

Advanced Steam Traction Trust

REPORT ON TRIALS AND RESEARCHES ON COAL SUBSTITUTION

John Hind and Ian Gaylor

A Recap...

Recap...

- Alternative fuel trials
 - June 2021
 - Initiative by the BVR
 - Working with the Heritage Railway Association
 - September 2021 – Stapleford using N&P Product
 - November 2021 – BVR using ‘improved’ Coal Products
 - Based on results from June trials
 - February 2022 – KWVR – 1st Standard Gauge using Coal Products Limited fuels
 - **24/2/2022 – the world changed!!**

Recap...

- Alternative fuel trials
 - Spring - Summer 2022
 - With CPL Fuels
 - BVR Phase 3 trials 21-22/3/22 and Phase 4 on 20-21/6/22
 - KWVR Trials
 - ELR Trials
 - National Trials
 - 5 Narrow Gauge
 - 7 Standard Gauge

Recap... – Some Test Engines



ELR – L&YR Class 23 - 51456



GWR 5643



L&YR 52322



KWVR – BR Standard 2MT - 78022

Recap...

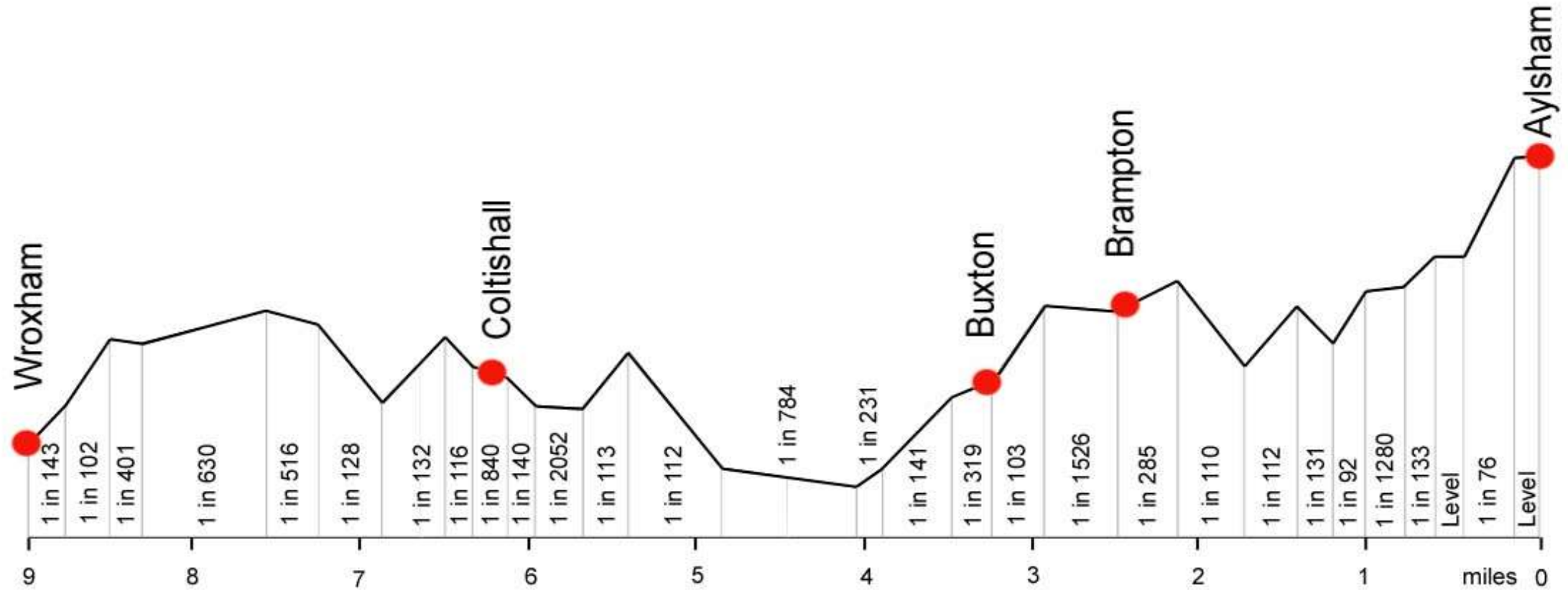
The tests were carried out in accordance with a previously agreed 'Preliminary fuel trial test methodology' with variations to the train consist:-

- For consistency the locomotive was No.6 Blickling Hall and the Driver was Scott Bunting
- Phases 3-4 Train consist was as follows:-
 - BVR No.6 'Blickling Hall'
 - 2 - 4 wheel brake van
 - 2 – 4 wheel Generator car
 - 16 – Bogie carriages
 - BVR No.3 (unpowered diesel locomotive)
- Total weight of consist approx. 71.8 tonnes



Recap...

The fuel trials were held at the Bure Valley Railway, BVR, over a nine mile line with switch back gradients :-

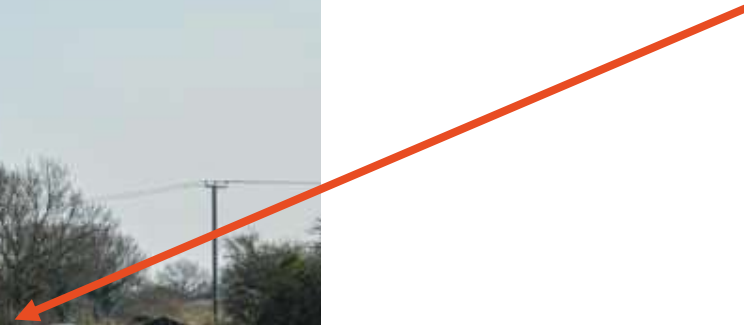


Gradient profile

Recap... - BVR Test Train



Normal length of a service train



Recap...

A critical parameter determining performance is the required maximum firing rate of the fuel which can be broadly categorised as follows:-

- 10-30 lbs/sqft grate/hr – *‘Undemanding work’* e.g. park and short museum lines etc
- 30-80 lbs/sqft grate/hr – *‘Average operating conditions’* for many heritage lines
- 80-120 lbs/sqft grate/hr – *‘Demanding work’* e.g. continuous steeply graded lines often using relatively small locomotives with large loads

Recap... - BVR & Standard Gauge Correlation

To validate the relevance of results obtained from testing 15” gauge locomotives at the BVR for other gauges a comparison with boiler performance of a standard gauge locomotive was made: -

	BVR No.6	Britannia	Notes
BVR No.6 'Demanding work', Peak firing rate Ffos-y-fran lbs/sqft grate/hr	80.1		See ASTT presentation (Energy of evaporated steam for BVR No.6 assumes a water feed temperature of 50 deg.F)
BVR No.6 'Demanding work', Average firing rate Ffos-y-fran lbs/sqft grate/hr	38.7		
Energy contained in fuel fired BTU	3426164		
Energy req'd to evaporate water BTU	2706888		
Grate area sq ft	4.0		See chart 18 BR Report 10800 dated April 1953
		42.0	
Boiler efficiency with exhaust steam injector %		83.8	
Benefit of coal economy from exhaust steam injector %		7.0	
Boiler efficiency without exhaust steam injector %	77.6	78.3	Identical within limitations of calculations

Comparison of BVR and Rugby test results

Thus the comparable results of the BVR study with historic Rugby tests for a Britannia illustrates the relevance of the scientific insights gained at small scale regardless of locomotive size which reduces the cost and size of equipment required to undertake future testing.

