GA no 282826

Production of Solid Sustainable Energy Carriers from Biomass by Means of Torrefaction

Deliverable No. D6.1

Description of existing handling and storage facilities and the associated issues

Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Nature		
R	Report	X
O	Other	

Deliverable Details		
Due date:	30.09.2012	
Submission date:	09.11.2012	
Editors:	Robin Zwart	
Involved participants:	E.ON	Will Quick, Susan Weatherstone
	RWE	Kirsten Theobald
	Vattenfall	Kristoffer Kollberg, Anna Hinderson, Gerth Karlsson, Nader Padban Rutger Quak, Raziyeh Khodayari
WP no. and title:	WP 6 Torrefaction	
WP leader:	ECN	
Task no. and title:	6.2 Outdoor storage and handling tests	
Task leader:	ECN	
Draft/Final:	Draft	
Keywords:	Torrefaction; Handling and storage; Risk assessment	

Table of Contents

1 Summary

In this report the handling and storage facilities at several existing coal-fired power plants are described and critical logistic steps are identified when switching from coal to torrefied biomass. This information forms deliverable 6.1 of the project. For this deliverable input from EON, RWE and Vattenfall is mandatory.

2 Description of deliverable no. 6.1

Deliverable 6.1 is a report describing existing handling and storage facilities at the existing coal-fired power plants of RWE, EON and Vattenfall. With this description the critical logistic steps are identified when switching from coal to torrefied biomass. By assessing several coal-fired power plants a distinction can be made between plant specific as well as more general issues.

Based on the identification of these critical steps, not only the desired parameters and their required values for small-scale logistic tests of Task 6.1 can be determined, but also the torrefaction and densification processes can be optimised towards co-firing in general and/or end-use in a specific plant in particular.

At the time of submission of the deliverable in total five existing plants are taken into consideration, *i.e.* the Reuter West plant in Germany and the Willem Alexander Centrale (WAC) in the Netherlands (both operated by Vattenfall), the Ibbenbüren and Niederaußem plants in Germany (both operated by RWE) and the Ironbridge B power plant in England (operated by E.On).

These plants not only represent the utilization of different coals (both lignite and hard coal), but also different conversion technologies, as the WAC power plant is based on entrained-flow gasification rather than combustion.

3 E.ON

E.ON operates a total of 26 coal power plants across 7 European countries. These include 3 lignite plants, 22 hard coal plants and one which uses a mixture of the two. Note that a number of these plants are currently scheduled to close under the Large Combustion Plant Directive (LCPD). A number of these plants have undertaken biomass co-firing, most notably the UK plant and Maasvlakte in the Netherlands, while biomass combustion projects are also underway on some plants.

3.1 Ironbridge B

3.1.1 General plant information

Ironbridge B Power station is reasonably representative of the UK coal fired fleet, most of which were built with 2 or 4 x 500 MW_e unit stations to a very similar design in the 1960s and 70s. It is fitted with Electro Static Precipitators (ESP) for particulate control and low-NOx burners and overfire air for NOx control, but is opted out of the LCPD and so is scheduled to close by the end of 2015.

Location	Ironbridge B power station Buildwas Rd Telford Shropshire TF8 7BL United Kingdom 
Owner & operator	E.ON
Type of plant	Hard coal power plant with 2 blocks with each 500 MW_e installed power
Fuel	Hard coal, approximately 3 000 – 6 000 tonnes every day
Boiler / burner type	Pulverised coal combustion
Experiences with biomass	Biomass co-firing in response to government incentives from the early 2000s Work started to convert the plant to firing 100% clean wood pellet

Biomass co-firing started in the early 2000s, in response to UK government incentives, and has continued to do so periodically since, with a wide variety of biomass types at a low percentage. In 2012, work started to convert the plant to firing 100% clean wood pellet. This includes replacement of the existing coal mills and handling systems, but the co-firing arrangement is described here as it is fairly typical of the systems still in use on a number of UK plants. Biomass fuels which have been trialled or used commercially include maize pellets, palm kernel expeller, milled palm nut, shea nuts, miscanthus pellets and wood pellet.

3.1.2 Handling and storage facilities

As with all UK power plants, coal at Ironbridge is stored outside. As such, the storage is unsuitable for the storage of pelletized biomass, although some plant do store some biomass types such as olive cake on a portion of the stockyard. At Ironbridge, the primary biomass store is a large silo, with additional storage space inside a large shed close to the site entrance. Coal is delivered to the station by rail or road and is discharged into ground level hoppers. From these it is sent by conveyor either directly to unit bunkers or stocks (Figure 1).

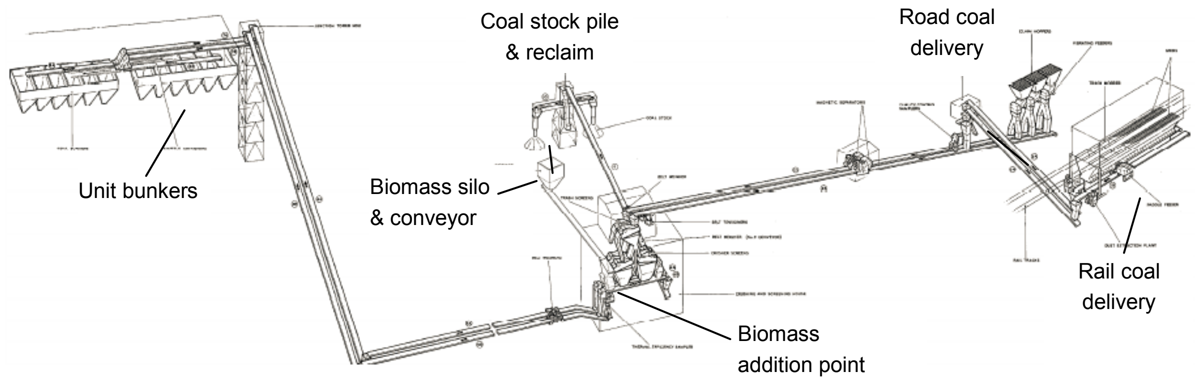


Figure 1: Layout of coal and biomass handling systems

Conveyor chutes are mainly ceramic lined and of half round or lobster backed design to minimise dust generation. Although most coal is delivered to Ironbridge by rail, there is no facility to accept biomass deliveries by the same method. Delivery is therefore by tipping trucks, primarily into a dedicated hopper adjacent to the biomass storage silo (Figure 2).

Figure 2: Biomass reception facility and silo

From this, a boot and bucket elevator raises the biomass 24 m onto a screw conveyor, which delivers it into the 650 te circular storage silo, which has a conical lower section. The conical section has a suspended vibrating cone at the outlet to assist in silo discharge. Fuel discharged from the cone is delivered into a short screw feeder and onto a belt conveyor (where it can be sampled).

There is no pre-blending of coal and biomass at Ironbridge, instead the conveyor discharges the biomass added on top of the coal conveyor after the junction tower to the coal yard. Biomass may also be delivered into a flat storage shed, from which it can be transported to the silo hopper by front loader as required. Some other UK stations only have flat storage facilities, fitted with hoppers inside which are stocked using front-end loaders.

The conveyors carry the material up to the unit bunkers, where it can be stored for up to 8 hours before milling. Ironbridge has 6 Foster Wheeler D9 tube/ball mills (Figure 3) per unit, with each mill feeding four burners; 5 mills are usually used when firing on coal. Fuel is delivered from the bunker to the mill by two drag link type feeders via the mill raw coal chutes.

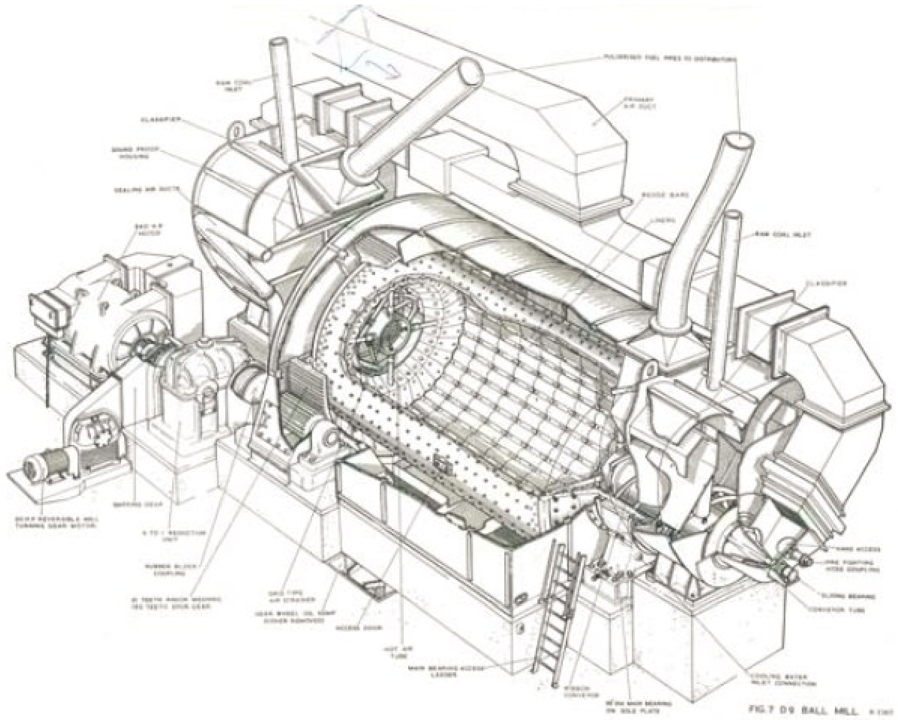


Figure 3: Schematic of Foster Wheeler D9 tube/ball mill

The raw coal drops into the ribbon conveyor from where it is fed into the mill drum. The D9 mills are a pressurised, double ended design in which raw coal is delivered to and pulverised fuel discharged from both the Drive Ends (DE) and Non-Drive Ends (NDE) of the mill. The mills consist of a rotating drum filled with a charge of steel balls. The internal surface of the drum is fitted with wear liners that incorporate wedge bars that raise the ball charge.

