Advanced Steam Traction Trust

WATTRAIN CONFERENCE 2024 CASTELLAMMARE DI STABIA, ITALY

JULY 19-21, 2024

www.advanced-steam.org

Bure Valley Railway and ASTT Trials of Alternative Fuels

JOHN HIND

ASTT CHAIR

Background

UK PERSPECTIVE

UK Heritage Coal Situation

- 35,000 tonnes of coal used by heritage sector each year
  - 26000 tonnes by heritage railways
  - 5000 tonnes – maritime steam, industrial museums, historic houses
  - 4000 tonnes by road going traction engines
- Estimated spend £7 million/year
- UK's last steam coal mine closed 2023
- Heritage railways are now importing coal resulting increased carbon emissions

Collapse of supply chain

- Coal is available ***BUT***
- It's the ability to buy the right coal at the right price.
- Importers face ever increasing costs - transportation, insurance, finance shipment.
- The size of the coal varies from fines to cobbles
  - Historically there were markets for all this material.
- The large UK industries who would or could take this material is all but gone.
  - The "coal" domestic market in England has also gone
- Typically, if 30,000 tons arrive
  - 15,000 tons is a usable size for most i.e doubles and trebles
  - What do you now do with the remaining material?
- ***Forces the use of ovoids***

Coal Supply

A problem everyone wants to solve and find the

Wonder Fuel

Testing the Alternatives

ASTT Trials - 2012

ASTT Trials - 2012

Wood Pellets
Torrified Wood
Bio-Coal

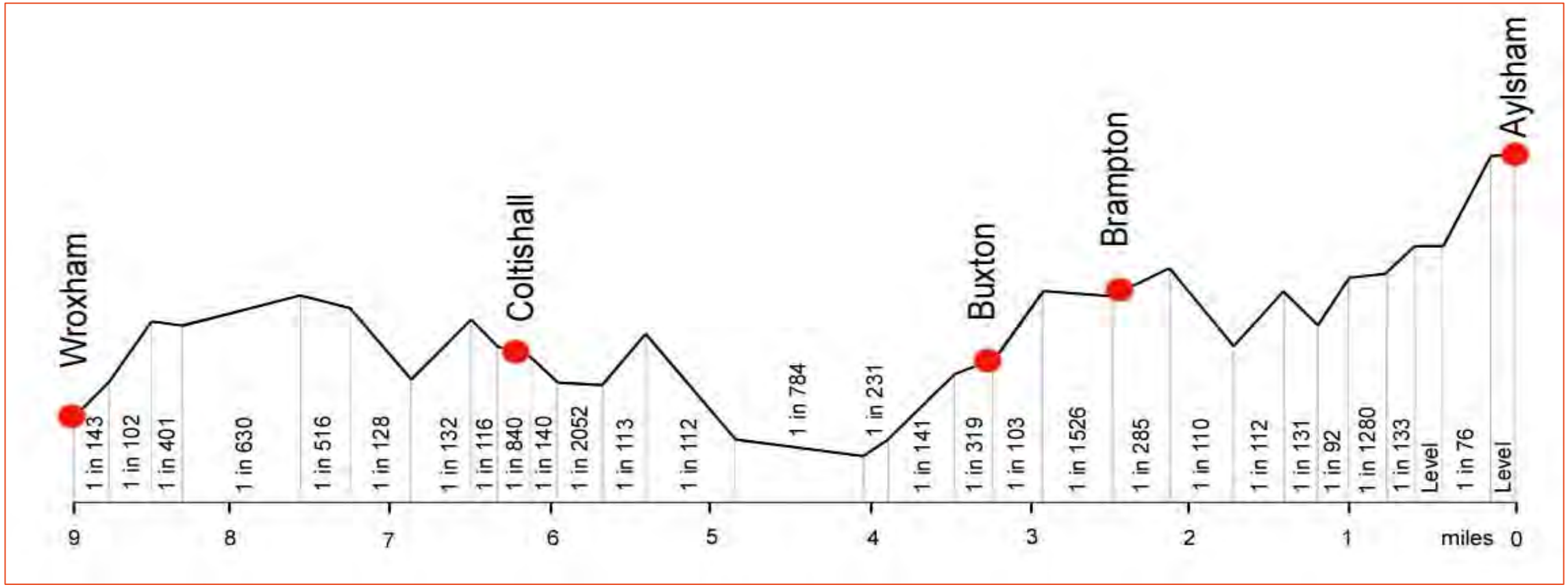
BVR Trials – 2021 to 2023

BVR Test Train

Normal length of a service train

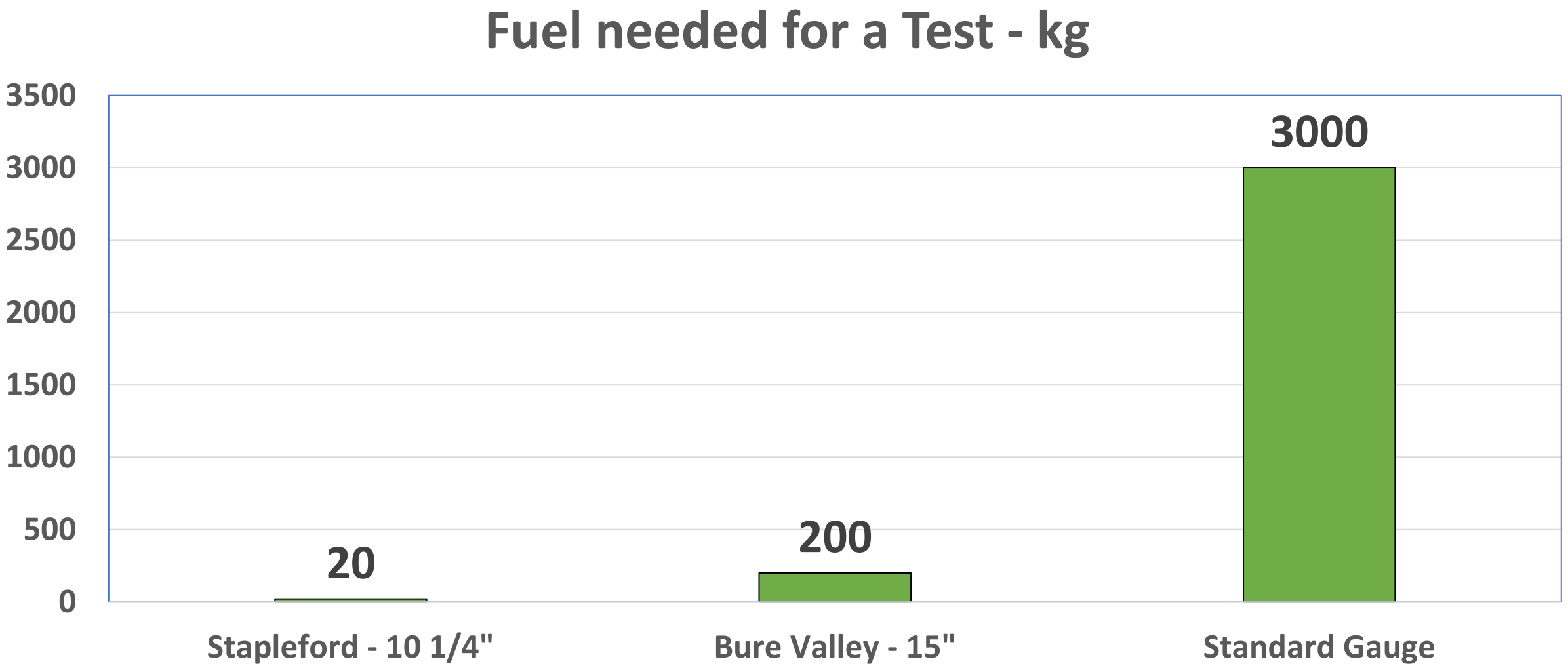
Background

BVR, over a nine mile line with switch back gradients :-



Gradient profile

Quantity matters



Fuels Tested at the BVR

JUNE & NOVEMBER 2021

Ffos-y Fran (as a baseline)