BVR Phase 5 Trials

APRIL 2023

Phase 5 – April 2023

- Later than previous years because of engine availability
- In operating season
 - No paths during day for test train
 - Departures were circa 1730 with returns circa 2030
- Test Team
 - Scott Bunting (Driver)
 - Gwion Clark
 - Ian Gaylor
 - John Hind
 - John Scott

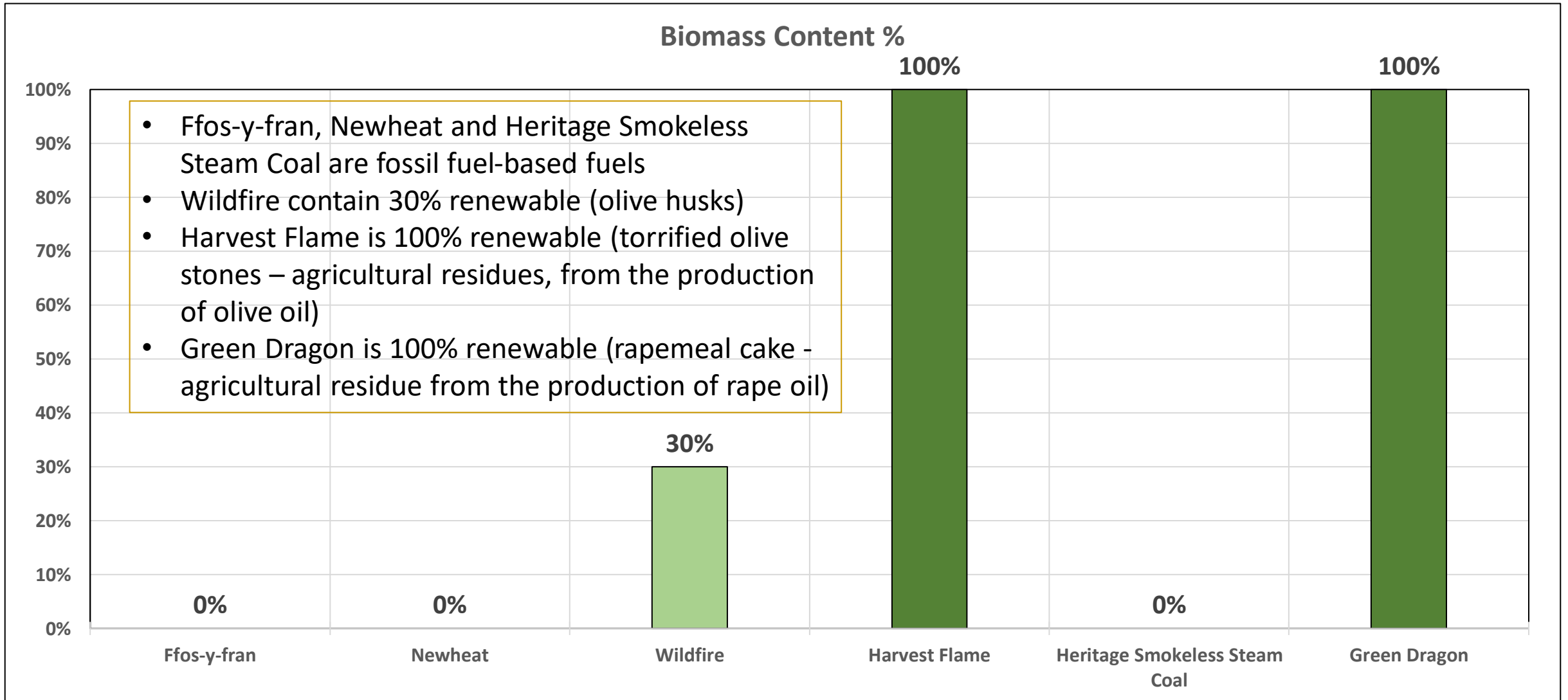
The fuels

- **Eire based, Arigna Fuels ‘Harvest Flame’**
 - 100% renewable fuel, made from torrefied olive stones
 - ‘Commercially available in Eire and currently costs circa €465 /tonne.
- **Phoenix Oils ‘Green Dragon’**
 - 100% renewable fuel made from rapemeal cake - waste product from rapeseed oil using domestically grown rapeseed.
 - This fuel is still under development, is available for trials but not available commercially.
 - Prices are expected to be circa £425/tonne.
- **CPL’s ‘Wildfire’**
 - contains up to 30% renewables in the form of crushed olive stones and currently costs £425/tonne.
- **CPL’s ‘Heritage Smokeless Steam Coal’**
 - uses anthracite as the base ingredient which is a fossil fuel. This is commercially available at circa £425/tonne.
- **Oxbow’s ‘New Heat’**
 - Uses between 60% and 65% petroleum coke* as its base ingredient with the balance predominately anthracite.
 - Commercially available at £475/tonne