Ground coal is transported from each end of the mill, via an aerodynamic classifier, by primary air, which is admitted to the mill drum through the hot air tube, central to the ribbon conveyer. Oversize material is returned to the mill.

A single mill trial of 100% wood pellet showed that the D9 mills were capable of grinding wood pellet, although optimisation of factors such as the ball charge, primary airflow and mill operation was not optimised during these tests. In the conversion project that is on-going at Ironbridge, the decision was made to replace these mills by hammer mills to improve the material throughput.

3.1.3 Issues foreseen with torrefied biomass

The D9 Tube/Ball mills installed at Ironbridge have previously shown issues with fibrous biomass types as they can interfere with the mill level control systems due to high rates of internal recirculation. Issues with high levels of dust in the conveyor system, particularly around chutes and transfer towers, have also been identified.

3.1.4 Demands set to torrefied biomass

No specific demands are currently set for torrefied biomass in addition to those already applicable for raw biomass and/or coal.

4 RWE

RWE currently operates 5 lignite and 3 hard coal power plants in Germany. To give an overview over the wide variety of fuel handling systems both a lignite and a hard coal plant were chosen for description.

The lignite plant Niederaußem (§4.1) is one of Germany's largest power plants. It features 9 blocks, that each need their mixture of lignite qualities. The plant's fuel handling facilities are accordingly designed to handle large quantities on the one hand and on the other to ensure that each block/boiler safely and reliably receives its fuel.

The hard coal plant Ibbenbüren (§4.2) is a comparatively small, single block plant. It is the last plant to run almost completely on a high-quality German anthracite coal excavated from the neighbouring mine (RAG). In recent years the plant has been modified to accept additional fuels like sewage sludge or meat and bone meal. Its fuel handling facilities have been successfully adapted to the reliable feed-in and mixing of different fuels.

4.1 Niederaußem

4.1.1 General plant information

Location	Kraftwerk Niederaußem Werkstraße 50129 Bergheim North-Rhine-Westphalia Germany
Owner & operator	RWE Power AG
Type of plant	Lignite power plant with 9 blocks ranging from 150 to 1 000 MW installed power and an overall net output of 3 627 MW_e net and 7 MW_{th}
Fuel	Lignite, 26 000 000 tons per year
Boiler / burner type	Pulverised coal combustion
Experiences with biomass	No large scale biomass tests, only co-firing trials at small on site test plant No experience with torrefied biomass

4.1.2 Handling and storage facilities

The fuel handling at the lignite power plant of Niederaußem covers four steps, i.e. *(i)* delivery to the plant, *(ii)* on site storage, distribution and transport, *(iii)* treatment and processing, including the removal of unwanted materials like fossil wood, stones and metal and *(iv)* combined drying and milling in fan beater mills at the boiler.

Figure 4 gives a schematic overview over the lignite handling and distribution system at Niederaußem. Table 1 describes the single process steps in more detail, supplemented by several pictures.

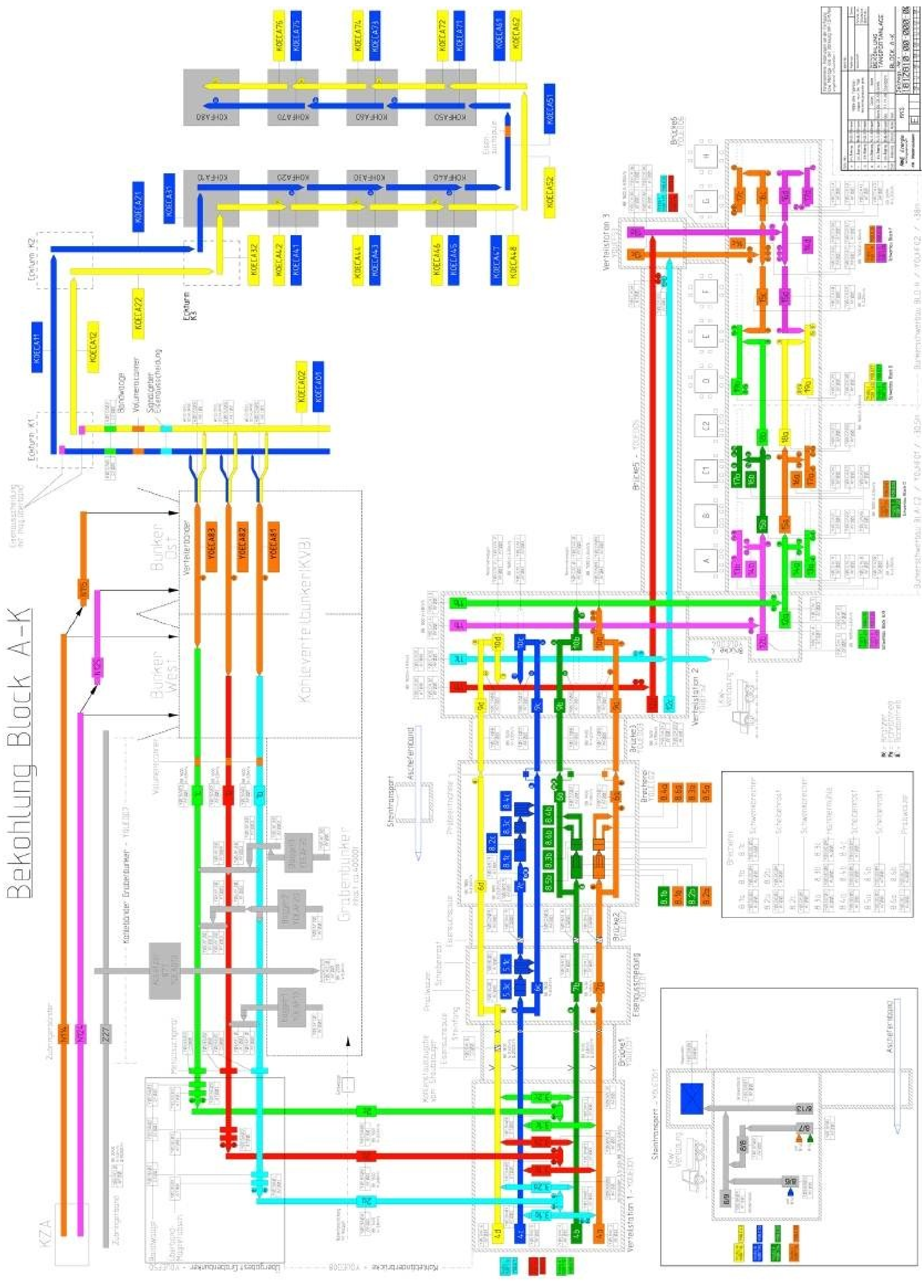


Figure 4: Schematic overview of the Niederaußem lignite handling facilities

Table 1: Description of the single process steps of the Niederaußem plant

Process step	**Details**	**Issues seen with biomass**
Delivery	• Raw lignite, delivered via train or encased heavy duty conveyor belt from the nearby lignite pits (see Figure 5 and 6) • Raw lignite o varies in quality o also contains fossil wood, stones, metal o water content between 50-60%weight	• Dust emissions
On-site storage	• Unloading from trains into ditch bunkers (Figure 7) o capacity: 20 000 tons o trains unload directly into the bunkers • Removal from ditch bunkers via bucket excavators • Transport to coal supply and distribution bunkers via conveyor belts	• Outside storage in ditch bunkers possible? And for how long? What about biodegradation? • Delivery and removal from bunkers; are the excavators suitable to move biomass? • Dust, risk of fires or explosion • Biomass also suitable for storage in underground slot bunkers? (filling and removal, amount of dust)
Fuel treatment / processing	• Combined crushing and screening unit for the removal of wood and stones (Figure 8) • Iron removal • Sample taking	• Do the pellets need to be crushed before drying and milling?
Drying & milling	• Combined drying and grinding in beater mills (Figure 9): o lignite is dried with hot gases from boiler (1 050-1 200°C) o input size: up to 80mm o output: R 1mm<6%	• Suitability of beater mills for pellets? • Premature ignition due to drying with hot flue gas

