

**Newhurst Energy Recovery Facility
Leicestershire**

**Environmental Permit (EP) Application
Appendix BATOT11
Acid Gas Abatement Review**



January 2010
SLR Ref: 407.0034.00032/BATOT/APP11

CONTENTS

1.0 INTRODUCTION.....	1
2.0 ENVIRONMENTAL ASPECTS	2
3.0 ACID GAS TREATMENT OPTIONS.....	3
3.1 Acid Gas Formation.....	3
3.2 Primary Control Measures	3
3.3 Secondary Control Measures	3
4.0 ENVIRONMENTAL CONSEQUENCES	5
4.1 Emissions to Air	5
4.2 Raw Materials.....	6
4.3 Ozone Creation Potential	7
4.4 Waste.....	7
4.5 Other Operational Issues	7
5.0 COSTS – ANNUALISED & ACID ABATED.....	8
6.0 CONCLUSIONS AND RECOMMENDATIONS	9
7.0 CLOSURE.....	11

TABLES

Table 2-1 Identification of Relevant Environmental Aspects	2
Table 3-1 Summary of Acid Gas Abatement Options	4
Table 4-1 Achievable Long-Term Air Emission Concentrations.....	5
Table 4-2 SO ₂ Long-Term Air Quality Impacts	5
Table 4-3 HCl Long-Term Air Quality Impacts.....	5
Table 4-4 Raw Material Consumption and Cost.....	6
Table 4-5 SO _x Emissions and POCP	7
Table 4-6 Solid Waste Residues and Costs.....	7
Table 5-1 Summary Estimates of Acid Gas Abatement Costs (£).....	8
Table 5-2 Comparison of Costs per Tonne Acid Abated	8
Table 6-1 Summary of Ranking.....	9

FIGURES

Figure 5-1 Abatement Options Cost Calculations	8
--	---

1.0 INTRODUCTION

Biffa Waste Services Limited (Biffa) is applying for an environmental permit to operate an Energy Recovery Facility (ERF) at Newhurst, Leicestershire.

The plant will be designed to use established direct combustion technology to treat approximately 300,000 tonnes per year of residual municipal and/or commercial and industrial waste. When fully operational it is anticipated that the ERF facility will have the potential to export approximately 25MW of electricity to the National Grid. Biffa intends to operate the plant as a Combined Heat and Power (CHP) scheme and has entered into discussions with potential users of the heat (see Heat Plan, SLR Ref 407.0034.00332/HP).

As part of the demonstration that Best Available Techniques (BAT) have been adopted for environmental protection, an options appraisal will be required to identify the most suitable means of controlling emissions of acid gases from the proposed installation. Relevant acid gases are oxides of sulphur (SO_x), hydrogen chloride (HCl) and hydrogen fluoride (HF).

The Sector Guidance Note¹ states that “You must provide an acid gas control cost/benefit study using the methodology in Horizontal Guidance Note H1 Environmental Risk Assessment to demonstrate the relative merits of primary and secondary measures. The comparison must show the cost per tonne of acid abated (as HCl) over the projected life of the plant using the asset lives and typical discount rates given in that document.”

This document presents the cost-benefit study that, in accordance with the EP guidance, considers the following options. Additional data on consumption rates, etc are obtained from the relevant European BREF note² or suppliers technical data, as appropriate.

Options considered:-

1. primary acid gas measures;
2. wet scrubbing system.
3. semi-dry scrubbing system; and
4. dry scrubbing system;
 - o using hydrated lime;
 - o using sodium bicarbonate.

It is assumed that the plant operates for 90% of the time, 7800 hours per year, with the remaining time for plant shutdowns and maintenance.

Section 2 of this document identifies the environmental aspects considered in the assessment. Section 3 details key features of each option. Section 4 presents the environmental impacts for each option and, where relevant, associated costs. Section 5 presents annualised costs and cost per tonne of acid abated. Conclusions and recommendations are presented in Section 6.

¹ Environment Agency, 2009. Sector Guidance Note EPR 5.01 - The Incineration of Waste.

² EC, 2006. BREF BAT Reference Document on Best Available Techniques for Waste Incineration.