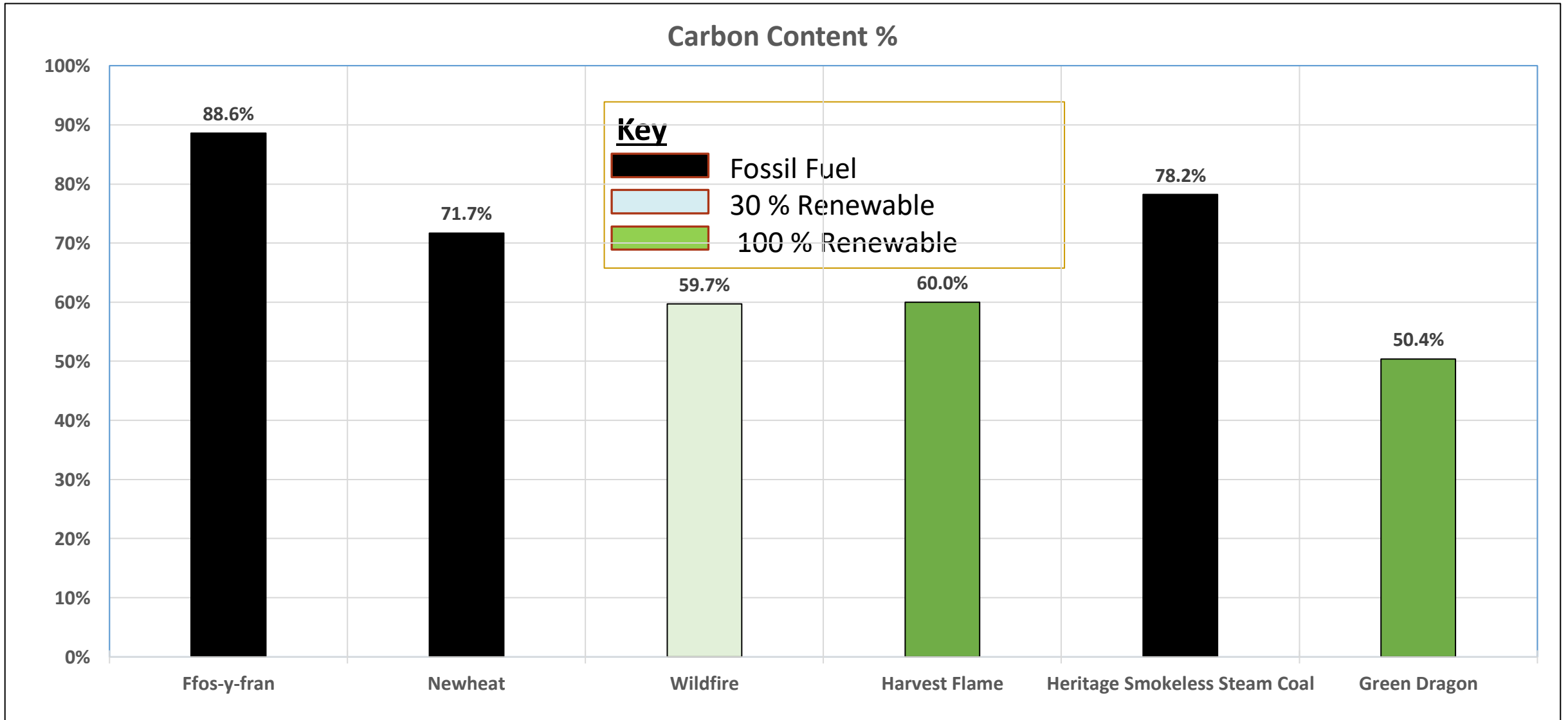
Some of the fuels



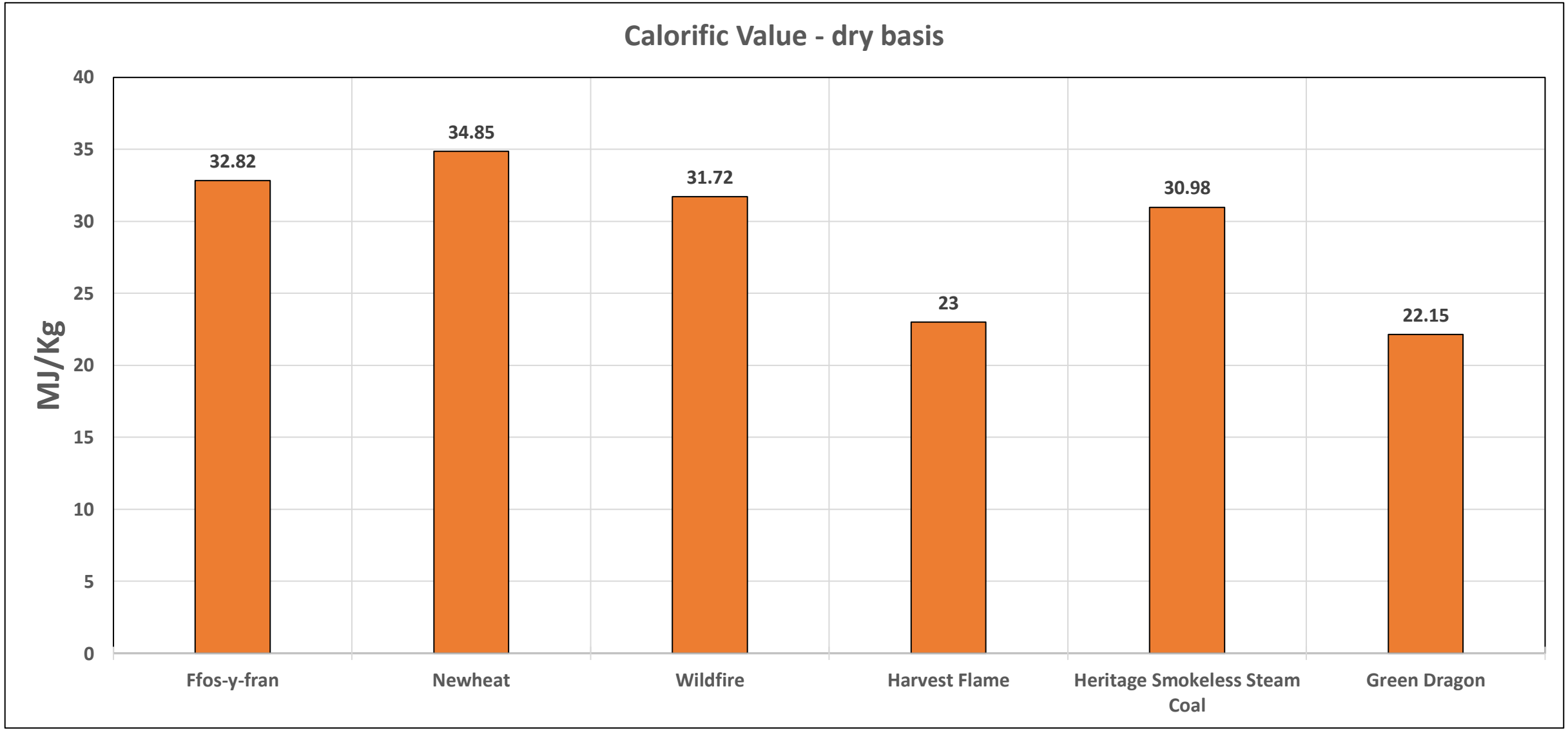
Renewable Content



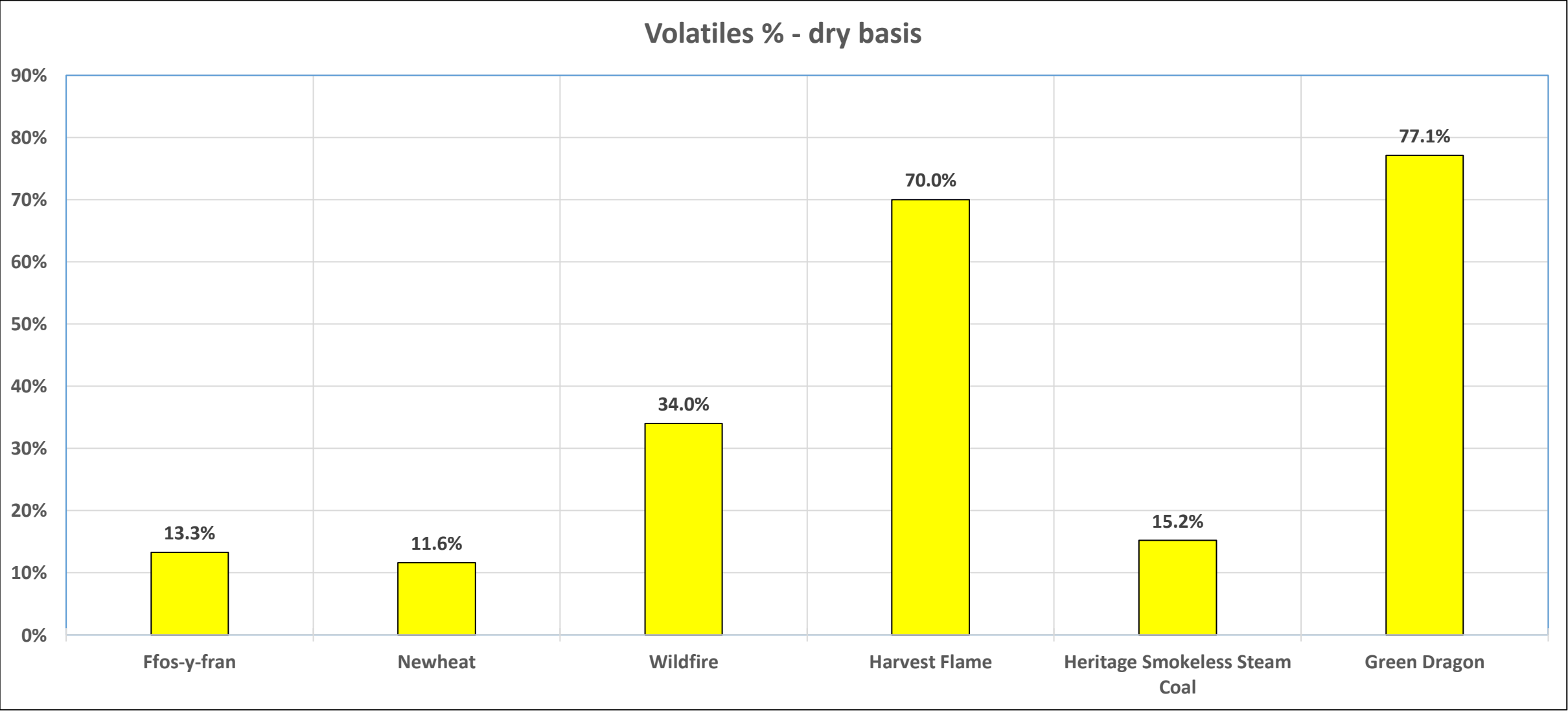
Carbon



Calorific Values

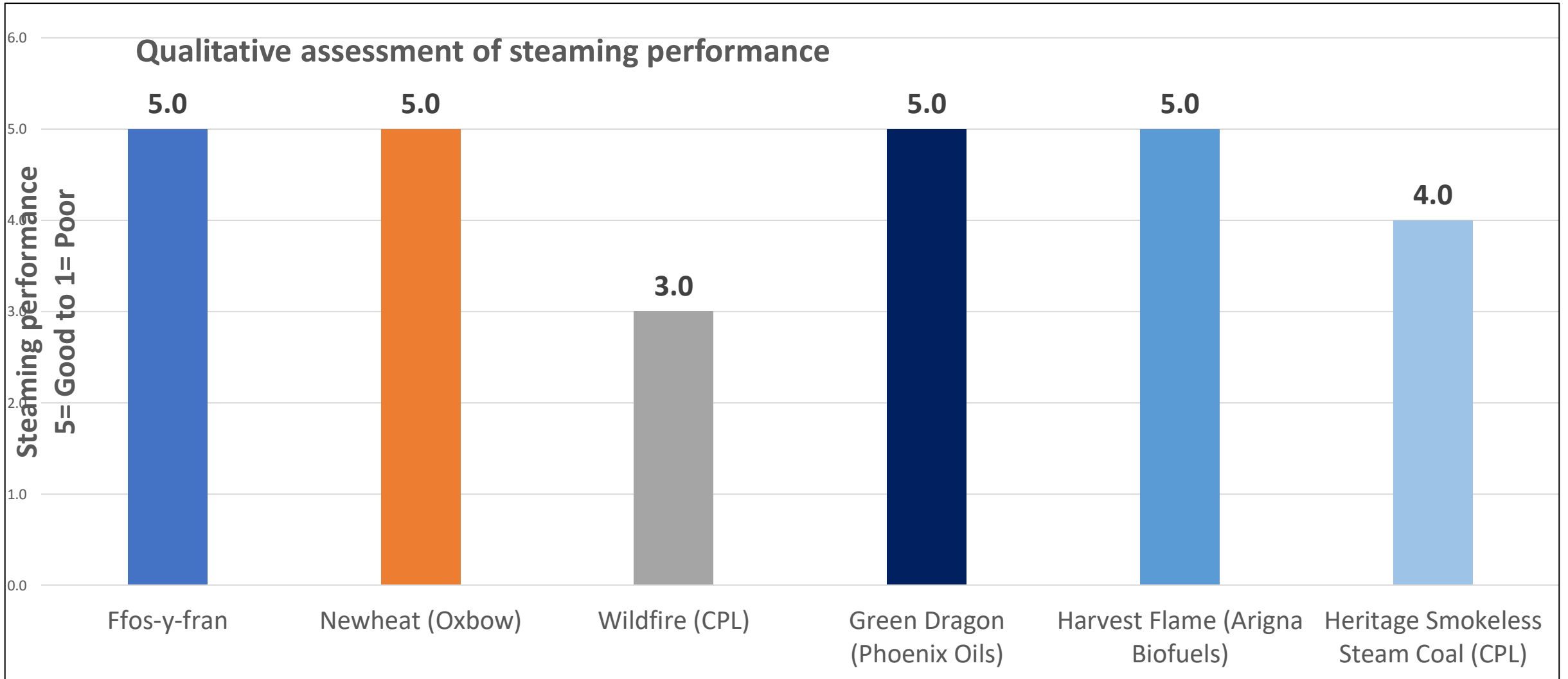