Figure 5: Raw lignite on conveyor belt

Figure 6: Lignite transport via train

Figure 7: Train unloading into ditch bunker

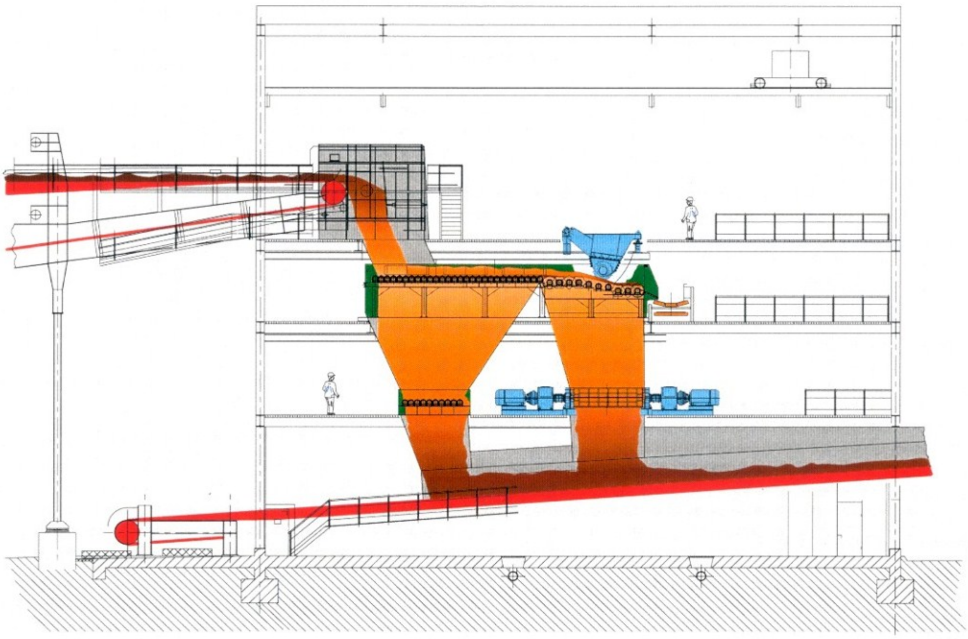


Figure 8: Combined crushing and screening unit

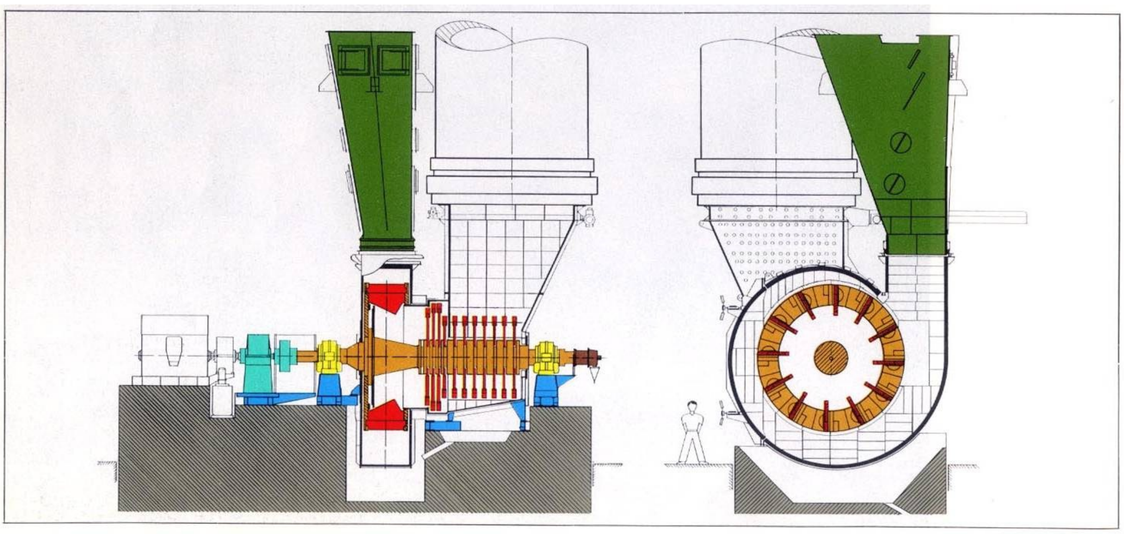


Figure 9: Pc-boiler fan beater mill

4.1.3 Issues foreseen with torrefied biomass

The issues foreseen with (torrefied) biomass are included in table 1 of §4.1.2.

4.1.4 Demands set to torrefied biomass

The raw lignite delivered to Niederaußem comes from different pits and within the pits from different seams. As a result lignite quality varies widely. Each boiler is provided with a mixture of lignite. This mixture is tailored to fit the boiler's needs.

If torrefied biomass is to be co-fired in a boiler, the torrefied biomass will have to "fit" into the lignite mixture (and in the best case improve it). The exact characteristics the biomass needs to have, cannot be assessed beforehand as there are too many influence parameters and interdependencies.

To find a suitable mixture a prequalification is necessary. The prequalification includes extensive lab analysis of all components (single and mixed) as well as small firing trials and "fine-tuning" of the mixture.

4.2 Ibbenbüren

4.2.1 General plant information

Location	Kraftwerk Ibbenbüren Schwarzer Weg 49479 Ibbenbüren North-Rhine-Westphalia Germany
Owner & operator	RWE Power AG Anthrazit Ibbenbüren GmbH (RAG)
Type of plant	Hard coal power plant with single block with 838 MW_e installed power
Fuel	Anthracite coal, approximately 1 500 000 tons per year, dried lignite dust to support combustion, and in limited quantities animal bone meal and sewage sludge
Boiler / burner type	Pulverised coal combustion
Experiences with biomass	No experience with torrefied biomass

4.2.2 Handling and storage facilities

The fuel handling at the hard coal power plant of Ibbenbüren like the plant of Niederaußem (§4.1) covers four steps, i.e. *(i)* delivery to the plant, *(ii)* on site storage, distribution and transport, *(iii)* treatment and processing, including the removal of unwanted materials and *(iv)* combined drying and milling in fan beater mills at the boiler.

Figure 10 gives a schematic overview over the lignite handling and distribution system at Ibbenbüren. Table 2 describes the single process steps in more detail, supplemented by several pictures.

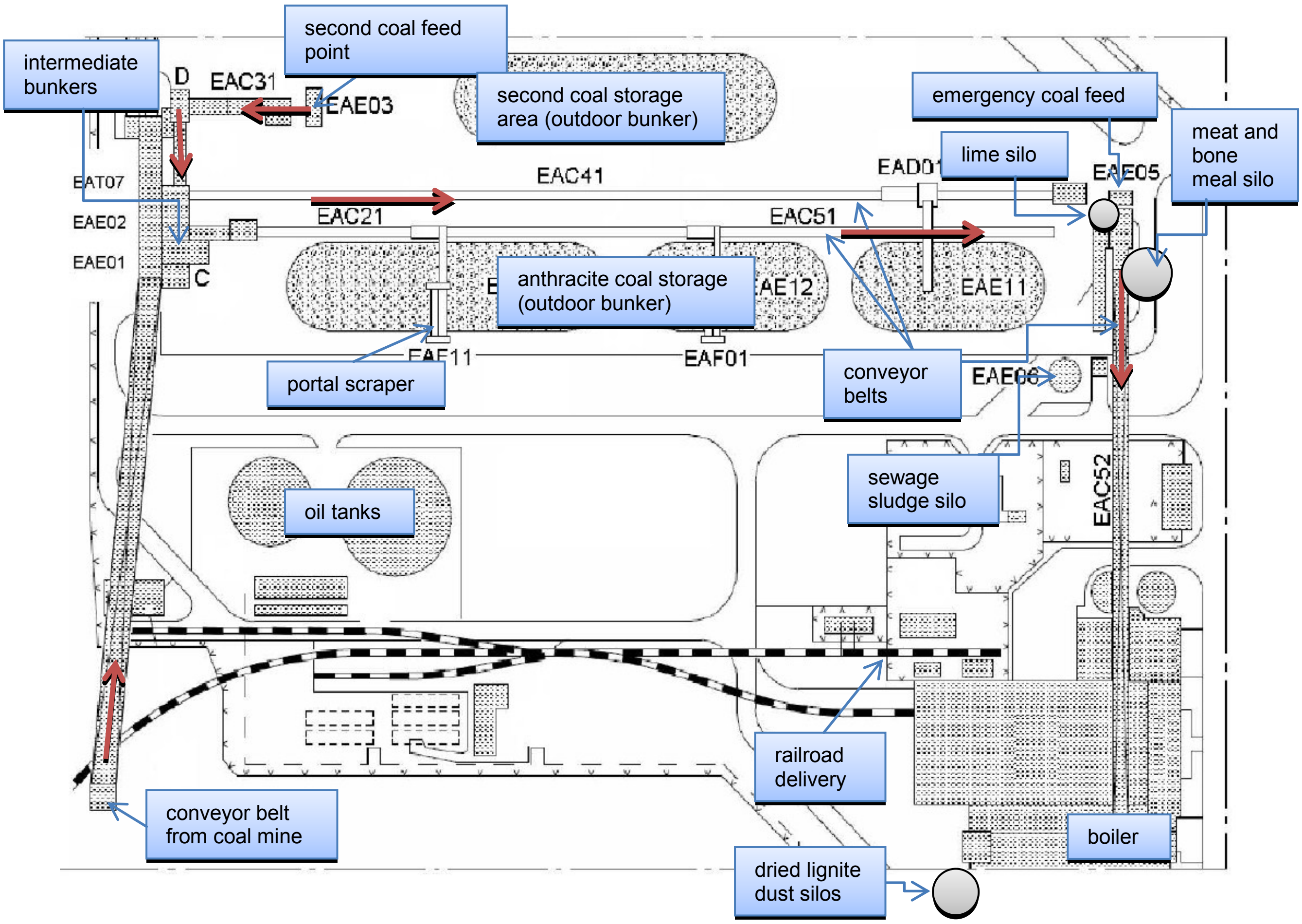


Figure 10: Schematic overview of the hard coal power plant of Ibbenbüren

Table 2: Description of the single process steps of the Ibbenbüren plant

Process step	Details	Issues seen with biomass
Delivery	• Anthracite coal o delivered by conveyor belt from the nearby underground coal mine o coal is delivered washed and sieved to power plant o particle size: 0.5 - 6.6.mm • Animal bone meal, sewage sludge and oil are delivered by truck • Dried lignite dust, o delivered by silo train car or silo truck o hazardous materials transport!	• Dust emissions, risk of fires or explosion
On-site storage	• Anthracite coal o first stored in intermediate bunkers (Figure 11) o then transported to outside bunkers (Figure 12/15) • Animal meal, sewage sludge and lignite dust are stored in silos • Oil is stored in tanks	• Outside storage in bunkers possible? And for how long? And what about biodegradation? • Delivery and removal from bunkers; are the scrapers suitable to move biomass? • Dust, risk of fires or explosion

Process step	Details	Issues seen with biomass
Fuel mixing	• Animal bone meal and sludge are added directly to the coal conveyor belt and transported to the boiler storage bunkers (Figure 13)	• Best place to add the torrefied pellets to the fuel mixture?
Milling & boiler feed-in	• Fuel is distributed into the 8 boiler bunkers (Figure 14) • Between bunker and mill the dried lignite dust is added (Figure 17) • Each boiler bunker feeds one bowl mill: 8x Babcock MPS 255, with a throughput of 37 t/h coal each (Figure 16) • Mills are heated to dry the fuel	• Suitability of mills for pellets? • Safe storage in boiler bunkers?

