The International Association of Engineering Insurers

IMIA Working Group Paper 101(17)
IMIA Annual Conference 2017, Munich

Energy from Waste

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Abstract

Enrgy from Waste (EfW) plants transfer an element of entrepreneurial risk, “prototypicality” and design risk to insurers. Guarantee maintenance brings work undertaken at manufacturers’ facilities under the scope of EAR policies and in conjunction with design and workmanship exclusions. Inhomogeneous waste composition and wrong operation or process design are a sources of many risks impacting plant performance, emissions, interruptions of the processes by fouling, (wet) corrosion, erosion, fires and explosions, e.g. in the bunker, the furnace or flue gas treatment equipment. The most common causes of damage, during operational, but also during commissioning and maintenance phase are caused by fire. For the operational phase, Property Insurance (FLEXA) accounts for about 55% and Machinery Insurance (MB) for about 45% of the premium. Vice versa, FLEXA Business Interruption (BI) insurance premium is lower than MB BI premium, implying that there are fewer reported technical incidents, but if so, they cause more cost on the BI indemnification. Turbines, followed by generator and boiler, cause the largest BI-claims. Operational Engineering BI-losses seldom exceed EUR 3 Mio. Inadequate maintenance and plants operated outside of design specifications are the main reason of MB claims in many markets. EPC (Engineering Procurement Construction) or O&M (Operations and Maintenance) contractors possibly try to claim this and hence, the definition of damage and demarcation from defect is key. If the incineration process is unavailable, it is costly to reroute waste to other facilities or divert to landfill. If the main source of revenue is the gate fee, heat & power production incineration of waste is the priority and the critical processes are furnace, boiler and FGT (Flue Gas Treatment) systems. Lead-time for key process equipment (crane, boiler, turbine-generators) can be 6 to 15 months putting up to 35% of the Total insured Value (TIV) at risk per event. Failure modes of major concern affecting these process components can have the following BI and PD implications:

Waste reception:

1. Bunker fire: 2 to 6 months, 10% of TIV
2. Waste out of specification: 1 month, 5% of TIV
3. Breakdown crane / shredder: 6 months, 10% of TIV

Combustion and Steam Generation:

4. Corrosion: 1 month, 5% of TIV
5. Refractory: 2 months, 5% of TIV
6. Hazardous waste: 1 month, 5% of TIV
7. Extremes of Weather: 2 months, 5% of TIV (boiler & district heating)
8. Pumps / Fans: 3 months, 10% of TIV (boiler dry cooking)
9. Fire: 6 months, 10% of TIV

Heat & Electricity Generation:

10. Physical & BI/DSU damage: 12 months, 30% of TIV
11. Overhaul Unexpected PD: 15 months, 35% of TIV
12. Wet Steam Erosion: 15 months, 35% of TIV

Flue Gas / Ash Handling:

13. Wet Corrosion: 4 months, 5% of TIV
14. Fouling: 1 months, 5% of TIV
15. Fire/Explosion: 4 months, 5% of TIV

Scope of this Paper

This is a collection of underwriting, operational and claims experience structured along the process flow of a typical **Energy from Waste (EfW)** incineration plant, focusing on **physical damage (PD)** - grouped by failure modes - and assessing their **Business Interruption / Delay in Start Up / Advanced Loss of Profit (BI/DSU/ALOP)** implications. The paper focuses purely on **Erection All Risk / Construction All Risk (EAR/CAR), Machinery Breakdown (MB)** and **Fire** coverages. To manage the identified risk exposure we recommend appropriate policy wordings.

Although EfW plants share the majority of their risk characteristics with conventional power plants and Erection/Operational All Risks projects, this paper will focus only on those aspects, which are specific to EfW. This document gives an update on the following publications:

- Waste incinerators - Underwriting and Technical Aspects (IMIA 16-58, 1993)
- Waste incinerators Questionnaire (IMIA WGP 16-64, 1995)
- Municipal Waste Treatment Plants (Swiss Re, 1996)
- Risks Associated with the Construction and Operation of Environmental Plant and Equipment (IMIA WGP 16, 2001)

Quantitative measures have been included wherever possible to supplement the qualitative observations herein. Policy language, which deals with the issues identified, is given in italics.

Overall Plant

Figure 1: Scheme of EfW plant, Mallorca, Spain

Conventional fossil fuel plant design is more standardized compared to EfW plants. Hence, no two EfW plants are the same and therefore an element of entrepreneurial risk (IMIA WGP 77, 2012) and "prototypicality" (London Engineering Group, 2010) is transferred to insurers. The specifications and criteria for operation can differ between countries and local municipalities depending upon feedstock quantity and composition, **calorific value (CV)**, emission restrictions, local regulations, waste management organization and requirement for pre-treatment of waste. For better understanding, we recommend the following EfW video playlist (Energy from Waste Video Playlist, 2017).

Experience shows that fires and explosions are today by far the most common causes of damage in EfW plants. Underwriters should keep in mind that many clients buy policies with a low fire deductible, but higher machinery deductibles. For the operational phase, FLEXA accounts for about 55% and MB for about 45% of the premium. The bunker, crane operator's cabin, boiler house, turbine hall and **flue gas treatment (FGT)** process and control room should always be designed as separate fire zones. Desirable, but seldom seen, is the configuration of the boiler house as a fire zone. . "Fires in waste to energy power generation plants - A guide to loss prevention" give effective recommendations and standards (HSB Engineering Insurance Limited - Munich Re, 2014).

Policy wording, terms and conditions – general remarks

EfW projects are tailor made designs whose limited standardization gives rise to complex interactions and interfaces between financiers, owners/operators, designers, regulators and public authorities during planning, engineering and on site. Architects, designers, consultants, suppliers and vendors may be insured under an EAR policy in addition to Owner/Developer and the main **Engineering, Procurement and Construction (EPC)** Contractor. However, in order to avoid any adverse interaction with the maintenance clauses and design exclusions within the policy, cover should be limited to their physical work carried out on the project site. This avoids the inadvertent provision of cover for Professional Indemnity, which could be a significant exposure where more advanced designs are incorporated within the project.

The LEG Multiple Insureds Clause (London Engineering Group) manages the relationship between different parties insured under the policy relative to the continuance of cover following a vitiating act committed by one or more parties.