CPL - Ecoal 50

CPL - Brite Flame

CPL - Home Fire Ovals

MARCH & JUNE 2022

CPL - Heritage Blend 3

CPL – Heritage Blend 4

CPL – Wildfire

CPL – Heritage Blend 3 - Low Chlorine

CPL – Wildfire – Low Chlorine

APRIL & NOVEMBER 2023

CPL – Heritage Smokeless Steam Coal – large

CPL – Heritage Smokeless Steam Coal - small

Oxbow – Newheat

Oxbow – Newheat Steam

CPL – Wildfire

Blend of Olive Husks and Anthracite

Arigna Fuels – Harvest Flame

Torrified Olive Husks

Phoenix Oils – Green Dragon

Rapemeal Cake – Small and Large

Some of the fuels

Oxbow - Newheat
Anthracite based Ovoid

Arigna – Harvest Flame
Torrified Olive Husks

Phoenix Oils – Green Dragon
Rapemeal Cake

Trials at other railways - 2022

- Trial Record sheetssSent out to HRA members March 2022
- 29 received from 6 standard and 5 narrow gauge railways
  - Hargreaves - Trevithick Ovoids
  - CPL Products – HB3, HB4, Wildfire
  - Ffos-y-fran – 1 response
- Wood log based fuel – 1 response from Chatham Dockyard
  - Separated out from the anthracite fuels as it is an ‘outlier’
  - Suggests that this a viable fuel for shorter lines with smaller locomotives and loads
- Feedback sent out to HRA members in May 2022

- Narrow Gauge
  - Brecon Mountain
  - Bure Valley Railway
  - Talyllyn Railway
  - Welshpool & Llanfair
  - Whipsnade Light Railway
- Standard Gauge
  - Chatham Dockyard
  - Dean Forest
  - East Lancashire Railway
  - Isle of Wight Railway
  - Keighley & Worth Valley
  - Severn Valley Railway

Test Engines

HB3 Low Chlorine – tested on 78022 & 5643
Wildfire Low Chlorine – tested on 78022, No6 and 51456

ELR – L&YR Class 23 - 51456

GWR 5643

L&YR 52322

KWVR – BR Standard 2MT - 78022

Test Methods

BVR Trials – to measure is to know

BVR Trials – to measure is to know

Fire temperature

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

23.11..23. Steam Newheat Wroxham Bank 1100 deg.C

22.11..23. Heritage Smokeless Steam Coal Large Wroxham Bank 1200 deg.C

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

20.4.23. Green Dragon Small at Aylsham 1200 deg.C

22.11..23. Heritage Smokeless Steam Coal Small Wroxham Bank 1100 deg.C

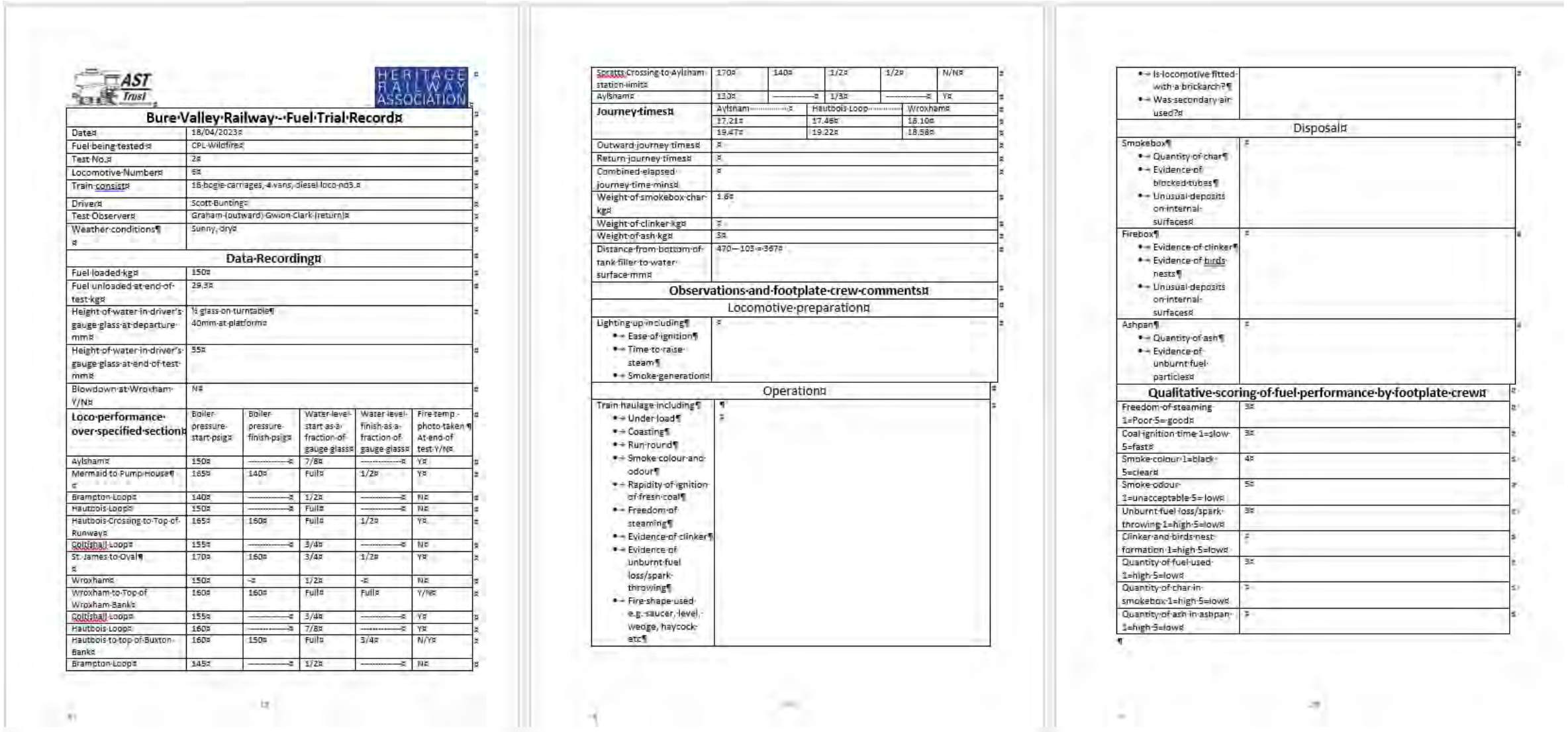
23.11..23. Green Dragon Large at Runway 1100 deg.C

