformers or low voltage switchgear was to be replaced, it would inevitably impact on the cables connected to the equipment.

2.12 Control and Instrumentation systems

2.12.1 Introduction

In general control and instrumentation system equipment and installations are regularly inspected and replaced as condition dictates or on component failure.

During the past seven years upgrade and migration of control systems into the distributed control system (DCS) has taken place to provide centralised control and monitoring from the plant control room.

Further key components such as uninterruptible power supply (UPS), programmable logic controllers (PLC), boiler auxiliary control systems, control valves and transmitters have been and continue to be replaced during the last 8-9 years.

Control areas and cabinets are kept clean, tidy and dry. However, for a small number of cabinets internal wiring is untidy and not dressed correctly.

More detailed information on the condition of the control and instrumentation systems is provided in the following sections.

2.12.2 Brief Description of Installed Systems

The plant control and monitoring systems at LEL consist of a mix of equipment which have been installed and updated over the life of the plant. The main point of control and supervision is via a mix of operator workstations, control desks and control panels located in the central control room.

A [redacted] distributed control system (DCS) system is installed and is the main point of control and monitoring for the process plant. The [redacted] network has a decentralised redundant structure/architecture with a number of control processors spread throughout the plant with operator workstations located in the central control room desk.

The boiler and its auxiliaries were migrated between [redacted] the [redacted] with control and supervision provided via the operator workstations located on the central control room desk. A number of boiler auxiliary package control system have local panels based on PLC's which are located within the boiler house, firing aisle and throughout the plant.

The [redacted] main turbine alternators (TA) control and supervision systems are PLC based and independent of the DCS with status and alarms transmitted to the DCS. The turbine control panels containing the governor and TA supervisory equipment are in the turbine hall next to each turbine alternator set.

Work is currently in progress on the migrating of the Effluent Treatment Plant (EFP) control and supervision to the DCS, this work is expected to be completed during [redacted]

The Fuel Gas Treatment (FGT) plant control and supervision is based on [redacted] which is networked to the DCS.

In general plant control systems have redundant power supplies or UPS systems.

Control panels are provided in the central control room for the remote operation of the 11kV and 3.3kV systems these will become obsolete and will be removed once new switchgear is installed in 2020.

2.12.3 Valmet DNA distributed control system

Replacement of the [redacted] based control systems for a [redacted] distributed control system (DCS) commenced in [redacted] and has been implemented in phases over several years. The first phase consisted of the migration of the [redacted] systems and their auxiliaries, this migration was completed in [redacted] providing centralised control and supervisor via [redacted] operator workstations from a control desk within the control room.

The performance and availability of the DCS is good, as expect of relatively new installation. However, operator workstations which were installed and been in operation since [redacted] reaching their life expectancy and a first failure has occurred.

The DCS runs [redacted] operation systems for which Windows support ends in [redacted]. [redacted] that they will continue to maintain these systems. However, it will become problematic in obtaining parts and drivers. Therefore, these operating systems will need to be replaced in the short term by the latest recommended proven operating systems [redacted].

LEL and [redacted] developed and agreed a 'Road Map' for the life cycle of the DCS equipment indicating support end and obsoletion dates for both hardware and software. This road map is a 5 year plan providing details and dates when the DCS hardware will become obsolete and software support ceases. Included in the road map is a recommended programme for replacement of both hardware and software to maintain a fully operational and reliable system. It is understood that LEL has signed up to this road map and the [redacted]

LEL also have in place a support contract with [redacted]t covering DCS maintenance for both hardware and software, failure callout and online support. Records are maintained of [redacted] outs, any failure and the work carried. A range of callout records where made available mainly from 2018 which demonstrated DCS failure rates are very low.

2.12.4 Central control room equipment

The central control room has developed over the life of the plant and contains a mix of control equipment for various sections of plant.

The MV electrical system is controlled form [redacted] switchboards, [redacted] for the 11kV switchgear and [redacted] for the 3.3kV switchgear all are original. The MV switchgear is to be replaced in [redacted] after the signing of contracts during [redacted] as a result the MV switchboards will become obsolete and will be decommissioned, removed and replaced by an operator workstation for switchgear operation and alarm display.

The existing general alarm cabinet which houses [redacted] of the MV system is to be decommissioned and removed in [redacted] with the replacement of the [redacted] and 3.3kV switchgear.

Mounted on the central control desk are the DCS operator workstation, remote boiler drum level indication and emergency stop push buttons. This desk is the main area for remote control and supervision of the plant.

A new addition to the central control room is the crane operator system consisting of an operator desk containing [redacted] crane control stations, a bank of [redacted] monitors and a server panel.

The house set generator control panel is located in the central control room installed in [redacted]as part of the new house turbine alternator. The house set and this generator control panel is programmed to be decommissioned and removed during the second half of [redacted]A new house set will be installed along with a new generator control panel during late [redacted].

A turbine pressure governor system desk sits in the central control room and used for main steam common line pressure control. However, some original functions of this system are not operational and the control [redacted]. To ensure long term reliability of this system replacement of the [redacted] should be considered.

2.12.5 Control and monitoring system UPS

The DCS, control systems, PLC's and instrumentation are powered from several UPS located in switchrooms and control panels throughout the plant. It was reported in [redacted] survey that all UPS equipment was approximately [redacted], which makes them now approximately [redacted] The UPS observed during this survey where all in good condition and working order.

2.12.6 Boiler Control Systems

During the WID upgrade in [redacted], all the boilers and primary equipment were rewired including soot blowers, primary air fan, secondary air fan, riddling conveyor and roller grates. During this upgrade approximately [redacted]odules on the boilers were replaced and replacement of the [redacted] modules of the boilers was scheduled for [redacted]

As part of the upgrade to a [redacted] the majority of the [redacted] had been replaced by the end of [redacted] There are still a small number of old [redacted] remaining used for I/O collection with all control and supervision software been migrated to the [redacted]. These remaining Allen Bradley I/O are approaching obsoletion and will need to be replaced in the near future.

2.12.7 Turbine alternator control and supervision

The control and supervision systems for the turbine alternators [redacted] a mix of original turbine instrument panels with later digital Woodward governor controller and [redacted]. The turbine alternator control and supervision system for [redacted] again employing a digital [redacted] controller and [redacted]. All turbine PLC's and I/O modules where replaced during [redacted]

A number of upgrades have taken place on the instrument racks of [redacted]However, the majority of equipment is obsolete and repairs will be difficult without spares.

2.12.8 Fuel Gas Treatment Plant (FGT)

The FGT plant control and supervision is based on [redacted] networked to the [redacted]however the [redacted] are old and spares are not available. LEL has recently signed a contract with Valmet for the replacement of the [redacted] systems for integration to the DCS. This work will commence during the second half of[redacted]

The variable speed drives for the [redacted] booster fans where replaced in [redacted] with variable speed drives [redacted]

2.12.9 Effluent Treatment Plant (ETP)

The ETP plant control and supervision system has been replaced and migrated to the Valmet DCS due to old and obsolete equipment.

2.12.10 Fuel Gas Precipitators

LEL replaced the precipitator control systems for all [redacted] and all are in good condition.

2.12.11 Actuated Valves

LEL have in place an ongoing policy as spares become unavailable for a particular type of valve or actuator a suitable modern equivalent replacement is purchased and held in readiness for installation in case a failure occurs. This is an ongoing process and most old valves or actuators are been replaced once a failure occurs.

2.12.12 General instrumentation

LEL have in place an ongoing policy for the replacement of instrumentation, any instrumentation that fails and spares are available will be repaired where no spares are available the instrumentation is replaced with the modern equivalent. When spares become unavailable for a particular type of instrument, a suitable replacement is purchased and held in readiness for future replacement on occurrence of a failure of that type of instrument.

The majority of transmitters on the [redacted] years.

Replacement of boiler analysers has taken place with O_2 analysers upgraded in [redacted] and replacement of CO analysers was completed in [redacted]

2.12.13 Boiler Sootblower control systems

The boiler sootblower control system consists of a separate control panel for each boiler located in the boiler house and a common alarm panel located in the firing aisle.

Each sootblower control panel is Allen Bradley PLC based which have or are approaching end of life cycle and discontinuation within the next few years.

2.12.14 Auxiliary PLC Systems

There has been an on-going programme to replace all PLC's throughout the plant with Valmet ACN controllers and the migration of control and supervision to the DCS. All PLC's were replaced on the [redacted]

Despite PLC's replacement during the migration to the Valmet DNA DCS, and the PLC update programme, there still remain a number of Allen Bradley PLC's some off which will be replaced during the upgrade and migration of the FGT and ETP control systems. The remaining Allen Bradley PLC's have or are approaching end of life cycle and discontinuation within the next few years and will require replacement.

2.12.15 Spare parts

Where available spare parts are held in stock. However, for obsolete equipment suitable replacements are held are in stock.

2.12.16 Summary/Conclusions

The DCS 'Road Map' signed between LEL and Valmet will ensure upgrade and replacement of obsolete hardware and software over the next 5 years maintaining long term low failure rates, high availability and life expectancy for the [redacted]

The systematic replacement of auxiliary control system PLC's requires to be continued so that all systems that are either obsolete or approaching end of life cycle are updated to provide functional, reliable systems [redacted].

The ongoing replacement of obsolete failed instrumentation and actuators with suitable modern equivalent will need to continue to maintain plant operation.

Investment requires to be maintained in spare parts for key components where either equipment is obsolete, approaching end of life cycle or where redundancy does not exist.

If the present replacement and maintenance policy is continued the system can be expected to be fully operational through to 2025.

2.13 Quality Management Systems

LEL is certified according to the following standards:

- ISO 9001
- Environmental Management System 14001
- HMS 18001

LEL has systematic maintenance programmes. A print out of the task list describing all preventive maintenance activities is available at LEL. This comprehensive list included the following information for each activity:

- short description of activity,
- the standard frequency with which each activity is to be carried out,
- number of person required for each activity,
- duration of activity etc.

Ramboll considers it important to apply such database systems in the operation and maintenance of an EfW facility. Generation of work orders from the database and keeping track of the operating history of each subcomponent/subsystem makes preventive maintenance more efficient.

However, in connection with the review of the documentation at Edmonton it was observed that key documentation such as PIDs, layout drawings, O&M-manuals were in some cases difficult/not possible to obtain. Although Edmonton is an old EfW facility the following activities are recommended regarding plant documentation:

- Gather all PIDs systematically in folders.
- Preferably update the PIDs according to the current configuration of the plant.
- Make listings of O&M-manuals with systematic reference to physical position.
- Gather all relevant layout drawings in folders

No other documentation/information regarding QMS has been available.

2.14 Strategic spare and wear parts

Ramboll recommends that LEL reviews their stock of strategic spare and wear parts for the entire plant and ensures that it corresponds to the target operational availability.