Design exposures

The most appropriate clauses for EfW projects are the LEG Design Exclusions 1 to 3 (London Engineering Group, 2006) for manuscript wordings and Munich Re EAR Endorsement 200 and Swiss Re (Swiss Re, 2007) forms for use within their own policy forms. The complexity and proven nature of the technology associated with the project, along with the quality of suppliers and experience of designers and EPC contractors will determine, how comfortable the underwriter is, in accepting the design risk.

Operative clauses

It is the intention of insurers to cover only physical damage when it arises from a cause that is sudden, unforeseeable and accidental in nature. Other bespoke wordings seen in the insurance market may omit the "sudden and unforeseen" and even the "physical" language, therefore widening the interpretation of damage.

A plant that is operated outside of its design specification, might compromise the design life of certain components of the plant, due to e.g. overheating, accelerated erosion/corrosion and unexpected fuel contaminants. The EPC or **Operations & Maintenance (O&M)** contractor could possibly try to claim this from insurers. As such, the definition of damage and demarcation from defect is very important.

Guarantee maintenance

The bespoke nature of the equipment within EfW plants poses an increased ‘Manufacturers Risk’. Guarantee maintenance brings work undertaken at manufacturers’ facilities under the scope of the EAR policy and in conjunction with the design and workmanship exclusion, there is a significantly increased exposure above Visits or Extended Maintenance.

Keep in mind that an operational policy purchased after the project phase will almost certainly overlap with extended and guarantee maintenance. In some markets, first year operational cover following Practical Completion is becoming more common in order to address overlap of maintenance and operational coverage. A consistent panel of insurers on both the EAR policy and the first year operational policy also alleviates issues caused by when a plant is operating but has not formally achieved Practical Completion (due to outstanding snagging works or punch list items for example).

Wilful, reckless or malicious act by the Insured or his representative(s)

The underlined statement clarifies:

> *The Insurer will not indemnify the Insured in respect of loss, damage or liability expected or intended or directly or indirectly caused by or arising out of or aggravated by wilful, reckless or malicious act, wilful or gross negligence by the Insured or his representative(s). A behaviour or act is considered as wilful, reckless or grossly negligent even absent an intention to cause loss or damage or consciousness of the possibility of such a consequence, including without limitation in case laws, rules, regulations, procedures, generally accepted best practices etc. have been breached or disregarded.*

The proposed exclusion could be complemented with a carve back for employees listed as such in the project schedule in the form of the following endorsement:

> *The above exclusion does not apply to acts, omissions or behaviours of subordinate personnel, unless such acts, omissions or behaviours are ordered, endorsed or tolerated by directors, managers or responsible site officials of the insured or any of its agents.*

In many situations, the above would put the loss adjuster in a much stronger position e.g. cases where the operating model is ‘run to failure’ instead of a proactive model such as **Reliability Centred Maintenance (RCM)**.

Maintenance in Machinery Breakdown policies

Unfortunately, breakdown maintenance instead of preventive maintenance is common. Experience has shown that inadequate maintenance is the main reason in about half of the Machinery Breakdown claims in many markets.

While following manufacturers’ recommendations is usually required for coverage, it is very difficult in practice to reject claims due to lack of maintenance. Risk surveys and demand maintenance protocols could mitigate this exposure.

Item	Repairs each x years	Repairs in e.g. 30 years lifetime
Waste crane	1	30
Grate	1	30
Boiler & pressure parts	5	1-6
Filter System	4	7
Turbine / Generator	4	7
Electric motors	12	2
ICS/DCS/SCADA	16	1

Table 2: Example of recommended repairs, checks & maintenance

Recommendation to include evidence:

> *The insured shall take all reasonable steps, and provide evidence of such, to maintain the insured property in efficient working order and to ensure that no item is habitually or intentionally overloaded. The Insured shall fully observe the manufacturers' instructions for operating, inspection and overhaul, as well as government, statutory, municipal and all other binding regulations in force concerning the operation and maintenance of the insured plant and machinery.*

It is recommended to avoid provisions like *"The policy also covers events related to errors in design or construction, short-circuits, electric arcs, defective material, defects in the labour and incorrect assembly. … Excessive heating of the material and/or equipment due to lack of lubrication or cooling. …"*

EfW related legislation

Risk managers, underwriters and claims handlers should know the legal framework for EfW risks. Waste quality, required process and operation and measurement equipment influence its lifetime and loss exposure. As an example the European legislation:

- Directive 2000/76/EC on the Incineration of Waste (EUR Lex - EU Law, 2000)
- Directive 96/61/EC on Integrated Pollution Prevention and Control (EUR Lex - EU Law, 1996)
- Directive 1999/31/EC on the Land filling of Waste (EUR Lex - EU Law, 1999)
- Decision 97/283/EC on harmonizing measurement of Dioxins and Furans relating to 94/67/EC Hazardous Waste Incineration Directive (EUR Lex - EU Law, 1997)
- Industrial Emissions Directive 2010/75/EU (EUR Lex - EU Law)
- Pressure Equipment Directive 2014/68/EU (EUR Lex - EU Law, 2014)
  - approves a boiler for a certain fuel type after statutory inspection
  - can be used as a fuel control framework for the insurer.

Waste Reception / Storage

The CV, biogenic content, moisture and size differ between municipal waste from households, household-like commercial and industrial waste, and commercial and industrial waste. Mixed municipal waste has a CV of about 10 MJ/kg whereas **refuse derived fuel (RDF)** range between 11 and 15 MJ/kg.

Figure 2: Waste bunker & tipping hall

Underwriters should understand the contract between the local authority and the EfW plant. These often contain a requirement that the plant must accept the waste or find alternative methods of disposal. If the incineration process is not available, it is costly to reroute the waste to other facilities and even more expensive to divert it to landfill. Aside from the costs of diverting and transporting the waste itself, taxes are often payable in addition. For example in the UK, the 2016 inert or inactive waste disposal tax is £ 2.70 per ton whereas it is £ 86.10 per ton for standard waste.

If the main source of revenue is the gate fee, the critical process will be the furnace, boiler and FGT system as incineration of the waste is the priority.

Negative air pressure is usually maintained in the waste bunker (i.e. tipping hall) in order to reduce odour from the waste affecting the plant's neighbours. This is achieved by taking primary combustion air directly from the waste bunker. If combustion is not taking place then this negative pressure cannot be maintained and it is unlikely that waste can be stockpiled in the bunker in the event of an outage unless the plant is equipped with a stand-by filtration system.