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

BVR - Fuel Trial Record Sheet



Bure Valley Railway – Fuel Trial Record

Dated	18/04/2023
Fuel being tested	CPL Wildfire
Test No.	2
Locomotive Number	6
Train consist	16 bogie carriages, 4 vans, diesel loco no5.
Driver	Scott-Bunting
Test Observers	Graham (outward) Gwion Clark (return)
Weather conditions	Sunny, dry

Data Recording

Fuel loaded kg	150
Fuel unloaded at end of test kg	29.3
Height of water in driver's gauge glass at departure mm	½ glass on turntable 40mm at platform
Height of water in driver's gauge glass at end of test mm	55
Blowdown at Wroxham Y/N	N

Loco performance over specified section	Boiler pressure start psig	Boiler pressure finish psig	Water level start as a fraction of gauge glass	Water level finish as a fraction of gauge glass	Fire temp - photo taken At end of test Y/N
Aylsham	150	———	7/8	———	Y
Mermaid to Pump House	165	140	Full	1/2	Y
Brampton Loop	140	———	1/2	———	N
Hautbois Loop	150	———	Full	———	N
Hautbois Crossing to Top of Runway	165	160	Full	1/2	Y
Coltishall Loop	155	———	3/4	———	N
St James to Oval	170	160	3/4	1/2	Y
Wroxham	150	-	1/2	-	N
Wroxham to Top of Wroxham Bank	160	160	Full	Full	Y/N
Coltishall Loop	155	———	3/4	———	Y
Hautbois Loop	160	———	7/8	———	Y
Hautbois to top of Buxton Bank	160	150	Full	3/4	N/Y
Brampton Loop	145	———	1/2	———	N
Spratts Crossing to Aylsham station limits	170	140	1/2	1/2	N/N
Aylsham	130	———	1/3	———	Y

Journey times	Aylsham	Hautbois Loop	Wroxham
	17.21	17.46	18.10
	19.47	19.22	18.58

Outward journey times	
Return journey times	
Combined elapsed journey time mins	
Weight of smokebox char kg	1.6
Weight of clinker kg	
Weight of ash kg	3
Distance from bottom of tank filler to water surface mm	470 – 103 = 367

Observations and footplate crew comments

Locomotive preparation

Lighting up including • Ease of ignition • Time to raise steam • Smoke generation	

Operation

Train haulage including • Under load • Coasting • Run round • Smoke colour and odour • Rapidity of ignition of fresh coal • Freedom of steaming • Evidence of clinker • Evidence of unburnt fuel loss/spark throwing • Fire shape used e.g. saucer, level, wedge, haycock etc	

• Is locomotive fitted with a brickarch? • Was secondary air used?	

Disposal

Smokebox • Quantity of char • Evidence of blocked tubes • Unusual deposits on internal surfaces	
Firebox • Evidence of clinker • Evidence of birds nests • Unusual deposits on internal surfaces	
Ashpan • Quantity of ash • Evidence of unburnt fuel particles	

Qualitative scoring of fuel performance by footplate crew

Freedom of steaming 1=Poor 5=good	3
Coal ignition time 1=slow 5=fast	3
Smoke colour 1=black 5=clear	4
Smoke odour 1=unacceptable 5= low	5
Unburnt fuel loss/spark throwing 1=high 5=low	3
Clinker and birds nest formation 1=high 5=low	
Quantity of fuel used 1=high 5=low	3
Quantity of char in smokebox 1=high 5=low	
Quantity of ash in ashpan 1=high 5=low	

BVR - Fuel Trial Record Sheet

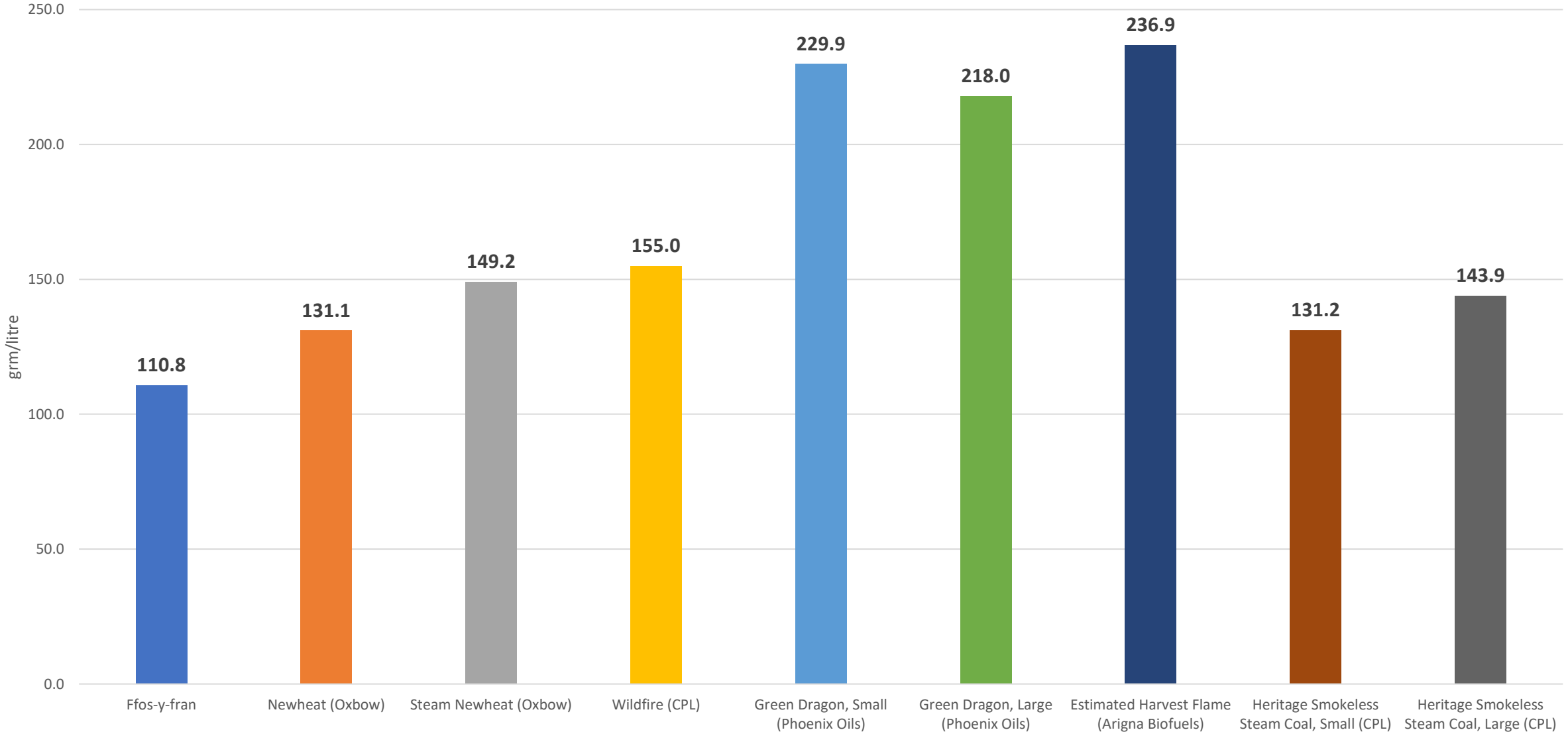
Qualitative scoring of fuel performance by footplate crew	
Freedom of steaming 1=Poor 5= good	3
Coal ignition time 1=slow 5=fast	3
Smoke colour 1=black 5=clear	4
Smoke odour 1=unacceptable 5= low	5
Unburnt fuel loss/spark throwing 1=high 5=low	3
Clinker and birds nest formation 1=high 5=low	
Quantity of fuel used 1=high 5=low	3
Quantity of char in smokebox 1=high 5=low	
Quantity of ash in ashpan 1=high 5=low	