3 Regulatory Aspects

3.1 Background

The facility has been operational since the early nineteen seventies and has been subject to a number of significant upgrades since. In many cases, upgrades have been driven by regulatory changes. The most notable are:

- 1996 - addition of extra air pollution control equipment to meet revised emission requirements under the first municipal waste incineration directive (MWID)
- 2005/6 – refurbishment of combustion equipment and the fitting of additional NOx emissions abatement capacity. These changes were largely carried out to meet revised emission requirements under the Waste Incineration Directive (WID) (2000/76/EC)

The latter upgrade resulted in significant works and expenditure, although not all of the formal legislative requirements were met, and some reliance upon available exemptions (WID Article 6(4)) is required. As allowed by the WID, the Environment Agency has issued the plant with such an exemption, as the combustion residence time requirements are not satisfied at the plant.

The Environment Agency issues a permit for the operation of the plant and regulates the facility to:

- check and enforce compliance with the terms of the permit,
- alter the permit as may be required (for example to implement new/revised legislation or take account of advances in technology, or environmental knowledge/circumstances)

The necessary regulatory permits are in place. There are no plans at this time to vary the current conditions for EfW operations.

Table 3-1 below shows that appropriate permits are in place for current EfW plant activities.

Type	Purpose	Date	Reference
Consolidated main permit	Authorises site operations and releases, including all works for WID upgrade	28 07 05	YP3033BE
Variation	Administrative changes to correct description of authorised clinical waste inputs so that only low grade (non-hazardous) clinical waste is treated.	30 07 07	CP3036VA
Variation	Amendment to formal list of permitted waste types to reflect EU waste catalogue codes.	15 10 07	BP3733XM
Variation	Amendment to the monitoring of CO	05 05 2011	YP3033BE v7

Table 3-1 Permits

The permit in place does not contain an end date for operations. The UK Environmental Permitting Regulations currently provides the legislative framework for the implementation of the Industrial

Emissions Directive (IED2). Both the UK regime and the EU Directive require that the plant operates in accordance with the Best Available Techniques. When assessing the permit application, the Environment Agency, in line with its statutory duty, also carried out an assessment of BAT, and the permit was issued taking into account site specific cost and environmental factors, including the WID Article 6(4) derogation in respect of the furnace residence time, subject to compliance with the conditions it sets.

It should be noted that a new edition of the EU BAT reference note is under way. Little is known as to any changes in requirements when it comes to existing facilities, but its publication is as a minimum likely to cause increased attention on the environmental performance of EfW facilities and a change in the understanding of performance requirements to warrant the term BAT.

All documents relating to regulatory aspects of the plant are included at Appendix F.

3.1.1 Improvement Conditions

The current permit (issued to implement WID) also contained five "Improvement Conditions". It is understood that all five conditions have been discharged.

3.1.2 WID Derogation

The most significant conditions under which the WID derogation is granted are:

- It is limited to the existing furnace and boilers
- It requires compliance with "other requirements" of the Directive (Permit)

The facility currently operates under a permitted derogation, issued by the Environment Agency, as the 'two second combustion residence time' requirement of the Waste Incineration Directive cannot be achieved with the existing boiler design.

Rather than an absolute requirement, the 850°C two seconds obligation is derived from an empirical correlation to the production of lower emissions. At installations where the operator can demonstrate suitable compliance with emissions, and other requirements of the Directive, the requirement holds less precedence. This also reflects the fact that the cost implications of replacing and resizing furnaces may be considered to be excessive in relation to the marginal improvement in emission level reductions achievable.

In the period up to 2020 it was considered that the continued good emissions record from the Edmonton facility resulted in a low risk of this derogation being withdrawn. However, in the longer term, with a greater proportion of plants achieving emissions well below the WID emission limit values, it is Ramboll's view that the risk of a potential withdrawal increases.

The EA has not revealed any plans to examine or revoke the derogation.

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[2] The Industrial Emissions Directive (IED) draws together seven complimentary Directives into one single place. Of relevance to the Edmonton EfW, the IED includes a recast of the Waste Incineration Directive (WID) and the Integrated Pollution Prevention and Control Directive (IPPCD). It was transposed into UK law on 6 January 2013.

3.2 Recent regulatory history and current situation

3.2.1 Emissions to air

3.2.1.1 Review of Edmonton Data from 2018

Analysis of the CEMS data provided from 2018 is presented in Appendix K.

The analysis comprises air emission data of continuous monitoring of CO, TOC, Particulate matter, HCl, SO_2, NOx, and NH_3 in 2018, and results are summarised in Table 3-2 below. Results are held against the current set of limit values and in Section 3.4 the current operation is compared with the expected future limit values as indicated in the BAT-conclusions of the Final draft BAT reference note of the EU.

Results show that the current limit values are largely complied with, and exceedances are reported to be related to specific incidents in most cases. There are single exceedances of HCl and SO_2, and several for CO and TOC. It should be noted that mitigation of HCl and SO_2 comes from flue gas treatment while CO and TOC are related only to the combustion conditions.

mg/Nm³, dry flue gas at 11% O2	CO*	TOC	Particulates	HCl	SO2	NOx	NH3
95% of 10-min average	150	NA	NA	NA	NA	NA	NA
½-hourly limit value	NA	20	30	60	200	400	NA
Daily average limit value	50	10	10	10	50	200	NA
South stack, A1 Measurements							
Annual average	22.9	1.2	1.5	5.2	13.2	161.0	3.4
Annual ½-hourly maximum	393	39	18	34	203	252	75
Annual daily average maximum	81.5	5.3	7.4	7.9	31.4	187.5	12.6
South stack, A1, exceedences							
Number of months exceeding ½-hourly limit value*	1	3	0	0	1	0	0
Number of months exceeding daily average limit value	4	0	0	0	0	0	0
North stack, A2 Measurements							
Annual average	31.5	1.7	1.2	5.5	10.5	180	8.2
Annual ½-hourly maximum	198	70	14	96	169	313	62
Annual daily average maximum	72	10.2	6.2	8.8	30.2	193.5	21.3
North stack, A2, exceedences							
Number of months exceeding ½-hourly limit value*	1	8	0	1	0	0	0
Number of months exceeding daily average limit value	2	1	0	0	0	0	0

* for CO this refers to 95% of 10-min. avg. values

NA: not applicable

Table 3-2 – Air emission continuous monitoring and limit value fulfilment in 2018

The flue gas treatment process appears to run steadily with only a few peak values outside the EU limit value for the half hour values (the ones that shall be fulfilled at all times).

The combination of relatively low values for the clean emissions and the relatively low consumption of lime (around 9-10 kg/tonne of waste treated) indicate that the input waste is MSW with relatively low content of chloride and sulphur.

Following the last formal Permit Review in 2011, the short-term CO limit was amended from 100 mg/m³ as a half hourly average to 95% of 10 minute averages no greater than 150 mg/m³. This change was to allow for short term peaks in CO emissions that may exceed the half hour limit but will not affect short term air quality. The requirement for periodic monitoring of CO was also removed. This variation was at the operator's request.

No exceedance of daily average ELV were recorded for Particulates, HCl, SO_2 or NOx, but some exceedances are observed for CO and TOC. For comparison, no exceedance of daily average ELV were recorded for any parameter in 2013-2015.

On ½-hour level, a total of around 16,000 measurements have been recorded for each CEMS parameter in 2018. One minor exceedance was observed for SO_2, and several for TOC and CO (for CO this applies to the 150 mg/Nm³ limit value applicable for maximum of 95% of the measurements). For comparison, for particulate matter one ½-hour exceedance was recorded in 2014-2015, and one TOC exceedance.

The general fulfilment of HCl and SO_2 limit values may be a sign that the control with HCl and SO_2 monitoring at FGT inlet has allowed an optimisation of lime dosage, saving lime without exceeding ELVs.

The analysis of Appendix K also reveals that periodic measurements in 2016, 2017 and 2018 of hydrogen fluoride, heavy metals (Sb+As+Pb+Co+Cr+Cu+Mn+V+Ni), Cd+Tl, mercury, and dioxin and furans are all well below the current respective limit values.

The EA has not expressed any concerns regarding dispersion from the stack. the stack was designed to disperse much higher emission concentrations than currently experienced and thus dispersion issues would not be expected.

3.2.2 Emissions to water

No specific regulatory concerns were raised by the EA in 2018. However as described in the above section regarding the effluent plant it should be noted that the measurement point for discharge of waste water is positioned after mixing with bleed off water from the cooling water system.

Emissions to water are low and do not provide a significant regulatory concern, this situation is unlikely to change in the long term. A small risk remains that the discharge measurement point is moved to the outlet from the effluent plant (before dilution with bleed off water from the cooling water plant). If this should occur, the effluent plant may have to be upgraded in order to comply with the discharge limits.

3.2.3 Monitoring

The monitoring of final stack emissions (in both the North and South flues) rather than individual lines complies with the WID/IED requirement to monitor at the point of discharge. It is noted that any exceedances are traced back to specific causes on specific lines (via operational parameters e.g. O_2) and this is therefore considered an appropriate means of ensuring that each line is operated/checked according to BAT.

Additional monitoring equipment (particulate monitors and FTIR gas analyser) has been installed to ensure that there is full redundancy of the CEMs, and a complete new and redundant set of CEMs were installed in 2016. This ensures that plant operation is not impacted by CEMs equipment failures.

It is considered that current monitoring arrangements are adequate, and well managed.

3.2.4 Waste reception, storage and loading

Overall, no specific regulatory concerns are identified. No specific regulatory risks are apparent in the long term (unchanged 2013).

3.2.5 Permit, improvement conditions and reviews

The situation with respect to permits is as follows:

- The Permit is a standard WID/EID permit, with the 6(4) derogation
- Any new line would be non-derogated
- All previous improvement conditions are discharged
- Audits (inspections) are carried out 2 times per year
- Formal permit reviews are expected every 6 years

3.2.6 Other issues

Very few complaints have been reported to the EA in recent years.

No current active anti-incineration group is known to the EA.

There have been no odour issues related to the EfW facility.

Overall, the impression given by the EA was that they considered the operation at Edmonton to be competently run with a well trained staff and management team.

Political pressure upon the EA in respect of their regulation of the plant would currently appear to be low.

3.3 Future regulatory Issues

Previous discussions with staff from the EA who have responsibility for future regulatory issues indicate that:

- the IED of 2010 (WID merged with IPPC Directive) and the new EPR permitting regime, both appear to amalgamate rather than change the regulatory requirements i.e. no new challenges arise from this Directive.
- the (IED) Industrial Emissions Directive does not appear to present an immediate regulatory change for the waste incineration (WI) sector, although there is some uncertainty over how the link to the updated BREF will relate to the sector – at existing facilities this is not likely to have a major impact until 2020/21 at the earliest.
- The main EU regulatory focus tends to be upon the larger polluters (e.g. Large Combustion Plants (LCP) in the electricity supply industry) and given the relatively low emissions from dedicated EfW plants it may be anticipated that the focus will fall upon those other sectors.
- The main focus of modern environmental regulation at a Governmental and EA level is one of "risk based regulation" i.e. action and regulatory resources should be directed in proportion to the environmental risks. With this being the case, and the current evidence showing that a) the impact of emissions from EfW plants operated at IED ELVs is so low as

to not be measurable3, and b) the contribution of the emissions from the Edmonton plant to local air quality are dwarfed by other sources (e.g. traffic on the North Circular), the EA is unlikely to see reductions in emissions at the plant as a priority, unless the reductions can be achieved at a proportionately low cost

- It may be concluded from the EU BAT work that larger installations in areas of poor air quality may be expected to have tighter ELVs for some emissions, however this would be expected to apply first of all to new installations. it is noted that the proposed ERF was required to seek NOx limits below the BREF limits.