Possible failure modes to consider:

1. Bunker fire
2. Waste which is out of specification, e.g. low CV
3. Breakdown of the crane or shredder

1. Bunker Fire

Waste bunker fires and explosions caused by spontaneous auto-ignition or during the shredding process are frequent and can occur during operation or commissioning. It is not uncommon for plants to experience an extended period of hot testing and commissioning or early operations whilst they are fine tuned to operate within their design parameters. Owners rarely issue a practical completion certificate prior to a plant achieving these parameters. Bunker fires can affect bunker cranes, shredders and waste hoppers impairing the operation of the entire plant. Whether waste is processed inside the bunker, elsewhere on site or just fed directly into the feed chute is relevant. Smoke extractors are necessary in the bunker area to deal with the smoke and heat of any fire.

Munich Re MB Endorsements 321 and Munich Re CMI Endorsements 1363 "Cover for Conveyor Belts and Chains" address this topic (Munich Re).

Feed hopper, waste bunker, refuse storage area, shredder and conveyors should be equipped with heat detection and fire fighting installations (infrared cameras, thermocouples in the bunker floor water or foam cannons, sprinklers or similar). Every part of the bunker should lie within the range of at least two monitors.

> *In absence of the insured's fuel bunker/ storage maintenance plan during testing and commissioning it may be appropriate to consider restricting the policy further. This could be achieved by limiting the number of days' waste, which is stored on site and policy conditions to ensure that monitoring and regular cleaning of storage areas are carried out by the insured.*

The high temperatures generated by bunker fires can destroy the structural steel components in the delivery area or even the bunker itself along with its crane. In some instances, sprinkler systems have been used to protect steel roof structures above fuel bunkers in order to prevent collapse of the roof. Rebuild periods are significant after a major fire, involving lengthy periods of debris removal, contamination clean-up, replacement of major equipment as well as the rectification of smoke damage which can affect the control room, switching equipment and the like.

Loss example

A bunker fire can damage up to 10% of the plant value and cause BI or delay of up to 2 months if the crane is not affected and up to 6 months if the crane is damaged.

- Video of a bunker fire in Bielefeld, Germany (www.nonstopnews.de, 2016)
- Video of a bunker fire in Winterthur, Switzerland (TELE TOP, 2014)
- Video of a bunker fire in Ludwigshafen, Germany (Crash24, 2010)
- Denmark: During regular maintenance work by operatives of a shredder manufacturer, sparks from metal grinding works ignited polystyrene waste. Water used as a fire extinguisher caused the burning polystyrene to scatter quickly through the pit and a large fire spread rapidly. Forensic investigation concluded that the hot works permit procedures were not followed and that neither the property owner nor the operative understood their obligation with regard to fire protection. Loss amount approx. € 2m.

2. Waste out of specification

The composition of the waste arriving at an EfW plant is never known precisely. This lack of homogeneity is the source of many risks. Refuse trucks which tip waste directly into the bunker may sometimes carry out-of-specification fuel without the drivers being aware. Deliveries can contain large items (e.g. furniture, gas cylinders etc.). The underwriter may consider whether fuel is always supplied from the same source or whether short term disposal contracts are envisaged, where varying fuel types may be encountered.

Pre-treatment and removal of unacceptable waste increase the CV by mechanical sorting, shredding, homogenization and processing techniques that remove moisture, recyclates and organic matter in order to create RDF or **Solid Recovered Fuel (SRF)**. Pre-treatment facilities require energy and are sometimes co-located with EfW facilities. They are supplied with the electricity and/or heat generated from the EfW plants they feed.

Long periods of incinerating wet waste can cause reduced efficiency and problems in the boiler (for example corrosion of boiler tubes or excessive wear and tear to the refractory lining). Additional costs for fuel oil are very likely as this is used to get the boiler to sufficient temperature by supplementing the energy which is taken to evaporate the moisture in the wet waste. Many plants will only achieve their required emissions levels once combustion has reached its optimum design temperature.

Risk managers, underwriters and claims handlers should have an understanding of the waste composition and pre-treatment processes as this influences the plant design and the loss exposure of the plant.

Waste Framework Directive (European Commission, 2008) has set a target to reuse, recycle or compost 50% of waste from households by 2020. In 2010, Austria achieved 70% recycling (including composting) alongside 30% waste, which was incinerated; Germany achieved 62% recycling alongside 38% incineration; while Belgium achieved 62% recycling alongside 37% incineration. This compares to the UK with 39% recycling and 12% incineration. Some EU countries have overcapacity in EfW plants, but instead of reducing recycling rates, this has led to the importation of waste from other states with insufficient capacity, reducing landfill across the EU.

Exposure from low quality waste can be addressed with a waste quality clause by excluding:

> *Failure, destruction of or any Damage including flashback or flame-out to Property in normal operation or course of construction or erection, dismantling, revamp or undergoing testing or commissioning including mechanical performance testing, unscheduled shutdowns and any Business Interruption resulting therefrom where or in which:*
>
> *Waste is introduced to the apparatus intentionally or by wilful act where such Waste does not meet the criteria for acceptable waste specified in the Insured's contracts with waste suppliers and their Subcontractors.*
>
> *For the purposes of this exclusion, Waste shall mean domestic waste as defined in the original supply contract.*

EfW plants operating directly under the control of municipalities generally experience less problems regarding supply of feedstock, quality of feedstock and disposal of residuals as they are in full control of the fuel supply chain (waste collection, transportation and treatment).

For the performance test, volume, composition and source of EfW fuel should fall within the design criteria of the plant.

3. Breakdown of the crane or shredder

Alternative ways of feeding waste into the furnace or the availability of spare crane claws can be relevant for DSU/BI considerations. The lead-time and replacement of a crane can require up to six months. Normally the roof has to be opened to enable repair or replacement. See also the following crane erection video (Allerton Waste Recovery Park , 2016).