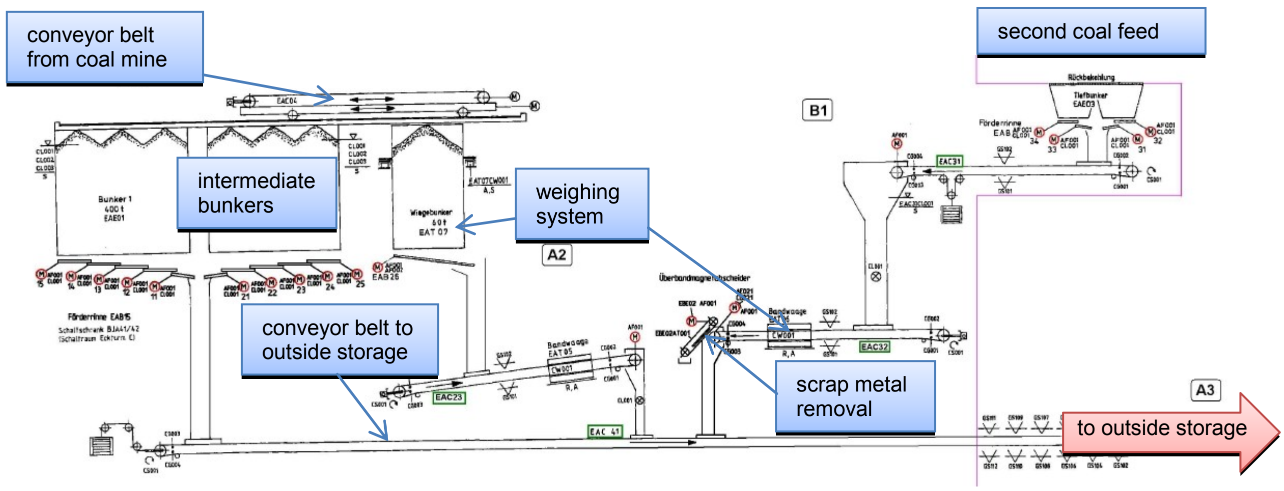


Figure 11: Fuel handling system part 1: coal delivery and first onsite storage

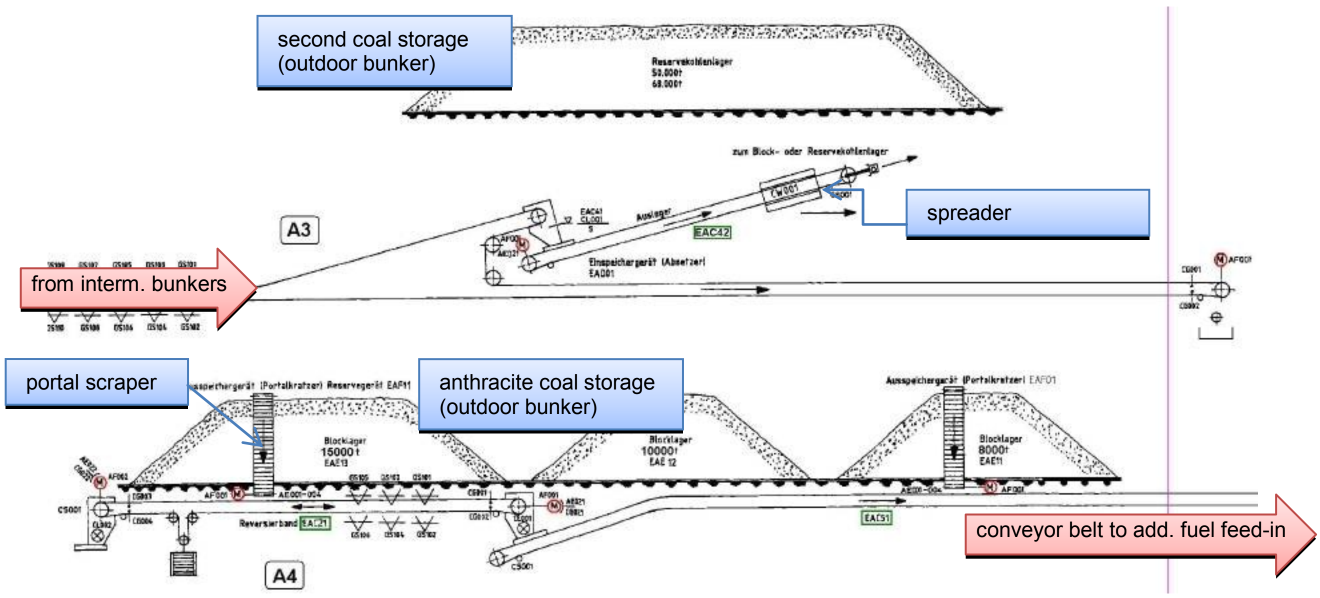


Figure 12: Ibbenbüren fuel handling system part 2: outside storage

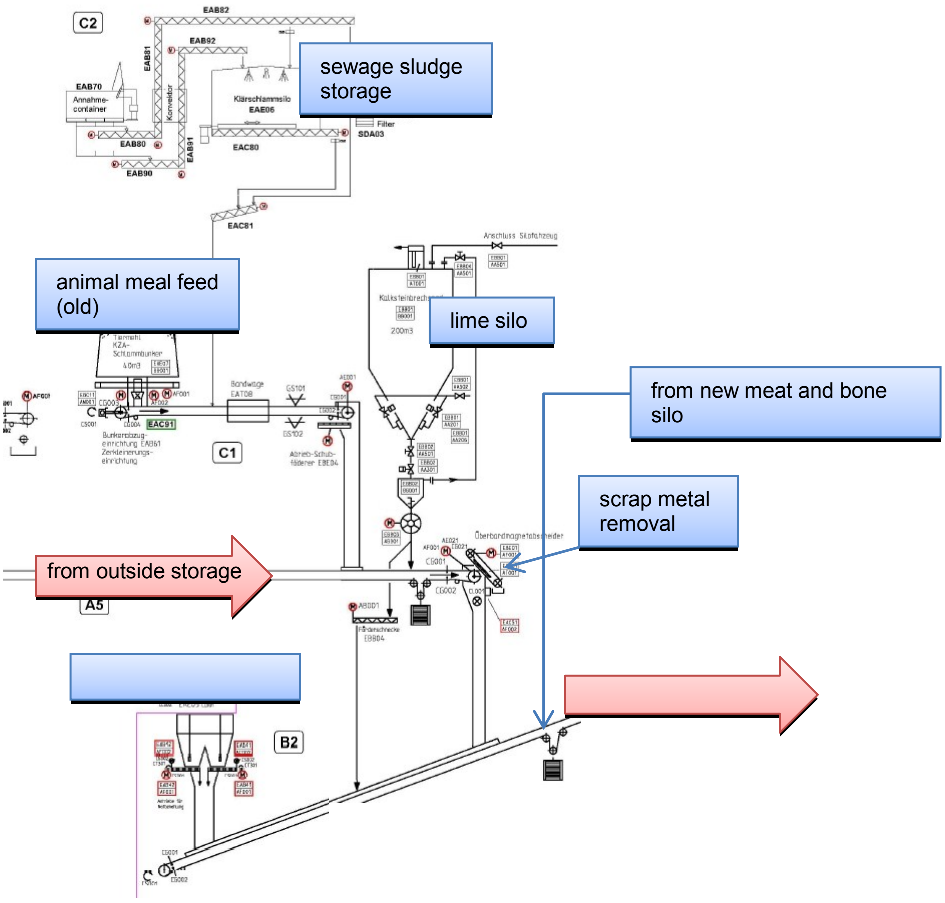


Figure 13: Ibbenbüren fuel handling system part 3: sludge, lime and emergency feed-in

