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Wood and Coal Co-firing – one route towards a reduced carbon footprint

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The Author

Markus Benter-Lynch is an Energy and Process Engineer by training, who has worked in the energy and industry sectors both in New Zealand and Europe. Markus' experience ranges from technology development to energy and process plant operations, BOO(T) contract development and delivering projects through EPC/EPCM contracts. While Markus' experience is not limited to the energy sector, he has been involved in numerous projects in this sector. One of Markus' key strengths is to bridge the gap between technical and commercial thinking. Currently with MWH NZ Ltd, Markus assists New Zealand and international clients in a number of areas ranging from concept development, contracting strategy development, economic assessments and project governance, to maximising plant efficiency and, if viable, helps clients switching to renewable fuels for energy generation.

Markus was awarded an EECA BANZ Bioenergy Scholarship to undertake a visit to Europe to explore the conversion of coal plant to wood fuel firing.

Abstract

Converting coal fired boilers to co-firing with biomass offers one route to greater use of a renewable fuel, thus reducing carbon emissions. While this approach is being adopted widely in Europe and the United States, there is limited knowledge of it in New Zealand. This paper provides a summary of the findings of a recent Bioenergy Association of New Zealand (BANZ) funded study tour of several boiler plants in Europe which have been converted from coal firing to co-firing of coal and wood and to wood firing only. It suggests that while converting grate fired boilers from coal to co-firing is far less common than converting pulverised coal fired, utility scale boilers, it is feasible and has been done in Europe. However, there are a number of issues to consider before embarking on such a conversion, especially, if more than 10% by volume of wood fuel is to be used.

1. Introduction

In 2012 BANZ awarded a travel scholarship to Markus Benter-Lynch, MWH NZ Ltd. The purpose of the scholarship was to learn about recent overseas experience with co-firing wood and coal and assist in disseminating this information in New Zealand.

The project began with a desktop study to identify potential destinations for this study tour (refer Appendix 1 for a global database of co-fired plants). The desktop study revealed that while numerous pulverised coal fired boilers have been converted to co-firing, conversion of grate fired boilers is far less common. Eventually a small number of boilers in Sweden, Denmark and Germany were selected for this study tour. These boilers had been using coal fuel only and had been converted to using a mix of coal and wood fuel or purely wood fuel (refer Appendix 2 for details of the plants visited). This report presents the findings from this study tour.

2. Background

The majority of New Zealand's electricity is generated from renewable fuels. However, heat for industrial processes, e.g. for the dairy and meat industries but also hospitals and other institutions, is usually generated with coal fired boilers. At the same time, New Zealand has a significant forest estate. This and the associated wood processing generate significant amounts of wood waste which can be used as a fuel. However, except for the wood processing industry itself, wood is not widely used as a fuel in New Zealand.

From an environmental (i.e. climate change) perspective it may be argued that it would be preferable for coal boilers to be replaced entirely with dedicated wood fuel boilers. However, it is unlikely that many owners of existing coal boilers in New Zealand will replace these with new, dedicated wood fuel boilers, unless the price of wood fuel drops significantly below the price of coal or the cost of carbon emissions increases. While the price of coal and carbon remains low, burning wood fuel in existing coal boilers provides a potentially economic route to greater use of a renewable, carbon neutral fuel in New Zealand. Careful modification of a coal boiler to co-firing can result in satisfactory boiler efficiency and emission levels at limited cost.

The use of wood fuel in existing boilers may also have a positive side effect on the uptake of new, dedicated wood boilers. The wood fuel supply chain in New Zealand is somewhat less mature than that for coal and other fossil fuels. An immature fuel supply infrastructure is a hurdle to investing in a dedicated wood fuel boiler, as the investor runs the risk of fuel supply shortages or price fluctuations. Increasing the use of wood fuel by using it as an additional fuel in existing coal boilers, will help the wood fuel supply chain to mature as demand for wood fuel grows.

Central and Northern Europe have long been recognised as leaders in the use of renewable energy, specifically in the use of wood and other biomass as a fuel. Denmark for example has just introduced a scheme whereby owners of coal fired boilers can access government funding of up to 50% of the capital cost of converting boilers from coal to renewable fuels (usually wood fuel), which is expected to lead to significant further uptake of the use of biofuels in Denmark.

One mechanism to increase the use of renewable energy that has gained widespread support over the last decade in Europe, as well as the United States, is the use of wood fuel in boilers that were originally designed for coal fuel only. The burning of wood and other similar biomass, together with coal, is typically referred to as “co-firing” or “co-combustion”.

The industry distinguishes between different ways of co-firing, these include:

1. **Direct co-firing:** The biomass fuel is combined with the coal before entering the furnace or in the furnace and burned in the same furnace.
2. **Parallel co-firing:** The biomass is burned in a separate furnace to the furnace in which the coal is burned but the steam/hot water is used for the same application (e.g. steam turbine).
3. **Indirect co-firing:** The biomass is gasified first and the gas is burned in the same furnace as the coal.

As the co-combustion of wood with coal in the same, existing furnace (1. above) is the most cost effective way of co-firing woody biomass with coal, this article focuses on this mechanism only.

While the majority of co-fired boilers in Europe and the United States are large pulverised coal fired boilers (i.e. power stations, similar in size and operation to New Zealand’s Huntly Power Station), there are also some smaller grate fired boilers, similar to the majority of New Zealand’s coal fired boilers that have been converted to wood fuel or co-firing.

2.1 Differences between coal and wood fuel properties

Co-firing small amounts of wood fuel (<10% by volume) can be achieved in many coal boilers, without any changes to the equipment. However, co-firing larger amounts of wood fuel is challenging and typically requires modification of the equipment. These challenges are related to the differences in the physical properties and chemical composition of wood relative to coal.

The following table provides a generic summary of the key differences between coal and wood fuel. It is noted that there are physical and especially chemical differences between different coals as well as between different types of wood. For the purposes of this report these are, however, not documented. Coal and wood fuel properties have been studied for many years and a large number of papers detailing the findings are publicly available.

It is further noted that the following points mainly apply to wood chips and saw dust, i.e. the most common and lowest cost forms of wood fuel available in New Zealand.

Physical/chemical property	Wood	Coal
Energy content	Lower	Higher
Bulk density	Lower	Higher
Moisture content	Higher	Lower
Ash content	Lower	Higher
Ash melting temperature	Lower	Higher
Sulphur content	Lower	Higher
Volatile content	Higher	Lower
Flow characteristics	Poor	Good
Quality variation over time	Variable	Relatively constant

Figure 1: Relative differences between wood fuel and coal

2.2 Practical issues related to co-firing

Numerous papers and books have been published on the subject of co-firing. Only two are mentioned here. The first one ("Biomass Co-Firing – an efficient way to reduce greenhouse gas emissions" by European Bioenergy Networks, 2003) because it provides a good overview. The other ("Co-Firing Opportunities – knowing what to expect" by A H Clemens and D Gong, CRL Energy Ltd, 2003) because it is based on New Zealand research. The following section provides a brief introduction to this subject only and focuses on conversion of grate fired boilers.