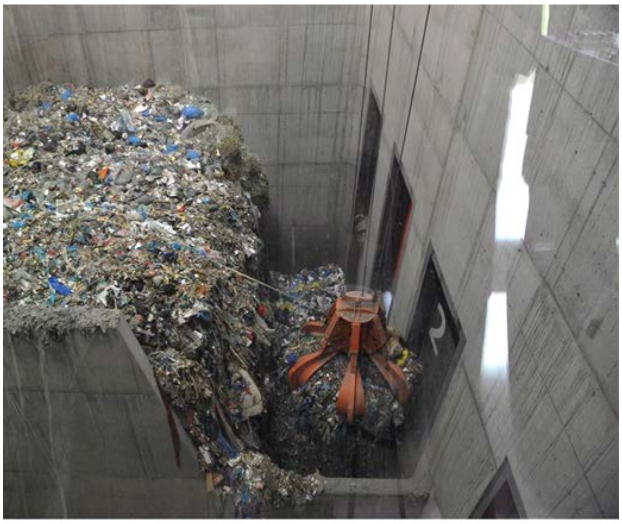

Figure 3: Waste crane

The shredder area should be located separately and equipped with its own fire extinguishing system, which avoids fire propagation from the shredder area to the bunker (Robertson IMIA/Liberty, 2009). Long-term dust build-up on motors or other sources of heat and/or ignition can cause fire. Good housekeeping practices can prevent such events.

The adequate examination of waste upon receipt and subsequent mixing, bunker management and control of the combustion of the waste on the grate can mitigate the fire, explosion and physical damage and consequential BI exposure.

The crane and its operators must remove out-of-spec items from the bunker whenever possible.

Inspection and **Remote Operations Support (ROS)** by O&M can mitigate Machinery Breakdown and associated BI exposure.

Combustion and Steam Generation

The private energy sector prefers standardised plants, processes, fuel quality and availability. EfW boilers are generally smaller than conventional power plant boilers and less standardised with inherent design exposure. Risk managers and underwriters should understand the responsibilities of the various stakeholders in an EfW plant. Otherwise, this increases the risk of claims due to contractual disputes. It is important that developers define the fuel quality and quantity specification within the fuel supply contract which is used as the basis for the boiler design.

If the boiler is unavailable, waste cannot be incinerated, nor accepted resulting in loss of gate fees. If the main source of revenue is gate fees, the boiler can be considered a more critical system than the steam turbine from a DSU/BI perspective. IMIA WG paper 95 about Supercritical Boilers explain boiler related topics more in detail (IMIA WGP 95, 2016)

Failure of the steam turbine may also lead to the plant being unable to accept waste, as a boiler often cannot continue to operate without a steam turbine. In order for a boiler to operate independently of a steam turbine, the plant would need to be fitted with a turbine bypass and a condenser of adequate size, able to receive 100% of steam output.

Figure 4: Combustion & steam generation

Possible failure modes to consider:

4. Corrosion, e.g. high plastics/chlorine content
5. Refractory Coating/Lining
6. Hazardous waste (e.g. butane canisters)
7. Extremes of Weather
8. Pumps / Fans
9. Fire

4. Corrosion / Erosion

Incineration of out of spec fuels, e.g. high volumes of plastics, a thin waste layer on the grate or aggressive molten slag will cause thermal and chemical stress and high-temperature corrosion on the incineration grate and reduces the lifetime of the grate and furnace if subjected to these conditions for a prolonged period. Video monitoring and thermocouples of the grate area can mitigate this exposure.

Generally, boilers with steam properties below 420°C and 40 bar carry a normal risk of boiler corrosion. Any increase in the steam properties will lead to a much higher corrosion risk. Due to harsh operating conditions, wear and tear is increased and access for maintenance, repair or replacement can be an issue which should be taken into consideration for BI assessments. See the following video of a boiler repair (Wisdom Station , 2013)

Minimum boiler maintenance measures to be checked by underwriters:

- Annual wall thickness measurements and long term tracking
- Proactive maintenance based on lifetime expectations e.g. predictable corrosion rates (Inconel makes the boiler more resistant against hot and wet corrosion)
- RCM
- Spare part management
- Pressure equipment directive indicates if a boiler is safe to operate and if the inspector has noted problems that needs follow up.

CM insurance – Munich Re Endorsement 1373 "Special conditions: inspection and overhauling of boilers" and Munich Re MB Endorsement 345 "Inspection and Overhaul of Boilers" address this topic (Munich Re).

Corrosion/erosion clauses

Corrosion and erosion can have a significant impact on an EfW plant if materials have been incorrectly selected relative to the type of waste or if incorrect or unexpected waste is introduced. Steam turbine blades and steam feed piping may also be at risk if the boiler feed water is incorrectly managed.

Underwriters may wish to consider the adequacy of the corrosion/erosion clause within the policy. It is usual to adopt a 'consequences' type clause, where the corrosion/erosion itself is excluded, however any resultant damage would be indemnified.

However, if the underwriter is particularly concerned with the exposure, such as with an aged facility undergoing refurbishment and a change of fuel use, a more restrictive clause or a total exclusion may be considered. The London Engineering Group will publish 2017/18 a new "LEG Corrosion Exclusion" on their web page.

Examples of two common clauses are included below.

Wear and Tear and Corrosion Exclusion (consequences clause)

"The cost of replacing, repairing or rectifying that portion of the Insured Property rendered necessary by:

a) its own wear and tear or gradual deterioration provided always that this Exclusion shall not apply to other portions of the Insured Property lost destroyed or damaged as a result of such wear, tear and gradual deterioration;

b) loss destruction or damage consisting of or caused by any form of corrosion or the action of which accelerates or otherwise aggravates another condition or mechanism howsoever the same may arise provided always that this Exclusion shall not apply to other portions of the Insured Property lost destroyed or damaged in consequence of the above loss destruction or damage."

Complete exclusion

Damage resulting from any mechanism of corrosion, oxidation or erosion whether sudden or gradual and regardless of any other cause or event contributing concurrently or in any sequence to the loss.

5. Refractory Lining

The refractory lining inside of an EfW furnace is exposed to a corrosive environment which can lead to rapid deterioration of the hanging systems and cause the refractory to collapse if an incorrect material or method has been selected. Once refractory brickwork has been installed, it is critical that the refractory cement experiences adequate drying time. If the boiler is fired too soon, remnant moisture will rapidly turn into steam causing blowout of cemented joints and potential refractory collapse. In contrast to conventional boilers, which do not operate in such a corrosive environment, 100% of the first pass of EfW boilers should be lined.

The three clauses below offer alternatives of cover, either as a total exclusion or a more limited restriction where refractory damage resulting from other causes can be covered. The underwriter will need to consider the value of such refractory linings, the applicable deductible and if the insured has a documented refractories drying procedure before deciding upon the application or choice of such a clause.