3.4 New EU BAT Reference note

A new edition of the EU BAT Reference Note (BREF) is expected to be published in late 2019 based on the final draft of December 2018. There will be a time period for implementation from the moment of the publication, but all changes will go in the direction of fulfilling the BREF conclusions. Below is referred to the Final Draft for reference.

The BREF includes BAT conclusions with 37 BATs, the implementation of which shall be judged by the EA. A preliminary evaluation of the implementation at NLWA of 37 BATs is included in Appendix L.

With respect to emission, we expect the upper ends of the ranges indicated as BAT-AEL to form basis of emission limit values in future regulation. However, the EA may choose different values within the indicated BAT ranges.

It is the experience from implementation of other BREFs (power plants), for 'existing' plants which already have environmental permits, that the Environment Agency are likely to issue a 'Regulation 61' Notice to the Operator requesting information on how the BAT measures are implemented, and therefore how they should be in included within the environmental permit review. The applicable spreadsheet on content of such a notice is included in Appendix N. The operators were required to complete the spreadsheet following implementations of the BREF on large combustion plants (LCP).

3.4.1 Future Emission Limit Values

The Waste Incineration Directive (2000/76/EC) [referred as WID in this report] has been superseded by the Industrial Emission Directive (2010/75/EC) [referred as IED in this report]. This directive merges seven existing directives including e.g.: WID, Large Combustion Plant Directive, Solvent Emissions Directive and three directives on titanium oxides.

The emission requirements of the WID have been lifted directly into the IED. However, the IED includes a direct reference to the 'Reference Documents of the Best Available Techniques (BAT)' [referred as the BREF-note in this report]. These reference documents are prepared by the research institute of the EU Commission in Seville, Spain. The current BREF-note on waste incineration was published August 2006, and as mentioned above, a new edition is expected shortly.

Article 15 of the IED includes the following text:

Article 15, Emission limit values, equivalent parameters and technical measures:

<u>*3. The competent authority shall set emission limit values that ensure that, under normal operating conditions, emissions do not exceed the emission levels associated with the best available techniques as laid down in the decisions on **BAT conclusions** referred to in Article 13(5) through either of the following:*</u>

[3] Ref: DEFRA Report on Health Impacts of Waste Management 2004 and various studies since

> *(a) setting emission limit values that do not exceed the emission levels associated with the best available techniques. Those emission limit values shall be expressed for the same or shorter periods of time and under the same reference conditions as those emission levels associated with the best available techniques; or*
>
> *(b) setting different emission limit values than those referred to under point (a) in terms of values, periods of time and reference conditions.*
>
> *Where point (b) is applied, the competent authority shall, at least annually, assess the results of emission monitoring in order to ensure that emissions under normal operating conditions have not exceeded the emission levels associated with the best available techniques.*

The current (2006) BREF-note for incineration does not include specific BAT conclusions related to air emission values. The new edition includes a list of 'BAT Conclusions' along with a range of other changes which represent tightening of environmental requirements, including emissions. Any new requirements resulting from the revised BREF may be implemented over the following years. Hence, some tightening is most likely to arise in 2022 at the earliest. This is why many of the CAPEX risks are allocated to this year, cf. section 5.

The emission level considered BAT, the 'emission levels associated with the best available techniques', abbreviated BAT-AEL are for some pollutants significantly lower than the current emissions limits. The BAT-AEL values represent achievable levels under normal operation. It is not clear how the listed intervals will be used by EA to state new limit values that are valid at all time.

The BAT levels for air emissions listed in the new BREF-note are shown in Table 3 - 3. It is probable that the upper level BAT interval (measured as 24 hours average) will be the future requirement during normal operation.

Other pollutants than listed in the IED are addressed in the revised BREF, indicating that an ELV could be set. Such emissions include ammonia (NH_3), Nitrous Oxide (N_2O), polycyclic aromatic hydrocarbons (PAH) and PCBs (polychlorinated biphenyls).

Parameter	Unit, ref. dry flue gas at	24 h average	½h average[1)]
CO	mg/Nm^3	10-50 (50)	NA (100)[3)]
TOC	mg/Nm^3	<3-10 (10)	NA (NA/20)
Dust	mg/Nm^3	2-5 (10)	NA (10/30)
HCl	mg/Nm^3	< 2-8 (10)	NA (10/60)
HF	mg/Nm^3	<1 (2)	NA (2/4)
$SO_2 + SO_3$	mg/Nm^3	5-40 (50)	NA (50/200)
NO_x as NO_2	mg/Nm^3	50-150[2)] (200)	NA (200/400)
NH_3	mg/Nm^3	2-10 [9)] (NA)	NA (NA)
		Results of periodic sampling	
Cd + Tl	mg/Nm^3	0.005 - 0.02 (0.05)	
Σ 9 metals	mg/Nm^3	0.01 - 0.3 (0.5)	
Hg	mg/Nm^3	<0.005-0.020 [7)] (0.05) <0.001-0.010 [8)] (0.05)	
Dioxins and furans, I-TEQ [6)]	ng/Nm^3	0.01 - 0.06 [4)] (0.1) 0.01 - 0.08 [5)]	
Dioxins, furans and dioxin-like PCBs, WHO-TEQ [6)]	ng/Nm^3	0.01 - 0.08 [4)] (NA) 0.01 - 0.1 [5)]	
N_2O	mg/Nm^3	NA [10)] (NA)	

Table 3 - 3 BAT-AELs for incineration of MSW at existing plants according to the new edition of the WI-BREF (Final draft)
Current EU limits (cf. IED) are included in brackets

NA Not applicable
1) IED limit - ½h average is given for 97% percentile and 100% percentile If a plant decided to use the 97% percentile emission value then it is allowed to exceed this limit for 3% of the ½h values
2) The higher end of the BAT-AEL range is 180 mg/Nm3 where SCR is not applicable
3) ELV for CO also includes the possibility that as a minimum 95% of the 10-min average values must not exceed 150 mg/Nm^3 (evaluated on a daily basis)
4) Average over the sampling period (typically 6-8 hours)
5) Long-term sampling period
6) Either the BAT-AEL for dioxins and furans, or the BAT-AEL for Dioxins, furans and dioxin-like PCBs
7) Daily average
8) Long term sampling period
9) For existing plants fitted with SNCR without wet abatement techniques, the higher end of the BAT-AEL range is 15 mg/Nm3
10) Periodic monitoring required

A general, indirect tightening of ELVs may happen through changing the confidence intervals that are subtracted from the measured values before calculating ½-hour and daily average values for reports. It could also include a standardisation among member states on how these intervals are subtracted. Although these appear technicalities, the effect may be like lowering ELVs. The confidence intervals have not been addressed in the new BREF-edition. It is however, likely that the absolute number that is subtracted from the measured values because of the confidence interval will be reduced, if the daily average limit value is reduced, because the subtracted value must not exceed a certain percentage of the limit value.

It shall be noted that improved Hg monitoring is likely to be required, either through continuous monitoring or by long term sampling.

3.4.2 Would current operation fulfil the air emission requirements of the new BREF

The current air emissions are compared with the BAT-AEL values in Appendix K, including an analysis of number of exceedances that should be expected in case the upper values of the respective BAT-AEL ranges were applicable as limit values and operation continued without taking this into consideration. The findings of Appendix K are summarised below, including Table 3-4.

mg/Nm³, dry flue gas at 11% O_2	CO*	TOC	Particulates	HCl	SO2	NOx	NH3
95% of 10-min average	150	NA	NA	NA	NA	NA	NA
½-hourly limit value	NA	20	30	60	200	400	NA
BATAEL 2019 (upper daily average value for existing plants)	50	10	5	8	40	180	15
South stack, A1 Measurements							
Annual average	22.9	1.2	1.5	5.2	13.2	161.0	3.4
Annual ½-hourly maximum	393	39	18	34	203	252	75
Annual daily average maximum	81.5	5.3	7.4	7.9	31.4	187.5	12.6
South stack, A1, exceedances							
Number of months exceeding ½-hourly limit value*	1	3	0	0	1	0	0
Number of months exceeding daily average upper BAT-AEL	4	0	1	0	0	5	0
North stack, A2 Measurements							
Annual average	31.5	1.7	1.2	5.5	10.5	180	8.2
Annual ½-hourly maximum	198	70	14	96	169	313	62
Annual daily average maximum	72	10.2	6.2	8.8	30.2	193.5	21.3
North stack, A2, exceedances							
Number of months exceeding ½-hourly limit value*	1	8	0	1	0	0	0
Number of months exceeding daily average upper BAT-AEL	2	1	2	6	0	12	5

* for CO this refers to 95% of 10-min. avg. values

NA: not applicable

Table 3-4, Air emission monitoring 2018 compared with BAT-AEL, upper value of applicable range, and ½-hour limit values kept unchanged from current regulation

For HCl the current average emission is close to the BAT-AEL value, which is 20% below the current daily average limit value. Hence, unchanged operation would cause extensive exceedances. Control of HCl is related to the HCl content of raw gas (in turn related to the Cl-content of the input waste), lime dosing and the nature of lime. Improvements are necessary. Further reduction would require a relatively large amount of absorbent e.g. hydrated lime to remove the marginal pollutant content.

NOx and NH3 emissions are related to operation of the SNCR process and the raw gas NOx content resulting from furnace operation. NOx is reduced by carbamin injection, and excess carbamin and carbamin injected at relatively low temperature cause ammonia slippage. Improvements in the SNCR process are needed to cope with BAT-AEL values for NOx and NH3. This is discussed below.

Single exceedances of particulate matter BAT-AEL level could happen, as the upper level daily average is 5 mg/Nm^3 compared with current limit value of 10 mg/Nm^3. Emissions of particulate matter is related mostly to the state of maintenance of the bag house filters, including filter bags, corrosion that may cause by-pass, and gas-tightness of by-passes around the filter bags (if there are by-passes around the filters).

The CO and TOC BAT-AEL values do not represent changes compared with current limit values. However, continued attention on fulfilling CO and TOC is necessary as some exceedances are recorded under the current limit values. One means of reducing the CO level is improved combustion control as described in section 5.3.2.

Spot measurements of hydrogen fluoride, heavy metals (Sb+As+Pb+Co+Cr+Cu+Mn+V+Ni), Cd+Tl and mercury are all well below the current limit value and the upper BAT-AEL value.

This also applies to dioxin and furans, irrespective of including dioxin-like PCBs in the measurements or not. PCBs may be included under the dioxin ELV. This would probably be of little concern to LEL as the measurements made as part of some of the quarterly reports indicate a very low level of PCBs as well as dioxins.

For mercury the current monitoring is based on periodic measurements. It may be required to install continuous monitoring as a consequence of BAT-implementation, in which case it cannot be excluded that such measurements could reveal a pattern that calls for action. The mercury level can, if necessary, be reduced further by additional activated carbon and/or higher quality of activated carbon with regard to mercury capture

The current level of exceedances and current operation compared with BAT-AEL values are summarised in Table 3 - 5.