KWVR Trials

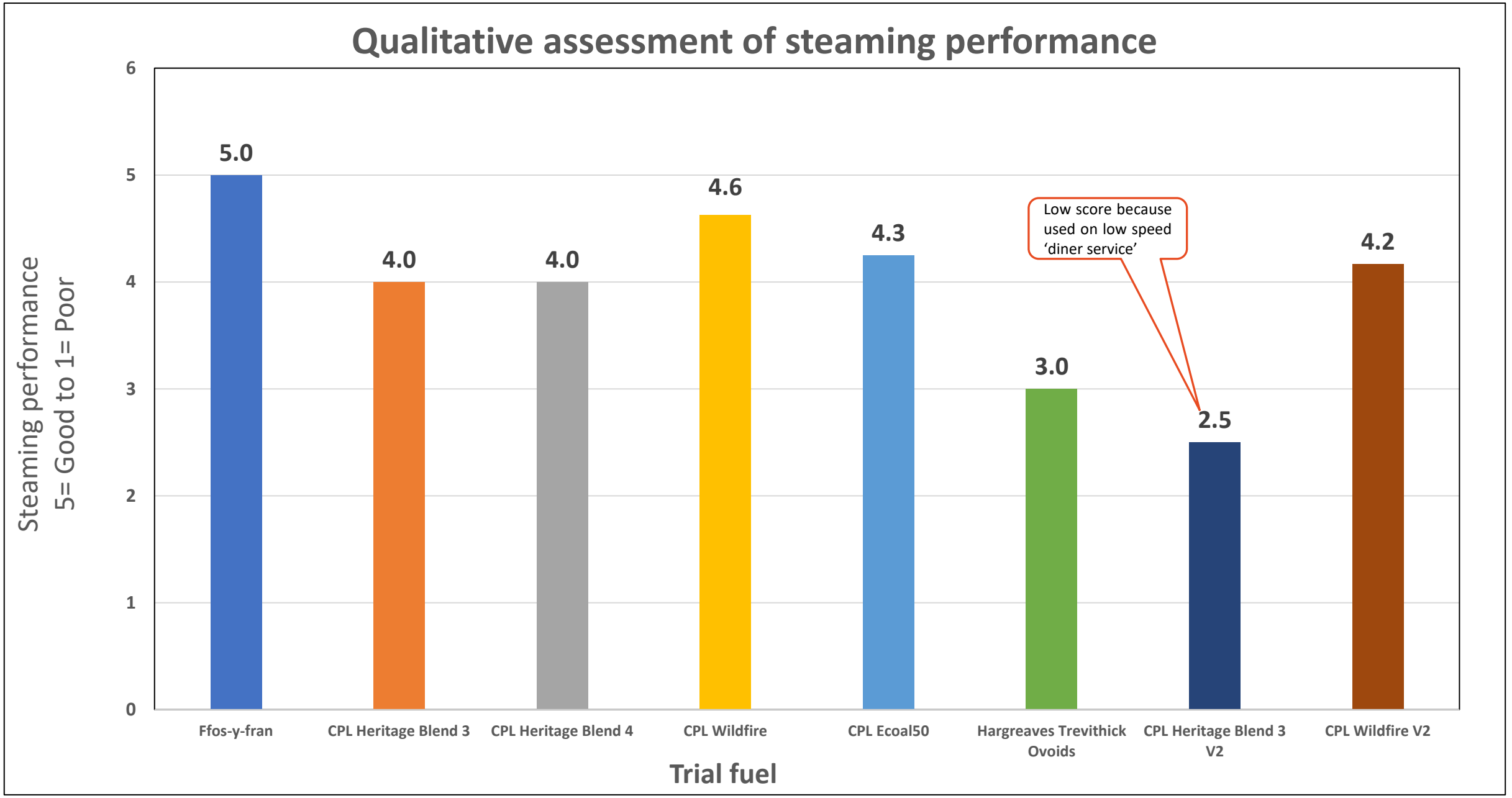
4000 kg of biocoal,averaging shovelful's, 'tender dipping'