Total Exclusion

> *It is hereby noted and agreed that this Policy does not cover Damage to refractory linings or brickwork.*

or

Refractories Clause

> *It is hereby noted and agreed that this Policy does not cover Damage to refractory linings or brickwork as from the time of the first application of heat except when arising out of loss or damage to other portions of the Contract Works for which the Insured is indemnified by this Policy.*

Alternatively, the *Munich Re MB Endorsement 319 "Cover for Refractory Materials and/or Masonry in Industrial Furnaces and Boilers"* (Munich Re) increases contract certainty and provides indemnification for an extra premium.

Explosion inside the furnace of (flue) gases, **carbon monoxide (CO)** from incomplete combustion, dust, erosion or hot corrosion by CO or organic compounds affect the grate, furnace and boiler from the inside, e.g. the refractory lining or the membrane walls and can cause backfire through the hopper, igniting the contents. This can impair the operation of the entire plant. Where supplementary fuel burners are used to ensure more complete combustion, these must be equipped with suitable flame monitoring. Measures must be taken in the furnace design to prevent detonations from blow-back into the hopper and ignition of its contents. Burning liquids can drain down into the ash hoppers underneath the furnace, where they can spread a fire that is difficult to extinguish. However, by design, the fire and explosion hazard in the combustion chamber and the boiler is relatively small.

Escape of flammable substances in liquid (e.g. lube oil, hydraulic oil, fuel), dust or gas form (e.g. CO, flue gases) and of ammonia from the denitrification process can cause fire and contamination of the surrounding area. This can be exacerbated by the dispersion of contaminated water from fire fighting operations.

Munich Re Endorsement 303 "Exclusion of Flue Gas Explosions in Boilers and Furnaces" and Endorsement 313 "Cover for Internal Fire, Internal Chemical Explosion and Direct Lightning" address these topics.

Loss example

Areas of the refractory lining failed, with widespread cracking and movement of the refractory elsewhere. This necessitated removal of the entire refractory and replacement of the refractory hanging systems. A negotiated settlement due to the presence of the LEG3/06 design exclusion took place. This demonstrates the interaction between policy clauses, in particular the design exclusion, refractories clause and corrosion/erosion exclusion.

6. Hazardous Waste

Compressed gas cylinders and tanks can be expected to be present in municipal waste from time to time. Sometimes these will be identified and separated from the waste in the bunker. Locations with shredders (e.g. for RDF), the shredders occasionally will cause explosions of gas tanks. They have to be designed to direct the explosions up. For those which make their way into the furnace, relatively low combustion temperatures make large explosions rare, however the temperatures are sufficiently high for the brass valves/fittings to deform and liberate the contents of the cylinders. These can act as projectiles causing damage within the internals of the boiler itself.

7. Extremes of Weather

District heating provided by EfW is particularly common in colder climates such as those found in Scandinavia. Steam is taken from taps off the Steam Turbine or directly from the boiler via pipework, which may need to span relatively long distances, and is often exposed to the elements.

During commissioning and restart, underwriters should take into consideration cold seasons where the ambient temperature is below 0ºC. They should check that precautions are taken to avoid freezing damage to the boiler, refractory, water and steam pipes. Experience shows that leaks emanating from freeze damage can cause BI or delays of up to 2 months.

8. Pumps / Fans

The feed water pump represents a high exposure. Failures here can shut down the entire facility. Both mechanical damage and corrosion are common. Feed water pump redundancy and emergency operation should be carefully evaluated as unlike gas or coal fired plants where fuel supply can be switched off, waste in the boiler will continue to generate heat until fully combusted, causing potential dry cooking of the boiler.

Figure 5: Combustion air fan

Likewise, the combustion air fans are critical to the operation of the boiler. They maintain negative pressure in the waste bunker. In the absence of combustion air, the incineration process will be interrupted and could lead to a BI loss.

Lead-time of at least 1 month should be taken into consideration.

9. Fire

UK CAR/EAR projects refer to the UK specific clause of the Joint Code of Fire Practice on the Protection from Fire of Construction Sites and Buildings Undergoing Renovation dated 2015. It applies only to projects with a contract value in excess of £25,000,000. Its use for EfW projects is common practice in the UK. (Fire Protection Association FPA, 2015). The analogue European CFPA guideline is No 21:2009 F - Fire prevention on construction sites.

> *"It is a condition of this policy that all permanent fire detection, protection and suppression systems shall be in place and fully operational prior to the first introduction of fuel into the boiler."*

This may be amended to read as below where the underwriter may have concerns over the fire loading where fuel arrives at the project some time in advance of first fire of the boilers:

> *"It is a condition of this policy that all permanent fire detection and protection systems shall be in place and fully operational prior to the first arrival of fuel at the facility."*

For fire prevention, see also an abstract of the UK NFPA 850 "Recommended Practice for fire protection of electric generating plants":

> *"… water supply for the permanent fire protection installation should be based on providing a 2-hour supply for all of the following:*
>
> *(1) Either of the following, whichever is greater:*
>
> *(a) The largest fixed fire suppression system demand*
>
> *(b) Any fixed fire suppression system demands that could reasonably be expected to operate simultaneously during a single event [e.g., turbine underfloor protection in conjunction with other fire protection system(s) in the turbine area, [fuel] conveyor protection in conjunction with protection for related [fuel] handling structures during a conveyor fire, adjacent transformers not adequately separated according to 5.1.4*
>
> *(2) The hose stream demand of not less than 1890 L/min*
>
> *(3) Incidental water usage for non–fire protection purposes"*
>
> *The following Endorsements address also this topic*
> - *Munich Re CAR/EAR 112/206 "Special Conditions Concerning Fire-Fighting Facilities"*
> - *Munich Re CPI 1263 "Special conditions: fire protection"*
> - *Swiss Re EPI 41 "Fire Fighting Facilities"*

Loss examples

1. A 37MW EfW facility suffered damage to boiler tubes during hydrostatic testing. The boiler tube bundles had been constructed in Eastern Europe, with the majority of welding being carried out off-site. A high number of tube welds failed at a test pressure, well below the final design operating pressure, evidenced by widespread leakage. Upon further investigation, it was evident that the tube welds were already cracked prior to the marine transit to site. Due to poor packing of the tube bundles on the vessel, the cracks in the welds became exposed to salt-laden air resulting in corrosion within the cracks. This additional corrosion contributed to the failure of the welds. Due to the difficulty in the apportionment of liability across the marine and

construction policies, the marine 50/50 clause was invoked, sharing the loss across both policies. The final amount paid was not known. This loss demonstrates the importance of the quality of selected vendors and how quality management, acceptance and hand-over procedures are managed, not only on site, but also at the premises of vendors. Similar loss examples resulted in project delays of up to nine months exposing approx. 5% of the plant value.