It reveals that action is necessary to cope with the BAT-AEL values. This applies particularly to HCl, NOx, NH3, and attention is also required with respect to particulate matter, CO and TOC.

Table 3 - 5 Air emission limit value fulfilment 2018, number of exceedances at current limit values and BAT-AEL upper value

Exceedances	Continuous or Periodic 2)	Current	BAT-AEL 1)
CO	Continuous	Several	Several
TOC	Continuous	Several (½-hour)	Single (daily average)
Particulate	Continuous	OK	Single
HCl	Continuous	Single	Extensive
SO_2	Continuous	Single (½-hour)	OK

Exceedances	Continuous or Periodic [2)]	Current	BAT-AEL [1)]
NOx	Continuous	OK	Extensive
NH_3	Continuous	No limit value	Extensive
HF	Periodic	OK	OK
Hg	Periodic	OK	OK
Sb+As+Pb+Co+Cr+Cu+Mn+V+Ni	Periodic	OK	OK
Cd+Tl	Periodic	OK	OK
Dioxins and furans	Periodic	OK	OK
Dioxins, furans and dioxin-like PCBs	Periodic	No limit value	OK

1) BAT-air emission levels, cf. Final Draft EU BAT reference note of DEC 2018.
   Value represents upper daily average value of listed BAT-AEL range applicable for existing plants, which is judged as a likely future limit value.
2) Applies to current measurements

From a lifecycle assessment point of view, it makes sense to focus on the emissions of NOx, mercury (Hg) and to some degree heavy metal emissions. The current limits for the acidic gases HCl, SO_2 and HF already secures that these pollutants have a very limited impact on the environment.

For **Nitrous Oxide** the BREF requires periodic monitoring. Elsewhere (outside of the UK), required operational level is seen at around 20 mg/Nm³ for grate fired boilers, if any. With a level currently in the range 10-30 mg/Nm³ (from a few spot measurements in quarterly reports), reaching this level may be a challenge. The solution could be to increase the injection temperature of carbamin or change reactant to ammonia water instead of carbamin as described below. Such a change may also reduce the CO level slightly.

PAH emission is usually associated with incomplete combustion (like CO and TOC). There is no indication in the BATs of a potential ELV for PAHs. Improved combustion control as suggested for CO and TOC is likely to control also PAHs.

3.4.3 Reducing NOx emissions – and ammonia

The daily average **NOx** level at Edmonton is current around 170 mg/Nm³, with values frequently exceeding the BAT-AEL upper value of 180 mg/Nm³. Lowering of the current daily average limit value of 200 mg/Nm³ to 180 mg/Nm³ is considered minimum. It cannot be excluded that the EA would reduce the NOx limit value further, considering the increased focus on NOx emissions as indicated by the future limits on vehicles in London and that the new ERF facility NOx emissions are required to be below 100 mg/Nm³ to fulfil air quality requirements.

There is currently no incentive for LEL to decrease NOx further as it increases the chemical consumptions, thereby increasing Opex. The average carbamin consumption in 2016-2018 was recorded as 1.6 – 2.0 kg per tonne waste treated, representing a remarkable decrease compared to the 2011 level of around 3.7 kg 40% urea per tonne waste treated. The consumption is thus relatively low, indicating that the raw concentration of NOx is relatively low.

Injection of carbamin is the cause of ammonia slip, caused by injection at relatively low temperature in the afterburning chamber, short residence time at high temperature after injection, uneven distribution of injected carbamin, uneven flue gas flow at injection area or excessive injection compared with the raw gas NOx -level. The current slip is frequently relatively high with exceedances of the BAT-AEL value of 15 mg/Nm³.

It is likely that the current SNCR system can reduce the NOx level to around 150-170 mg NOx/Nm³ to meet a possible limit value of 180 mg/Nm³ by adding more carbamin, but with the current system this would most likely yield higher ammonia slip, which would not be acceptable.

To reduce the NOx-level without an unacceptable slip of NH_3, the SNCR system would need to be upgraded. This upgrade is likely to include more injection nozzles, e.g. at one or two additional levels, improved temperature monitoring in the injection area and monitoring of ammonia slip after each boiler, including automated control based on NOx and ammonia measurements.

At modern facilities optimised SNCR systems (e.g. additional injection layer and more sophisticated control) can reduce the NOx level to 100-120 mg/Nm³. However, due to the relatively high temperature in the normal ammonia injection area (upper level of the first pass) and the low residence time in the reaction window it may be difficult to reach 120 mg NOx/Nm³ at Edmonton, even if the most sophisticated control measures are implemented, such as acoustic temperature monitoring system and including individual control of nozzles.

Another measure to improve the SNCR performance could be a change of reactant from carbamin to ammonia water (or a mixture), which will lower the required injection temperature. In turn nitrous oxide emissions would probably be reduced from the current level by 10-30 mg/Nm³, because carbamin is known to be a precursor for nitrous oxide to a greater extent than ammonia.

Reducing NOx emissions below 100-120 mg/Nm³ at Edmonton would require installation of Selective Catalytic Reduction (SCR). This would be costly and complicated by severe physical restrictions on site and there may be planning issues associated with the introduction of this extra cleaning step.

3.4.4 Conclusion on future emission limit values

Our review of the current plant performance through CEMS data indicates the plant can treat flue gas with a good margin below the current limit emission in IED.

We estimate that the system (in its current condition) should be able to fulfil the future emission requirements for all pollutants in case of minor tightening of emission limit values when processing waste of similar nature to that which has been treated historically at the site. Introduction of waste with higher content of chloride or sulphur would put additional pressure on the flue gas treatment system. To meet the BAT-AEL values, particularly with respect to HCl, some improvements would need to be implemented. It is likely that additional lime dosing would be sufficient, possibly together with improved control of lime dosing.

For CO there are some exceedances, which calls for continued focus on combustion control and other measures to maintain low CO and TOC emissions. Relatively small changes in ELVs may cause the number of exceedances to increase considerably adding to the necessity of mitigating actions, such as improvement of combustion control as described in section 5.3.2.

For NOx and ammonia some improvements of the SNCR system is necessary to meet the BAT-AEL values. Some tightening of NOx ELVs to a level of approximately 180 mg/Nm³ may be coped with by increased SNCR dosing combined with additional carbamin injection levels, temperature surveillance and control based on NOx and ammonia slippage monitoring at each boiler as described in section 5.3.1. Potentially also carbamin should be replaced with ammonia water to reduce ammonia slip and nitrous oxide emissions.

Future stricter NOx ELVs may reach a level where current SNCR (including potential upgrades) would have difficulty achieving them on a continuous basis.

3.5 Overall conclusions on future regulatory risks:

The probability of emission limit values and other requirements being significantly tightened in the short to medium term would appear to be low, however it is rather more difficult to predict with any great certainty how regulation might move during the medium to long-term period. Furthermore, the EA stress that they are not in a position to offer any sort of long-term guarantees and have the right (subject to sufficient legal justification) to change the permit at any time.

4 Historical Performance

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted] [redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted]

[redacted]

[redacted] [redacted]

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- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted] [redacted]

[redacted]

[redacted] [redacted]

[redacted]

[redacted]

[redacted]

4.3 Operational availability

The boilers' average annual operational availability for the past 16 years calculated as actual boiler operational hours' percentage of the theoretical boiler operational hours, is presented in Table 4-5 below.

[redacted]

Table 4-5 indicates that the average operational availability of the boilers has improved slightly after the WID upgrade in years 2004 and 2005 and after a poor 2009 (when a number of events occurred as discussed below), operational availability has continued to climb and remains close to/over 85%.

The operating period of the boilers between outages is largely determined by the lifetime of the superheaters. Now there is approximately [redacted] the outages. LEL informed that this is an increase compared to earlier where approximately every [redacted] superheaters were to be replaced. This is the primary explanation of the increase in the operational availability of the boilers which can be observed from Table 4-5, [redacted]

Operational availability decreased significantly in 2009 due the turbine fire. LEL has carried out a detailed study based on the imaginary case of no turbine fire. The corresponding average boiler availability in [redacted] would have been 83%. This is still below the average availability for the period [redacted] and was caused by the following incidents in [redacted]:

- [redacted]
- [redacted]
- [redacted]
- [redacted]

A total shut down due to black out of the SCADA is not expected to reoccur as the UPS for the SCADA has been replaced since the incident. Extended turbine outage can normally occur without affecting the boiler availability. Furthermore, when LEL installs its larger house set, all [redacted] boilers can be in operation when one of the [redacted] turbines is out.

Normally the operational availability of the FGTs and the turbine/generators do not affect the operational availability of the boilers. This is because the planned outages of the FGTs and the turbine/generators are normally carried out simultaneously with the furnace/boiler outage works.

During the boiler outage periods, [redacted] boilers can be operated at full load with only three turbine/generators and three FGTs in operation. Provided that the boilers and FGT's in service are not blocked, there is no flue gas flow restriction and all turbines can operate to their maximum steam capacity.

On modern/new built EfW plants guarantee values of 8,000 hours of availability and 8,000 hours of continuous operation are provided. This corresponds to a minimum of 91% operational availability.

Plant availability at LEL would be expected to average to 85% per annum during operations to 2025, noting that higher availability could be achieved in some years and lower availability in other years i.e. planned/unplanned outage impacts.

The realised average availability for the period [redacted] 86.8%, which is higher than the expected average for the period up to 2025. This figure is though slightly lower than the average of 89.2 % for the period [redacted]. The drop is attributed to the increase in boiler unplanned outages, based on performance data analysed.

4.4 Analysis of FGT operation

The performance of the FGT-plant is characterised by its capability to fulfil emission requirements without excessive consumption of consumables. The performance in terms of air emission fulfilment is described in Section 3.2.1. The focus below is on lime usage. Lime is used for absorbing the flue gas content of the acid gases HCl, SO_2 and HF to comply with respective limit values. HF concentration is usually low and often not considered. An excess of lime is required to ensure sufficient absorption, and a residue is generated which includes the reacted lime, unreacted lime, inert material and activated carbon added to the flue gas stream.

In 2008 LEL carried out trials with [redacted]Sorbacal. Subsequently, in 2009, LEL switched to use of Lhoist Sorbacal instead of ordinary hydrated lime in the FGT because of its higher efficiency for HCl and SO_2 absorption

The analysis below, which is based on results of APC residue samples before 2008, has been updated with results from analyses of residue in 2013 and 2015.

LEL has been working closely with [redacted], the manufacturer of the new lime (Sorbacal). LEL advised that analysis has been undertaken and according to Lhoist, LEL has achieved stoichiometric factor as low as 1.4, i.e. the lowest stoichiometric factor for any EfW plant worldwide. This corresponds to approximately 90 kg/hr which is considered as optimum. LEL was also in discussion with [redacted] to install SO_2/HCl monitors to the inlets of each FGT, thus providing a feed forward signal as well as the normalised feedback signal from the actual emission level. These monitors have recently been installed.

There are three major ways of evaluating lime consumption.

The direct way is to record hourly consumption or consumption in kg per tonne of input waste. This is a simplistic approach, as the effect of varying HCl and SO_2 content in flue gas is not considered.