2.0 ENVIRONMENTAL ASPECTS

To identify BAT for acid gas abatement all environmental impacts of the installation need to be considered, not simply the effects of emissions of acid gases. This includes air quality, energy & global warming potential (GWP), photo-chemical ozone creation potential (POCP), and wastes arising. The Environment Agency's H1 Assessment tool³ provides a systematic approach to evaluating the environmental significance of each of these aspects and has been used as the basis of this assessment.

Table 2-1 identifies relevant environmental aspects for consideration as part of the acid gas abatement review.

Table 2-1 Identification of Relevant Environmental Aspects

Impact	Comments	Relevance
Emissions to Air	Significant differences between options. Techniques result in different releases of SO ₂ HCl & HF that are significant for acid gas abatement options. ^{Note 1}	Y
Emissions to Water	Not applicable. No releases to water except potentially for wet scrubbing method. Wet scrubbing is discounted as design philosophy is to minimise water use.	N
Noise & Vibration	Same for all options.	N
Odour	Same for all options.	N
Raw Materials	Potential differences in types & quantities of reagents used.	Y
Visual Impact	Same for all options.	N
Risk of Accidents	Similar for all options	N
Global Warming Potential	Options considered involve similar technologies associated with dosing flue gases with alkaline reagents and use of a bag filtration system to remove contaminants. The main energy users will be the pumps and motors associated with the handling of reagents, and the suction fan downstream of the filters. Consequently energy consumption and GWP would be similar for all of the options considered.	N
Ozone Creation	Potential significant differences between options.	Y
Waste Generation & Disposal	Potential significant differences between quantities of waste generated by each option. Air pollution control residues (APCR) will be generated and removed from the installation as hazardous waste.	Y

Note 1: Primary control measures are unable to meet the Waste Incineration Directive (WID) limits. Consequently this option does not represent BAT and is not considered as a viable option in isolation.

³ Environment Agency (2008) EPR H1. Environmental Risk Assessment Part 2. Assessment of pointy source releases and cost-benefit analysis.

3.0 ACID GAS TREATMENT OPTIONS

3.1 Acid Gas Formation

Hydrogen Chloride

Hydrogen chlorides are formed when wastes containing chlorinated organics or chlorides are burned releasing the chlorine component, which then reacts with hydrogen in combustion air to form HCl. Polyvinyl chloride (PVC) currently accounts for around 50% of chlorides from waste combustion but declining chlorinated plastics should help to reduce this contribution in future.

Hydrogen Fluoride

HF is formed in the same way as HCl, with the released fluorine reacting with hydrogen in combustion air. Sources of fluorine are typically fluorinated plastics or textiles.

Sulphur Oxides

Sulphur oxides are formed as a consequence of burning wastes containing sulphurous compounds, such as waste paper and plaster board. Typically over 95% of sulphur oxides are in the form of sulphur dioxide (SO₂), but some may be released as sulphur trioxide (SO₃).

3.2 Primary Control Measures

Fuel oils are required during start-up and shut-down and to fire the auxiliary burners. In accordance with regulatory requirements, low sulphur fuel oil will be used. The limit for sulphur in oil is 0.1% by mass; set by the EC and implemented into UK regulation in 2000⁴.

Waste materials containing chloride, fluorides and sulphur are the primary sources of acid gases. Significant undiluted volumes of these materials are not expected to be received at the installation. Rigorous pre-acceptance procedures only permit non-hazardous municipal, commercial and industrial, wastes for treatment. Where bulk loads of these materials are received, site waste acceptance procedures ensure that loads are isolated and quarantined wherever possible. For smaller quantities deposited in the waste bunker, operational measures to mix the wastes prior to feeding them into the furnace minimise the potential for "slugs" of these contaminating materials passing through the plant.

3.3 Secondary Control Measures

Table 3-1 summarises options available for treatment of acid gas emissions to air. Acid gas abatement systems can be based upon dry, semi-dry or wet methods.

Dry methods involve injection of an alkaline reagent into the flue that reacts with acid gas to form salts that are removed typically by bag filter prior to storage in silos. Recirculation of the reagent / contaminant mix from the bag filter optimises reagent efficiency. The reagent is usually hydrated lime or sodium bicarbonate and both are considered in this assessment.

⁴ Statutory Instrument 2000 No. 1460. The Sulphur Content of Liquid Fuels (England and Wales) Regulations 2000.