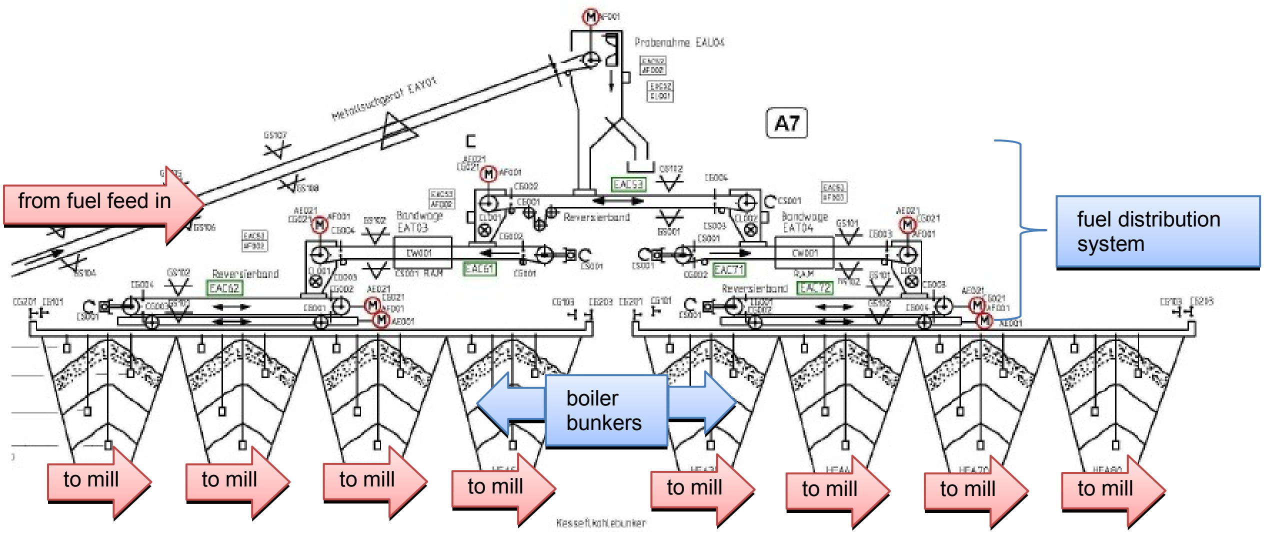


Figure 14: Ibbenbüren fuel handling system part 4: distribution to boiler storage bunkers

Figure 15: Outside storage with portal scrapers

Figure 16: Bowl mills

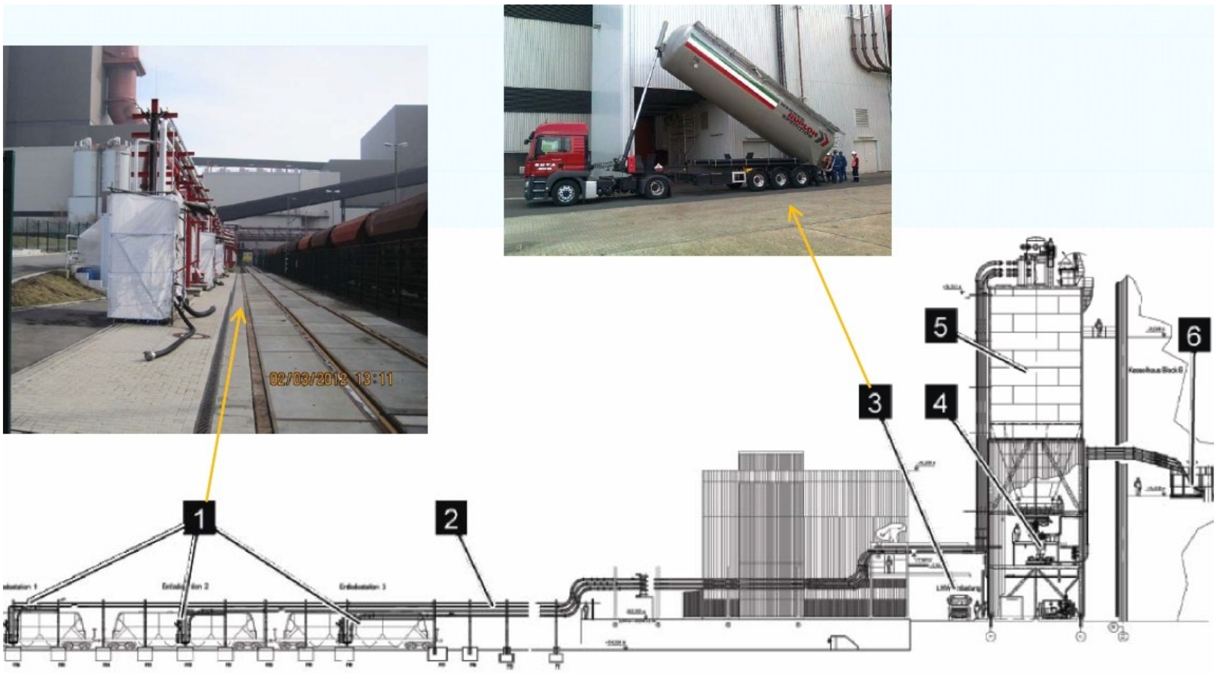


Figure 17: Lignite dust handling system at Ibbenbüren
1) unloading from silo train cars; 2) pneumatic transport to storage silo; 3) silo truck unloading; 4) lignite dust removal from silo; 5) storage silo (feed-in at top, removal at bottom); 6) boiler feed-in before mill

4.2.3 Issues foreseen with torrefied biomass

The issues foreseen with (torrefied) biomass are included in table 2 of §4.2.2.

4.2.4 Demands set to torrefied biomass

Information needed of torrefied biomass/ pellets to judge whether or not this fuel can be fed into the boiler at Ibbenbüren (as well as Niederaußem) together with the coal are *(i)* the physical properties, *(ii)* the chemical properties, *(iii)* the safety issues and *(iv)* more supply related the deliverable quantities. As such, information has to become available on almost all parameters presented in table 3.

Table 3: Information needed of torrefied biomass to judge whether or not the fuel can be fed in the boiler

Physical properties	• Particle / pellet size • Grindability • Bulk density
Chemical properties	• LHV • Carbon content • Oxygen • Water content • Element analysis • Heavy metals
Safety issues	• Explosion characteristics • Need for additional security measures
Other	• Deliverable quantities

5 Vattenfall

Vattenfall is Europe's fifth largest generator of electricity and largest producer of heat. Black pellet technologies, among which those produced via torrefaction, take a prominent place in the current strategy of Vattenfall to reach their renewable energy targets. In the short term Vattenfall wants to generate 20 % renewable energy in 2020, currently this is 8,5 %. A part of the production should be covered by biomass. At this moment Vattenfall utilises more than 1 Mtonne biomass and that volumes should increase this decade to 8-10 Mtonne. Existing coal power plants will utilise the major part of that biomass by co-firing.

Increasing the co-firing percentages requires pre-treated biomass. For the description of existing fuel handling and storage systems, as well as the identification of critical steps in handling and storage of torrefied materials 2 plants are selected, i.e. the coal fired Integrated Gasification Combined Cycle (IGCC) plant Willem Alexander Centrale (WAC) located in Buggenum, the Netherlands, and a typical hard coal fired combustion plant Reuter West (RW) located in the centre of Berlin, Germany. In both plants large scale tests with thermally treated biomass have been performed with promising results.

The biomass co-firing rates will vary and currently there are only coarse estimations for the plant individual rates and therefore this study assumes a general rate of 50 % biomass. The share of biomass is given as percentage on energy bases, as is done throughout this report. As both the Reuter West power plant and Willem Alexander Centrale are using grinded fuels and therefore only fuel chains including feeding of grinded fuels are considered here.

100 % hard coal should remain as a back-up option for the biomass/coal blend in the plants to secure production and plant availability, and decrease the need of large biomass storage on site. With regards to biomass, torrefied biomass in the traded form of pellets is the main option. Briquettes could be an alternative and are discussed as well.