The flue gas way is based on the fundament that lime consumption is caused by absorption of HCl and SO_2. When measuring raw gas and clean gas contents of HCl and SO_2 together with the flue gas flow rate, lime consumption can be put in relation to absorbed mass flows of HCl and SO_2, and the so-called stoichiometric ratio[5] (SR) can be calculated as a measure of lime usage efficiency.

The third way is based on analyses of residues. Here residue content of reacted lime is put in relation to the total content of lime, reacted and free lime. The SR is calculated as the proportion between lime, which has reacted with HCl and SO_2, and total lime (total lime is measured by the total content of Ca, and reacted lime is measured by the content of Cl and S in the residue).

[5] Stoichiometric ratio (SR) is the consumption of lime relative to the absorption of HCl and SO_2. The stoichiometric ratio is calculated on molar basis, meaning that an SR of 1.0 is the theoretical optimum where all lime is used for absorption of HCl, SO_2 and HF. A typical SR is 2.0.

The residue analysis can also be used to estimate the raw flue gas content of HCl and SO_2 by using the percentages of Cl, S and Ca in the residue together with the lime injection rate (kg/h) to estimate the mass flows of absorbed HCl and SO_2. The raw gas composition may then be calculated by division with flue gas flow rate (at reference conditions) and correction for the clean gas contents of HCl and SO_2.

[redacted]

Figure 4-1, Lime consumption per tonne waste (cf. data in Table 4-3)

[redacted]

The above consumption rate is not in excess of that normally observed for similar FGT plants, [redacted] for fulfilling the WID requirements (according to the performance test report). However, there may be room for improvement, depending on the actual raw gas composition. Until the installation of HCl and SO_2 monitors at the FGT inlet there was no continuously recorded data available to confirm if the consumption is adequate or excessive for the actual conditions. The only means was residue analyses, which have been made to a limited extent.

4.4.2 Lime efficiency by raw gas measurements

In order to analyse lime consumption, one should monitor the raw gas content of HCl and SO_2 (and HF) and calculate the theoretical consumption for comparison with the actual value.

Prior to 2008 there was no on-going program for continuous monitoring or spot sampling of raw gas. With the new raw gas analysers installed it would be possible in the future to calculate SR from flue gas data.

4.4.3 Lime efficiency by residue analysis

Another way would be to analyse the residue for excess lime (and preferably its content of chloride and total sulphur) and calculate the proportion between reacted and total lime. The contents of free lime, chloride and sulphate are main indicators of efficiency. For lime efficiency to be high free lime concentration should be as low as possible, while the content of chloride and sulphate (including sulphite) should be high. However, chloride content above some 20% could cause problems with agglomeration and clogging at low temperature levels in the residue handling systems.

Excess lime in the residue was analysed at regular intervals [redacted] in the years [redacted]1. Occasional measurements [redacted] were made thereafter. The analysis in Table 4-6 below is therefore based on old, historical data. It is updated with more recent data from 2013 and 2015 in table 4-6A after the change of absorbent to Sorbacal.

Excess lime was on average [redacted]. The three measurements taken in [redacted]

The drop in free lime and the increase in chloride and sulphate show that lime efficiency is much higher now, after the change to Sorbacal.

[redacted]. This indicates that much more sulphate is captured (relative to the chloride content), in turn indicating that the ratio SO_2/HCl in the raw flue gas has increased.

[redacted]

Data on free lime, chloride and sulphate in combination with PAC and lime consumption is detailed in Tables 4-7 and 4-7A. This data provides inputs for estimating residue composition. Free lime, calcium chloride, calcium sulphite/sulphate and PAC constitute the majority of the residue. The remaining part is inert (including calcium carbonate) from the hydrated lime and residual fly ash after the ESPs.

"Base components" are the main components relevant for assessing the lime usage efficiency. A high efficiency is characterised by high Cl-content (around 20%), and low content of residual lime, $Ca(OH)_2$. The "suggested composition" represents a best estimate of the chemical compounds present based on the analysis. In Table 4-7A, the total mass includes other constituents than the ones listed, e.g. inerts from fly ash and PAC.

[redacted]

4.4.4 Estimating the raw gas content of HCl and SO_2

The mass flows of chloride and sulphur in the residue originate from the raw flue gas. Back-calculating to raw gas data (Table 4-8) shows HCl and SO_2 contents of approximately 500 mg/Nm³ and 100 mg/Nm³, respectively in 1999-2007. The raw gas HCl is unchanged 500 mg/Nm³ judged from the residue samples in 2013-2015, but the SO_2-content appears to have increased to 150 mg/Nm³.

Estimated raw flue gas composition	Unit	Value from back-calculation, 1999-2007	Value from back-calculation, 2013-2015	Values from performance test 1997
Flue gas flow rate, wet	Nm³/h	120,000	120,000	126,100
O_2	%, dry	12	12	12.4
H_2O	%	12.9	12.9	12.4
Flue gas flow rate, dry flue gas at 11% O_2	Nm³/h	94,100	94,100	95,000
Main pollutants, ref. dry flue gas at 11% O_2				
Dust	mg/Nm³	250	-	210*
HCl	mg/Nm³	500	500	1070
SO_2	mg/Nm³	100	150	130

Table 4-8 Estimated raw gas data back-calculated from residue composition representing the period 1999-2007, 2013-2015, and values measured at performance tests in 1997, respectively.
*: estimated design value

In Table 4-8 the result for 1998-2007 and 2013-2015 are also compared with values collected during performance testing of the FGT in 1997, when the HCl content was much higher.

The flue gas flow rate is determined by the thermal input to the EfW plant and the excess air level, characterised by the O_2-content.

[redacted]

[redacted]

[redacted]

The performance test (extracts are shown in table 4-10), show fulfilment of IED-requirements even at elevated HCl-content in the raw gas. The pre-condition is a significant increase in hydrated lime consumption [redacted]

[redacted]

The chemical composition of residue of 1999-2007 indicates a stoichiometric ratio of 3.2 [redacted]. This is relatively high when the concentration of HCl and SO_2 is as moderate as [redacted] respectively.

The [redacted] data using Sorbacal yield a stoichiometric ratio of around [redacted] average, ranging from 2.1 to 3.1. This is a notable decrease, although it is higher than the initial tests of Sorbacal indicated.

The chloride content of [redacted] average in the residue in [redacted] is low and indicates potential for improving lime usage efficiency, which has now been realised through the use of Sorbacal at [redacted].

It should be noted that increasing the chloride content from [redacted] corresponds to approximately 30% reduction in lime consumption.

As the chloride level exceeds [redacted] from similar plants indicates that increasing attention is needed to avoid agglomeration and clogging caused by the hygroscopic nature of calcium chloride in the residue. The chloride percentage is reduced to a small extent by dilution of the residue with inert matter from fly ash escaping the ESP. Therefore, improvements in dust separation in the ESPs has the adverse effect of imposing a lower limit of lime consumption, and addition of inert matter (e.g. ash) could allow further optimisation of lime usage.

In a modern plant equipped with a semi-dry FGT system, fly ash and FGT-residue would be mixed and extracted in the bag house filter. The content of fly ash would dilute the chloride concentration and hence, in principle, allow further optimisation of lime use before a critical concentration of chloride is reached.

4.4.5 Summary of lime usage

The consumption rates of PAC and lime (based on ordinary hydrated lime before switching to Sorbacal in 2009) was not in excess of what is normally observed in similar installations.

However, following the switch to Sorbacal in [redacted] in the average quantity of lime consumed per tonne of waste which is a significant improvement. Although Sorbacal is a more effective reagent weight for weight, it is more costly and reduced consumption must be considered against higher cost. More recently in [redacted] in lime usage is increasing again. This is can be explained by the objective to eliminate SO_2 and HCl exceedances in [redacted] but this may be ascribed as well, at least partly, to increased SO_2 content in the raw flue gas.

There may be a potential for further savings through the systematic monitoring of residue quality and use of the installed measurements of HCl and SO_2 as discussed in Section 5.3.

This may be counteracted by increased chloride concentration in the residue as a result of optimisation of lime consumption. The potential for optimisation of lime usage is, thus, limited by potential agglomeration or clogging problems that could occur in the residue system as a result.

4.5 Analysis of boiler corrosion rates

In order to evaluate the necessary replacement of boiler pressure parts in the period 2016 to 2025 corrosion rates are evaluated in the following section.

The evaluations are based on the thickness measurement reports which are included in appendix G.

In 2017 all three economiser sections on [redacted] replaced with new economiser sections. Before this replacement extensive thickness measurements of the economiser bends and corresponding corrective works were carried out. However, after the replacement and based on the experience of the failure mechanism of leakages at the bends of the former economisers no reoccurrence of leakages at the bends are expected for the period until 2025. As there is good access conditions to the economiser bends, it is still recommended that a few thickness measurements at the economiser bends in the bottom sections are carried out during annual outages to keep track of the corrosion rates.

LEL has decided to replace the evaporator tube bundles on all [redacted] annual outages. LEL advised that this is partly due to the current age of the evaporator tube bundles (and thereby increased risk of leakages) and partly due to ash blocking problems in the narrow gaps between the evaporator tubes, which especially in the bottom part of the evaporator bundles cause blockages that sometimes require shut down for manual cleaning. On this basis, no further analysis of thickness measurements and corresponding corrosion rates of evaporator tube bundles has been carried out.

4.5.1 Tube walls in the radiation pass

A comprehensive tube wall thickness monitoring scheme in the radiation pass is implemented by LEL. LEL has decided to consider most of the unprotected carbon steel tube wall areas as wear parts – the only exception being the screen walls where Inconel tubes and [redacted] composite tubes (see details in section 2.4.2) protect against corrosion.

In the following sections 4.5.2 to 4.5.6, Ramboll have made an assessment of which areas of the tube walls should be considered wear parts in order to provide value for money (also taking into account the risk of tube leakages/unplanned outages). When evaluating the thickness measurements, it must be considered that there can be some uncertainty with the readings and therefore in areas with high corrosion rates the risk of tube leaks is higher.

Installation of [redacted] in the tube walls is approximately between [redacted] as expensive as installation of plain carbon steel tubes depending on the size of the area which is replaced (as installation cost is the same for plain carbon steel tubes as for Inconel tubes it is only the material cost that differs).

All tube walls in the radiation chamber, at the superheaters and at the evaporator tube bundles - consist of [redacted]

Replacement of tubes is usually carried [redacted], however on low corrosion rate areas replacement [redacted]

4.5.2 Screenwall

The screen wall is protected partly by [redacted] cladding and partly by [redacted] composite tubes (reference is given to section 2.4.2 where this is specified in detail).

Based on visual inspection the [redacted] cladding appears to be in a good condition without visible pitting corrosion. LEL informed that spot check thickness measurements of Sandvik tubes as well as Inconel cladded tubes show no loss of thickness. Furthermore, replacement of [redacted] half [redacted] composite tubes with Inconel cladded tubes in 2015 revealed that the [redacted] tubes appeared to be still in good condition.

On this basis Ramboll expect that there is no need for replacement of the screen walls for operation until 2025.

