Dunball Biomass Project - Mechanical Considerations – SM Comments/Thoughts

Design considerations
These are significantly linked to the section on **type of biomass fuel**, as the characteristics of the fuel are integral to the design of the boiler needed and more detail on this would be useful to so that the boiler is fit for purpose, and a link can be made between the two. E.g. the significance of automatic boiler tube cleaning and the need for full ash removal due the increased ash content of wetland materials. The work RSPB had undertaken by Sustainable Energy Ltd specified the following:

Ash Removal
Due to the increased levels of ash produced from combusting the rush and reed, it is vital that the biomass boiler selected has a FULL ash removal system. There are many boilers on the market that claim to have a full ash removal system but in reality many just remove ash from one area of the boiler allowing ash to build up in other areas of the boiler.

The ash removal system should remove ash from ALL internal sections of the boiler on an ongoing basis, the ash should then be automatically collected and auger fed to an ash bin.

Boilers offering manual and partially automated ash removal systems should be excluded from consideration (e.g. Partial automated ash removal is a boiler that may have an auger that evacuates the ash from below the grate but does not include provision for fly ash in the secondary chambers.

Ash disposal
There are a variety of options for ash disposal. The ash can be removed from site as non-hazardous waste, by a licensed waste remover, or it can used on the land as a soil fertiliser. Ash tends to have a high pH and so it is not desirable to use too much in one place but can be very valuable if distributed thinly. The Biomass Energy Centre give an indicative dosage of 3tonnes per hectare; the ash can also be added to compost heap at a rate of about 15% of total by weight.

I have a contact for the contractor who operates the green waste composting operation for Durstons, who I am sure would be keen to receive ash to mix with this material (ash is a valuable source of potash), especially as it would be uncontaminated.

Boiler Grate
Different biomass boilers have different grate designs which broadly fall into two categories – a moving grate and a fixed grate. A moving grate boiler allows automatic de-ashing at programmable frequency, whereas a fixed grate does not allow ashing to be fully evacuated from the furnace zone and so manual intervention is required to scrape ash from the edges of the hearth. Due to the high levels of ash produced by combustion of rush and reed, fixed grate boilers should be excluded from consideration.

Automatic Boiler Tube Cleaning
Biomass boilers have either vertical or horizontal boiler tubes. The selected boiler should include continuous automatic boiler tube cleaning. Vertical tubes with reciprocating turbulators have been found to be slightly more effective in preventing the build-up of ash within the tubes as the ash falls downwards into a collection area that is extracted into an automatic ash extraction system. Horizontal tube boilers could be acceptable if a mechanical automated turbulator tube cleaning system is included.

Sustainable Energy completed a review of the chemical analysis of reed versus more traditional fuels confirms that a boiler fuelled by reed will generate ash at approximately 3-7.5% of input fuel by weight, compared to circa 1% ash for wood fuel. This means that when the plant is operational it will produce up to 7.5 times more ash than traditional wood fuel. This is not an issue for ongoing boiler performance as long as sufficient staff resource is allocated to de-ash and empty ash bins as and when required.

The presence of ash within the combustion zone will significantly affect the performance of a boiler, and so the requirement to automatically remove ash on an ongoing basis is included as a critical component within the biomass boiler specification. Also, the ash bins will need to be emptied much more regularly, so if normally an ash bin would require emptying on a weekly basis, if operating on wetland fuel, this would increase to daily emptying. It is therefore important that suitable and sufficient ash bins are provided to allow exchange of the bins while ash is being emptied.

	Reed	Wood chip	Miscanthus
Carbon, %	46.5	50.9	47.2
Hydrogen, %	5.9	6.6	6.5
Oxygen, %	42.5	42	41.7
Nitrogen, %	0.3	0.2	0.7
Sulphur, %	0.14	0.02	0.13
Chlorine, %	0.16	0.01	0.23
Ash Content, %	3 to 7.5	0.5 to 1.5	2.5 to 3
Volatile matter, %	67	84	81
Ash melt temperature 'C	<1500	1100	1300
Net calorific Value, MJ/kg	16.2	18.5	17.8
	46.5	50.9	47.2

Sustainable Energy also produced an indicative ash production per year for particular boiler sizes and are shown below, they assumed circa 6% ash generation by weight:

Boiler Output Required (kW)	Required Rated Capacity of Biomass Boiler (kW)	Amount of Fuel Needed per Year (tonnes)	Ash Produced per Year (tonnes) at 6%
20	29	7	0.4
25	36	7	0.4
30	43	19	1.1
40	57	12	0.7
50	71	16	1
60	85	18	1.1
75	110	24	1.5
100	143	124	7.5

Chlorine levels

Previous laboratory tests conclude that the Chlorine content in the reed could be circa 0.16%; this is over 10 times that of wood chip but is generally slightly lower than miscanthus. Miscanthus-derived fuel has been the subject of much boiler research and development in recent years, and it is generally accepted by boiler manufacturers that the high Chlorine content of the fuel can be managed by factoring in specific part replacements over the lifetime of the equipment and therefore does not preclude grassy fuels from use.