Many coal boilers can handle up to approximately 10% by volume of wood fuel without any changes. However, for larger quantities of wood, the difference in physical and chemical properties between the two fuels has a practical impact on the ability to co-fire wood fuel with coal. These impacts are summarised below, in the sequence in which the fuel moves through a system:

Fuel storage

Wood benefits from being stored under cover to reduce its moisture content. However, except for wood pellets which need to be stored in a dry place, wood fuels can and often are stored outside, similar to coal. However, wood fuel will degrade over time.

Fuel handling

Wood chips and saw dust require purpose designed handling equipment to avoid bridging (blockages). While small amounts of wood fuel can be handled in coal handling equipment, co-firing larger quantities of wood fuel requires installation of dedicated, purpose designed equipment, especially chutes and hoppers (belt conveyors can usually handle any combination of fuel type).

Fuel injection into the boiler

For grate fired boilers, coal is typically fed into the boiler and onto the grate, with either a spreader stoker or a guillotine door. Because wood chips and saw dust have a greater tendency to block and because of the higher moisture content, co-firing larger quantities of wood fuel requires a dedicated feed-in mechanism. It may be possible to install such a device next to the existing coal feed in system. The wood fuel feeder needs to achieve the following:

a) A build up of an even bed of fuel on top of the grate (even bed depth).
b) Ideally, injection above the grate to allow the wood to dry while in suspension (i.e. before it falls onto the grate).

An innovative solution to inject biofuel into an existing coal fired boiler has been developed by Aalborg Energie Technik a/s in Denmark. This combined coal and wood fuel stoker has been designed specifically for this purpose. Its compact design can enable installation of this dedicated unit in existing boilers with limited modifications.

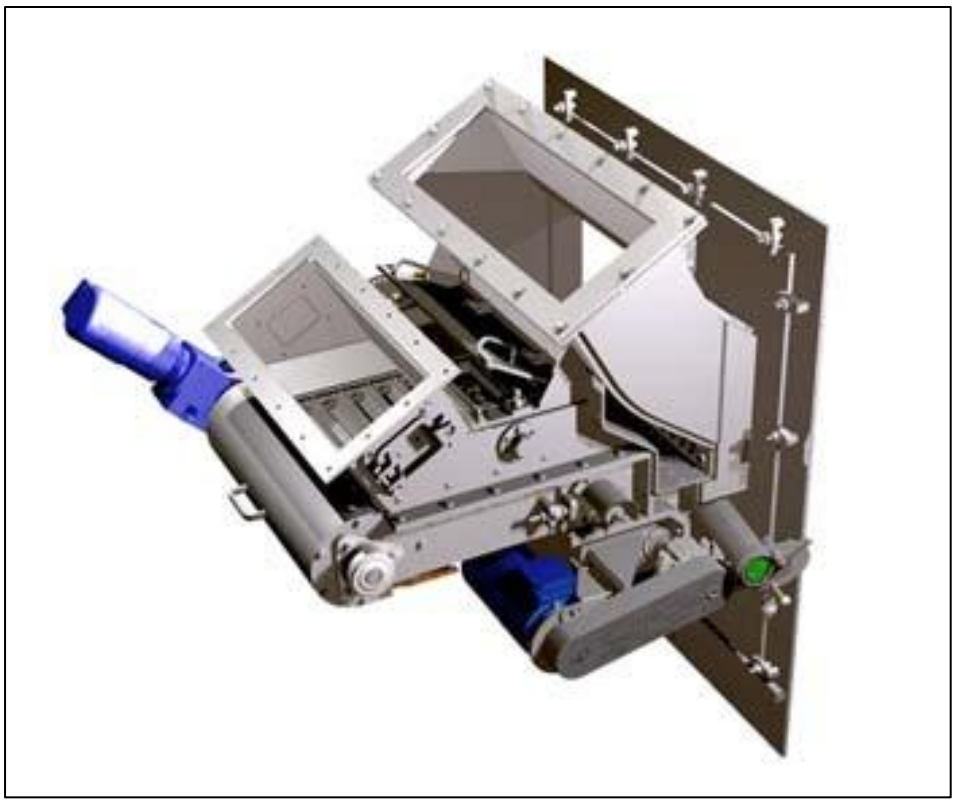

Figure 2: AET combi spreader schematic

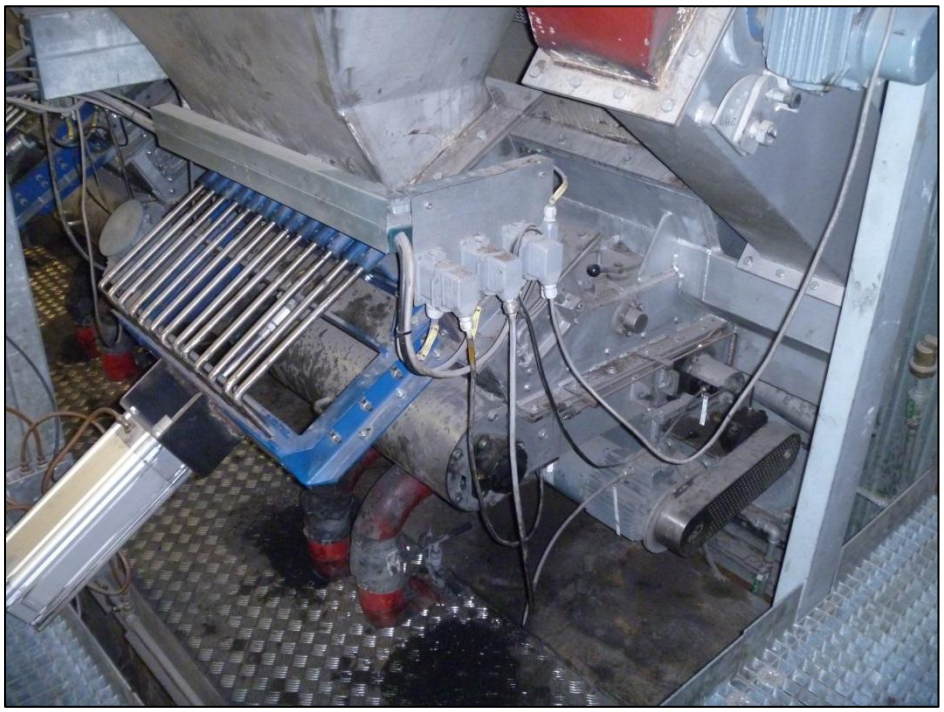

Figure 3: AET combi spreader installed at Randers plant (Denmark)

Grate and furnace

Ideally, the grate and furnace are not modified for co-firing to minimise capital cost. However, depending on the specific properties of the wood fuel to be co-fired (e.g. ash and moisture content), the design of the existing boiler, and the amount of wood fuel to be fired, modification of the furnace or replacement of the grate may be necessary, r.g. to provide room for injecting wood fuel in suspension (to enable drying, refer above), the grate may need to be lowered and the furnace extended downwards. To better control the airflow through the grate and spread the fuel evenly over the grate, a vibrating or step grate may need to be installed instead of the more common travelling grate for coal. Babcock Wilcox Voelund (Denmark) has successfully designed and implemented such changes, for example at Dalum Papir's Odense plant in Denmark (it is noted that this boiler, which was originally designed for coal and later converted to natural gas, was fully converted to wood fuel, i.e. not to co-firing).