Semi-dry systems add the alkaline reagent in an aqueous solution, such as lime milk (“slaked lime”). Water evaporates, thus cooling the gases and resulting in dry reaction products that are typically removed by bag filter.

Wet systems feed the flue gases through re-circulating alkaline solution (e.g. sodium hydroxide). Wet systems can produce a good level of abatement with low reagent consumption and solid waste generation but require an effluent treatment system and produce an additional emission and effluent burden for the sewage works. The installation will be designed to minimise water consumption with little or no routine effluent discharge. A wet scrubbing system would require a significant change in approach to this philosophy and hence is not considered to represent BAT for the installation.

Dry and semi-dry scrubbing systems are considered as part of the options appraisal.

Table 3-1 Summary of Acid Gas Abatement Options

Ref	Option	Technique
	Base Case	No secondary flue gas treatment measures in place.
	Wet Scrubbing	Flue gas is fed through re-circulating alkaline (e.g. sodium hydroxide) solution. Depending on the contaminant load up to four scrubber systems maybe used to produce a discharge of sufficient quality to meet regulatory requirements. Wet systems can generate significant effluent and may require pre-scrubbing to remove particulate. Wet systems tend to have higher corrosion rates and need energy for pumping, effluent treatment and reheat for plume prevention.
1	Semi-Dry Scrubbing	Alkaline reagent is sprayed into the flue as an aqueous solution, typically as lime milk. Water evaporates, allowing reagent products to be collected and reused. Reaction rates can be low so reagent is typically re-circulated until replete. However, recycling is not always effective, resulting in higher volumes of solid waste residue. Semi-dry systems need energy for pumping and reheat for plume prevention.
2	Dry Scrubbing a) Hydrated Lime	Dry lime is injected at the inlet of the bag filter. Dose rate depends on the temperature as well as on reagent type. Reaction products are solid salts and collected from the flue-gas as dust in a subsequent stage, normally a bag filter. Reaction rates tend to be low - so longer residence is typically achieved by re-circulating reagent to optimise efficiency. Higher volumes of solid waste residue can be generated. The advantages of using lime include: <ul style="list-style-type: none"> •very good removal rates; •less expensive; and •residues are low leaching.
3	Dry Scrubbing b) Sodium Bicarbonate	Dry sodium bicarbonate is injected at the inlet of the bag filter. At temperature dissociation creates a porous sodium carbonate with a large surface area that rapidly reacts with acid compounds in the flue gases to form salts. Though more expensive than lime, sodium bicarbonate has the following advantages: <ul style="list-style-type: none"> • lower reagent consumption producing less solid waste residues and hence lower disposal costs; • rapid reaction rate reducing emission spikes and providing more reliable compliance with WID limits; • greater reaction efficiency with minimal need for recirculation giving a simpler air treatment system with a reduced energy requirement; • easier handling of less corrosive substance; and • reduced capital and operating costs.

4.0 ENVIRONMENTAL CONSEQUENCES

4.1 Emissions to Air

Table 4-1 shows the long term emission concentrations associated with each option are provided in Table 4-1, which also shows the origin of each datum.

Table 4-1 Achievable Long-Term Air Emission Concentrations

Ref	Option	SO _x (mg.m ⁻³)	HF (mg.m ⁻³)	HCl (mg.m ⁻³)
	<i>WID limits</i>	50	1	10
	Base Case ^{Note 1}	200-1000	5-20	500-2000
	Primary control measures ^{Note 1}	200	5	500
1	Semi-dry process – lime ^{Note 2}	10	0.2	10
2	Dry process - hydrated lime ^{Note 2}	11	0.4	4
3	Dry process - sodium bicarbonate ^{Note 2}	<20 ^{Note 3}	<1 ^{Note 3}	<9 ^{Note 3}

Note 1 – Obtained from crude gas concentrations, as presented in BREF Table 3.6

Note 2 – Typical Information from technology provider.

Note 3 - Updated estimates from recent reports indicate sodium bicarbonate offers better performance than that shown

All options provide an improvement over the base case. Table 4-1 indicates that all secondary abatement options would be capable of meeting the WID requirements. There is variation with, for example, semi dry processes being better for HCl & HF treatment.