Some results

Fuel required to evaporate water grm/litre

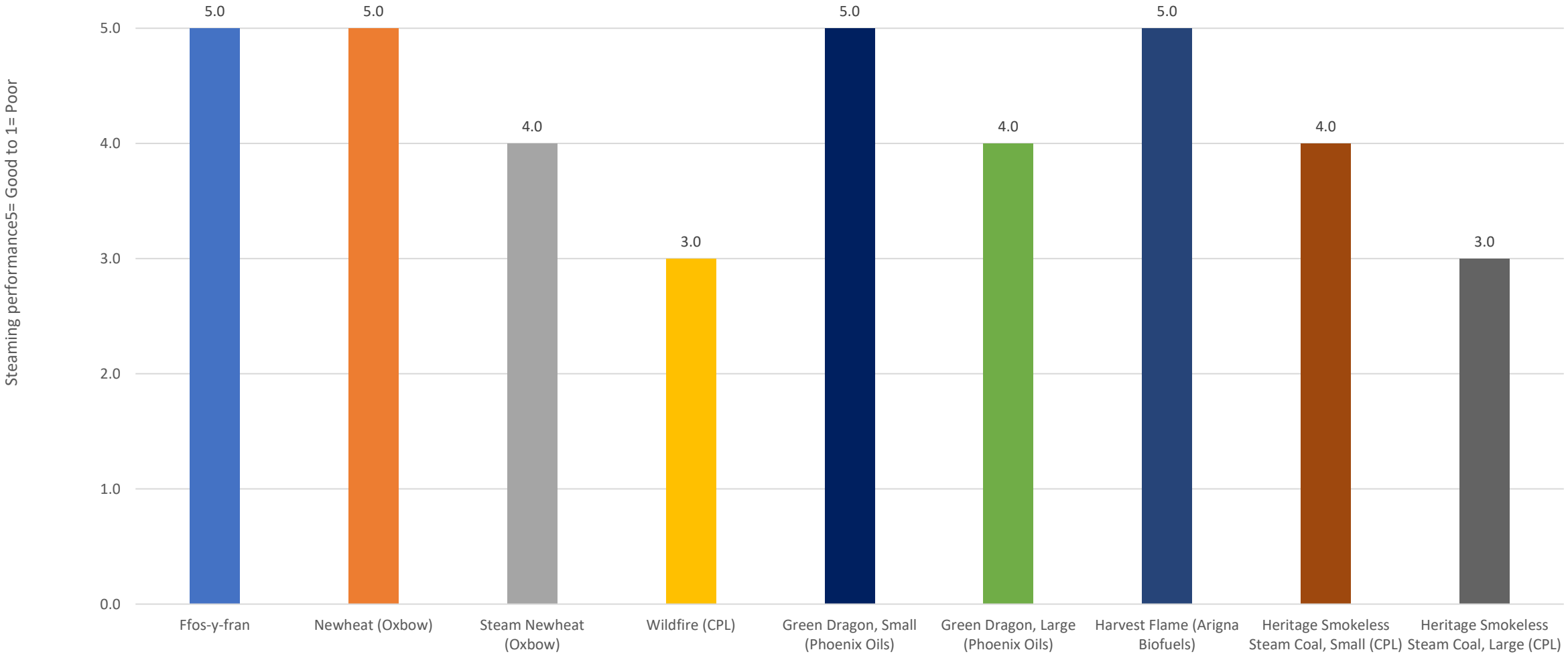


Qualitative assessment of steaming performance



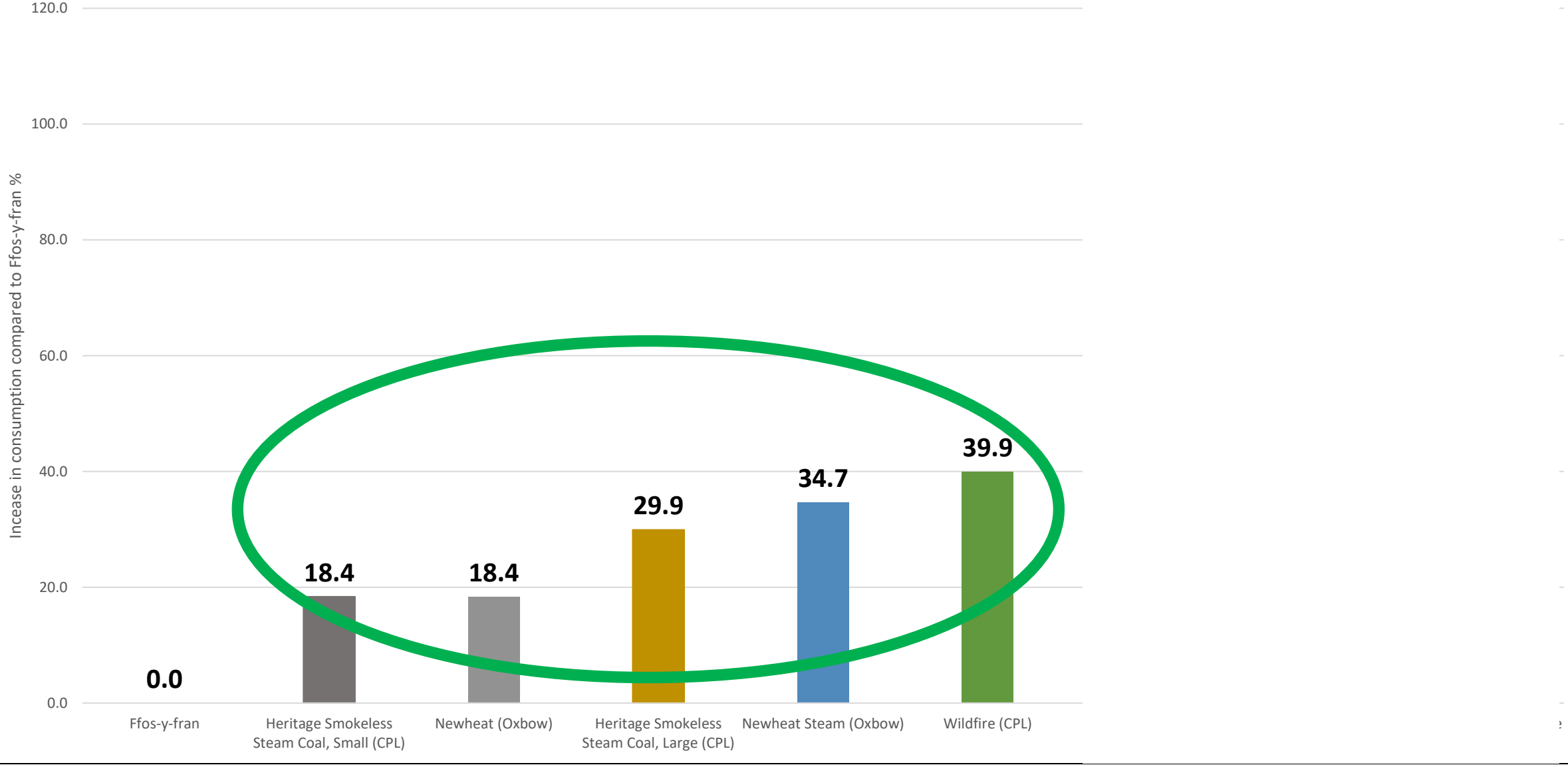
What we have learnt

Qualitative assessment of steaming performance

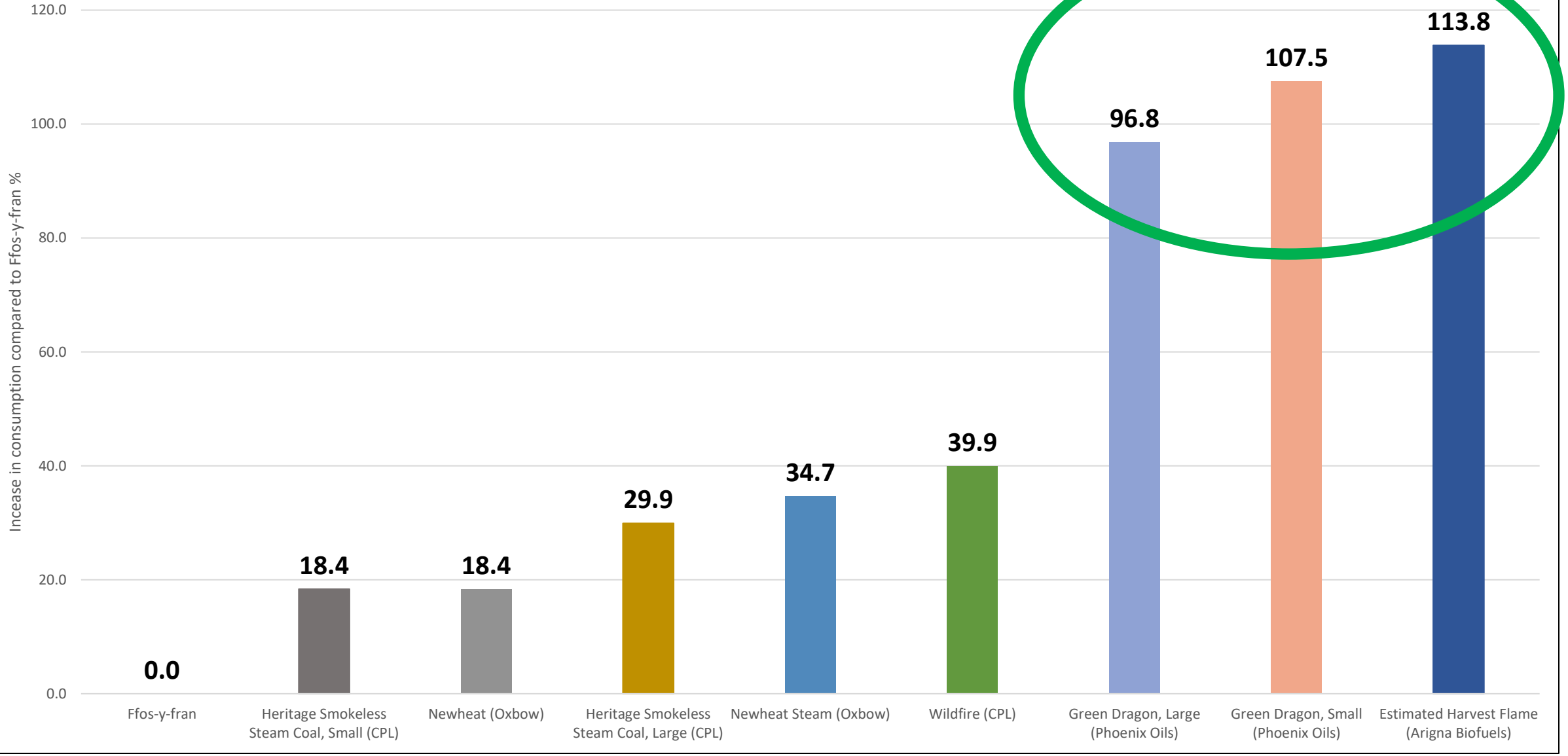


Note: - Both the BVR and Tal-y-llyn Railway report that Newheat burns very hot, with the Tal-y-llyn Railway reporting firedoor distortion and the BVR finding flakes of firebar in the ashpan contents.

% Fuel consumption increase compared to Ffos-y-fran



% Fuel consumption increase compared to Ffos-y-fran



Fuel Consumption- Anthracite

Fuel Consumption – Arigna

Spark emissions

Firebox Deposits

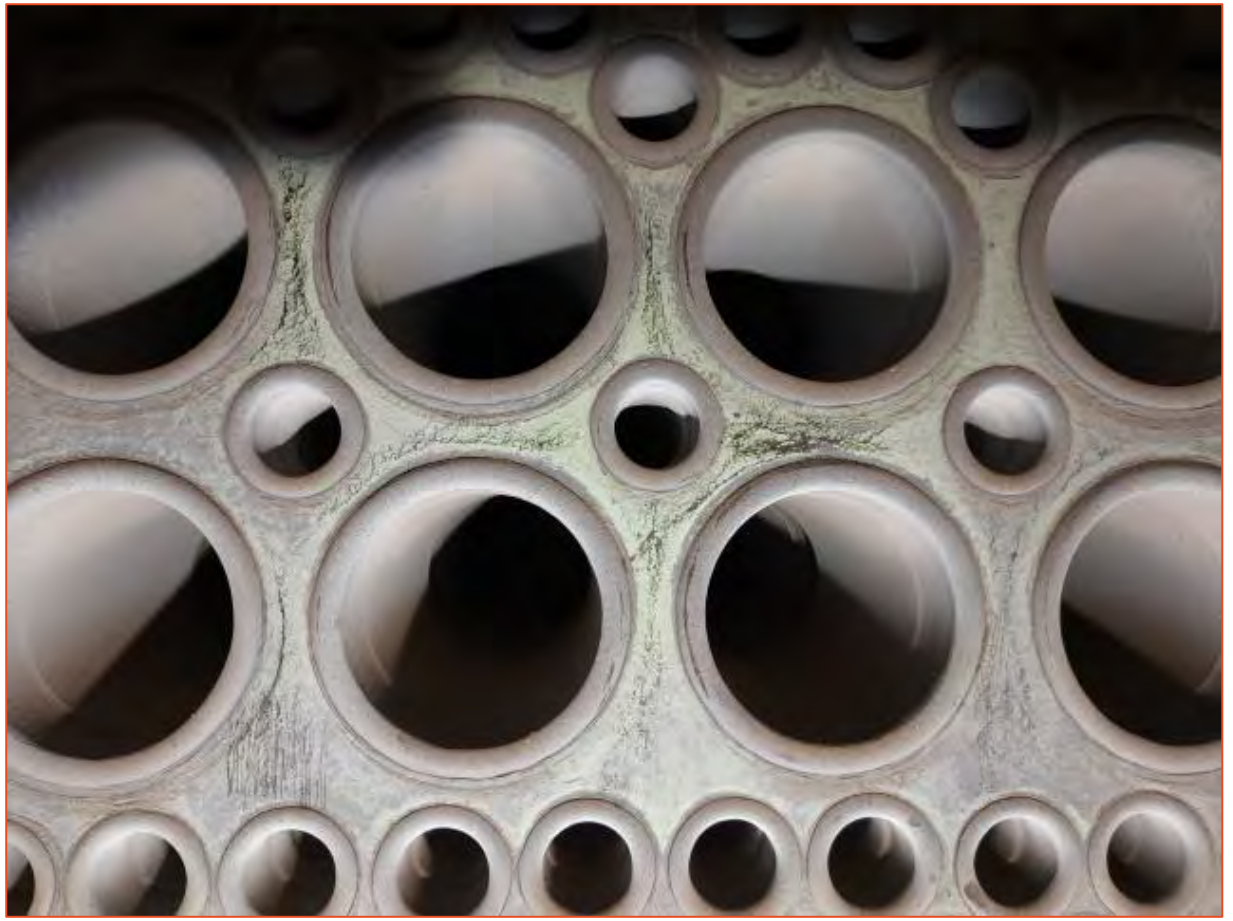
78022 - Firebox – 15/2/22

Normal Firebox
NB with new brickarch, so no deposits under brickarch

Firebox – 78022 – 15/2/22
With pre-existing deposits under brickarch

78022 Firebox – Green Patina - 15/2/22

Firebox Tubeplate



Close up - Firebox Tubeplate

Chlorine content

Coal	Chlorine Content
Ffos-y-fran	.07%
Kazak	.08%
Shotton	.02%

Fuel	Chlorine Content
Heritage Blend 2	.24%
Heritage Blend 3	.28%
Wildfire	.18%

Now Fixed!

Fuel	Chlorine Content
Heritage Blend 3 (R)	.03%
Wildfire (R)	.02%

After change in binder

78022 - Pictures courtesy of Ralph Ingham KWVR

Firebox Tubeplate with high chlorine HB3

Firebox Tubeplate with low chlorine Wildfire

Chlorine, Sulphur & Petroleum Coke

Sulphur and chlorine in fuels can cause boiler corrosion by forming acids that deposit on the boiler parts. The acids are sulphuric and hydrochloric, and they affect the firebox, firetubes, superheater, smokebox and chimney surfaces. The corrosion happens when the boiler parts are cooler than the flue gas dew point. Boilers that are not used continuously are more likely to have this problem.

There is substantial research on the effects of sulphur and chlorine on power station water tube boilers, however, no papers or research have been found on the effects of sulphur and chlorine on locomotive fireboxes, however there is anecdotal information in steam locomotive literature and recent experience on Heritage Railways.

Chlorine

Trials in 2022 with Manufactured Solid Fuels that contained between 0.18% and 0.28% chlorine rapidly led to harmful deposits in fireboxes. The coals used in the Heritage sector vary between 0.02% and 0.08% chlorine and when Manufactured Solid Fuels with chlorine contents of .02% and .03% were trialled no further harmful effects were observed.