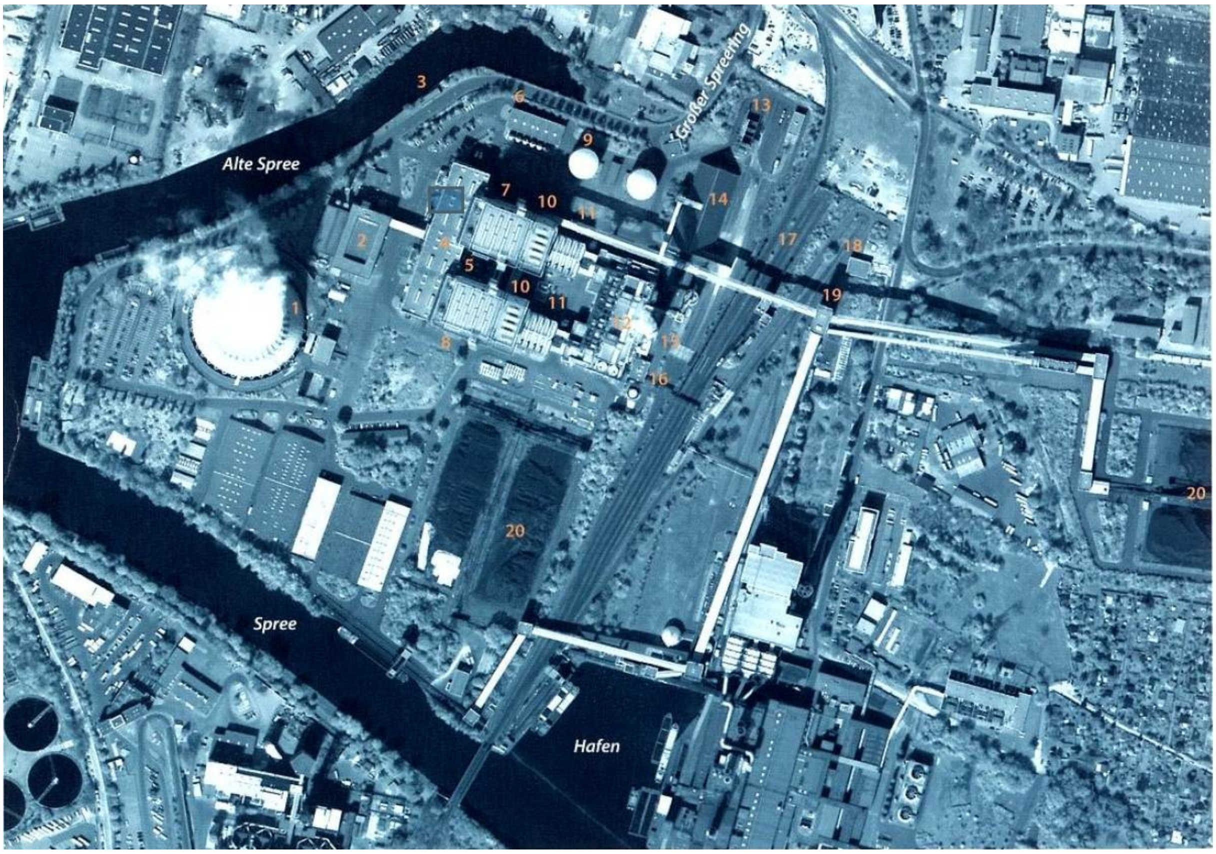
5.1 Reuter West

5.1.1 General plant information

Reuter West (RW) is a hard coal fired plant located 14 km west of Berlin's city centre in the Spandau district. It consists of two identically designed boilers (unit D and E) commissioned in 1987 and 1989. The firing capacity is 758 MW_{th}, and production 300 MW_e and up to 363 MW_{th} district heating, for each boiler. The total coal consumption is 3 300 tonnes per day. See Figure 18 for an overview of the RW plant units D and E.

The steam generators are Benson boilers with welded membrane walls. There are four burner levels, and on each level four low-NOx burners. To each burner level is connected one roller mill from Babcock. The nominal throughput for one mill is 28.4 tonnes coal per hour. After conventional flue gas cleaning the flue gas is emitted through a common stack.

Location	Heizkraftwerk Reuter West Großer Spreering 5 13599 Berlin Germany 
Owner & operator	Vattenfall Europe AG
Type of plant	Hard coal power plant with 2 boilers with firing capacity is 758 MW_{th}, and production 300 MW_e and up to 363 MW_{th} district heating each
Fuel	Hard coal, 3 300 tonnes per day
Boiler / burner type	Pulverised coal combustion
Experiences with biomass	Large scale tests with thermally treated biomass have been performed with promising results



1. Cooling tower with pump building
2. Visitor centre
3. Tanker unloading
4. Machine building
5. Transformer building
6. District heat station
7. Boiler building D
8. Boiler building E
9. Oil storage
10. DeNOx plant (SCR)
11. ESP (Electrostatic precipitator)
12. FGD (Flue Gas Desulphurisation)
13. Wet ash basin
14. Gypsum storage
15. Stack (Chimney)
16. Auxiliary power building
17. Railway
18. District Heat Distribution
19. Hard coal wagon unloading
20. Coal yard

Figure 18: Air-photo of Reuter West

5.1.2 Handling and storage facilities

The RW plant has a joint harbour with the nearby located power plant Reuter (also owned by Vattenfall) at the river Spree. The coal is delivered by barges. Typically, the barge transport is out of order for approximately six weeks per year, due to maintenance of the river locks/barges elevators. During this time and when the river is frozen freight train delivery is the only way to supply the plant with coal. However the train capacity is not sufficient to cover 100% of the fuel demand. As a back-up system, the coal can be delivered by trucks.

The barges are un-loaded at the northern bank of the river Spree using a ship grab un-loader (crane) or at the western bank of the harbour using a similar system. The un-loaders can take up to 12.5 tonnes load. Nominal throughput is 550 tonnes of coal per hour. From the harbour hopper, the coal is placed on either of the parallel belt conveyor lines to the RW plant, the nearby located power plant Reuter or the coal yard and main storage (Figure 19).

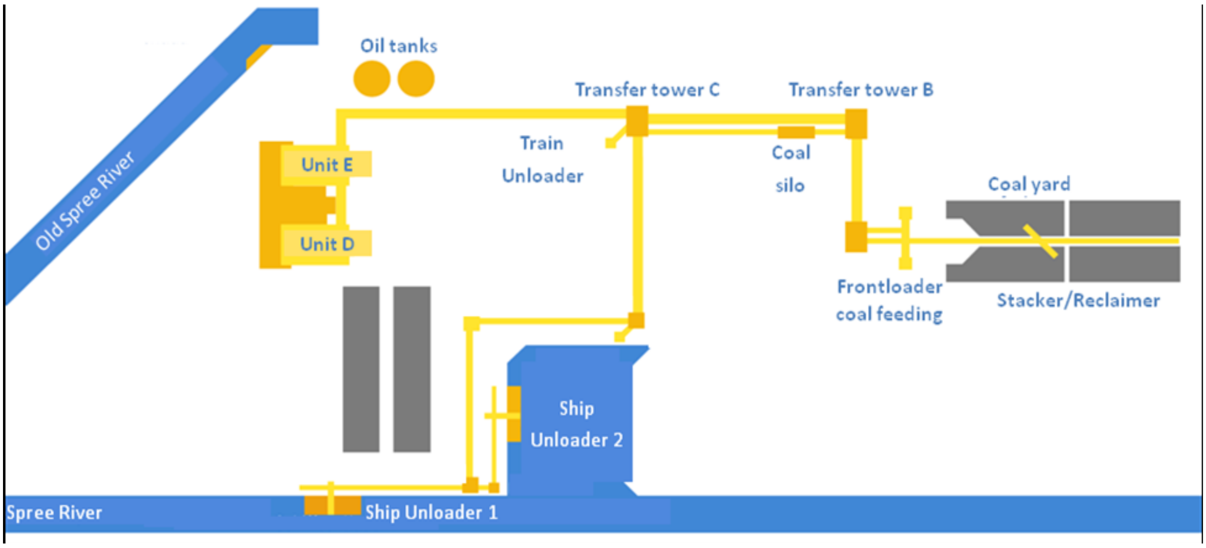


Figure 19: Schematic figure of the major systems in existing coal handling at Reuter West

The fuel is transported by conveyor belts via transition stations to the plant or the coal yard. The coal volume is determined by conveyor belt scales. Foreign objects in the fuel are removed by over-belt magnetic separators and metal detectors. Dust removal systems are installed at the transition stations.

The outdoor coal storage is designed for a storage capacity of maximum 220 000 tonnes of coal. There are two coal yards (370 m × 120 m and 170 m × 110 m respectively). The coal yard is filled up before the winter and a typical storage time will be 4-6 months. The coal storage corresponds to approximately 60 days of full-load operation.

Each coal yard is divided in two sections (stockpiles). The discharging and pick up machinery is running on tracks and are located in the middle between the stockpiles storage areas.

The surface of the coal yard is covered by a sealing layer. The surface water is collected in the water gully channels along the sides of the coal storage area. The water passes an oil separator and is discharged into the river.

An emergency coal feeder system consisting of two hoppers is located on the western side of the stock pile area.

From the coal yard the coal is transported by conveyors to the plant bunkers. By covered conveyors the coal is transported from the bunkers to the mills. For each bunker there is one roller mill connected, in total 4 mills per unit. In the mills the coal is dried, grinded and classified. Under normal operations the mills are operated with automatic control based on target value for electric production. The demanded coal quantity, air flow, mill and classifier settings are automatically adjusted.

5.1.3 Issues foreseen with torrefied biomass

As the issues foreseen with torrefied biomass at the RW power plant are similar to the issues foreseen at the Willem Alexander Centrale (§5.2), the description of how the fuel handling and storage of torrefied material might look like is given for both plants in §5.2.3.

5.1.4 Demands set to torrefied biomass

As the demands set to torrefied biomass at the RW power plant are mostly similar to the demands set at the Willem Alexander Centrale (§5.2), the description of the demands is given for both plants in §5.2.4.

5.2 Willem Alexander Centrale

5.2.1 General plant information

The Willem Alexander Centrale (WAC) is a coal fired Integrated Gasification Combined Cycle (IGCC) plant of 253 MW_e located in Buggenum in southeast of the Netherlands. The plant was built next to a coal fired power station at the river Maas.

Location	Willem Alexander Centrale Roermondseweg 55 P.O. Box 4035 6080 AA Haelen The Netherlands
Owner & operator	NUON Vattenfall
Type of plant	Hard coal power plant with single entrained flow gasifier and overall net output of 253 MW_e
Fuel	Hard coal, 2 000 tons per day
Boiler / burner type	Pulverised coal gasification
Experiences with biomass	Large scale tests with thermally treated biomass have been performed with promising results

The heart of the plant (Figure 20) is a single dry-feed entrained flow Shell gasifier. The gasifier operates at 25 bar and approximately 1 600ºC. The coal is ground to a particle size of less than 100 µm in three roller mills from Loesche (each of 55 % capacity). The fuel is pressurised by means of a lock hopper system (two trains) and is conveyed pneumatically to four side mounted burners with nitrogen as carrier gas.