A well known challenge with firing wood fuels is the lower melting temperature of wood ash, compared to coal ash. To avoid slagging and fouling as a result of co-firing, the surface temperature of the furnace and boiler internals needs to be kept below the temperature at which wood ash starts to soften, i.e. below approx. 600^{o}C. Where refractory needs to be installed, this may need to be water cooled, to limit the surface temperature. However, even if the surface temperature is limited, close spacing of tube bundles, e.g. superheater, can still result in build up of ash which existing soot blowers may not be able to remove as the ash particles can start to fuse. These issues need to be carefully considered for individual existing boilers before investing in co-firing. Also, erosion and corrosion, e.g. due to the particular ash composition of different wood and coal types and the higher gas velocities due to the greater amount of water vapour, need to be considered individually.

Application of more erosion and corrosion resistant materials, e.g. Inconel coating, may be necessary.

Flue gas treatment

While the lower sulphur content of wood fuel, compared to coal, means a reduction in SOx emissions when co-firing wood, co-firing with wood can result in greater carryover of particulates. This may require modification of the grit arrester to meet particulate emission limits and/or enable reliable operation of a bag filter downstream.

Heat recovery

The higher moisture content of wood fuel means that there is a greater amount of evaporated water (steam) in the flue gas. Where low temperature heat, e.g. <80^{o}C, has a use, e.g. for water heating, the flue can be cooled below its dew point to recover the energy (latent heat) stored in the water vapour in the flue gas. Depending on the moisture content of the wood fuel and the amount of wood co-fired with coal, the amount of energy which can be recovered from condensing the water vapour in the flue gas can be significant. While the condensate thus formed is corrosive due to the sulphur content in the coal, modern European boilers, which have a use for low temperature heat, typically use corrosion resistant materials to handle the flue gas stream and condensate.

3. Conclusion

As the above points illustrate, co-firing coal with wood in existing coal fired boilers using a grate can be achieved and provides a pathway to reducing carbon emissions. None of the above mentioned technical hurdles are typically insurmountable. However, before embarking on converting a coal boiler to co-firing, especially if more than 10% by volume of fuel is to be used, expert advice on the necessary changes, their technical feasibility and likely costs should be obtained.

Appendix 1: Global Database of Co-Fired Boilers

IEA Bioenergy Task 32 has prepared a global overview of around 150 initiatives where biomass is cofired in boilers that use different types of coal as the main fuel. The dataset is available as a searchable database at: http://www.ieabcc.nl/database/cofiring.html.

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
Indonesia		PT Indah Kiat Pulp & Paper		All	BFB			218			Coal	Peat, wood chips, bark, oil
Indonesia	Sumatra	Ocean Sky Co		All	BFB			155			Coal	Peat, bark, oil
Taiwan	Peikang		Ba Yu Paper	direct	CFB			NA			Coal	Sludge
Thailand	Chiang Mai		Provincial Electricity Authority of Thailand	All	CFB		20				Lignite	RDF
Australia	Collie	Muja	Verve Energy	All	PF		1040		5% mass	Trial, now C&D stage	Pulverised coal	Plantation forest waste and green waste
Australia	Ipswich, SE Queensland	Swanbank B	CS Energy	All	PF		4 x 125 (total 500 MW)		5% by weight	Trial	Pulverised coal	Wood waste
Australia	Lake Macquarie, Newcastle, New South Wales	Vales Point	Delta Electricity	All	PF	T-fired	2 x 660		<1% mass	Commercial	Pulverised coal	Wood waste
Australia	Liddell, New South Wales	Liddell	Macquarie Generation	All	PF	T-fired	4 x 500		<1% mass	Commercial	Pulverised coal	Wood waste (sawdust, shavings)
Australia	Lithgow, New South Wales	Mt Piper	Delta Electricity	All	PF	Wall fired	2 x 660		5% by weight, now <1% by weight	Commercial	Pulverised coal	Wood waste (fresh sawdust)
Australia	Lithgow, New South Wales	Wallerawang	Delta Electricity	All	PF	T-fired	2 x 500		<1% mass	Commercial	Pulverised coal	Wood waste (plantation sawmill residue and construction and demolition waste timber)
Australia	Rockhampton	Stanwell	Stanwell Corporation	All	PF	T fired	4 x 350 (1400)		5% by weight	Trial	Pulverised coal	Wood waste (sawdust and shavings)
Australia	Tarong	Tarong	Tarong Energy	All	PF		2 x 350		5% by weight	Trial	Pulverised coal	Wood waste
Austria	Ebensee		Solvay Osterreich	All	CFB			38			Coal	Lignite, gas, oil, wood
Austria	Frantschach	Mondi Papier & Zellstoff	Mondi Papier & Zellstoff	All	CFB		29	61	95,3% fuel power input (bark)	Commercial	Bark	Heavy fuel oil, coal, sewage sludge
Austria	Lenzing	Lenzing	Lenzing AG	All	CFB		40	108	64,6% fuel power input (bark)	Commercial since 1987	Bark	Heavy fuel oil, coal, sewage sludge, gas
Austria	St. Andrä	St. Andrä	Verbund Austrian Hydropower AG	All	Grate	2 T-fired, separate travelling grates under boiler	124	284 (2 x 5 MWth from biomass)	3% NCV	Commercial from 1995-2004, now closed	Pulverised coal	Wood chips, bark (major part)
Austria	Zeltweg	Biococomb	Verbund Austrian Hydropower AG	All	PF	Unknown	137	330 (10 MW fuel power input from biomass)	3% fuel power input (10 MW heat input)	Continuous operation	Pulverised Polish hard coal	Bark, sawdust, wood chips
Belgium	Les Awirs (Liege)	Les Awirs	Electrabel (www.electrabel.be)	All	PF		80		1	Fully commercial	Pulverised coal (no longer)	Wood pellets
Belgium	Rodenhuize	Rodenhuize	Electrabel (www.electrabel.be)	All	PF		180		1	Completely repowered	Pulverised coal (no longer)	Wood pellets