4.5.3 Furnace frontwall [redacted]

The corrosion rates in this area of the front wall are in the interval of [redacted]. LEL has decided to consider this area as a wear part.

Since the WID upgrade, LEL has proven to be able to mitigate unplanned outages caused by furnace front wall leakages through systematic tube thickness measurements and replacements. The like-for-like replacement of carbon steel tube represents the most cost effective solution. Therefore, it has been decided not to install [redacted] overlay welded tubes on the furnace front wall.

Tube replacement can be undertaken in parallel with other planned annual outage works and therefore has no adverse impact on availability.

4.5.4 Furnace roof, frontwall [redacted]

In most of these areas in the radiation pass average corrosion rates are [redacted] These areas are expected as an average to be replaced only once until 2025. Ramboll agrees with

LEL's decision to consider these as a wear part, with replacement being part of the planned maintenance programme.

4.5.5 Tube walls at the superheater banks

No measurements for the tube walls at the superheater banks and at the roof above the superheater banks were available.

The roof and the walls above the superheater banks are expected to be replaced only once until 2025 (comparable to the upper part of the radiation pass).

LEL informed that based on spot checks the current thickness of the walls at the superheater banks are similar to the walls at the evaporator tube bundles. Consequently, the risk to replace tube walls to operate until [redacted] superheater banks is assessed as medium.

4.5.6 Tube walls at evaporator

<u>Tube walls at evaporator tube bundles</u>

The thickness measurements from [redacted] of the baffle wall – rear side at the evaporator tube bundles show that the thickness is in the interval [redacted] mm. No recent thickness measurements were available.

The maximum corrosion rate has been [redacted].

No thickness measurements were available for the [redacted]. LEL stated that spot checks show a similar status.

Based on this the minimum tube thickness in 2025 is expected to be approximately [redacted] above figures and the quite limited amount of thickness measurements available result in a medium risk for need of replacement of the tube walls at the evaporator to operate to 2025.

4.6 Evaluation of turbine efficiency

The best way to compare efficiency of a TG-set, regardless of steam parameters, condensing temperatures and so on, is by looking at the Isentropic Efficiency – which is defined as:

$$\eta_{is} = \frac{\Delta h(actual)}{\Delta h(ideal)}$$

For modern turbines, isentropic efficiencies up to 90% can be achieved, though efficiencies at about 85% are more realistic.

[redacted]

Isentropic efficiency is calculated using the following assumptions:

- Uniform live steam temperature and pressure: [redacted]
- Deaerator temperature and pressure of [redacted]
- Condensate pre-heater extraction pressure and exit-temperature of [redacted]
- No steam consumption for autoclaves (autoclaves were out of operation when the measurements were done). However, some bleed steam is used for heating grab washing water.

As can be seen from the Table 4-11, the isentropic efficiency is somewhat 'poor' - compared to what can achieved by modern turbines. This is presumably due to:

- The turbines are somewhat oversized – meaning that they are running in part load most of the time which reduce efficiencies
- The turbines are relatively old – and thus no longer performing at their best (e.g. the turbine blades are worn)
- The turbine design is now almost 50 years old thus not comparable to new turbine designs.

Further performance deterioration shall be expected through the years, though part of the lost efficiency can be regained after an overhaul.

Assuming the isentropic efficiency had been [redacted] - the expected electricity output could have been approximately [redacted] higher than that achieved.

Please note, that the analysis above should not be regarded as a definitely analysis of the performance of the turbines, but rather as an indicative analysis – the data used for this study is subject to some uncertainties. A more thorough analysis and assessment of the historical data would be needed in order to justify a turbine replacement.

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted]

[redacted] [redacted]

[redacted]

[redacted]

[redacted]

5 Upgrades and maintenance programmes

5.1 Introduction

Based on the plant review reflected in the previous sections above, a number of potential EfW plant upgrades are identified. These include items first identified in 2009 with subsequent reviews undertaken in 2013 and 2016. This 2019 review has identified outstanding risks and estimated investment requirements. The sections below describe risks and sets out estimated investment requirements for operations to 2025.

Potential upgrades/CAPEX requirements Ramboll foresees have been divided into the following categories:

- CAPEX required to extend EfW plant life to 2025
- CAPEX potentially required for regulatory reasons

A summary of CAPEX estimates is presented in section 5.4 below.

5.2 CAPEX required to extend the plant life to 2025

5.2.1 Replacement of boiler pressure parts

The primary boiler pressure parts replacement detailed below can be carried out during the annual outage of each boiler. An estimate of the required time for the works is stated where the replacement is foreseen to extend beyond the annual outage period.

5.2.1.1 Replacement of evaporator tube bundles

LEL has decided to replace the evaporator tube bundles on all [redacted] boilers during the [redacted] annual outages. LEL advised that this is partly due to the current age of the evaporator tube bundles (and thereby increased risk of leakages) and partly due to ash blocking problems in the narrow gaps between the evaporator tubes, which, especially in the bottom part of the evaporator bundles, cause blockages that sometimes require shut down for manual cleaning. The new evaporator bundles are to be redesigned to allow larger distance/gaps between the tubes in the bottom part. LEL advised that the new redesign will include circulation calculations to verify the design change.

Ramboll fully supports LEL decision for replacement of evaporator tube bundles, including the specified design change.

[redacted]

5.2.1.2 Replacement of boiler walls at superheaters and boiler banks

Tube walls at the superheater banks and boiler banks are assessed to have a medium risk of needing replacement to operate to 2025.

[redacted]

5.2.1.3 Replacement of economiser exit ducts

LEL has planned to replace economiser exit ducts in 2020.

[redacted]

5.2.1.4 Refurbishment boiler drain water recirculation system

LEL has planned to refurbish the boiler drain water recirculation system in 2020.

CAPEX: [redacted], Year: 2020, Risk: High.

5.2.2 FGT Plant and Associated Equipment

5.2.2.1 ESPs trace heating

Trace heating of ESP hoppers is planned in 2019

Total CAPEX: [redacted] in 2019, Risk High.

5.2.2.2 FGT inspections

A detailed survey of the FGT plant is required to better inform its condition and remedial/replacement work requirements. Costs will include extensive need for scaffolding and NDT testing.

[redacted]

5.2.2.3 Partial replacement of the FGT

Considering the relatively short operating time to 2025, the repairs and replacements are foreseen to be based on remedy of faults rather than strategic replacement. This approach is to keep CAPEX and maintenance cost at relatively low level, but it is likely to reduce availability somewhat.

Some repairs of the FGT plant components will be required due to gradual degradation of the equipment, which has been accelerated because of its location outdoor and lack of weatherproofing. Planned outage for repairs is approximately 3 months per FGT line. This could potentially be undertaken in parallel with the electrical\CMS stream works.

As the risk of fault increases with component age, it is important that systematic planning identifies constraints in the supply of critical components, so planning is in place, should a component fail, and that stock of strategic spare parts is kept.

Key flue gas treatment equipment includes inter alia:

- Electrostatic precipitators
- Quench tower
- Reactor tower
- Baghouse filters
- Transport systems
- Tanks and Silos for reagents and residues
- ID and booster fans
- Ducts
- Insulation and cladding

Associated electrical and CMS system replacement would be part of general replacement of electrical and CMS equipment for the EfW facility as a whole

Identifying exact replacement needs and reducing the risk of unplanned stoppages requires regular thorough inspections. It should also be envisaged that the age of the facility makes it increasingly difficult to procure spare parts, causing relatively large replacements to be necessary for minor faults. Furthermore, corrosion is an ongoing phenomenon occurring at LEL's FGT and this would eventually make major repairs or replacement necessary.

The CAPEX estimate below excludes costs associated with plant outage or processing capacity reduction.

[redacted]

5.2.2.4 New filter bags in bag house filters

Filter bags to be replaced every 5 years, approximately. The replacement of all filter bags once is expected for operations to 2025.

[redacted]

5.2.3 Water Steam System and Turbines

5.2.3.1 Replacement of turbine ring nozzles

There is a risk that 3 nozzle rings will need to be purchased if turbine component failure occurs. This risk is considered low as minor repairs are carried out under the overhaul budget and the recent installation of the cyclone separators has reduced the risk of further damage considerably.

[redacted].

5.2.3.2 Replacement of turbine blading

A full inspection of every turbine is carried out every [redacted] years. There are no indications that turbine replacement will be required. However, blade replacements may be necessary in future.

The installation of the cyclone separators on each turbine has reduced the risk of further damage considerably. In addition, the rotor replication testing conducted in 2015 and 2016 did not reveal any creep damage in the rotor disc.

If partial failure was to occur on a few turbine blade rows, this would be managed through the overhaul budget and the new house set turbine would be operated to minimise any availability losses.

[redacted]

5.2.3.3 New Turbine Rotor and Diaphragm

LEL's steam turbines have been in service for more than double their designed lifetime. The turbines are operating at temperatures considerably lower than the temperature at which creep damage starts to occur (450 °C) and have had relatively few starts during their lifetime.

LEL has undertaken replica testing and this has not shown any concerns. Therefore, risks for new turbine rotor needs are considered low. However, Ramboll recommends an actual remaining lifetime study to further reduce the risks.

Following the TA2 damage in 2018 LEL, is considering purchasing a spare rotor in case of a similar incident occurs in one of the main TA. Purchase of the new house set mitigates the risk of lost waste processing capacity. On aftermath of the incident turbine protection and control will be upgraded on all TA's. Based on these two factors the probability for such an investment is considered very low.

<u>Remaining Life Time Study</u>

[redacted]

New Turbine Rotor and Diaphragm (should the above tests deemed for this to be required)

[redacted]

5.2.3.4 New Turbine Cooling Water Control Valves

LEL turbine CW control valves are due for replacement in 2021. Feedback from plant personnel is that they cannot report any issues with the currently installed valves.

Given the limited remaining operating lifetime of the facility after 2021 and the trouble-free operation of the current system such a replacement is considered as low likelihood to be realised.

[redacted]

5.2.3.5 Replace demin storage tanks

In order to mitigate incidents of demin water shortage which potentially results in complete plant shut down, LEL is planning to replace the existing demin water storage tanks with larger tanks.

[redacted]

5.2.3.6 Larger house set

LEL is installing an 8.3 MWe house set. This will replace the existing 2.5 MWe turbine and provide enhanced operational flexibility.

[redacted]

5.2.4 Electrical and Control System Surveys and Works

5.2.4.1 11 kV and 3.3 kV switchgear

LEL is in the process of replacing its 11 kV and 3.3 kV switchgear. These systems a critical plant items and are now close to 50 years old, thus well beyond the service life expected.

[redacted]

5.2.4.2 Transformers

Main export transformer T1 is estimated to have a remaining lifetime of 7 years. This is a critical plant component and poses a high risk for operations to 2025.

Main export transformer T2 is estimated to have an 11-year remaining life time, thus low to medium risk for operations to 2025.

[redacted]

[redacted]

5.2.4.3 General electrical components

According to the equipment datasheets, the average lifetimes for motors and drives is 20 years. By 2025, many of the components will reach a design life time approaching twice their original design life.