Volatiles



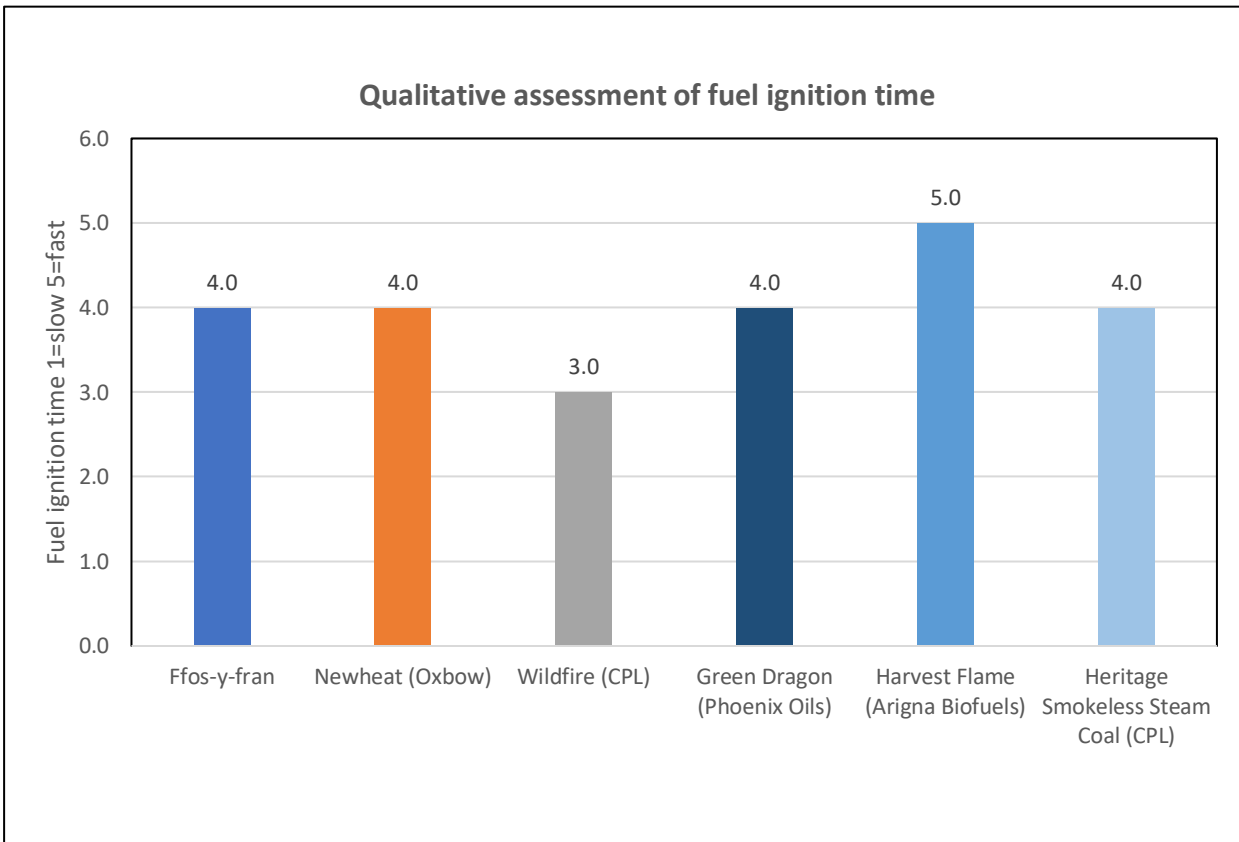
The results

Qualitative Steaming Performance



Fuel ignition time

The qualitative impressions of the footplate crew for fuel ignition time are:-

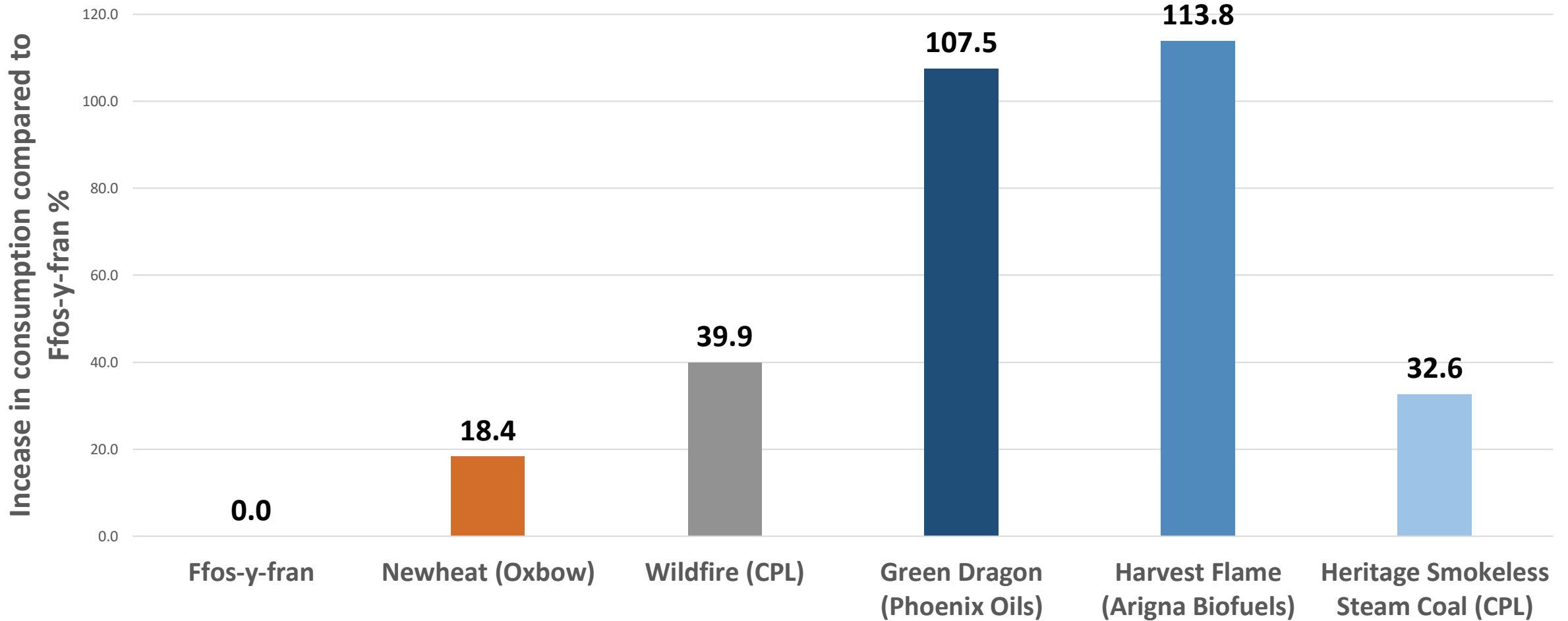