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
Belgium	Ruien	Ruien	Electrabel (www.electrabel.be)	All	PF	T-fired	540			Operational	Pulverised coal	Wood chips from recycled fresh wood, bark and hard and soft board residues
Denmark	Aabenraa	Ensted #3	DONG Energy	All	2 x grate	Straw boiler feeds steam to wood fired superheater, to #3 coal fired unit	40 MWe biomass in 630 MWe	95 MWth	6% heat of total steam prod in #3	Commercial since 1997	Coal	Straw, wood chips
Denmark	Aarhus	Studstrupvaerket #3	DONG Energy	Direct	PF	Separate straw burners	350	455	Max 20% heat, 7% continuous	Commercial since 2005	Pulverised coal	Straw
Denmark	Aarhus	Studstrupvaerket #4	DONG Energy	Direct	PF	Separate straw burners	350	455	Max 20% heat, 7% continuous	Commercial since 2003, experience since 1995	Pulverised coal	Straw
Denmark	Copenhagen	Amager #1	Vattenfall	All	PF	Same feeding lines, not simultaneously. 4 burners in each of 3 levels	80	250	Flexible from 0%-100%	Commercial since 2009	Pulverised coal	Wood pellets
Denmark	Copenhagen	Avedore #2	DONG Energy	All	Pf		365	480	70% pellets	Commercial since 2001	Natural gas	Wood pellets
Denmark	Copenhagen	Avedore #2	DONG Energy	All	Grate	Separate grate fired boiler, steam included in Avedore #2 main boiler	365	480	16% heat on total steam prod.	Commercial since 2001	Straw	
Denmark	Grena	Grenaa Co-Generation Plant	DONG Energy	Direct	CFB drum type	Pneumatic feeder	18.6	60	60% heat	Commercial since 2000	Coal	Straw
Denmark	Herning	Herningvaerket	DONG Energy	Direct	Grate		95	104	70% heat	Commercial since 2003	Wood chips	Natural gas
Denmark	Randers	Randers Cogeneration plant	Energi Randers	Direct	Grate (spreader stoker)		52	112	35% heat	Commercial since 2003	Coal	Wood chips
Finland	Anjalankoski	Anjalankoski mill	Stora Enso Publication Papers Oy Ltd	Direct	BFB		160	328		Operational	Biomass	Peat, REF, coal, HFO, NG
Finland	Anjalankoski	Myllykoski papermill	Myllykoski Paper Oy	Direct	BFB					Operational	Biomass	
Finland	Eura	Kauttua CHP plant	Fortum Power and Heat Oy	Direct	CFB		14	100		Operational	Peat	Biomass, coal, REF, HFO, LFO
Finland	Forssa	Forssan power plant	Vapo Oy	Direct	BFB		18	48		Operational	Peat	Biomass, HFO, LFO
Finland	Haapavesi	Haapavesi power plant	Vapo Oy	Direct	CFB		3	32		Operational	Peat	Biomass, Sludge, WSTGAS, LFO, HFO
Finland	Haapavesi	Haapavesi power plant	Kanteleen Voima Oy	Direct	PF		154	0		Operational	Peat	Biomass, HFO
Finland	Hamina	Summa mill	Stora Enso Publication Papers Oy Ltd	Direct	BFB		45	193		Operational	Biomass	Sludge, NG, peat, HFO
Finland	Heinola	Heinola Flutingmill	Stora Enso Oyj	Direct	BFB		25	161		Operational	Peat	Biomass, coal, sludge, HFO
Finland	Heinola	Heinola power plant	Lahti Energia Oy	Direct	PF		4	72		Operational	Biomass	Peat, HFO
Finland	Heinola	Rautsalo power plant	Vattenfall	Direct			15	35		Operational in near future	Biomass	Peat
Finland	Hämeenlinna	Hameenlinna power plant	Vattenfall Kaukolämpö Oy	Direct	BFB		60	175		Operational	Peat	Biomass, coal, LFO
Finland	Iisalmi	Iisalmi power plant	Savon Voima Lämpö Oy	Direct	BFB		15	65		Operational	Peat	Biomass, HFO, LFO
Finland	Imatra	Imatra mill	Stora Enso Oyj	Direct	BFB		154	859		Operational	Biomass	Peat, NG, Sludge, HFO, WSTGAS, Methanol
Finland	Joensuu	Joensuu plywood mill	UPM-Kymmene Wood Oy	Direct	Grate		4	23		Operational	Biomass	Peat, HFO

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
Finland	Joensuu	Kontiosuo CHP plant	Fortum Power and Heat Oy	Direct	BFB		50	120		Operational	Peat	Biomass, HFO
Finland	Jyväskylä	Keljonlahti	Jyväskylän Voima Oy	Direct	BFB					Operational in near future	Peat	Biomass
Finland	Jyväskylä	Rauhalahti CHP plant	Jyväskylän Energiantuotanto Oy	Direct	BFB		87	279		Operational	Peat	Biomass, coal, HFO
Finland	Jämsä	Kaipola mill	UPM-Kymmene Oyj	Direct	BFB		26	191		Operational	Biomass	Peat, HFO, sludge, coal
Finland	Jämsänkoski	Jamsankoski power plant	UPM-Kymmene Oyj	Direct	BFB		46	324		Operational	Biomass	Peat, REF, sludge, HFO
Finland	Kaipola			Direct								
Finland	Kajaani	CHP plant	Kainuun Voima Oy	Direct	CFB		105	206		Operational	Peat	Biomass, sludge, REF, coal, HFO, LFO
Finland	Kankaanp	Kankaanpaa power plant	Vatajankosken Sähkö Oy	Direct	BFB		6	31		Operational	Biomass	Peat, HFO, LFO
Finland	Kemi	Kemi mill	Oy Metsä-Botnia Ab	Direct	BFB		83	466		Operational	Biomass	Peat, HFO, WSTGAS, Methanol
Finland	Kemi	Veitsiluoto mill	Stora Enso Oyj	Direct	BFB		64	545		Operational	Biomass	Peat, sludge, LFO, methanol, hydrogen
Finland	Kerava		Keravan Lämpövoima Oy	Direct			21	48		Operational in near future	Biomass	Peat
Finland	Kirkkonummi	Kantvik power plant	Voimavasu Oy	Direct	Grate		4	55		Operational	Coal	HFO, peat
Finland	Kokkola	Kokkola CHP plant	Kokkolan Voima Oy	Direct	BFB		20	50		Operational	Peat	Biomass
Finland	Kokkola	Kokkola CHP plant	Fortum Power and Heat Oy	Direct	CFB		188	287		Operational	Peat	Biomass, REF, LFO, coal
Finland	Kotka	Hovinsaari power plant	Kotkan Energia Oy	Direct	BFB		50	85		Operational	Peat	Biomass, REF, LFO
Finland	Kuhmo		Kuhmon Lampo Oy	Direct	CFB			18			Coal	Peat, wood waste
Finland	Kuopio		Kuopion Energia	Direct						Operational in near future	Peat	Biomass
Finland	Kuopio	Haapaniemi power plant	Kuopion Energia	Direct	PF		89	180		Operational	Peat	Biomass, HFO, LFO
Finland	Kuopio	Savon Sellu	Powerflute Oy	Direct			18	73		Operational	Biomass	Peat, coal, HFO, LFO, sludge, REF?
Finland	Kuusamo	Kuusamo CHP plant	Fortum Power and Heat Oy	Direct	BFB		6	18		Operational	Biomass	Peat, HFO
Finland	Kuusankoski	Kuusankoski power plant	Kymin Voima Oy	Direct	BFB		80	185		Operational	Biomass	Peat, REF, sludge, HFO, NG
Finland	Lahti	Kymijarvi power plant	Lahti Energia Oy	Indirect	PF		175	263		Operational	Coal	NG, biomass, REF, HFO, LFO, peat
Finland	Lappeenranta	Kaukaa mill	UPM-Kymmene Oyj	Direct	BFB		90	559		Operational	Biomass	Peat, sludge, HFO, LFO, WSTGAS, Methanol, other
Finland	Lappeenranta	Lappeenranta power plant	Kaukaan Voima Oy	Direct	BFB		117	252		Operational in near future	Biomass	Peat
Finland	Lieksa	Kevatniemi power plant	Vapo Oy	Direct	CFB		8	50		Operational	Biomass	Peat, HFO, LFO
Finland	Lohja	Lohja heating plant	Fortum Power and Heat Oy	Direct	BFB		22	43			Coal	Wood waste, paper waste
Finland	Lohja	Lohja heating plant	Fortum Power and Heat Oy	Direct	BFB		22	43		Operational	Coal	Biomass, REF, HFO
Finland	Mikkeli	Pursiala CHP plant	Etelä-Savon Energia	Direct	CFB/BFB		61	141		Operational	Peat	Biomass, REF, HFO, LFO