Ash-melt temperature

Previous laboratory testing concludes that reed has an ash-melt temperature that is higher than that of miscanthus and wood chip and therefore the combustion of reed should not cause issues relating to low ash-melt temperature such as clinker and slag formation inside the furnace areas of the boiler.

Size of boiler

Once again the form of fuel to be used will impact on the sizing of the boiler for example due to the low bulk density of loose fuel, the actual thermal capacity of a boiler run on harvested soft rush and common reed will be 30%-40% lower than when run on wood fuels. This means that a standard biomass boiler with rated thermal capacity of 100kW will only actually generate 60-70kW thermal output when run on rush and reed. This was taken into consideration when reviewing boilers within the range required.

Sustainable Energy felt that the boiler would need to have a rated capacity of circa 42% higher than actual thermal capacity required.

Analysis

a) Integration of a new heating plant

As the existing store is too small to accommodate the size of the biomass boiler, consideration could be given to a containerised system – many boiler companies offer this as a completely contained system and easy to set up, designed for sites that don't have boiler rooms big enough. RSPB had one specified for a 32kW ETA Hack boiler at Lakenheath Fen, details below:

Kit specification / summary

The existing gas boiler will be retained as back up heat supply and interlocked with Biomass boiler control.

An ETA eHACK32 Biomass Pod container will be installed onto new base as per ETA specifications. The container will contain the eHACK 32 chip boiler, 825ltr buffer tank and all pumps, valves and equipment to provide a sealed heating system.

The container will incorporate a fuel store with agitator feed system suitable for wood chip and chopped reed fuel types. The container will have retractable roof above the fuel store to enable top filling of chip/reed via digger bucket.

The new biomass heating system will be connected to the existing heating system via subterranean pipework between the container and the garages adjacent to the existing plantroom. As the pipework enters the garages at low level it will be extended up at high level in carbon steel pipework and run at high level across the garages, into the existing plantroom.

The biomass system pipework will be connected into the existing boiler supply pipework before the existing loss header via a diverter valve. This valve will be controlled by the Biomass boiler and while running will lock out the existing gas boiler. In the event of an issue with the biomass the ETA boiler will activate the valve and gas boiler system as backup heat source.

The existing building heating controls will be retained and function as current with the boiler in direct control of the buffer charging.

c) Fuel supply

It would be advantageous to specify a little more detail about what 'high quality' is – this would relate to moisture content particularly, but also particle size, contamination, etc.

d) Fuel store

The size will also be dramatically affected by the type of fuel selected due to different bulk densities, RSPB have done some work on this, in relation to the use of AgBags (large plastic vessels), as a method of storing fuel as storage:

Boiler Output Required (kW)	Required Rated Capacity of Biomass Boiler (kW)	Amount of Fuel Needed per year (kWh)	Amount of Fuel Needed per Year (tonnes)	Amount of Fuel Needed per Year – Briquettes (m^3)	Amount of Fuel Needed per Year – Chopped (m^3)	Length of Agbag to Store Annual Chopped Fuel (m)
20	29	24,360	7	27	43	6.5
25	36	24,542	7	28	44	6.5
30	43	68,400	19	76	122	17.5
40	57	43,576	12	49	77	11
50	71	55,953	16	62	100	14.5
60	85	64,358	18	72	116	17

75	110	83,318	24	92	150	21.5
100	143	445,333	124	497	792	113.5

The figures in the above table were based on the following baseline figures below, with the fuel energy density taken from tests we had completed through MEDAC Ltd.

Fuel Type	**Typical Moisture Content**	**Net Calorific Value - Dry**	**Net Calorific Value – As Received**	**Bulk Density – as Received (kg/m3)**
Loose chopped Reed	10-25%	15.8MJ/kg	11.24MJ/kg (25% M/C)	100-150
Briquetted Reed	5-10%	15.8MJ/kg	13.9MJ/kg	400 - 480

The bulk density of the material plays a significant part in the way the feedstock needs to be supplied and of course effects how many times the hopper needs to be filled. Although each feedstock might provide a similar calorific value the wetland materials have a much lower bulk density which means far more volume per tonne is required which occupies the fuel store more quickly and hence means that the fuel store needs to be refilled more regularly. The following bulk densities have been recorded for the different materials in chopped form:

Material	**Bulk density**
Chopped common reed	60kg/m^3
Chopped soft rush	52kg/m^3
Chipped soft woodchip	150kg/m^3
Chopped miscanthus	85/kg/m^3

A typical fuel store size is 25m^3, which would mean that based on the figures above, the following estimated refills per year would be required if the feedstock was presented loose:

Material	**Bulk density**	**Estimated annual refills required with 25m^3 fuel store capacity**
Chopped common reed	60kg/m^3	12.3
Chopped soft rush	52kg/m^3	13.9
Chipped soft woodchip	150kg/m^3	5.2
Chopped miscanthus	85/kg/m^3	7.7

As wetland material has not been used previously as a feedstock it is difficult to assess what the above estimates would mean in reality, especially at a time when the boiler is working to fulfil the maximum heat demand. It was planned that the trials to be undertaken through the DECC project would enable us to gain this knowledge and understand the viability of wetland materials as feedstocks of the future.