Conclusion: -

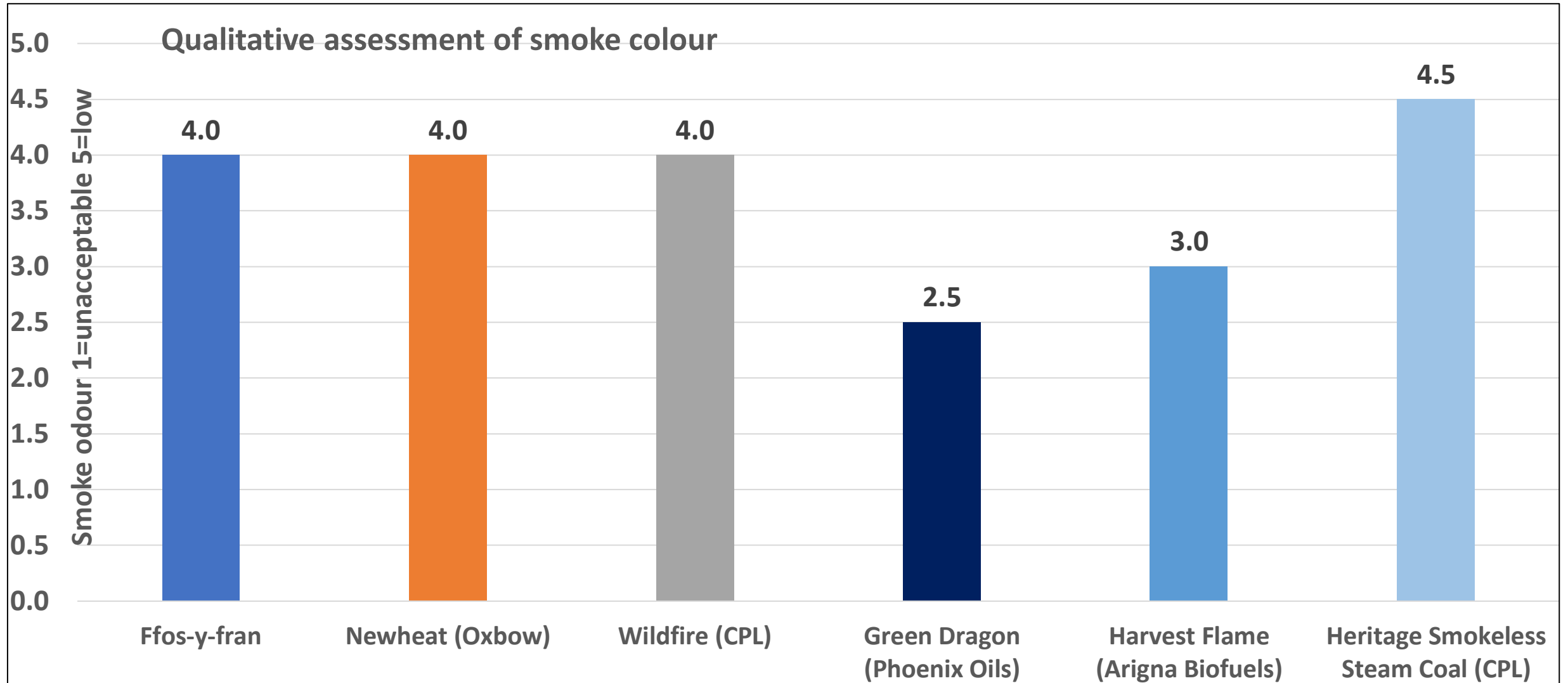
- The sample fuels had a comparative ignition time to that of *Ffos-y-fran coal* apart from *Wildfire* which was slightly slower and *Harvest Flame*, which was slightly faster.