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
			Oy									
Finland	Mänttä	Mantta power plant	Mäntän Energia Oy	Direct	BFB		25	184		Operational	Biomass	Peat, coal, HFO, sludge
Finland	Naantali	Naantali CHP plant	Fortum Power and Heat Oy	Direct	PF		260	440			Coal	Biomass
Finland	Naantali	Naantali CHP plant	Fortum Power and Heat Oy	Direct	PF		260	440		Operational	Coal	Biomass, WSTGAS, HFO, LFO
Finland	Oulu	Oulu mill	Laanilan Voima Oy	Direct	CFB, BFB		35	111		Operational	Biomass	Peat, REF, coal, HFO, LFO, WSTGAS
Finland	Oulu	Oulu mill	Stora Enso Oyj	Direct	BFB		95	569		Operational	Biomass	Peat, sludge, LFO, methanol, hydrogen
Finland	Oulu	Toppila power plants	Oulun Energia	Direct	CFB, BFB		188	401		Operational	Peat	Biomass, coal, HFO, LFO
Finland	Outokumpu	Outokumpo Oy		Direct	BFB			17.5, 24			Coal	Peat, wood waste
Finland	Pieksämäki	Pieksamaki power plant	Savon Voima Lämpö Oy	Direct	BFB		10	77		Operational	Peat	Biomass, coal, REF, HFO, LFO
Finland	Pietarsaari	Pietarsaari power plant	Oy Alholmens Kraft Ab	Direct	CFB,BFB		265	310		Operational	Peat	Biomass, coal, REF, HFO
Finland	Pori	Aittaluoto power plant	Pori Energia Oy	Direct	BFB		64	216		Operational	Peat	Biomass, REF, HFO, LFO
Finland	Pori	Pori mill	Porin Prosessivoima Oy	Direct	CFB		12	187.6			Coal	Biomass
Finland	Pori	Pori mill	Porin Prosessivoima Oy	Direct	CFB		12	188		Operational	Coal	Biomass, HFO, LFO, others
Finland	Pori	Pori mill	Porin Prosessivoima Oy	Direct	CFB		65			Operational in near future	Biomass	Peat, coal
Finland	Rauma	Rauma mill	UPM-Kymmene Oyj	Direct	CFB,BFB		76	350		Operational	Biomass	Peat, REF, HFO, coal, sludge
Finland	Rauma	Rauman Voima Oy	Rauman Voima Oy	Direct	BFB		50	190		Operational	Biomass	Peat, sludge, REF, HFO
Finland	Rautjärvi	Simpele mill	M-real Oyj	Direct	BFB		31	135		Operational	Biomass	Peat, sludge, REF, HFO, LPG, LGAS
Finland	Ristiina	Ristiina power plant	Järvi-Suomen Voima Oy	Direct	BFB		10	123		Operational	Biomass	Peat, HFO, LFO, REF
Finland	Rovaniemi	Suosiola power plant	Rovaniemen Energia Oy	Direct	CFB,BFB		32	89		Operational	Peat	Biomass, coal, LFO
Finland	Salo	Salo power plant	Voimavasu Oy	Direct	BFB		16	87			Coal	Biomass, peat, REF, HFO, LFO, B-gas
Finland	Salo	Salo power plant	Voimavasu Oy	Direct	BFB		16	87		Operational	Coal	Biomass, peat, REF, HFO, LFO, BGAS
Finland	Savonlinna	Savonlinna power plant	Järvi-Suomen Voima Oy	Direct	BFB		19	89		Operational	Biomass	Peat, REF, HFO, LFO, coal
Finland	Seinäjoki	Seinajoki power plant	Vaskiluodon Voima Oy	Direct	CFB		125	111		Operational	Peat	Biomass, coal, HFO, LFO
Finland	Säkylä	Sakyla power plant	Voimavasu Oy	direct	Grate		9.4	77			Coal	HFO, B-gas, peat
Finland	Säkylä	Sakyla power plant	Voimavasu Oy	Direct	Grate		9	77		Operational	Coal	HFO, BGAS, peat
Finland	Tampere	Naistenlahti power plant	Tampereen Sähkölaitos	Direct	BFB		190	260		Operational	Peat	Biomass, NG, LFO
Finland	Tornio	Tornio power plant	Tornion Voima Oy	Direct	CFB		40	90		Operational	Peat	Biomass, REF, coal, HFO
Finland	Turku	Linnankatu power plant	Oy Turku Energia Ab	Direct	PF		35	269			Coal	HFO, biomass
Finland	Turku	Linnankatu power plant	Oy Turku Energia Ab	Direct	PF		35	269		Operational	Coal	HFO, LFO, biomass

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
Finland	Vaasa	Vaskiluoto 2 - power plant	Vaskiluodon Voima Oy	Direct	PF		258	182			Coal	Biomass
Finland	Vaasa	Vaskiluoto 2 - power plant	Vaskiluodon Voima Oy	Direct	PF		258	182		Operational in near future	Coal	Biomass, HFO, LFO
Finland	Valkeakoski	Sateri power plant	Fortum Power and Heat Oy	Direct	BFB		14	90		Operational	Peat	Biomass, coal, REF, HFO, LFO, sludge, others
Finland	Valkeakoski	Tervasaari mill	UPM-Kymmene Oyj	Direct	BFB		46	270		Operational	Biomass	Peat, REF, sludge, WSTGAS, HFO
Finland	Varkaus		Corenso coreboard mill	Direct								
Finland	Varkaus	Varkaus mill	Stora Enso Oyj	Direct	CFB		121	441		Operational	Biomass	Peat, coal, REF, sludge, HFO, LFO, WSTGAS
Finland	Ylivieska	Tulolantie heating plant	Vieskan Voima Oy	Direct	BFB		7	44		Operational	Biomass	Peat, REF, HFO, LFO
Finland	Äänekoski	Aanekoski power plant	Äänevoima Oy	Direct	BFB		38	230		Operational	Biomass	Peat, sludge, HFO
Germany	Afferde			Unknown								Wood, straw
Germany	Bavaria	Bayernwerke AG		Direct	PF		108				Pulverised coal	Straw
Germany	Berrenrath		Rheinbraun AG	Unknown								Sewage Sludge, wood, straw
Germany	Boxberg		VEAG AG	Unknown								Sewage Sludge
Germany	Braunsbedra		EWAG	Unknown								Sewage Sludge
Germany	Bremen			Unknown								Wood, straw
Germany	Buschhaus		BKB	Unknown								Sewage Sludge
Germany	Duisburg Hochfeld		HKW II (Stadtwerke Duisburg)	Unknown								Sewage Sludge
Germany	Farge, Bremen		Preussen Elektra	Unknown								Sewage Sludge
Germany	Franken II, Frauenaurach		Bayernwerk	Unknown								Sewage Sludge
Germany	Heilbronn		EnBW	Unknown								Sewage Sludge, wood, straw
Germany	Jänschwalde	Jänschwalde	VEAG	All								Wood, straw
Germany	Karlsruhe		Rheinhafendampfkraftwerk	Unknown								Sewage Sludge
Germany	L?nen		Fechner GmbH	Unknown								Sewage Sludge
Germany	Lausward		Stadtwerke D?sseldorf	Unknown								Sewage Sludge
Germany	Lübbenau	Lübbenau (out of operation)	VEAG	All	PF	Wall fired	100		7% wt	Out of operation since 1996	Lignite	Wood, straw
Germany	Magdeburg	VEAG		Direct	PF		350				Pulverised coal	Wood
Germany	Moabit		BEWAG	Unknown								Wood, straw
Germany	Pforzheim		Stadtwerke Pforzheim	Unknown								Wood, straw
Germany	Saarberg	Saarberwerke AG		Direct	PF		75				Pulverised coal	Sewage sludge
Germany	Schwandorf		Bayernwerke	Direct	Grate			280			Lignite	Wood, straw pellets
Germany	Voerde		STEAG AG	Unknown								Sewage Sludge
Germany	Walheim		Neckarwerke	Unknown								Sewage Sludge
Germany	Weiher II		SaarEnergie AG	Unknown								Sewage Sludge
Germany	Weisweiler		RWE	Unknown								Sewage Sludge
Germany	Würzburg		Heizkraftwerk Würzburg	Unknown							Coal	Wood