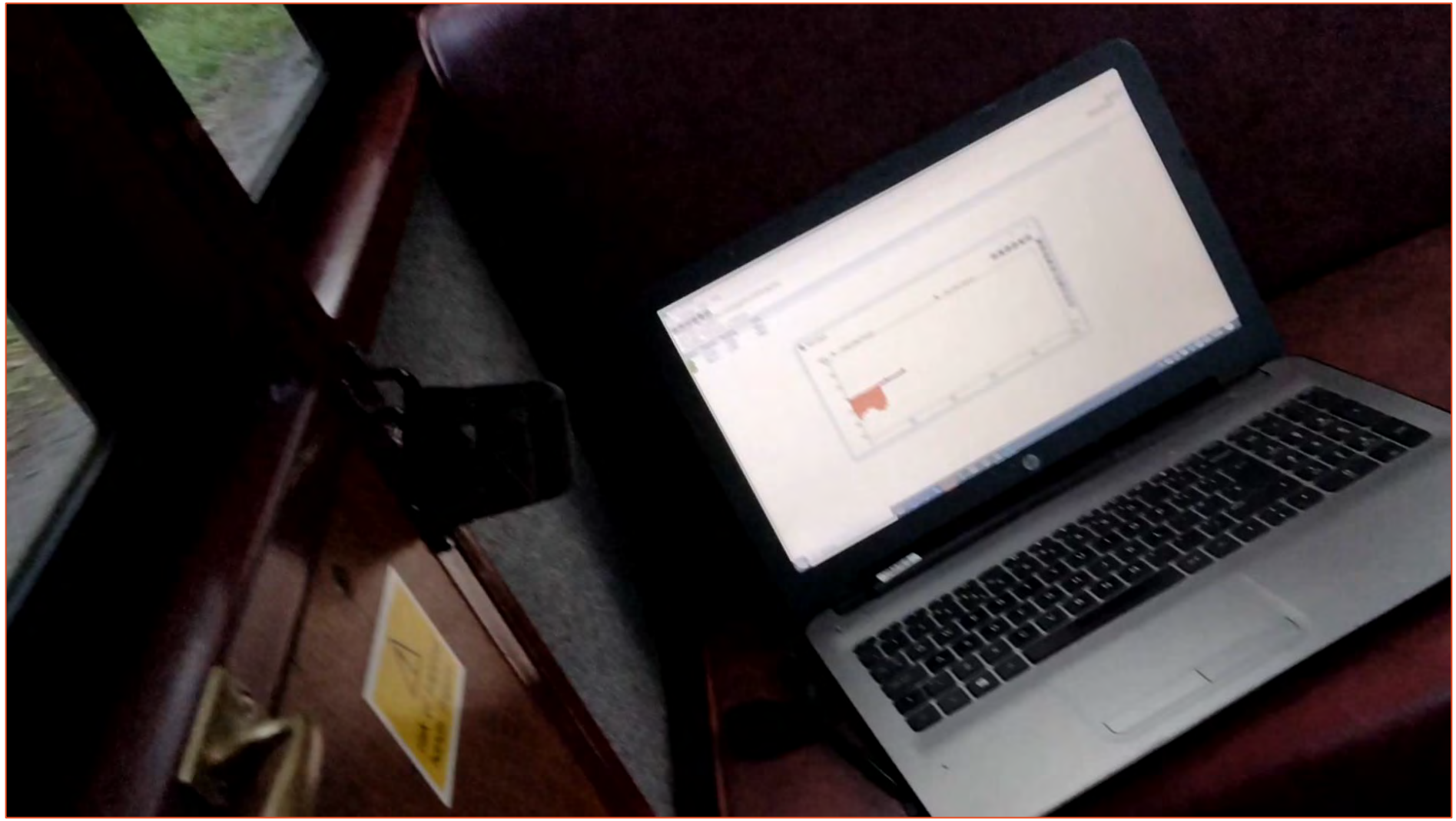
Sulphur

Typical coals used in the Heritage sector during 2022 varied between 0.23 % and 0.92% sulphur.

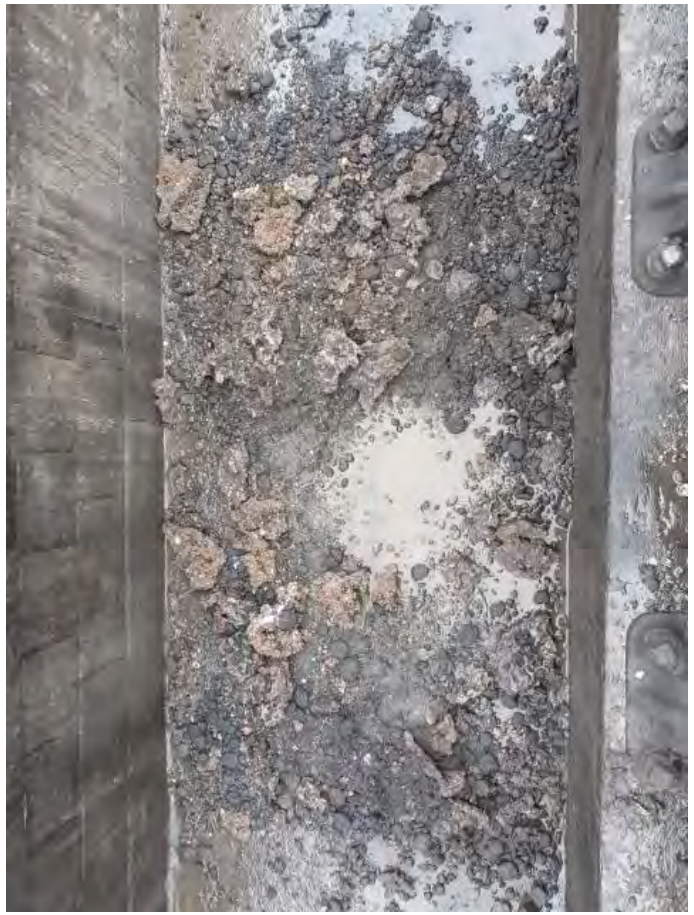
The National Railway Museum has historical records of the ‘proximate analyses’ of coals used by British Railways from 1948 to 1961. Over a range of 25 coals reviewed, the average sulphur content was .94%. Nineteen of the 25 coals had less than 1% sulphur. Of the six coals above 1% sulphur, five coals had sulphur between 1% and 1.29% and the sixth, as an outlier had a sulphur content of 1.72%.

A problem with ovoids

Rapemeal Cake



Clinker – you will still get it….