Increase in Fuel Consumption

Fuel consumption increase compared to Ffos-y-fran



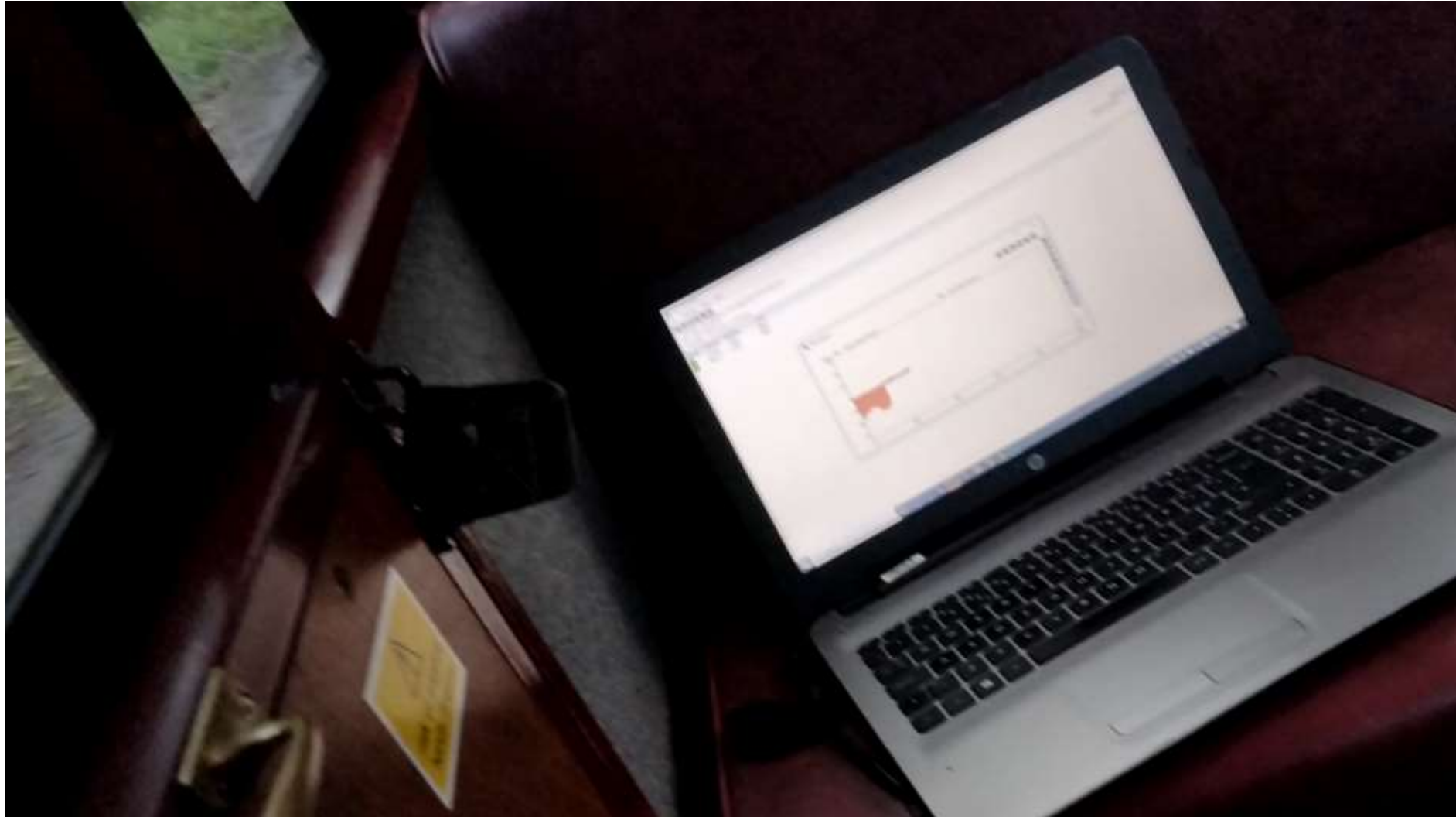
Qualitative Smoke Colour



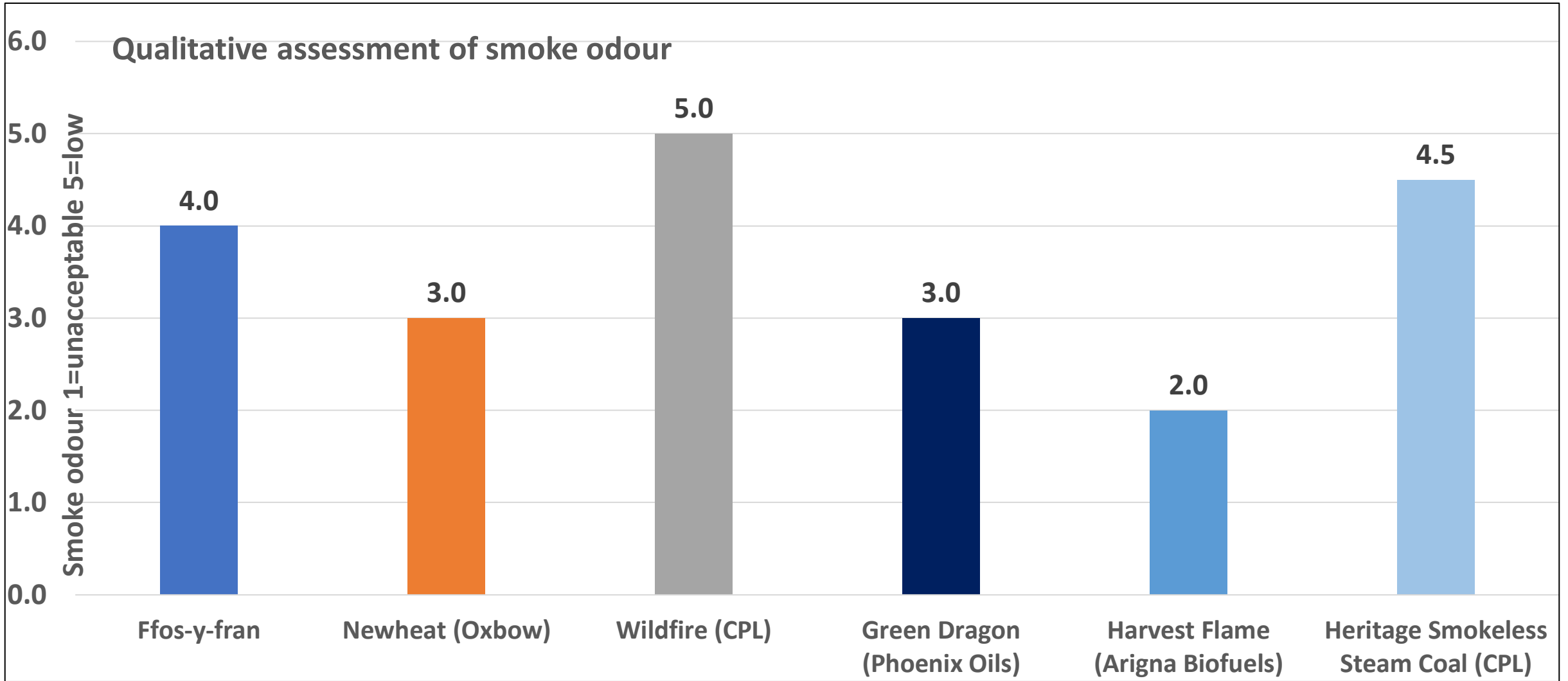
Arigna – New Flame - Torrified Olive Stones



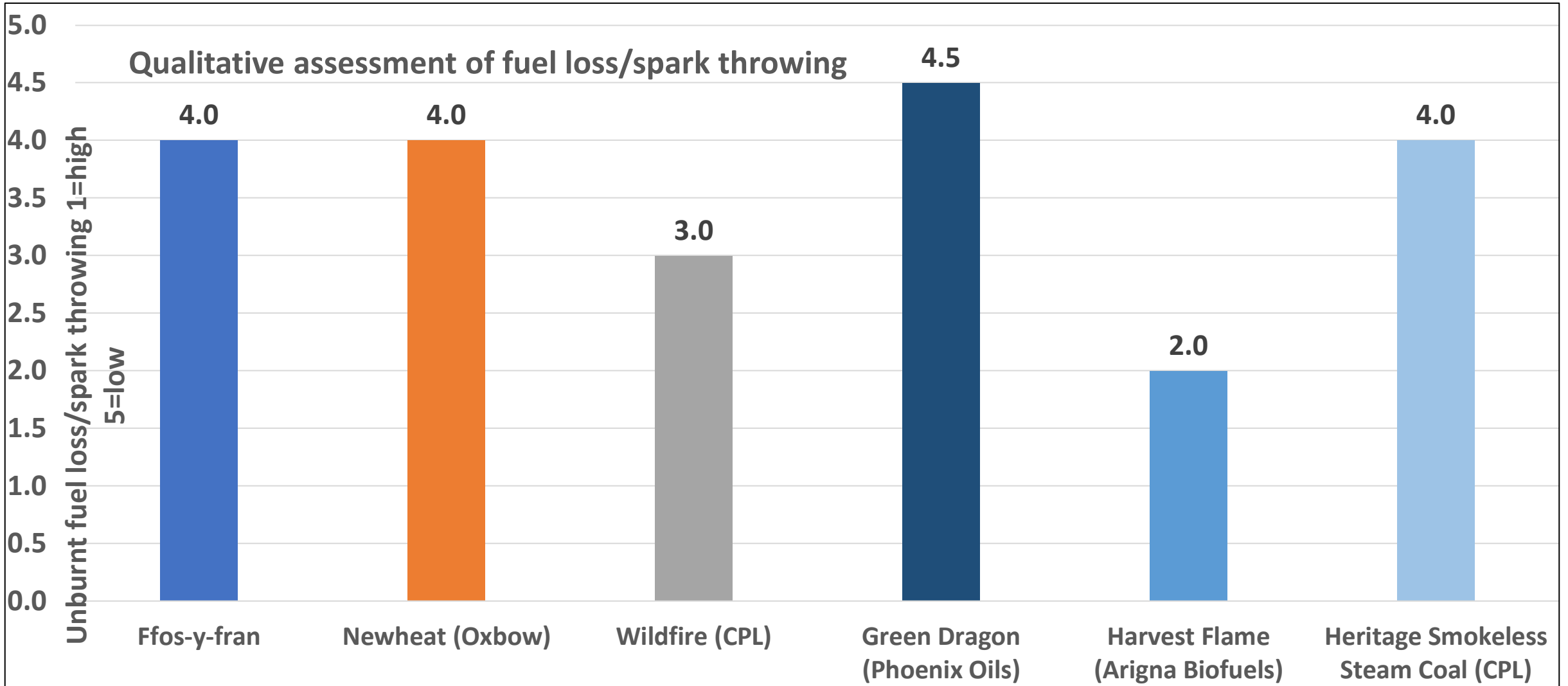
Phoenix Oils – Green Dragon - Rapemeal Cake



Smoke Odour



Fuel loss/spark throwing



Fuel Loss/spark throwing – CPL Wildfire



Fire temperature

For the most recent tests photographs of the fire were taken to assess fire temperature:-