The bulk density of the material will also have implications for storage and movement and it can be seen from the table of comparisons below that there is a vast difference between the bulk density of loose, pelleted and briquetted biomass. It is therefore only economic and carbon efficient if loose material is utilised close to the site of production, for transportation further a field then it is more efficient for the material to be compressed.

e) Fuel delivery
If there are difficulties with regards to space, another option is to site the main fuel store elsewhere and load the smaller fuel store connected to the boiler as needed. The logistics of how material is moved from the storage to the fuel store and how the store is to be filled needed to be considered so that the design can accommodate the most appropriate method. A number of filling mechanisms could be employed such as through a blower, direct tipping from the delivery vehicle; however, one of the most straight forward is the use of a tractor and front loader. This was the method to be employed at West Sedgemoor as it was considered to be the cheapest and most suitable option that could be undertaken via their existing equipment. As such the fuel store design had to be adapted to provide suitable access for this. To enable filling in this way the entrance to the store was constructed on an angle, which provided the necessary room to manoeuvre for the tractor and front loader operator.

Emissions and filters
Emissions play a key role when burning materials and there is a need to ensure that the standards set by the UK's Renewable Heat Incentive (RHI) for particulates (PM10's) and nitrogen oxides (NOx) are met. Material particle size and its relationship to the feed mechanism, moisture content and bulk density will all impact on how the material performs and should all form part of the decision-making process when selecting the best boiler for the job. The current oxides of Nitrogen (NOx) and Particulate Matter (PM) concentration allowable limits under the RHI are 30 grams of PM and 150g NOx per gigajoule net heat input. The laboratory tests undertaken indicate that there are no materials that would cause significant emissions of particulates or NOx. However, it is likely that due to the very dusty nature of winter cut common reed, they could be above acceptable environmental or RHI particulate limits, and as a result, particle abatement equipment in the form of filters may be required. Therefore, it may be necessary to install a ceramic filter or an additional multi-cyclone. My work on biomass did touch on the use of a cyclone filter and the two main instances are detailed below:

When working with Sustainable Energy looking at different boiler types for burning wetland biomass they stated/recommended that:
'In order to meet RHI emissions compliance a particle abatement may be needed such as a ceramic filter or additional multi-cyclone – indicative costs for this for a circa 50kW biomass boiler could be £5k - £10k.'

When working with Heizomat undertaking burn tests we did get to the stage of completing trial work using a cyclone filter. During our initial analysis of NOx and Particulates during the first trial burn, the NOx fell within the limits, but the average particulate readings were far too high and would not pass the necessary emissions standards. However, Heizomat felt that this could be addressed with an additional cyclone filter in the boiler flue, which they felt would reduce the particulate emissions enough to attain the necessary standard. Tests to confirm the effectiveness of the filter were completed in May 2017, however the results were never written up or shared by the company and so the appropriateness of the boiler to burn loose common reed was never established.

However, trials that we undertook with ETA boilers, manufactured in Austria which tested a tonne of 75mm reed briquettes, produced very satisfactory results, with the heat output described as 'remarkable' in the ETA SH30 boiler and produced the following results with regards to emissions:

Material type	Material form	Kg/m^3	Reference
Common reed	Loose	52	Ash, Wynne
Common reed	Pellets	666	Ash
Common reed	Briquettes	1198	Bilgin, Ertekin, Kurklu, Wynne
Soft rush	Briquettes	1,200	Wynne

Emissions	**RHI Standards** grams per gigajoule	**Briquette trial – heat up phase** grams per gigajoule	**Briquette trial – normal heating phase** grams per gigajoule
PM10s (particulate/dust)	30	33	2
NOx (nitrogen oxides)	150	175	117

An approved renewable heat incentive (RHI) testing laboratory confirmed that when testing for both NOx and PM10s for RHI accreditation, all readings are taken when the boiler is at full load and during the normal heating phase. Any readings taken during the heat up phase before the boiler is up to temperature are disregarded. This was very positive, with the readings falling well within the RHI set limits during ‘normal’ running.
Tests were also completed with loose reed, after the trial burn, it was found that there were deposits of clinker in the combustion chamber. However, it was considered that this could be reduced with fine-tuning of the boiler during combustion. Due to the small sample being tested, it was not possible during the trial to adjust the combustion settings. The clinker formation was therefore of little concern.

In relation to ash production, the ash resulting from the burn was a fine ash, which was found to be similar to that produced when burning woodchip.

The trial burn raised no other issues and the test was classed as satisfactory in the context of the points raised. As a result of both trials ETA were happy to warrant the installation of their boiler range if used for the burning of winter harvested common reed.