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
Germany	Zolling		Isar Amperewerke / Bayernwerk	Unknown								Sewage Sludge
Italy	Brescia	Termoutilizzatore	ASM BRESCIA S.P.A.	Unknown								Municipal solid waste, industrial (non hazardous) waste
Italy	Friuli Gorizia	Monfalcone	Endesa Italia		PF		165				Coal	
Italy	Friuli Gorizia	Monfalcone	Endesa Italia		PF		171				Coal	
Italy	Liguria	Genova	ENEL		PF		245					
Italy	Sardegna	Fiumesanto	Endesa Italia		PF							
Italy	Sardegna - SULCIS	Sulcis 2	ENEL		PF		340		16% th		Coal	
Italy	Sardegna SULCIS	Sulcis 3	ENEL		PF		240		10% th		Coal	
Netherlands	Amsterdam	Hemweg Centrale (HW8)	Nuon	All	Pulverized fuel	Opposed wall-fired	670 MWe, efficiency 41%(LHV basis)		Currently, no co-firing	Co-firing tests, with 5 types of biomass have been performed with one coal mill	Pulverized coal	
Netherlands	Borssele	Borssele 12	EPZ	All	Pulverized fuel	Tangential	403 MWe		10-15% (heat-based, 2006)	Commercial	Pulverized coal	Kernels, paper sludge, shells, fibers, Main properties : NCV 16,5 GJ/ton, ash 2%
Netherlands	Geertruidenberg	Amercentrale 8	Essent	All	Pulverized fuel	Tangential	600 MWe	250 MWth	10-12% (heat-based)	Commercial	Pulverized coal	Wood pellets
Netherlands	Geertruidenberg	Amercentrale 9	Essent	All	Pulverized fuel	Tangential	600 MWe	350 MWth	27 % (heat based) direct (= 35 % mass based), 5 % (heat based) indirect	Commercial	Pulverized coal	Waste wood (indirect firing): shreddered, max. 20 % moisture; Pelletized biomass (direct co-firing)
Netherlands	Nijmegen	Gelderland	Electrabel	All	Pulverized fuel	Opposed-wall fired	602 MWe		3% (heat-based, till 2007), from January 2008 ; 5 - 8% heat based	Commercial	Pulverized coal	Pulverized wood. Bulk density 165-185 kg/m3, Particle size 0-3 cm, Moisture content < 20% (dry basis)
Netherlands	Rotterdam	Maasvlakte 1+2	E-ON Benelux	All	Pulverized fuel	Tangential	2 x 531 MWe		6% (heat-based, 2006) 9% on mm	Commercial	Pulverized coal	Biomass pellets (paper sludge, compost residues,compost wood)meat and bone meal, woodpellets, coffee
Norway	Sande		Sande Paper Mill A/S	Direct	CFB			26			Coal	Wood, RDF
Poland	Czechnica	Czechnica K2	Kogeneracja	All	BFB OP-130 (RAFAKO) (Metso) retrofit		0/25	76	1	Operational	100% Wet Biomass	
Poland	Gdansk	Gdansk 2,3,4,5	EC Webrzeze	Direct	PF OP-230 (RAFAKO), natural circulation	Tangential	0/55	179		Operational	Bituminous coal	
Poland	Gdynia	Gdynia unit #1.2	EC Webrzeze	All	OP-230 (RAFAKO) natural circulation	Tangential Low Nox burners	0/55 (condensation/ cogen)	179	0.069		Bituminous coal	

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
					230 tph							
Poland	Krakow	Krakow 1	ECK	Direct	PF OP-380 (RAFAKO), natural circulation	Tangential	120/97	306		Operational	Bituminous coal	
Poland	Krakow	Krakow 2	ECK	Direct	PF OP-380 (RAFAKO), natural circulation	Tangential	120/97	306	0.2	Operational	Bituminous coal	
Poland	Krakow	Krakow 3.4	ECK	Direct	PF OP-430 (RAFAKO), natural circulation	Tangential	0/110	306		Operational	Bituminous coal	
Poland	Rybnik	Rybnik 1,2,3,4	ERSA	Direct	PF OP-650 (RAFAKO), natural circulation	Wall fired	215/0		0.06	Operational	Bituminous coal	
Poland	Rybnik	Rybnik 5,6,7,8	ERSA	Direct	PF OP-650 (RAFAKO), natural circulation	Wall fired	225/0			Operational	Bituminous coal	
Poland	Wroclaw	Wroclaw BC-1	Kogeneracja	Direct	PF OP-230 (RAFAKO), natural circulation	Tangential	0/55	179	0.45	Operational	Bituminous coal	
Poland	Wroclaw	Wroclaw BC-2 BC-3	Kogeneracja	Direct	PF OP-430 (RAFAKO), natural circulation	Tangential	0/110	306	25% (for BC-2 when BC-1 off-line)	Operational	Bituminous coal	
Spain	La Pereda	Hunosa power station		Direct	CFB			50			Coal	Coal wastes, wood waste
Spain	Sogoma			Unknown								
Sweden	?stersund		Ostersunds Fjarrvarme	Direct	CFB			25			Coal	Wood, peat, bark, wood waste, oil
Sweden	Alvesta	Avesta Energiverk		Direct	CFB			15			Coal	Peat, wood
Sweden	Fors	Stora Enso Fors Mill	Stora Enso Ltd	Direct	CFB		9.6	55	0.9	Continuous	Coal	Wood, bark
Sweden	Halsingbourgi	Vasthamnsvert CHP		Direct	PF		180				Pulverised coal	Wood
Sweden	Karlstad	Karlstad Energiverken		Direct	CFB			90			Coal	Wood waste
Sweden	Link?ping	Tekniska Verken Ltd 1	Tekniska Verken Ltd	Direct	Grate	Spreader-stoker with a wander grate					Coal	Rubber waste
Sweden	Link?ping	Tekniska Verken Ltd 2	Tekniska Verken Ltd	Direct	Grate	Moving grate					Coal	
Sweden	M?rsta		Brista Kraft AB	Direct	CFB		40	80			Coal	Wood, various wastes
Sweden	Norrkoping		Norrkopings Kraft	Direct	CFB			125			Coal	Wood
Sweden	Nukopoing		Nukoping Energiverk	Direct	CFB			80			Coal	Wood, peat
Sweden	Nykopping	Nykopping Energy		Direct	BFB		35	100			Coal	Wood waste, peat, oil
Sweden	S?dert?lje	Soderenergi AB		Direct	BFB			120			Coal	Wood waste, peat, oil
Sweden	Skelleftea	Hedesbyn	Skelleftea Kraft	Direct	BFB			25	1	Continuous operation	Coal (formerly)	Peat 20%, pellets 80%
Sweden	Stockholm	Hasselbyvaerket	Fortum Power and Heat AB	Direct	PF		279		1	Commercial	Pulverised coal	Wood pellets, olive waste
Sweden	Uppsala	Uppsula Energi	Uppsala Energi AB	Direct	PF		320				Pulverised	Peat, wood