17.4.23. Newheat at
Pumphouse 1200 deg.C



18.4.23. Wildfire at Hautbois
1300 deg.C



19.4.23. Heritage Smokeless
Steam Coal at Wroxham
Bank 1200 deg.C



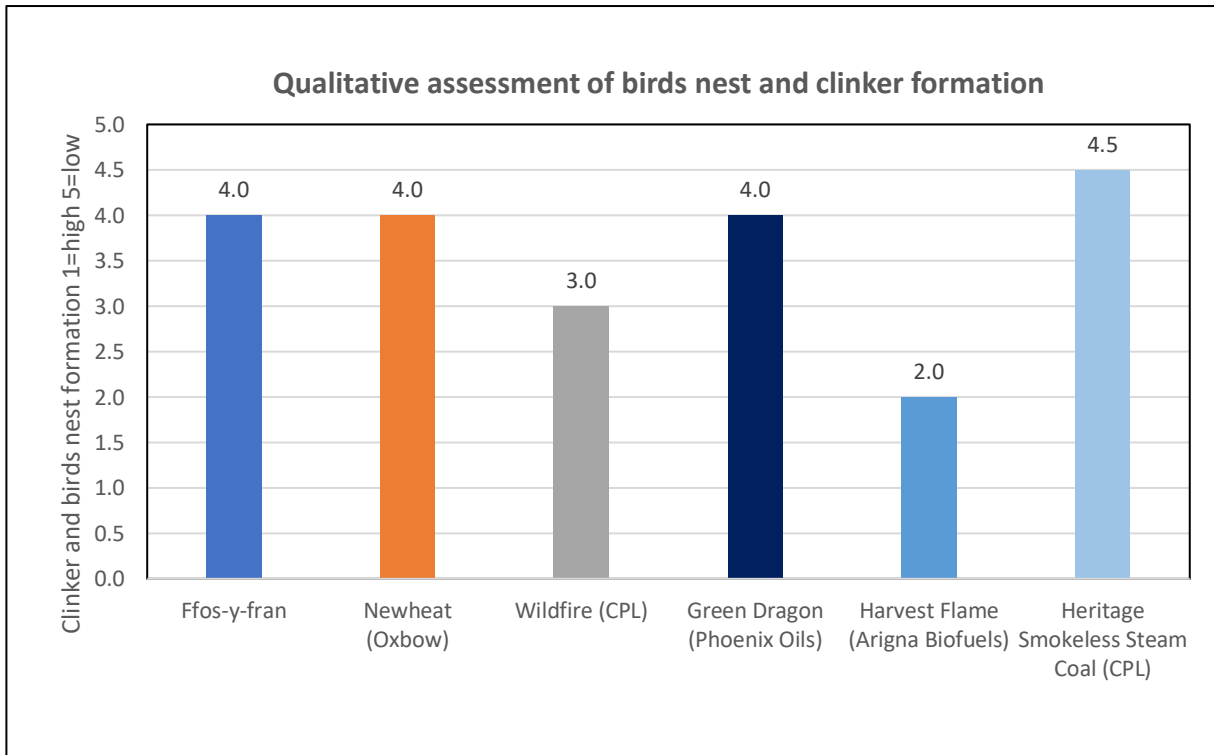
20.4.23. Green Dragon
at Aylsham 1200
deg.C

The temperature range from Red to White: -

- Red
 - Just visible: 525 °C (980 °F)
 - Dull: 700 °C (1,300 °F)
 - Cherry, dull: 800 °C (1,500 °F)
 - Cherry, full: 900 °C (1,700 °F)
 - Cherry, clear: 1,000 °C (1,800 °F)
- Orange
 - Deep: 1,100 °C (2,000 °F)
 - Clear: 1,200 °C (2,200 °F)
- White
 - Whitish: 1,300 °C (2,400 °F)
 - Bright: 1,400 °C (2,600 °F)
 - Dazzling: 1,500 °C (2,700 °F)

Typical maximum fire temperatures were around 1200 deg.C

Firebed clinker



- *Newheat, Heritage Smokeless Steam Coal and Green Dragon* produced around the same amount of clinker as *Ffos-y-fran coal*. Note, however there is some anecdotal concern that the quantity of clinker with *Heritage Smokeless Steam Coal* could be greater with prolonged high fire temperatures.
- *Harvest Flame and Wildfire* produced slightly more clinker than *Ffos-y-fran coal*.
- Spark arrestor blockage was an issue *Harvest Flame*.
- Severe 'Birds Nests' formed on the test shared by *Harvest Flame and Heritage Smokeless Small*, though it was not possible to attribute it to either fuel.

Summary

Trial Issues

- *Harvest Flame* and *Heritage Smokeless Steam Coal* were tested on a 9-mile single journey rather than the full 18-mile return journey and are not strict comparisons with previous tests.
- As the fuels were changed at Wroxham the consumption of the *Harvest Flame* may be overstated and the *Heritage Smokeless Steam Coal* understated.
- For the test of these two fuels, the quantitative consumption figures have had estimated corrections made, based on previous results.
- Retests are being planned for November.
 - These are not expected to substantially change the result's but will give a like for like comparison with fuels tested in 2021,2022 and 2023.
- Qualitative results from footplate crew verbatim observations are valid.

It's not just how it burns...

CORROSION RISKS FROM CHLORINE & SULPHUR

Chlorine, Sulphur & Petroleum Coke

%s on a Dry Basis	Ffos-y-fran	Arigna Fuels 'Harvest Flame'	Phoenix Oils 'Green Dragon'	CPL 'Wildfire'	CPL 'Heritage Smokeless Steam Coal'	Oxbow 'Newheat'
Petroleum coke content	Not applicable	Not applicable	Not applicable	Not applicable	Approximately 20%	>60% <65%
Chlorine	.07%	<.03%	.03%	.06%	.02%	Not given
Sulphur	.92%	.07%	.06%	1.63%	1.29%	1.91%

- The sulphur content of Newheat trialled is higher than the sulphur contents of fuels traditional used by British Railways
 - Risk of accelerated boiler corrosion.
- Oxbow plan to produce a small production run with reduced sulphur of between 1% and 1.2% for the next series of trials.

Trial Issues

- The results of the trials with *Harvest Flame* and *Heritage Smokeless Steam Coal* were and are not strict comparisons with previous tests.
 - As the fuels were changed at Wroxham, the consumption of the *Harvest Flame* may be overstated and the *Heritage Smokeless Steam Coal* understated.
 - This effected the fuel consumption figures which have had estimated corrections based on previous results.
 - Retests are planned for later in the year. These are not expected to substantially change the result's but will give a like for like comparison with the other fuels tested in 2023 and 2022.
- Due to data recording issues water consumptions during the trials of *Newheat* and the *Green Dragon* were estimated as an average based on previous trial results.
- Both the BVR and Tal-y-llyn Railway report in separate trials that *Newheat* burns very hot, with the Tal-y-llyn Railway reporting firedoor distortion and the BVR finding flakes of firebar in the ashpan contents.
- Although no causal link is known on two separate occasions Drivers reported headaches when burning *Green Dragon* at both the BVR and Fairbourne Railways (possibly closeness of exhaust plume to the Drivers' head on narrow-gauge replica engines is a contributory factor).
 - Phoenix Oils have arranged laboratory tests to understand the constituents of the smoke.

Post Trial Issues

- The CPL fuels performed adequately in the April tests
- The batch produced in May 2023 performed significantly worse with severe clinkering
- Effected services on 3 railways
 - BVR
 - Welshpool & Llanfair
 - NYMR
- Traced to a change in coal supply

Future funding?

Future Funding?

- National Heritage Lottery Fund funding review 2023

<https://www.heritagefund.org.uk/about/heritage-2033-strategy/protecting-environment>

What we mean

We will support natural heritage and environmentally sustainable projects that help the UK meet its nature recovery targets and mitigate the impact of climate change on heritage.

What we will do

Environmental footprint: We will support heritage projects that reduce adverse environmental impacts and help heritage to adapt to our changing climate. If projects involve construction, we will encourage restoration, conservation and reuse, rather than new build.

What we have learnt

AFTER 3 YEARS OF TRIALS

What we have learnt

- It's not just performance 'on the road'
 - Effects on crew health
 - Smoke
 - Odour
 - Effects of too high a chlorine and sulphur content
 - Storage
 - Must not deteriorate in storage
 - Manufactured Solid Fuels have potential to reduce fire risk
 - Manufacturing process must be capable of industrialisation
 - Manufactured Solid Fuels need quality control in manufacture

What we have learnt

- **Currently** there is no 'like for like' *solid fuel* replacement for coal
 - Fuel consumption
 - Emissions
 - Cost

Does not mean one cannot be found!!

Questions?