Ash from hopper

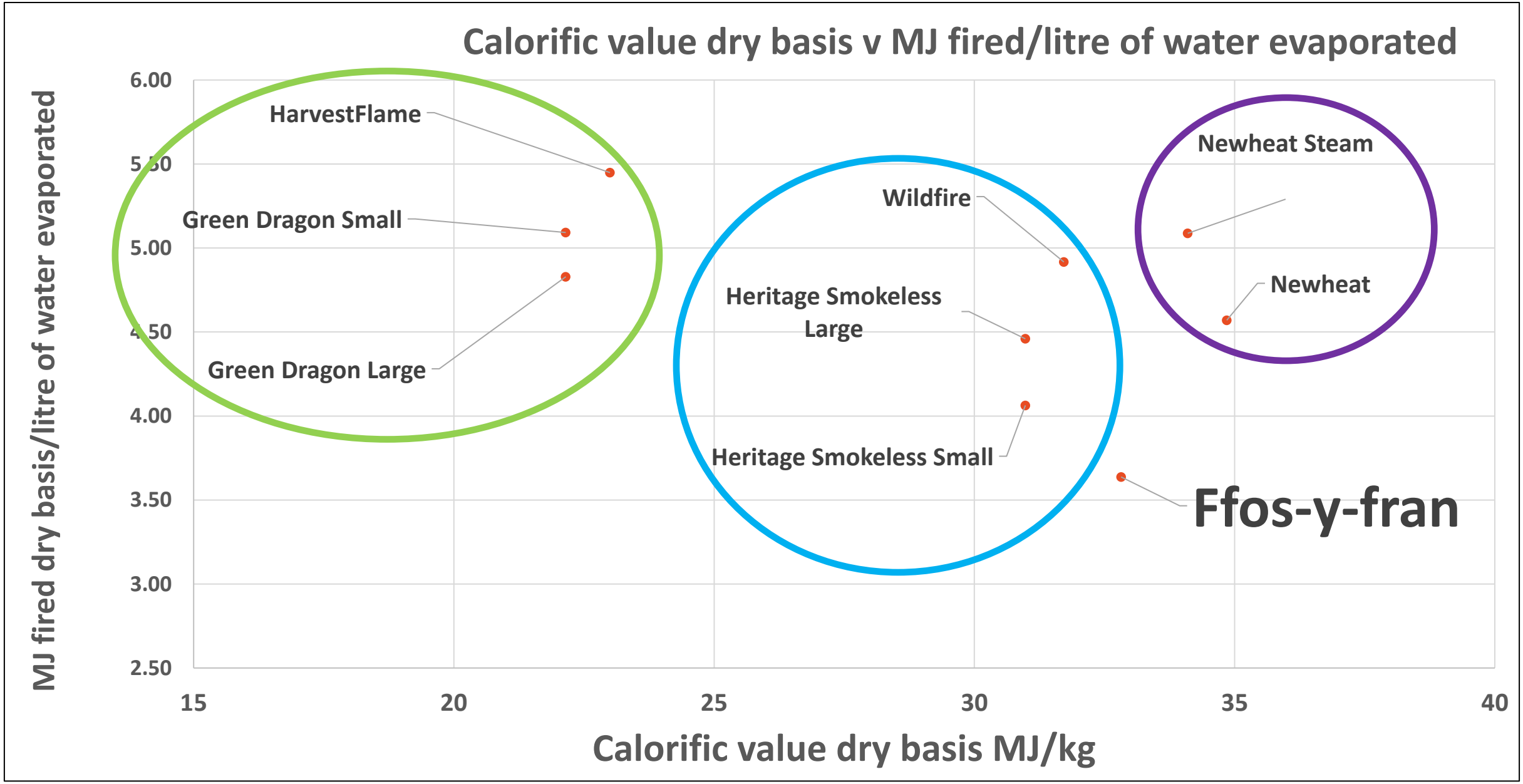
Clinker

Clinker

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
  - Manufactured Solid Fuels need quality control in manufacture

What we do not understand


Calorific value dry basis v MJ fired/litre of water evaporated
MJ fired dry basis/litre of water evaporated
6.00
5.50
5.00
4.50
4.00
3.50
3.00
2.50
15
20
25
30
35
40
Calorific value dry basis MJ/kg
HarvestFlame
Green Dragon Small
Green Dragon Large
Wildfire
Heritage Smokeless Large
Heritage Smokeless Small
Newheat Steam
Newheat
Ffos-y-fran

Long Term Effects

- Tests to date are ***only*** on performance
- Long term effects on boiler corrosion, erosion and fouling are not known
  - To avoid corrosion, fuels with high chlorine and sulphur content should be avoided.
    - Chlorine should be < .08%
    - Sulphur should be < 1.72% but ideally < .92%
- Long term effects, particularly on erosion will only be known as mileage and hours in traffic grow across the Heritage fleet
  - NB Firetube boilers in other industries using ***wood chips*** suffer from corrosion after less than 10,000 hrs of operation

Alternative Fuels

The *Ideal* Alternative Solid Fuel

- Carbon neutral
- Similar CV to coal
- As dense as coal
- Available in large sizes – fist size
- Heat transfer as coal in a locomotive boiler
- Does not foul the boiler
- Does not break up in handling or combustion
- Does not degrade in outdoor, long term storage

The *Ideal* Alternative Fuel – other factors

- Available from existing processing plant
- Supply chain exists or can be created for the raw material
- ***Sustainable fuel from a renewable source***
- Can use current distribution system
- No capital expenditure by the user
- No additional waste handling
- ***A profitable market for a supplier***

Barriers

- Continued availability of coal
- Cost
  - Same costs but not the same performance!
- Hesitant about change
  - The clue is in the name of our movement!!!!

What we have learnt

- ***Currently*** there is no ‘like for like’ *solid fuel* replacement for coal

Does not mean one cannot be found!!

In 2024 – is there a solution?

What type of Railway are you?

- Undemanding work
  - Park and short museum lines
    - 10-30 lbs/sqft grate/hr
- Average operating conditions
  - Many Heritage Lines
    - 30-80 lbs/sqft grate/hr
- Demanding work
  - Continuously Steep Graded or Mainline
  - Need to ‘steam against the injector’
    - often using relatively small locomotives with large loads
    - 80-120 lbs/sqft grate/hr

In 2024 is there a solution?

	Wood Pellets	Torrified Fuels	Manufactured Solid Fuels	Coal	Oil
Park & Short Museum Lines	√	√	√	√	χ

√ - Could go green
√ - usable but not green
χ - capital costs not affordable

In 2024 is there a solution?

	Wood Pellets	Torrified Fuels	Manufactured Solid Fuels	Coal	Oil
Park & Short Museum Lines	√	√	√	√	χ
Most Heritage Lines	?	?	?	√	χ

√ - Could go green
√ - usable but not green
χ - capital costs not affordable

? – worth a trial and could go green
? – worth a trial but not green

In 2024 is there a solution?

	Wood Pellets	Torrified Fuels	Manufactured Solid Fuels	Coal	Oil
Park & Short Museum Lines	√	√	√	√	χ
Most Heritage Lines	?	?	?	√	χ
Continuously Steeply Graded or Mainline	χχ	χχ	?	√	√ √?

√ - Could go green
√ - usable but not green
χ - capital costs not affordable

? – worth a trial and could go green
? – worth a trial but not green

? – may work dependant on gradient and length of run
χχ - will not generate sufficient steam
√ √? – will work, with suitable oil could go green

Thanks to the team at BVR and ASTT

L to R

- Scott Bunting
- John Hind
- John Scott
- Andrew Barnes
- Ian Gaylor

Not on the shot

- Gwion Clark
- Mike Stocksbridge
- Mike Horne
- Richard Coleby
- Chris Newman

Questions?