Dry lime appears to provide a better performance than sodium bicarbonate systems. In fact for all systems lower emission concentrations are possible; however, this is achieved at the expense of reagent use and corresponding increased solid waste residue. BREF² data (BREF tables 4.37 4.46 & 4.47) generally indicate a better performance profile. In practice activated sodium bicarbonate (activated by temperature 80-400°C) has a greater efficiency than lime sorbents. Bicarbonate systems are typically 'once through', whereas dry lime injection systems using a recycle loop to increase residence time.

Table 4-2 & Table 4-3 show the long term air quality impacts of SO₂ and HCl derived from H1 estimation using values in Table 4-1. Only SO₂ and HCl are shown as there is no long term environmental assessment level for HF. H1 is used for options comparison only - detailed air quality modelling has been undertaken and is reported separately.

Table 4-2 SO₂ Long-Term Air Quality Impacts

Ref	Option	Process Contribution (PC) (µg.m ⁻³)	% PC of headroom (EAL-background) ^{Note 1}	PEC (µg.m ⁻³)	% PEC of EAL
	Primary control measures	1.53	3.05	10.5	21.1
1	Semi-dry process - lime	0.083	0.168	9.08	18.2
2	Dry process – lime	0.084	0.168	9.08	18.2
3	Dry process - sodium bicarbonate	0.153	0.306	9.15	18.3

Note 1 – EAL = 50 µg.m⁻³, background = 9 µg.m⁻³, therefore headroom = 41 µg.m⁻³

Table 4-3 HCl Long-Term Air Quality Impacts

Ref	Option	Process Contribution (PC) (µg.m ⁻³)	% PC of headroom (EAL-background) ^{Note 1}	PEC (µg.m ⁻³)	% PEC of EAL
	Primary control measures	3.82	19.1	7.81	39.1
1	Semi-dry process - lime	0.226	1.13	4.23	21.3
2	Dry process - lime	0.0306	0.153	4.03	20.2
3	Dry process - sodium bicarbonate	0.0687	0.306	4.06	20.3

Note 1 – EAL = 20 µg.m⁻³, background = 4 µg.m⁻³, therefore headroom = 17.7 µg.m⁻³

Tables 4-2 and 4-3 indicate that all secondary treatment options would be likely to result in acceptable ground level concentrations. There are slight differences between the dry and semi dry techniques but the differences appear to be marginal.

Values for sodium bicarbonate may underestimate performance – i.e. end values are likely to be better than those indicated above suggesting a better performance than lime.

4.2 Raw Materials

Table 4-4 presents consumption and costs obtained from the BREF (section 4.4.3). Each option uses a different type of physical and / or chemical reagent. Estimates of raw material use vary substantially with consumption rates for lime and bicarbonate being from 7-45 kg/tonne MSW (2,000-13,000 tonnes per year). Typical value estimated for rates provided by BREF notes, the technology provider and other facilities are given.

Table 4-4 Raw Material Consumption and Cost

Ref	Option	Hydrated lime (t.yr ⁻¹)	Dry lime (t.yr ⁻¹)	Sodium bicarbonate (t.yr ⁻¹)	Water (m ³ .yr ⁻¹)	Estimated cost (£)
	Raw material costs ^{Note 1}	£73.t ⁻¹	£70.t ⁻¹	£155.t ⁻¹	£0.5.m ⁻³	
1	Semi-dry process – lime ^{Note 2}		5774		20280	£414,303
2	Dry process - lime ^{Note 2}	5420			28359	£395,633
3	Dry process - sodium bicarbonate ^{Note 2 & 3}			5371		£832,438

Note 1 – Based on information from technology suppliers

Note 2 – Consumption estimated as average from data provided in BREF notes, technology supplier and other reports. Estimates of raw material use vary for lime and bicarbonate from 7-45 kg/tonne MSW (2,000-13,000 tonnes per year).

Note 3 – BREF note Table 3.48 indicates a significantly lower rate for bicarbonate use. Data from technology provider indicates a much higher rate for bicarbonate use.

Table 4-4 suggests that the dry lime and dry bicarbonate process use the least raw materials but that the dry lime process is the least expensive option to implement. The semi-dry process uses substantially more raw water (and additionally needs to reheat the gas stream to prevent plume formation). However, the estimates of raw material use vary significantly depending on process design including maximum residence time offered by recirculation of the residues from the bag filter to optimise reagent consumption.