A survey should be undertaken for remaining lifetime to be evaluated. It is understood that majority of the electrical components are going beyond their design age. Ramboll expects significant refurbishment of the following systems will be needed, some may require wholesale replacement if, on inspection, remedial work is deemed uneconomic:

- Generators (alternators) electrical insulation (rotor and stator windings)

- Transformers (LV)
- Emergency Standby System
- Low voltage cables
- Low voltage switchgear
- Electrical motors and associated drive equipment
- UPS equipment

[redacted]

5.2.4.4 CMS

Control and instrumentation systems contain components with varying manufacturers lifetime expectances ranging from approximately 6 for some CMS components to 15 years for instrumentation.

With the Valmet 'Road Map' agreement triggered the DCS equipment and components that have reached lifetime expectance will be replaced over the next 5 years and would be expected to provide secure operation to 2025 and thereafter to 2030. The replacement of other control and instrumentation systems on a rolling programme will need to be maintained to provide operation once the "Road Map" programme is implemented in full, with consideration as to the replacement of obsolete and unsupported equipment as a priority.

[redacted]

5.2.5 Civil, structural and building services items

5.2.5.1 Corroded steelwork and continued programme of repair

A detailed inspection should be carried out to identify corroded steelwork and programme of repair which has started should continue to be implemented.

The detailed inspection noted above should also identify those structural steel elements that are corroded but whose structural integrity is not compromised to the extent that replacement is required. A programme of corrosion protection should be implemented on this steelwork.

[redacted]

5.2.5.2 Cladding to boiler hall, turbine building, residuals building, FGT plant and other structures

Cladding on areas of main buildings or residual buildings is corroded or damaged through impact. It is important to maintain buildings water tight to protect plant and equipment. Therefore, corroded cladding and that which is missing or damaged by mechanical impact should be replaced to maintain the integrity of the buildings

[redacted]

5.2.5.3 Mechanical and electrical building services

A rolling programme of investments is required to maintain integrity and update mechanical and electrical building services items.

[redacted]

5.2.6 Automation of Waste Cranes

LEL is in the process of installation automated waste cranes. These cranes are replacing the manually operated cranes in place.

[redacted]

5.2.1 Effluent treatment plant upgrade

LEL is in the process of upgrading the effluent treatment plant.

[redacted]

5.2.2 Capex Contingency

The forecasted period to 2025 corresponds to plant age of approximately 55 years. There will be Capex which currently cannot be specifically stated. Key plant items likely to require additional maintenance include, inter alia:

- Ram feeders
- Roller grates
- Bottom ash transport systems
- Soot blowers
- Hydraulic systems
- Compressed air systems
- Burners
- Selective non-catalytic reduction (SNCR) system
- Primary Air and Secondary Air fans
- Bottom ash extraction
- Bottom ash transport
- Metal separation
- Feed water pumps
- Condensate pump
- Deaerators
- Waste cranes

[redacted].

5.3 CAPEX potentially required for regulatory reasons

5.3.1 General environmental management

BAT 1 of the new BREF edition implies improving the overall environmental performance, BAT is to elaborate and implement an environmental management system (EMS) that incorporates a range of features. Although LEL already has extensive environmental planning, additional planning, its implementation etc. is foreseen as a result of the new BREF.

[redacted]

5.3.1 Tightened Emission Limit Values for HCl, HF and SO_2

Following the implementation of the new edition of BREF, the limit values of HCl and SO_2 are likely to be lowered around 20%. This is in turn likely to require additional measures to ensure fulfilment, as the current operation would exceed the tightened level. Such measures could include improved feed forward control of lime dosing according to raw gas measurements and changes to lime injection systems. It is suggested to include capex for such investigations and upgrades.

[redacted]

5.3.1 Tightened Emission Limit Values for Particulates

Increased attention necessary to filter bag replacement, PAC dosing and ensuring gas tightness from inspection for corrosion of bag house filters including by-pass systems, including necessary repairs. We suggest including CAPEX for such investigations and repairs, although the extent is not known at present. CAPEX for new filter bags is included in section 5.2.2.4,

[redacted]

5.3.2 Further NOx reduction

If NOx emission limit levels are lowered to 150-180 mg/Nm^3 (and ammonia slippage to 15 mg/Nm^3), compliance can be achievable by optimisation of the existing SNCR-process, requiring more injection options, better monitoring of temperature and process result through NOx and ammonia measurement downstream of the ESP of each process line and automated control of carbamin dosing and shift between injection points.

As part of the optimisation process, particularly if further reduction than to 150 mg/Nm^3 is needed, consideration should be given to a change from urea to ammonia water, which is known to work at lower temperature than carbamin. Ammonia is also expected to give less nitrous oxide as by-product.

Should further NOx reduction (down to comply with a limit value of around 120 mg/Nm^3) be required, the principle options to achieve this are as follows:

- Primary combustion controls & equipment – equipment replacement would lead to major expense and is unlikely to be justifiable, further controls over and above those already in place to assist with WID compliance may be of limited assistance, although additional SNCR injection nozzles and improved temperature surveillance may have some merit by improving control.
- Increased SNCR dosing – this is considered likely to give rise to only marginal NOx improvements as dose optimisation and ammonia slip monitoring to limit the ammonia slip has already been required to reach 150 mg/Nm^3 and the lack of a wet scrubber means there is a low downstream NH_3 capture rate. There is no commercially available method for capturing ammonia other than a wet scrubbing system. The fitting of such a system likely to be unsuitable due to extensive cost (CAPEX), plume visibility and space aspects.

- Use of SCR – technically this method would achieve the NOx reduction (even down to 20 mg/Nm³) without the other issues raised above. However, cost and space requirements are significant and this would then trigger changes to the plant layout that are likely to have logistical and planning permission requirements.

Based on the risk assessment in section 3.2.1.1 reducing NOx emissions (perhaps to the 150-180 mg/Nm³ range together with ammonia slippage not exceeding 15 mg/Nm³) has high probability. The improved NOx reduction is probably achievable by addition of more SNCR nozzles and installation of NOx and ammonia raw flue gas measurement on individual lines after the ESPs and conducting an optimisation program and continued use of carbamin as reagent.

[redacted]

In case carbamin is not sufficient to comply with the potential requirements on ammonia slippage and N_2O-emissions a potential change to ammonia water and improved temperature surveillance could be necessary with an additional cost of

[redacted]

5.3.3 Improved combustion control

If further reduction of CO/TOC levels is required, the following upgrades should be investigated:

- Improvement of the combustion control. Different combustion control philosophies exist. However, the so-called Dynamic Sensing Combustion Control DSCC (or similar systems) could potentially improve the combustion process at Edmonton.

- An investigation of potential for improved mixing/turbulence in the after burning chamber and thereby improved burn out/reduced CO & TOC should be carried out. This includes CFD-modelling and potentially adjustments in the configuration/position of the secondary air nozzles.

Based on signals from standard plant instrumentation the DSCC generates a signal which indicates the instantaneous position of the waste and main combustion zone on the grate. This signal is a calculated factor which also indicates the grates instantaneous combustion load. The signal is influenced by the dynamics in the combustion process hence it is suited as a fast feed forward signal for control of the waste pusher and grate movement in order to limit the variations in the combustion process. The signal also indicates the thickness of the waste on the grate which can be used to avoid having an excessive waste mass load on the grate when there is a drop in the calorific value.

A detailed analysis of the combustion control system and the parameters used for optimisation is outside the scope of the current report.

There is high probability that investigations in relation to further reduction of CO/TOC levels will be required, with the likelihood that the findings will be that mostly relatively minor process optimisation rather than capital expenditure.

The CAPEX related to the following investigations:

- The investigations of potential improvements of the combustion control system by implementing DSCC (or similar system) on one of the [redacted] furnace/boilers

- Performing CFD analysis to investigate potential reduction of CO/TOC levels caused by adjustments in the configuration/position of the secondary air nozzles

If the test/implementation of DSCC (or similar system) on one of the [redacted] furnace/boilers reduces the CO/TOC levels, implementation on the remaining [redacted] boilers would probably need to be carried out. Furthermore, if the CFD analysis was to reveal a potential reduction of CO/TOC levels by adjustments in the configuration/position of the secondary air nozzles can be achieved, this could be carried out as a trial on one boiler. If the physical test on this boiler is positive the same modifications are likely to be required to be carried out on the [redacted] other boilers.

[redacted]

5.3.4 Emission of PCDD/F at start-ups and shut downs

Although the IED or the BREF does not require PCDD/F emission to be verified during startup/shutdown, at LEL the combustion gas from start-up /shut down will have to leave the plant mixed together with the flue gas from the lines in operation. Therefore, the fulfilment of the PCDD/F ELV may be required also during start-up/shut down of one process line while the others are in operation.

No reports are available of PCDD/F levels during start-up at LEL. The risk of elevated emission of PCDD/F during start-up/shut down is, nonetheless, estimated to be low.

This is founded on the following analysis. The concern of potential elevated PCDD/F formation in the raw flue gas during start-up arises from international literature reporting elevated PCDD/F content during start-up. These observations are made at EfW-facilities starting up using gas oil as start-up fuel. A likely explanation is that incomplete combustion of oil generates complex organic precursors for dioxin formation, and then dioxin is formed in the temperature interval 300-500 °C on the surface of ash deposits and metal in the boiler. At LEL natural gas is used, and this is estimated to give little formation of precursors due to the simple chemical structure of the molecules contained in natural gas. Furthermore, all combustion gas leaving the facility, including flue gas from start-up/shut down, passes through the FGT-reactor and bag house filter. In the reactor it will meet pulverised activated carbon injected for the very purpose of capturing PCDD/F, and the bag house filter ensures capture of the carbon particles.

In the unlikely case that the PCDD/F-content should be elevated downstream of the boiler, and this (also unlikely) could lead to high emissions being measured at the stack, a mitigation measure could be to implement controlled over-dosing of PAC before and during start-up and shutdown.

Improved control of the PAC dosing rate is in itself judged to be an improvement over the current installation as it raises the potential to ensure that PAC is dosed at the intended rate at all times. This would provide an improvement in emissions control (Hg and PCDD/F), offer potential cost savings for PAC and reduce the risk of overdosing which in turn reduces the risk of fire in the bag house filters. Such an improvement could also in itself be a comfort to the authorities. Altogether, installation is considered likely, although the likelihood of a formal requirement is considered low.

It should be noted that, in the event that the EA were to place a particular focus upon avoiding start-ups and shut-downs for any reason, a scheme for reducing the number of planned and unplanned stops would then have to be developed, including for instance increasing the redundancy of critical systems. Ultimately, increasing the continuous period of operation may entail boiler replacement. The small free-board at the installation may be seen as a significant obstacle, as it gives rise to frequent start-up/shut downs due to fouling and corrosion of heating surfaces, including superheaters. The long term risk of this is considered to be negligible but if the risk is realised, the magnitude will be very high. This is due to the costs related to boiler replacement, with the consequent need to alter the plant civil structure, the WID derogation and planning permission associated to such changes.

In the unlikely event that a problem is encountered with PCDD/F emissions when mixing the start-up flue gas with the flue gas from the other lines in operation, other solutions are available. One such solution could be to ensure that start-up flue gas is emitted through its own stack pipe (WID ELVs would not apply as no waste is being treated at this point). This is less costly than replacing boilers.