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
											coal	
UK		Ironbridge	Eon	Direct	PF		970			Trial	Pulverised coal	Wood
UK		Tilbury	RWEnpower	Direct	PF		1085			Trial	Pulverised coal	Wood
UK	Cottam	Cottam 1,3,4	EDF Energy	Direct	PF	Front wall (John Thompson)	500/0			Operational	Bituminous coal	
UK	Cottam	Cottam 2	EDF Energy	Direct	PF	Front wall	500/0		0.1	Operational	Bituminous coal	
UK	Didcot, Oxfordshire	Didcot	RWEnpower	Coal / biomass mix	PF	Wall fired	2100		10% heat	3 years operation	Pulverised coal	Wood, Animal feeds, Crop husks and pulp, in meal and pellet forms, Grass
UK	Kent	Kingsnorth	Eon	Direct	PF		2034			Trial	Pulverised coal	Cereal residues
UK	Lancashire	Fiddlers Ferry	Scottish and Southern Energy	Direct	PF		1995			Commercial	Pulverised coal	Various
UK	Near Retford Nottinghamshire	Cottam	EDF Energy	Indirect	PF	Wall Fired	2000	0	0.05	Commercial - 2 years	Pulverised coal	Various
UK	Near Retford Nottinghamshire	West Burton	EDF Energy	Indirect	PF	Corner fired	1980	0	0.05	Commercial - 2 years	Pulverised coal	Various
UK	North Yorkshire	UK	Drax Power	Direct	PF	Opposed wall	4000		Heat based	Commercial	Pulverised coal	Various
UK	Nottinghamshire	Ratcliffe	Eon	Direct	PF		2010			Trial	Pulverised coal	Various
UK	Rugeley Staffordshire	Rugeley	International Power	Direct	PF	Front wall fired	1000		None	Trial	Pulverised coal	N/a
UK	Scotland		Caledonian Paper plc	Direct	CFB			43			Coal	Wood, oil
UK	Scotland	Cockenzie	Scottish Power	Direct	PF		1200			Trial	Pulverised coal	Wood
UK	Scotland	Longannet	Scottish Power	Direct	PF		2400			Commercial	Pulverised coal	Sewage sludge
UK	Slough	Slough Heat and Power Ltd.	Scottish and Southern Energy	Direct	CFB		35		40% heat		Coal	RDF from waste paper and plastics
UK	Wales	Aberthaw	RWEnpower	Direct injection indepen-dent of coal burners	PF	PF is front and rear wall down shot burners. Solid biomass is horizontally fired in from the side wall	1599 Turbine upgrade		Max 5%	4 years with liquid/solid /energy crop	Pulverised coal	Tallow/palm oil /Bio18 Saw dust/wood chip/pellet/miscanthus/rape grass/willow maximum moisture 60% o
UK	Wales	Uskmouth	Welsh Power Group Ltd	Direct	PF		363			Commercial	Coal	Various Agri-products
UK	West Burton	West Burton 1,2,3,4	EDF Energy	Direct	PF, assisted circulation	Tangential (ICL)	500/0			Operational	Bituminous coal	
UK	Yorkshire	Eggborough	British Energy	Solid biomass is blended with coal and co-milled using existing coal mills, liquid	PF	Wall Fired	1960	5200	Max 10% by mass solid, liquid biomass as a replacement for HFO for starts and flame stabilisation	Commercial 5 years solid and 2 years Liquid	Pulverised coal	HFO - LCV 40 MJ/Kg, Ash < 0.1%, Water <1.0%

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
				biomass through								
UK	Yorkshire	Ferrybridge	Scottish and Southern Energy	Direct	PF		2035		6% mass co milled and 12% thermal bioswirl	Commercial	Pulverised coal	Various wood ,olives, shea, PKE
Canada	Ontario	Atikokan	OPG	Direct	PF	Front Wall	227	20 to 100			Lignite	Wood Pellets
Canada	Ontario	Lambton 1	OPG	Direct	PF	Tangential	500	10 to 20			Pulverized Coal	Dry Distillers Grain
Canada	Ontario	Nanticoke 4	OPG	Direct	PF	Opposed Wall	500	10 to 20			Blended Coal	Agricultural residues
Canada	Ontario	Nanticoke 6	OPG	Direct	PF	Opposed Wall	500	10 to 20			Blended Coal	Agricultural residues, wood pellets
Canada	Ontario	Nanticoke X	OPG	Direct	PF	Opposed Wall	500	20 to 100			Blended Coal	Wood Pellets
Canada	Ontario	Thunder Bay 2	OPG	Blended on Coal Pile	PF	Tangential	155	10 to 20			Lignite	Wood Pellets
Canada	Ontario	Thunder Bay 3	OPG	Direct	PF	Tangential	155	10 to 20			Lignite	Grain Screenings
USA	Ashland, Wisconsin	Bay Front Station	Northern States Power Company	Direct	Grate	Stoker grate boiler	44		100% wt	Continuous	Coal	Wood, shredded rubber, railroad ties
USA	Bismark, ND	North Dakota State Penitentiary	North Dakota Dept. of Corrections and Rehabilitation	Direct	Grate	Travelling grate		28,000 lb/h, 200 psig		Not yet finished	Lignite	Wood waste
USA	Burlington, VT	McNeil Generating Station	Future Energy Resources (FERCO)	indirect	Grate	Stoker grate boiler	50		15% heat	Since 1998	Coal	Wood chips
USA	Chesterton, In	Bailey Generating Station #7	NIPSCO	Direct	PF	Cyclone	160		10% wt	57 tests, 300 hours total	Pulverised coal	Urban wood waste, petroleum coke
USA	Coosa, Georgia	Hammond Generating Station #1	Southern Company/Georgia Power Company	Direct	PF	Front fired	100		13% wt	3 days	Pulverised coal	Sawdust and tree trim
USA	Dresden, New York	Dunkirk Steam Station #1	Niagara Mohawk Power Corp.	Direct	PF	T-fired, natural circulation	90		20 % heat	Long-term (six months) planned	Pulverised coal	Wood Residue and willow (energy crop)
USA	Dresden, New York	Greenidge Generating Station #6	New York State Electric and Gas (NYSEG)	Direct	PF	Tangentially fired with 4 elevations	108		30% wt	16 hrs/day	Pulverised coal	Wood chips
USA	Dublin, GA.		Southeast Paper	Direct	CFB		65	125			Coal	Sludge
USA	England	BL Station #1	Northern States Power Company	Direct	PF	Front-wall-fired cyclone	120		12% wt	2 months, 2 days with TDF, wood, and coal	Pulverised coal	Shredded pallet wood waste
USA	Fort Drum		Black River Partners	Direct	CFB			168			Coal	Anthracite, wood
USA	Gadsden, Alabama	Gadsden Steam Plant #2	Southern Company/Alabama Power Company	Direct	PF	T-fired with 3 levels	60		12% wt	3-4 weeks	Pulverised coal	Switchgrass
USA	Hammond	Georgia Power		Direct	PF		100				Pulverised coal	Waste wood
USA	Johnstown, Pennsylvania	Shawville Generating Station #2	Reliant Energy	Direct	PF	Wall fired	138		3% wt	7 days, 3-4 hours	Pulverised coal	Various ground wood
USA	Johnstown, Pennsylvania	Shawville Generating Station	Reliant Energy	Direct	PF	Tangentially fired twin furnace	190		3% wt	7 days, 3-4 hours	Pulverised coal	Various ground wood