The purchase cost of sodium bicarbonate is generally twice that for lime products. Consequently the costs for this option are markedly greater, even though the mass of material may be slightly less. The semi-dry process uses the greatest mass of raw material, comprising dry lime reagent and water.

Sodium bicarbonate neutralises acid gases more efficiently than lime with a stoichiometric ratio around for bicarbonate of ~1.25 and for lime of ~2-4 (dependant on flue acid gases). Bicarbonate systems have efficiencies >55% and are typically 'once through' whereas dry lime injection systems have an efficiency of around 5-10% and use a recycle loop to effectively increase residence time. In practice to provide a similar degree of treatment a bicarbonate system requires a lower dose rate (around 90-95% of lime) and produces less waste (around 60% of the quantity from lime).

4.3 Ozone Creation Potential

Table 4-5 gives the total annual emissions of SO_x and the associated photochemical ozone creation potential (POCP). The EA H1 guidance gives a SO_x POCP value of 4.8. Values in Table 4-5 are calculated from achievable limits in Table 4-1.

Results indicate that the lime based processes perform better in terms of lower annual POCP. Estimations use conservative values for sodium bicarbonate and in practice POCP for both options 2 & 3 are likely to be similar.

Table 4-5 SO_x Emissions and POCP

Ref	Option	Annual SO _x emission (tonnes)	POCP
	Primary control measures	330	1582
1	Semi-dry process - lime	16	79
2	Dry process - hydrated lime	18	87
3	Dry process - sodium bicarbonate	33	158

Based on 7800 operating hours per annum

4.4 Waste

Table 4-6 shows the quantity and potential disposal costs of wastes arising for each option. In practice amounts of waste generated can vary depending on operational controls the characteristics of waste burned and the efficacy of dust collection plant. Cost estimates include current taxes and transport costs but may be reduced in some circumstances.

Table 4-6 Solid Waste Residues and Costs

Ref	Option	Annual Produced (tonnes/year)	Cost (£)
	Primary control measures		
1	Semi-dry process - lime	15,600	£1,872,000
2	Dry process - hydrated lime	14,100	£1,693,353
3	Dry process - sodium bicarbonate	10,500	£1,260,000

Based on 7800 operating hours per annum.

Based on disposal cost £120 per tonne

4.5 Other Operational Issues

Semi dry systems introduce additional problems for the need to manage water and to prevent 'sticky' solutions and substances from obstructing equipment – particularly in the use of re-circulating reagent systems. Semi-dry processes use more energy including that required to reheat the gas stream to prevent plume formation.

Dry lime processes typically have a larger plant footprint area with the need for additional plant and energy reagent recirculation systems. Though a higher capital cost than other options, dry lime systems can ultimately achieve a high degree of emissions reduction.

Gas treatment systems based on sodium bicarbonate are typically a small plant area being of simpler design because they may not be dependant on a residue recycle loop. They are typically a lower capital cost with a greater opportunity for the reuse of the residues.

Lime is potentially more hazardous than sodium bicarbonate and introduces additional requirements for the safe handling, storage, transport and use.

5.0 COSTS – ANNUALISED & ACID ABATED

The methodology provided in H1 was used to provide an annualised cost comparison. Estimated capital and operating costs were obtained from technology advisers. The approach as summarised in H1 is provided in Figure 5-1.

**Figure 5-1
 Abatement Options Cost Calculations**

<p>Equivalent annual cost factor = $\frac{r}{(1+r)^n - 1} + r$, where r = discount rate, in this case 4% (minimum suggested in EPR H1 is 6%); and n = lifetime of plant, in this case 25 years.</p> <p>Present value factor = $\frac{1}{\text{Equivalent_annual_cost_factor}}$</p> <p>Present value option cost (£) = CAPEX + (OPEX × Present value factor), where CAPEX = Initial capital expenditure OPEX = Annual operating expenditure.</p> <p>Equivalent annual cost (£) = Present value option cost (£) × Equivalent annual cost factor</p>

Table 5-1 summarises costs for the three main options. The upper level of capital expenditure estimates have been used to give the annualised costs. Costs are estimates only based on best available information.