In this event, installation of [redacted] additional stack pipes and installation of additional dampers in the common flue gas manifold could be considered. As the flue gas from [redacted] furnace/boilers can be cleaned by three FGTs, start up and shut down of the fifth boiler can be carried out without mixing with the flue gas from the other boilers. It is considered that this argument will make it unrealistic for the EA to demand such a change (because the CAPEX spend will not improve the emissions). The only purpose for the installation of [redacted] additional stack pipes and additional dampers would be to avoid verifying PCDD/F emissions during start-up/shutdown (as for other plants).

Continuous measurement of PCDD/F is currently not possible. Instead, the PCDD/F level in the stack could be verified by continuous sampling, where each sample represents some days or weeks. Typically, 2 weeks sampling time is used.

[redacted]

[redacted]

[redacted]

5.3.5 Upgrade of the effluent plant

There is a small risk (estimated to be in the order of 10%) that the EA require the discharge measurement point of the effluent plant to be moved upstream to the outlet of the effluent plant (before dilution with bleed off water from the cooling water plant). Dilution of processed effluent with relatively clean cooling water assists with meeting the emission limits per m^3 of water discharged. If this should occur, the effluent plant may have to be upgraded by improving the heavy metal separation in order to comply with the discharge limits.

[redacted]

5.3.6 Installation of individual emission monitoring stations on each FGT

It cannot be excluded that during the time to 2025 the authorities will require emissions monitoring on the flue gas discharge from each of the [redacted] FGT lines. LEL currently monitors emission in the [redacted] stack pipes combining flows from flue gas streams. This will require [redacted] additional emission monitoring stations.

In 2013, LEL were considering the merits of monitoring the discharge of each FGT to optimise lime dosing rather than due to any regulatory pressure; currently as [redacted] FGT systems exit into one common flue, there is no indication of which of the [redacted] FGT systems is emitting elevated concentrations of emissions, and hence limited means of controlling the FGT processes.

In 2009, it was also suggested that monitoring concentrations of HCl and SO_2 downstream of each FGT could serve a different purpose as a necessary means for optimising the FGT-process for saving hydrated lime and residue generation. HCl and SO_2 monitors have now been installed at FGT inlets and provide feed forward information to the lime dosing process. It is noted that no SO_2 breaches have been recorded in 2014 and 2015.

The fact that outage of emission monitoring is considered as a non-compliance, contributing to the maximum 60 hours allowance when exceeding ELVs, may also indirectly justify doubling of the EMS.

Assuming that at least one of the two points above is applied, purchase and installation of [redacted] EMS in addition to the existing stack measurements, including sampling and housing facilities to accommodate the EMS-system and associated equipment.

[redacted]

5.3.7 Pneumatic Transport

There is a risk that additional pneumatic transport will be required. Boiler ash from 2nd/3rd pass is directed to the bottom ash. There is a potential risk that environmental authorities could require the 2nd/3rd pass boiler ash to be directed to the silos with ESP ash/APC residues. Such a change of permit would require new ash transport systems to be installed for all 5 boilers.

[redacted]

5.3.8 ATEX Compliance

There is a risk that the plant is not in compliance with the ATEX-directive. Therefore, an ATEX plant survey is to be carried out and any necessary rectifications to comply with EU/UK legislation have to be implemented. A realistic estimate of the Capex can only be made once the survey is undertaken.

5.3.9 Continuous Monitoring of Mercury Emission

BAT 4 of the new BREF edition may be interpreted as requirement of installation of continuous emissions monitoring for mercury. Considering the time to 2025, it is likely that the EA may be willing to accept current level of monitoring – given the history of low mercury emissions measurements.

[redacted]

5.3.10 Continued Derogation from the IED/WID

The facility currently operates under a permitted derogation, issued by the Environment Agency, as the 'two second combustion residence time' requirement of the Waste Incineration Directive (this requirement is now transferred directly from Waste Incineration Directive to the Industrial Emission Directive) cannot be achieved with the existing boiler design.

Rather than an absolute requirement, the 850°C two second obligation is derived from an empirical correlation to the production of lower emissions. At installations where the operator can demonstrate suitable compliance with emissions, and other, requirements of the Directive, the requirement holds less precedence. This also reflects the fact that the cost implications of replacing and resizing furnaces may be considered to be excessive in relation to the marginal improvement in emissions achievable.

In the period up to 2025 it is considered that with a continuation of the continued good emissions record from the Edmonton facility there is a low risk of this derogation being withdrawn. However, in the longer term, with a greater proportion of plants achieving emissions well below the IED emission limit values, it is Ramboll's view that the risk of a potential withdrawal increases.

In the event that the derogation is revoked, significant redesign of the combustion chamber and boilers would be required, with notable civil design and planning implications. The remedial work would also require significant outages.

[redacted]

Table 6-5 includes a list of upgrades/CAPEX, which are potentially required for regulatory reasons.

5.4 CAPEX Estimate

Based on the above analysis this sets out a summary of the suggested/required CAPEX split into the following two categories:

- CAPEX required to extend the plant life until 2025
- CAPEX which are potentially required for regulatory reasons

For each of these investments the following information is included:

- A brief description of these investments
- year of investment
- if applicable the risk of having to carry out the investment (primarily regulatory risk)

5.4.1 M&E Capex required to extend the plant to 2025

Table 5-2 includes a list of upgrades/CAPEX required to extend plant life until 2025.

[redacted]

[redacted]

Table 5-2 Capex required to extend plant life to 2025

5.4.2 Civil Capex to extend the plant life to 2025

Table 5-3 includes a list of civil maintenance CAPEX required to extend plant life until 2025.

[redacted]

5.4.3 Contingency Capex to extend the plant life to 2025

Table 5-4 details a contingency CAPEX allowance for unforeseen risks/costs for extending plant life to 2025. This encompasses contingencies for mechanical, electrical and civil works/risks.

[redacted]

Table 5-4 Contingency Capex required to extend the plant life to2025

5.4.4 Capex potentially required for regulatory reasons

Table 5-6 includes a list of upgrades/CAPEX potentially required to address regulatory requirements.

[redacted]

** Work as a consequence of the derogation being revoked

Indicative Capex for SCR and loss of the WID derogation are discussed at section 5.3.

6 Future performance

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted].

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[redacted]	[redacted]	[redacted]
	[redacted]	
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

6.2 Operational availability and waste throughput

In the description/analysis of the historical operational availability of the boilers in Section 4.3 it was concluded that:

- Taking into account the special conditions at LEL, average annual availability of 85% for operations to 2025 is considered acceptable.

- Generally, the operational availability of the FGTs and the turbine/generators do not affect the operational availability of the boilers i.e. planned maintenance of the FGTs and the turbine/generators can normally be carried out during the boiler survey period without impacting boiler availability.

The expected average operational availability for the furnace/boilers is subject to good operation and similar waste types and provided that the recommended upgrades and level of maintenance is carried out. Furthermore, we assume significant changes to waste composition and waste types processed.

6.2.1 Waste throughput

Based on the operational availability of 85% and current waste throughput rates of [redacted] per furnace/boiler, annual waste throughput can be expected to be [redacted]

If the calorific value of the waste increases, then the throughput of the plant will be reduced accordingly (to maintain the same energy input).

Continued processing of MSW at Edmonton is discussed/analysed in this section.

6.2.1.1 Future residual MSW capacity

If the future composition of the waste remains the same as today, our estimate of the future plant capacity would remain at [redacted]

The capacity (measured in tpa) of the facility, depends on the calorific value of the waste.

If the facility continues to receive residual MSW from the same sources as today, waste composition can be expected to change somewhat as a consequence of increasing recycling.

Other waste producer consumption patterns may also affect waste composition, but we have no reliable estimate of how this may develop.

A detailed consideration of NLWA's current waste properties and planned waste collection etc. practice changes are required to inform future calorific value estimates and plant throughput expectations.

6.2.1.2 Risk from waste with a high calorific value

It is important to note that LEL was built to process low calorific value waste i.e. residual MSW. According to the firing diagram (included at Appendix D), the maximum CV the facility is designed to process is [redacted] Introducing significant quantities of waste with a higher CV could increase the risk to the plant in the following areas:

- Corrosion (as outlined above)
- Maintenance of stable operation
- Emission control issues
- IBA composition
- FGT residues quantities, and
- Availability (as outlined above)

6.3 Risks

All risks identified in connection with the plant survey have been discussed/assessed in Section 5. In the following section, a summary of the key risks is provided.

Risks of lower availability due to severe damage to the plant equipment

The following risks of severe damage to the plant equipment have been identified:

- The 11 kV switchgear and 3.3. kV switchgear is critical for plant operations. LEL is in the process of replacing this switchgear together with associated elements of power and control cabling. Should this switchgear replacement project be completed successfully, the risk posed to the plant would be significantly reduced/addressed.

Risk of a plant stand still based on lacking strategic spare and wear parts

- Strategic spare parts/wear parts are defined as spare parts/wear parts that have a long delivery time and will cause a severe loss in profit since the plant is unable to operate. Ramboll recommends that LEL reviews their stock of strategic spare and wear parts for the entire plant and ensures that it corresponds to the targeted operational availability.

Risk of loss of O&M key staff

Risk of loss of key O&M staff, including imminent retirements. Recruitment and training to be ensured. We understand that LEL will produce a separate report to assess this risk and set out its mitigation measures.

Regulatory risks

In general, regulatory risks have been analysed and quantified in Section 3.2. For each of these risks a corresponding upgrade/CAPEX has been defined and is included in the list of CAPEX in Section 6.3.3.

Corrosion related risks

The following corrosion related risks have been identified:

- Corrosion to the FGT casing and structural steelwork. This is included in the Capex programme suggested in Section 5.2. Furthermore, Ramboll recommends LEL to carry out thickness measurements/repair works to the common flue gas ducting in connection with the expected total shut down of the plant (for overhaul of the common steam and cooling water system).

- Corrosion from the inside in the chilled water piping system. Based on information from LEL inspections and operation experience this risk has been assessed to be minimal. However, Ramboll recommends LEL to carry out thickness measurements inside the cooling water pipes in connection with the expected total shut down of the plant (for overhaul of the common steam, cooling water system and HV system). Potentially significant replacement of main cooling water pipes could be needed.

Risk of lower throughput due to increasing CV

Risk of decrease in tonnage throughput capacity of the plant due to potential increase of the NCV of the future waste has been quantified for different scenarios of future waste (reference is made to Section 6.1.2)

Risk of increase in disposal costs

The disposal costs for APC residue and bottom ash constitute a significant part of the OPEX costs. As a consequence, the risk of increase in disposal costs is important to assess:

The APC and bottom ash disposal contracts/conditions should be obtained from LEL in order to assess the risk of increase in disposal costs.

Risk of increase in consumable prices due to increased energy prices

Increase in energy prices will have an impact on the following consumables:

- Gas
- Consumables which are sensitive to energy prices (e.g. carbamin)

However, as such increases usually will be accompanied by increase in electricity prices the overall effect on EfW economy would be expected to be neutral/positive.