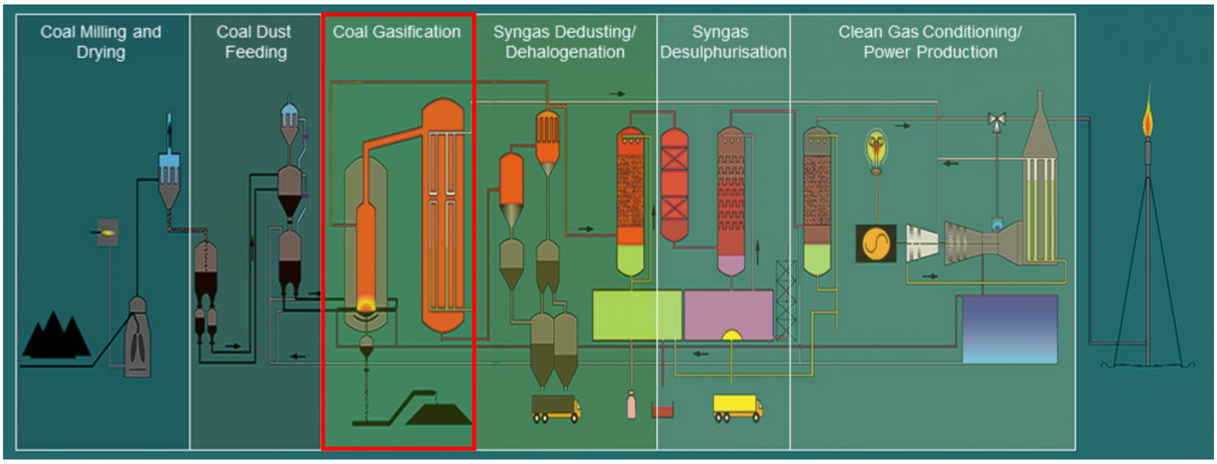


Figure 20: Schematic scheme of the Willem Alexander Centrale

During 2011 and 2012 extensive test campaigns with large share (>50 %) of thermally treated biomass pellets have been performed at the Willem Alexander Centrale (WAC). The tests included a complete programme with logistics, milling, co-gasification, etc.

5.2.2 Handling and storage facilities

Coal is delivered to the plant by barges, 1 500 – 2 000 tonnes per shipment. It is discharged by a grab crane into a harbour hopper. By means of a conveyor belt it is transferred from the hopper to conveyor and sent to the open coal yard or to the plant for storage. The coal yard at WAC has the dimension approximately 50 m × 180 m.

The removal of the coal from the coal yard is done by rotating reclaimers. Blending of different type of coals is achieved by using different operational setups of the two reclaimers (for example excavation depths, rotation speed, and location speed). The removed coal from the coal yard is transported via conveyors to any of the three plant bunkers. Before the coal is discharged on the conveyor it passes a magnetic separator and sieve building.

At the coal yard it is also possible to store wet coal separately that when used is mixed with the dry coal on the conveyor before the bunkers. In addition, biomass can be fed directly from a dedicated biomass storage facility (Figure 21). Biomass powder is added directly to the blow egg feeding vessels, i.e. is blended with the coal downstream the milling and drying.

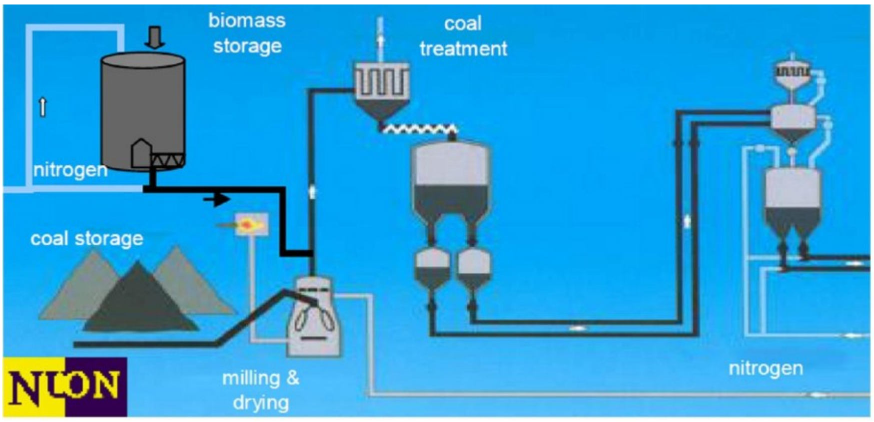


Figure 21: Fuel preparation at Willem Alexander Centrale

5.2.3 Issues foreseen with torrefied biomass

The following description shows how the fuel handling and storage of torrefied material might look like and do not describe any existing or planned solution. The aim is to highlight the critical points and issues that need extra considerations. The description is valid for both RW and WAC, and in case of issues related to only one of the plants it is mentioned specifically.

5.2.3.1 Delivery and un-loading

Biomass is assumed to be delivered by barges in similar way like the coal. To WAC there is no train connection to the plant so the only alternative supply route is by trucks. This can be an option for biomass for short distances for example from a nearby hub, as back up.

Biomass will be un-loaded by a grab crane and forward to the harbour hopper that deliver the biomass on a conveyor belt. Biomass that is not possible to discharge by the crane is removed by using manual reloading tools. If there is too large share of fines, this fuel might need to be handled separately. As “tight” crane as possible should be used to avoid pellets from falling out. An existing coal crane may need adjustments. A consequence may be need of extra cleaning of the off-loading area.

Compared to coal, special consideration needs to be taken regarding dusting. Full scale tests with thermal treated biomass indicate increased dusting compared to coal handling. High level of dust in the air increases the risk of dust explosion. It may also be a health and work environment issue.

A critical step is when the crane drops the fuel in the harbour hopper. To reduce dusting the height from which the crane drops the fuel should be low. A system for reducing the dust concentration must be used. It can be a water dispersion system (Figure 22) or a dust evacuation system.

Figure 22: Un-loading with water dispersion system in operation during full scale test at RW

The most critical issues in delivery and un-loading are *(i)* durability with related moisture content connected to dusting problem and *(ii)* parameters for dust explosion.

5.2.3.2 Transportation and transition stations

From the harbour hopper biomass will be transported on belt conveyors, via transition stations (for change of direction or level of conveyors), to storage in silos.

The conveyors are of conventional type. Concern should be given to dusting and to avoid layers of dusting on surfaces and equipment to avoid dust explosion. This is especially important in the transition stations (Figure 23). These should be insulated/tight and fit with de-dusting system. For thermally treated pellets it will be important to ensure removal of all dust layers with extra cleaning.

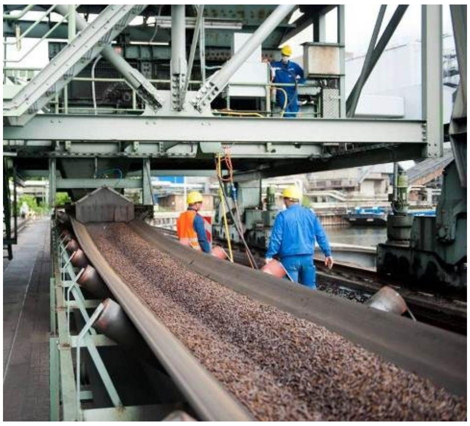



Figure 23: From harbour hopper to conveyor belt with water dispersion system (left) and at transition station (right) during full scale test at RW

Fire in conveyor belts is a common problem generally in plants. The conveyor belts are often made of some kind of rubber material. Simultaneous increase dusting might worsen the problem. To reduce the risk choice of material need to be considered.

The conveyor belt should be constructed in a way that prohibits the pellets from falling off. This is in most cases a minor and easily fixed problem. Other risks to consider are that pellets will fall backwards if the angle of inclination of the conveyor belt is too high and the height of transition station. Consequences may be a need of more complex reconstructions to longer conveyors and more transition stations.

The most critical issues at the transportation and transition stations are *(i)* durability with related moisture content connected to dusting problem, *(ii)* parameters for dust explosion, *(iii)* transportability due to shape of pellets and *(iv)* odour.

5.2.3.3 Storage

For the WAC plant, outdoor storage is not an option due to the location with nearby neighbours. The main reasons are risks for odour and dust emission to the air. By using a solution based on silos, weather resistance properties of the biomass become less important.

Biomass will be transported by an elevator to the top of the silos (assuming two silos). Possible crushing of the pellets during the filling of the silo or by the own weight of the biomass in the silo needs considerations. Discharge from the silo is from the bottom for example by a screw or rotary valve.

Extra considerations concerning storage time of the biomass are required. To minimize the risk of self-ignition the biomass should not be stored for a longer period than necessary. This is especially important in case of operational interruption in the plant. It must be possible to empty silos if needed, for example in case of a fire. The silo shall be equipped with e.g. de-dusting system and temperature measurements. Bridging is not expected to be a problem.

The most critical issues for silo storage are *(i)* durability with related moisture content connected to dusting problem, *(ii)* self-ignition and *(iii)* bulk density.

For outdoor storage (Figure 24) additional concerns must be taken regarding the risk of odour, especially if the plant is located close to neighbours, and also from a working environmental point of view. Also off-gassing of different organic compounds (like acetic acid, formic acid, formaldehyde) may be a problem, and must be checked that it does not exceed limits for working areas. Also the system for taking care of the eluate from the storage may need additional arrangement compared to coal. Sufficient weather resistance properties need to be verified. Biological activity is another factor to take into consideration.