Table 5-1 Summary Estimates of Acid Gas Abatement Costs (£)

Ref	Description	Capex ^{note 1}	Opex/yr ^{note 1}	Present Value Cost	Equivalent Annual Cost
1	Semi Dry	7,815,543	3,112,484	56,439,018	3,612,772
2	Dry Lime	8,440,591	2,191,564	42,677,375	2,731,863
3	Dry Bicarb	6,500,427	2,489,963	45,398,828	2,906,068

Note 1: Estimates obtained from technology advisers. Opex includes a future uplift for dry lime of 5% and reduction for bicarbonate of 10%.

Table 5-2 compares estimated costs per tonne of total acid abated. Costs are estimates only based on best available information and using information from Table 5-1. Values indicate that Dry Lime is marginally cheaper.

Table 5-2 Comparison of Costs per Tonne Acid Abated

Ref	Description	Acid Abated tonnes/year	Equivalent Annual Cost (£)	Equivalent annual cost per tonne of Acid Abated (£)
1	Semi Dry	1,128	3,612,772	3,202
2	Dry Lime	1,136	2,731,863	2,404
3	Dry Bicarb	1,112	2,906,068	2,613

Note 1 Tonnes of acid abated estimated from difference in achievable releases from primary control and options as shown in Table 4-1

6.0 CONCLUSIONS AND RECOMMENDATIONS

To establish BAT for the treatment of acid gases the impacts of various treatment options were considered, along with some of the associated implementation costs. The use of primary control measures only were not considered a suitable option on their own as emissions would not meet the mandatory emission limit values required by WID.

Consequently the review focussed on the use of a semi-dry method using water and dry lime as the reagent or dry abatement technologies using either hydrated lime or sodium bicarbonate as the reagent. A wet abatement process was not considered as the installation is designed to avoid the generation of a process effluent stream.

Table 6-1 provides a simple summary ranking of performance and costs. Ranks are left blank where it has been deemed that differences between options are not distinctive. Results indicate a marginal preference for the use of dry treatment systems.

Table 6-1 Summary of Ranking

	Options and Ranking		
	Semi-Dry Lime	Dry Lime	Dry Bicarbonate
Performance Ranking			
Acid Gas	1	3	2
Raw Material	3	1	2
POCP	3	1	2
GWP			
Waste	3	2	1
Energy	3	2	1
Visual	3	1	1
Noise & Vibration	n/a	n/a	n/a
Cost Implementation Ranking			
Raw Material Cost	2	1	3
Disposal Cost	3	2	1
Capex	3	2	1
Opex	3	1	2
Overall	27	16	16

Note: Similar ranking applies where there is minimal difference in performance

The following key conclusions were reached:

1. All abatement options considered meet the mandatory emission limits.
2. Current data appears to suggest marginal differences in acid gas emission performance and long term ground-level concentrations between the use of dry lime and dry sodium bicarbonate.
3. Sodium bicarbonate is significantly more expensive than lime. However reductions in quantities of raw material used and residues disposed of can mean that overall the use and disposal of both lime and sodium bicarbonate are similar in cost terms.
4. Semi-dry and dry lime systems require a larger plant footprint and additional equipment to provide a robust recirculation system. Sodium bicarbonate systems tend to be smaller and less complex. Capital costs for bicarbonate system are lower.

5. Annualised cost and cost per treatment of acid gas abated indicate that systems using dry lime are cheaper than sodium bicarbonate.
6. Simple ranking indicates marginal differences between the use of lime or sodium bicarbonate. Closer examination suggests marginal environmental benefit with the use of bicarbonate but with potentially significant additional costs.
7. Sodium carbonate is potentially less hazardous than lime and has simpler requirements for the safe handling, storage, transport and use.

It can be concluded, therefore, that the dry abatement process using either hydrated lime or sodium bicarbonate is considered to be BAT for Newhurst ERF in that both achieve a high degree of performance. Consequently, selection of the treatment technique is likely to be based on operational considerations. Currently this EP application has been made using sodium bicarbonate, however, the final selection is likely to be made at the detailed design stage.

7.0 CLOSURE

This report has been prepared by SLR Consulting Limited with all reasonable skill, care and diligence, and taking account of the manpower and resources devoted to it by agreement with the client. Information reported herein is based on the interpretation of data collected and has been accepted in good faith as being accurate and valid.

This report is for the exclusive use of Biffa; no warranties or guarantees are expressed or should be inferred by any third parties. This report may not be relied upon by other parties without written consent from SLR.

SLR disclaims any responsibility to the client and others in respect of any matters outside the agreed scope of the work.