2. Dry cooked boilers due to boiler leakages are another well-known corrosion induced loss pattern and can cause severe damages and down time of at least 2 to 4 months according to the loss examples, which are at our knowledge. See also "Boiler damaged as a result of continued firing on low water level" (IMIA.com, 2000)

Figure 6: Leaking welds of boiler tubes

3. A 38MW EfW facility suffered damage to the boiler, when solid expansion joints at the feed water pump were replaced by rubber ones during erection to reduce vibrations and noise. The rubber did not resist the operating conditions including the water chemistry of pH 9.5 and burst during the maintenance phase. The boiler ran dry. Claim settled at €2.7m.

Figure 7: Solid expansion joint

Figure 8: Flexible expansion joint

4. Super heater tubes from the three pass pre-heater have suffered various kinds of corrosion and abrasion, despite intensive wall thickness monitoring.

Figure 9: Super heater tubes damages by abrasion

5. Sand caused the segments of the grate to bind and crack (green arrow); it also left a heavy deposit of slag on the walls of the combustion chamber (red arrow), necessitating replacement of the refractory lining.

Figure 10: Damaged incineration grate

Heat & Electricity Generation

For plants whose main revenue stream is electricity generation or which require taps on a turbine in order to supply steam of a specific pressure/temperature, the Steam Turbine Generator is a critical aspect and must be assessed, especially in terms of spares availability and DSU/BI concerns.

A wide range of steam conditions and operational flexibility are often requirements of bespoke steam turbine design. Understanding the level of entrepreneurial risk is important not only from a physical damage potential but also from a sparing and financial loss perspective, since the lead repair and replacement times and insured delays could be very long.

Figure 11: Steam turbine

Possible failure modes to consider:

10. Physical Damage & Special Considerations for BI/DSU
    a. Access Delays
    b. Lead times
    c. Seasonality
11. Unexpected Wear/Damage Discovered During Overhaul
12. Wet Steam Erosion

10. Physical Damage & Special Considerations for BI/DSU

The turbosets within EfW plants are exposed to many of the same perils and loss scenarios as turbosets in conventional power plants. EfW plants are usually more congested and specific consideration should be given not only to physical damage but also repair and replacement times.

Where possible, plants should be designed to easily accommodate the disassembly or complete change of the turbine. This can include passive design features such as placing the turbine at the extremity of the plant building for easy access by mobile crane, or active design features such as integrated gantry cranes and removable/opening roofs.

Figure 12: Generator

Like electricity, heat and process steam can be subject to fluctuations in demand. E.g. outdoor temperature is key for heat production demand which could also concentrate the annual BI to a few months a year. This will affect the **Estimated Maximum Loss (EML)** and even more so, the **Probable Maximum Loss (PML)/Normal Loss Expectancy (NLE)**.

11. Unexpected Wear/Damage Discovered During Overhaul

The IMIA publication "Maintenance and Overhaul of Steam Turbines" (IMIA WGP 42, 2005) addresses this topic from a technical perspective. Any Overhaul Clause for Turbo-Generator-Sets should address certain minimum requirements:

- Maximum overhaul interval;
- Obligation of the Insured to perform regular overhaul to the recommendations of the manufacturer;
- Obligation to inform the insurer about any unusual events in the operation or a change of operation regime;
- Limitation of indemnification after exceeding agreed overhaul interval to exclude any overhaul related cost or outage.

Munich Re MB Endorsement 344 "Overhaul of Steam, Water and Gas Turbines and Turbo-Generator Sets" and Munich Re CM insurance – Endorsement 1372 "Special conditions: overhauling of steam, water and gas turbines and turbo-generator sets" address these topics.

Inspections, maintenance and overhauls are planned during the down season - in the case of heat production, the summer – when the district heating can be down causing less financial distress and time pressure during downtime. Prolonged maintenance and overhaul intervals are BI relevant.

12. Wet Steam Erosion & Load Changes

Most steam turbines are modified for the unique conditions in which they are designed to operate. These conditions are determined by the type of waste or the mix of heat and/or electricity being produced. Extraction steam turbines are equipped with multiple extraction options to meet specific process or district heating needs. This can lead to inconsistent mass flow and quality of the steam including wet steam erosion at the blades and inner casing downstream. Although the EfW steam turbines are often at the lower output level, they are rarely 'off the shelf' standard designs and BI relevant lead times of around 12 months are usual for replacement.

Loss examples

Repair or replacement of turbine components, generator or transformer can cost up to 35% of the plant value and cause delays and interruptions of up to 15 months due to long lead-times for replacement parts and repairs.

1. A steam turbine suffered damage of a 17.5 MW EfW project when a speed transmitter fell on the collar of the HP turbine rotor shaft. The resultant vibration caused movement of the rotor which then made contact with the casing. This was aggravated by very fine clearances built into the updated turbine design to improve efficiency. Rubbing between the rotor and the stator at high speed caused heat and distorted the rotor resulting in a delay of several months to source material and forge a new rotor.

   It was believed that DSU mitigation would be feasible by substituting the steam turbine from the sister plant (believed identical) running several months behind the schedule of the plant suffering the loss. They found out that the other steam turbine could not be used as the rotational direction was reversed. Spacing challenges at the sister plant resulted in design changes and the need to locate steam piping on the opposite side of the steam turbine. Underwriter should therefore take into consideration layout and unique designs of an EfW facility. Loss amount PD £755k + ALOP/DSU £1.5M

2. Damage to the gearbox of a 17.5 MW steam turbine set. The casing of the **high pressure (HP)** turbine was pulled out of alignment including the support of several steam pipes (in one case 8.5mm), with resultant uneven wear between the HP turbine pinion and the wheel of the double-helical gearbox. Damage to the wheel translated into wear on the teeth of the LP turbine pinion, as well.

   The turbine contractor was responsible for installing the turbine and the EPC contractor for installing and connecting the pipework. This loss occurred during the defect liability period, so it was crucial to identify both the cause and the timing to determine whether liability would attach to the CAR policy. Costs involved in determining cause and liability were high, including forensic engineers and lawyers. Loss amount: PD £795k paid as a maintenance claim.