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
		#3										
USA	Kansas City, Kansas	La Cygne Generating Station #1	Kansas City (MO) Power & Light	Direct	PF	Supercritical cyclone	840		5% wt	1 month, 2 shifts/day	Pulverised coal	Chipped railroad ties / PRB
USA	Lake Michigan, Indiana	Michigan City Generating Station #12	Northern Indiana Public Service Company (NIPSCO)	Direct	PF	Cyclone	469		20% wt	6 tests over 5 days	Pulverised coal	Urban wood waste / Shoshone coal / PRB blend
USA	Lakeland, Florida	Lakeland Electric #3	Lakeland Electric	Direct	PF	Wall fired	350		2% heat		Pulverised coal	RDF
USA	Madison, Wisconsin	Blount Street	Madison Gas and Electric Company	Direct	PF	Wall fired	2 x 50		15% wt	Unknown	Pulverised coal	Switchgrass
USA	Marshalltown, Iowa	Ottumwa Generating Station #1	IES Utilities Inc	Direct	PF	Tangentially fired with 6 elevations	650		2.5% heat	Ongoing	Pulverised coal	Switchgrass
USA	Memphis, Tennessee	Allen (T.H) Fossil Plant	TVA	Direct	PF	Cyclone	272		20% wt	10-24 tests, 3-6 hours each	Pulverised coal	Sawdust
USA	Milbank, South Dakota	Big Stone Plant #1	Otter Tail Power Co.	Direct	PF	Cyclone	450		1% heat	continuous (several years)	Pulverised coal	Seed corn and soy beans
USA	Milledgeville, Atlanta, Georgia	Harlee Branch Generating Station	Southern Company/Georgia Power Company	Direct	PF	Opposed fired	250, 319, 480, 490		1% heat	continuous (several years)	Pulverised coal	Sander dust
USA	Moncks Corner, South Carolina	Jefferies Generating Station #3 and #4	Santee Cooper	Direct	PF	Wall fired	165		20% wt	6 months	Pulverised coal	Wood chips
USA	Niagara Falls		UDG Niagara Goodyear	Direct	CFB			149			Coal	Tyres
USA	Oakridge, Tennessee	Kingston Fossil Plant #5	TVA	Direct	PF	Tangentially fired with 3 elevations	180		5% wt	9 tests, 3-4 hours each	Pulverised coal	Hardwood sawdust
USA	Oakwood, Illinois	Vermilion Power Station #1	Illinois Power Company (IP)	Direct	PF	T-fired	75		25% heat	3 hours	Bit coal	Railroad ties
USA	Pelzer, South Carolina	Lee (W.S) Steam Station #3	Duke Power Company	Direct	PF	Tangentially fired with 5 elevations	170		5% wt	2 days	Pulverised coal	Shredded railroad ties
USA	Pittsburgh, Pennsylvania	National Institute of Occupational Safety and Health (NIOSH)	NIOSH (National Institute Occupational Safety and Health)	Direct	Grate	Stoker grate boiler		55,000 lb/hr, 200 psig	40% wt	5 burns	Coal	Wood chips
USA	Pittsburgh, Pennsylvania	Pittsburgh Brewing Company	Pittsburgh Brewing Company	Direct	Grate	Travelling grate		42,000 lb/hr, 140 psig	40% wt	16 burns of 4-16 hours, One 72 hour burn	Coal	Wood chips
USA	Pittsburgh, Pennsylvania	Seward Generating Station #12	Reliant Energy	Direct	PF	Wall fired	32		12 % wt	Ongoing	Pulverised coal	Sawdust
USA	Port Wentworth, Georgia	Kraft / Riverside Plants #2	Southern Company/Savannah Electric and Power Company (SEPCO)	Direct	PF	Tangentially fired with 2 elevations	46		36% heat	11 tests, 8-10 hours a day	Pulverised coal	Sawdust from pallets
USA	Prewitt, New Mexico	Escalante Generating Station #1	Tri-State Generating & Transmission Association, Inc.	Direct	PF	T-fired with 5 levels	250		1% wt	2 years	Pulverised coal	Waste paper sludge
USA	Rumford, Maine	Rumford Cogen Co.	Rumford Cogen Co.	Direct	CFB		76	260			Coal	Oil, wood
USA	Savannah	SEPCO		Direct	PF		54				Pulverised	Waste wood

Country	Location	Plant name	Owner	Cofiring type	Boiler	Burner config	Output (MWe)	Output (MWth)	% heat	Status	Primary fuel	Cofired fuel(s)
											coal	
USA	Spring Grove, Pennsylvania	Spring Grove Paper Mill	P.H.Glatfelter Co	Direct	CFB			132			Coal	Anthracite, wood, oil
USA	Stillwater, Minnesota	King (Allen S.) Generating Station #1	Northern States Power	Direct	PF	Cyclone	560		5% wt	2 years (In commercial operation)	Pulverised coal	Kiln dried wood / pet. coke / PRB blend
USA	Tacoma, Washington	City Of Tacoma Steam Plant No. 2	Tacoma Public Utilities	Direct	BFB		18		80% heat	Ongoing	Coal	Wood, refuse-derived fuel (RDF)
USA	Tampa, Florida	Gannon (F.J.) Generating Station #3	Tampa Electric Company (TECO)	Direct	PF	Cyclone	165		5% wt	21 days (over a 60 day period)	Pulverised coal	Paper pellets
USA	Thomas Hill Reservoir , Columbia, MO	Thomas Hill Energy Center #2	Associated Electric Cooperative, Inc.	Direct	PF	Cyclone	175		7% wt	1 week	PRB coal	Railroad ties
USA	Tuscumbia, AL	Colbert Fossil Plant #1	TVA	Direct	PF	Front wall fired	182		5% wt	Up to 24 hours tests (ongoing)	Pulverised coal	Sawdust

Appendix 2: Boiler plants visited

Location	Owner/Operator	Fuel Originally Used	Fuel Used Now	Combustion Type and Output
Norrkoeping (Sweden)	e-on	Coal	Wood	Vibrating grate; $38MW_{el}$, $116MW_{th}$
Odense (Denmark)	Dalum Papir	Coal, then natural gas	Wood	Vibrating grate; 45t/h steam at 60bar, 480°C
Randers (Denmark)	Energie Randers Produktion	Coal	Coal and wood	2 x travelling (chain) grates; $52MW_{el}$, $110MW_{th}$
Berlin (Germany)	Vattenfall	Coal	Coal and wood	Pulverised coal; $255MW_{el}$, $363MW_{th}$

Norrkoeping plant