Figure 24: A pile of thermally treated biomass pellets from top of reclaimer during full scale test at RW

Also for outdoor storage the risk of self-ignition will be a major concern. To reduce the risk contamination by foreign objects/materials must be avoided and temperature gradients monitored. It may also limit the height of the storage and thus request a larger space, compared to coal.

Coal storages are often compacted by using a wheel loader. The use of wheel loader on pellet storage may break the pellets and increase the amount of fines/dust. It may also be difficult/dangerous due to the pellet flow properties and require a low angle of repose, and thus a larger space for the storage is needed. Increased dusting can also be expected if a stack reclaimer is used for transporting the fuel in the storage area (Figure 25).

Figure 25: Reclaimer in operation handling thermally treated biomass pellets during full scale test at RW

The most critical issues for outdoor storage are *(i)* odour, *(ii)* eluate properties, *(iii)* off-gassing, *(iv)* biological activity, *(v)* weather resistance properties and *(vi)* height of piles as use of front loaders might be limited.

5.2.3.4 Fuel mixing, grinding and feeding

Good mixing of biomass with the coal needs to be secured to avoid an inhomogeneous mix that may cause disturbance in the milling process, as well as in the gasifier. The simplest way of mixing the fuel is that the biomass is falling down on the coal conveyor belt before the fuel reaches the bunkers. Mixing could also possibly be made with a front loader at the coal yard.

With regards to milling, during performed full scale tests at WAC with thermally treated biomass pellets it became clear that co-milling of biomass and coal decreases the capacity of the mills. However, the reduction of capacity can be compensated by using a third mill. The WAC has three mills but in normal coal operation two mills with a max capacity of 90 tonnes per hour are used to reach the maximal electricity production at the plant. Milling in a dedicated bio-mill and mixing with coal before the gasification in the WAC is not considered to be the best solution in the existing process due to the existing sluicing system between mills and gasifier. In a plant like RW a separate biomass mill (or mills) could be an option and with the biomass fed separately on one (or more) of the burner levels.

The most critical issues in fuel mixing, grinding and feeding are *(i)* the mixing point and determining the best point of mixing, *(ii)* the mills, in particular capacity, energy consumption and effects of heterogeneous fuel, and the choice between co-milling or dedicated milling and *(iii)* parameters for dust explosion.

It is noted that it is expected that thermally treated biomass delivered in form of briquettes can also be ground in existing mills but verification tests are needed. Briquettes might have specific advantage compared to pellets, though not specifically in milling. It is in particular assumed that briquettes have a lower production cost than pellets. In addition, durability and dusting properties, and risk for self-ignition when storing briquettes might be different though these are still open questions.

5.2.3.5 Summary

The most critical issues in the handling of torrefied biomass on-site at RW and WAC are summarised in Table 3. The fuel properties affecting the handling and logistics on-site will be crucial for a successful implementation of thermally treated biomass fuels. In all steps considerations must be taken regarding safety, workplace environment and health aspects, emissions to air and consequences on fuel properties affecting the plant performance.

Key fuel properties are *(i)* durability with related moisture content connected to dusting problem, *(ii)* self-ignition and consequential safety measures that must be applied and *(iii)* odour and consequential safety aspects and possibility to use the fuel in residential areas.

Dusting has been identified as a particularly critical issue connected to handling of thermally treated biomass and there is a crucial need for a method for quantifying dusting properties.

Vattenfall has started the work to develop and evaluate a method. Chemical fuel properties must be considered but was not in the scope of this study (§5.2.4).

Table 3: The most critical issues foreseen by Vattenfall when introducing torrefied pellets

System	Critical issues	Comments
Delivery and un-loading	• Durability with related moisture content connected to dusting problem • Parameters for dust explosion	• Solution to avoid /minimize effect of dusting are needed • Safety measures connected to dust explosion must be applied
Transportation and transition stations	• Durability with related moisture content connected to dusting problem • Parameters for dust explosion • Transportability due to shape of pellets • Odour	• Solution to avoid /minimize effect of dusting are needed • Safety measures connected to dust explosion must be applied • Keep equipment and surfaces free from dust • Avoid pellets fall off from the conveyor or backwards due to high inclination • Evacuation system may be needed to avoid odour
Storage	• Durability with related moisture content connected to dusting problem • Self ignition • Bulk density • Odour • Eluate properties • Off-gassing • Biological activity • Weather resistance properties • In case of outdoor storage - height of piles	• System for smooth feeding into silo may be needed to avoid fines • In case of outdoor storage use of front loaders might be limited • System for handling of eluate will be needed • Evacuation system may be needed to avoid odour • Safety protection system to avoid self-ignition will be needed
Fuel mixing, grinding and feeding	• Mixing point, where is the best point of mixing • Mills, co-milling or dedicated milling, capacity, energy consumption and effects of heterogeneous fuel • Parameters for dust explosion	• Control of feeding rated • Extra mill supervision for optimal operation • Safety measures connected to dust explosion must be applied

5.2.4 Demands set to torrefied biomass

The European standard EN450-1 establishes the requirements for the chemical and physical properties for siliceous fly-ash to be used as additive for concrete production. Therefore the application of the EN450-1 requirements is necessary. Previous large scale co-firing test with 43 % thermally treated biomass pellets performed by Vattenfall has shown results fitting the requirements. For plants not applying EN450-1, higher share of biomass is possible.

6 Conclusion

On the basis of the description of the handling and storage facilities at five existing coal-fired power plants in Europe as well as the experiences with co-firing biomass (and in some cases also thermally pre-treated biomass) the critical logistic steps are identified when switching from coal to torrefied biomass. The five plants cover differences in coal utilized (both lignite and hard coal) as well as conversion technology applied (both pulverized coal combustion and entrained flow gasification).

General specifications required for co-firing (torrefied) biomass

Although the focus in this report is on the critical logistic steps, some specific issues are identified not related to the handling and storage. In any case, primary physical as well as chemical properties, as well as specific safety issues have to be provided for the biomass as would be needed for coal as well. A summary is provided in the table below.

Physical properties	• Particle sizes and size distribution • Grindability • Bulk density • Ash fusion temperatures
Chemical properties	• Calorific value • Carbon content • Oxygen • Water content • Proximate and ultimate analysis • Ash mineral analysis • Heavy metals
Safety issues	• Explosion characteristics • Need for additional security measures
Other	• Deliverable quantities • Complying with EU EN450-1

In case fly-ashes are used as additive for concrete production, it will be necessary to apply to the EU standard EN450-1 requirements for the chemical and physical properties for siliceous fly-ash. These requirements can limit the share of biomass to be co-fired. For plants not applying EN450-1, higher share of biomass will be possible.

Specific issues foreseen in handling and storage of (torrefied) biomass

Although the five power plants taken into evaluation apply different coals and/or conversion technology the existing handling and storage facilities are not that different, and as such the issues foreseen in handling and storing (torrefied) biomass are rather similar. In the handling and storage, a distinction can be made between *(i)* supply to the power plant, (*ii*) the handling and *(iii)* the storage at the power plant and (*iv*) the end-use in the power plant.

The specific issues related to these four sections are presented in the table below. The table also provides some possible requirements to deal with the specific issues. Although the table highlights the critical points and issues that might need extra considerations it will have to be determined by means of tests if all these foreseen issues are indeed relevant.

System	**Specific issues**	**Specific requirements**
Supply *(delivery and un-loading)*	• Durability in relation to moisture content and dusting problem • Parameters for dust explosion	• Solution to avoid /minimize effect of dusting are needed • Safety measures connected to dust explosion must be applied
Handling *(transportation & transition station)*	• Durability in relation to moisture content and dusting problem • Parameters for dust explosion • Transportability due to shape of pellets (or briquettes) • Odour • Delivery and removal from bunkers	• Solution to avoid /minimize effect of dusting are needed • Safety measures connected to dust explosion must be applied • Keep equipment and surfaces free from dust • Avoid pellets fall off from the conveyor or backwards due to high inclination • Evacuation system may be needed to avoid odour • Modify existing excavators • Modify existing scrapers
Storage *(coal yard and boiler bunkers)*	• Durability in relation to moisture content and dusting problem • Bulk density • Biodegradation • Weather resistance properties • Height of outdoor stock piles • Self heating and ignition • Odour • Off-gassing • Eluate properties	• System for smooth feeding into silo may be needed to avoid fines • In case of outdoor storage use of front loaders might be limited • Safety protection system to avoid self-ignition will be needed • Evacuation system may be needed to deal with odour and off-gassing • System for handling of eluate will be needed
End-use *(mixing, drying, grinding & feeding)*	• Effects on homogeneity of the fuel • Decision on mixing point • Effect on milling capacity & energy • Parameters for dust explosion • Risk of drying with hot flue gas	• Control of feeding rate • Extra mill supervision for optimal operation • Either co-milling in existing mills or dedicated milling in new mills • Safety measures connected to dust explosion must be applied

In all steps considerations must be taken regarding safety, workplace environment and health aspects, emissions to air and consequences on fuel properties affecting the plant performance.

The key fuel properties identified are *(i)* the durability of the pellets in relation to the actual moisture content and the consequent dusting problem, *(ii)* self-ignition and consequential safety measures that must be applied and *(iii)* odour and consequential safety aspects and possibility to use the fuel in residential areas.

Dusting has been identified as a particularly critical issue connected to handling of thermally treated biomass and there is a crucial need for a method for quantifying dusting properties.