3. Steam turbine vibration loss: The plant was constructed in 1998. Licensed incineration capacity 118k tonnes per annum. The plant is fitted with two boilers, burning capacity up to 7 tonnes of waste and producing up to 20 tonnes of steam per hour each. It can generate 8MW of electricity.

   High level of vibration was recorded during turbine operation. Inspection of the last turbine stage showed severe corrosion and erosion of blade tips. They removed opposing blades and cut off the tip to allow the turbine to operate with no vibration. After performing this type of repair repeatedly over a period of 8 months, the turbine efficiency was so low, that they had to replace the entire set of blades.

   Figure 13: Cut of blades

   Forensic investigation of the failed blades identified silicon particle deposits on the blade surface. Investigation of the source of contaminants suggest, that either the water chemistry was deficient or the steam turbine valve filters and boiler feed pump filters were too coarse and contributed to a significant amount of particles carried by the steam through the turbine.

   Figure 14: Silicon particle deposits on blades

   Figure 15: Inadequate filters

4. Tripping incident affected the electrical generator, associated with a failure on the UPS control system unit. This prompted the main circuit breaker protecting the generator to open and immediately the generator was isolated from the grid. The same shutdown command, however, was not simultaneously transmitted to the steam valve to shut down the steam feed to the turbine. Consequently, the turbine instantaneously accelerated to over speed and catastrophic failure. The generator disintegrated and the shaft bearings ruptured, sending large metal fragments through the roof of the turbine hall, causing major damage to the two turbines. Furthermore, oil from the lubrication system was ignited and caused damage to the surrounding equipment.

Figure 16: Turbine, generator massively damaged

Flue Gas / Ash Handling

The purification of exhaust gas from EfW plants and the handling of residues resulting from the thermal treatment of municipal solid waste are aspects common to all EfW plants. In this area, the principal risks stem from the proper handling of bulk solid substances (hydrated lime, activated carbon, boiler ash and air pollution control system residues) in terms of dust control, risk of fire or explosion, and the spread of hazardous substances. Other risks involve the corrosive nature of flue gases from EfW plants.

CM insurance – Endorsement 1375 "Special conditions: flue gas purification plants" addresses the FGT exposure.

Possible failure modes to consider:

13. Wet Corrosion
14. Fouling
15. Fire/Explosion

13. Wet corrosion

Flue gases contain gaseous acids such as HCl and SO_2 which are corrosive below their dew point temperature of around 150°C where they condense. Systems which are in contact with flue gases should be kept above 150°C with trace heating and insulation, otherwise an anti-corrosive coating should be applied.

Figure 17: Wet corrosion of ash ducts

Wet corrosion damages e.g. on FGT components may happen earlier than expected and may lead to an insurance claim, which is difficult to deny.

Dry flue gas treatment methods do not pose this potential exposure, however combustible dust build up could be an alternative exposure.

Consequential damage caused by the release of acidic flue gases is also an exposure to the remaining installations of the plant.

Figure 18: Wet corrosion of slag expeller

14. Fouling

Fouling is a potential exposure along the flue gas path which can impair the availability, operation and performance of the FGT. This is also a potential BI exposure. See below consequences of fouling and clogging by wet ash of boiler harps.

Figure 19: Fouling & clogging of horizontal boiler path by wet fly ash

15. Fire/Explosion

Powdered activated carbon or coke for the removal of dioxins and furans always poses a fire and explosion risk, whether during storage, use or disposal. The fly ash extractor, coke silo and filters must be equipped with CO differential monitoring (input/output).

Ammonia for denitrification is sprayed into the flue gas stream at various points to reduce **oxides of nitrogen (NOx)**; ammonia storage poses an explosion risk.

Whilst there does not appear to be a specific catalyst clause related to EfW plants, insurers may consider exclusions seen in petrochemical related policies such as "*Special condition 1 for Munich Re Hydrocarbons processing industries*", which introduces an outright exclusion.

Some plants employ a wet ash handling system where ash on a conveyor is sprayed or falls into a water bath to cool. Hot ash may accumulate and large pieces entering the bath may cause a steam explosion.

Loss examples

- Fire damage to the FGT. Video from KVA Oftringen, Switzerland (Regio Live TV, 2015)

Business Interruption / Delay in Start Up

For EfW, the BI premium for machinery is higher than the FLEXA BI premium, implying that there are fewer reported technical incidents, but if so, they cause more cost on the BI indemnification.

Statistically there is annually one BI-claim per policy in Germany, while only one in five years for Scandinavia. The largest BI-claims are caused by steam turbines, followed by generator and boiler. Operational Engineering BI-losses seldom exceed EUR 3 Mio.

Figure 20: Relative BI loss amounts by plant component

Investment, Revenues; DSU & BI implications

The insured parties will be the owner and lender/financier only. The addition of other affiliated and subsidiary companies on an automatic basis should be treated with caution without knowing the full structure of the owner and how revenue earned elsewhere within the group but dependent on the project could inadvertently become insurable under the project policy.

A DSU and BI assessment requires an evaluation of the revenue split for an EfW plant:

- Gate fee per ton of waste
- Heat & power production per MWh as part of a power purchase agreement
- Interdependence and interaction of the steam / heat consumer with the EfW plant
- Sale of recyclables
- Potential governmental grants, incentive schemes or subsidies

The DSU Tool Box jointly developed by a working party sponsored by IMIA and LEG (IMIA / LEG, 2013) can be used as basis for finding the correct BI sum insured. The classification of different revenues should be observed as well as the annual additional cost of plant operation without steam-turbine. It should be noted, if costs or turnover is non-linear.

It is essential to understand how the DSU/BI sum insured has been calculated, and how it is exposed through the duration of the indemnity period. Not all exposures are linear, and may have significant financial exposures on key dates. Misinterpreting such information may lead to unexpected exposure to larger than expected losses, or to the client or insurer being exposed to a policy wording that is not fit for purpose.

If the sum insured is made up of different revenue streams, the underwriter can show the split clearly as separate items within the policy schedule. This approach has the benefit of avoiding the over indemnification of any single revenue stream, which may be subject to dramatic escalation during the indemnity period (for example power sales price or landfill costs), as failure to show a split can allow access to the entire DSU sum insured. If efforts have been made to ensure that the DSU sum insured is correct and that a transparent declaration has been made, the schedule should clearly reflect such split, or may make reference to the split by using words such as:

> *"split in sums insured are as per the supplied DSU sum insured calculation worksheet dated dd/mm/yy".*

Alternatively the Insured may request cover for fixed costs and debt service, although being a more limited cover still requires a thorough understanding. It has to be made sure, that indemnification in this case will not exceed the amount of cost the insured is able to generate without the loss.

> *"If at any time during the Period of Insurance Insured Property suffers Damage which is indemnifiable under Section 1 (works) of this policy thereby causing a Delay this Section shall indemnify the Principal Insured for the actual loss sustained due to such Delay in the manner and to the extent as hereinafter defined under this Section."*

Where major concern exists over the stability of the sum insured, i.e. where revenue streams could be subject to market fluctuation, or where there is uncertainty over the accuracy of the sum insured, or a waiver of underinsurance is agreed on or if sum insured is based on first loss, the underwriter may wish to consider limiting the daily indemnity to a maximum of the average daily value of the sum insured. This has the effect of avoiding peaks in the exposure and the danger of losing the majority of the indemnity period sum insured over shorter periods.

> *"the maximum daily indemnity payable under this section shall be limited to the average daily value of the sum insured".*

Or

> *"The amount payable as indemnity hereunder shall be the amount of fixed costs and debt service that would have been payable had the delay not occurred, but not exceeding the monthly amount of USDXXXXXXX as declared and not exceeding USDXXXXXXX per month in respect of debt service payments. The amount payable hereunder shall be capped to the average monthly value multiplied by the Percentage of Indemnity Ratio calculated as follows:*
>
> *Percentage of Indemnity ratio shall mean the percentage calculated as the amount by which the actual Gross Profit achieved during the Indemnity Period falls short of the Gross Profit which would have been achieved had the delay not occurred."*

The wording of exclusions such as *"Fines or damages for breach of contract"* will need to reflect the cover afforded, since the revenue streams of an EfW plant may be affected by reductions in revenue, which at first glance may be viewed as fines or penalties, are actually part of the revenue stream. For example a gate fee may have been paid to the EfW plant in advance, then a penalty applied where the EfW plant is unable to accept waste due to indemnified delay. A thorough understanding of the sums insured will ensure correct use of terms within the list of exclusions.

Depending on the country, grants can be due if the plant meets certain criteria relating to efficiency, emissions and output level. It should be noted that these financial exposures may not be linear in their nature, and could be payable on a fixed date or dates or lost entirely if a planned commencement date is missed. The period of delay can be exposed if the plant is unable to reach its contractual emissions, output and efficiency ratings due to necessary redesign following damage. It is important to understand the criteria for achieving these grants, and how they are payable. Hence, it can be profitable to incinerate waste regardless of demand for heat, power or recyclables.

Investors seek long-term waste contracts guaranteeing a certain gate fee. Contracts usually also include guaranteed minimum ton per year. This gives the plant a minimum guaranteed source of income. Securing long-term waste supply contracts can be challenging and such contracts are usually only available for local authority waste. Commercial waste contracts are generally much shorter, making it harder to finance projects taking primarily commercial and industrial waste.

Private equity investors target ROE (Return on Equity) of approx. 15 %. To develop a profitable EfW plant, process types with proven performance at commercial scale are preferred. Minimum guaranteed throughput and waste composition can change over time. This can affect the efficiency of an EfW plant. Electric power production by EfW is normally more costly than conventional sources. This means that EfW projects depend on how long-term power purchase agreement can be secured with a utility at the beginning of a project (The World Bank, 2016).

Business interruption, Loss of Profit & Additional Increase in Cost of Working

This clause differs from the usual increase in cost of working, being subject to an economic limitation, by affording the ability to spend more than a dollar to save a dollar. As opposed to Increased Cost of Working (ICOW), which is subject to the same limit as the main sum insured, Additional Increased Cost of Working (AICOW) will be subject to an inner limit. The limit selected will depend on the potential additional costs foreseen by the insured, likely to be the additional costs of disposing waste in the event of a delay. The clause either may be drafted as a universal clause intended to cover any additional costs, or may be more specifically drafted in respect of waste disposal costs or landfill costs.

For example, contractual agreements for steam and heat delivery can be different from the normal power agreements. This is important when assessing the accuracy of the suggested BI sum insured. The commitment to provide heat for x amount of houses in a network: Let's assume the insured lose all regular boilers and the insurer's commitment is triggered and the only measure to fulfil could be to install heating fans in each and every building. This can be above ordinary PML scenario and exhaust limits a lot quicker than the indemnity period.

This creates a potential risk for being underinsured but if a first loss basis for BI/AICOW is used the limits may be reached a lot earlier than anticipated. Redundancy capacity outside of ordinary production requirements is key to assessing the exposure.

Important for BI and AICOW assessments are seasonal fluctuation of heat or steam supply which results in concentration of revenues during the high season. Indemnity periods of e.g. 18 months mean that the peak season may be hit twice with a single loss whilst not having a full 24 months of TSI.

If these losses occur during September-November in Scandinavia, most of the annual AICOW indemnity limit will be exhausted.

A 16 MW EfW boiler represents an annual BI SI of £10m where of AICOW is 85%, if forced to move from waste to back up oil-fuelled boiler.

The BI share of BI+AICOW varies between 15% and 30% depending on:

- Size of turbines
- Presence of process steam sales
- Waste receiving contracts
- Redundancy if waste boiler goes down (is your additional capacity in bio-boilers or oil fuelled boilers)

Listing of failure modes, loss scenarios & BI/PD implications

Failure mode	Scenario examples	BI	PD of TIV
1	Waste bunker fire	2 months	10%
1, 2, 3	Waste crane breakdown	6 months	10%
3	Conveyor fire	2 months	5%
4	Boiler leakage	1 months	5%
4	Boiler dry cooking	3 months	10%
4	Grate melt-through due to irregular waste	2 months	10%
5	Refractory Lining collapse	2 months	5%
5	Boiler explosion	12 months	25%
7	Condenser or district heating leakage	2 months	5%
8	ID fan failure	2 weeks	5%
8	Boiler feed water pump damage	2 weeks	5%
10	Generator end winding damage	2 months	5%
10	Transformer rewinding	12 months	30%
10	Transformer fire	12 months	30%
11/12	Turbine blade failure	9 months	10%
11/12	Turbine over speed & explosion followed by lube oil fire	15 months	35%
13	FGT reactor fire	4 months	5%
13	Electro filter or bottom ash system corrosion	1 month	10%
15	Fabric filter fire	4 months	5%

Table 3: Loss scenarios & PD/BI implications

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