Advanced Steam Traction Trust

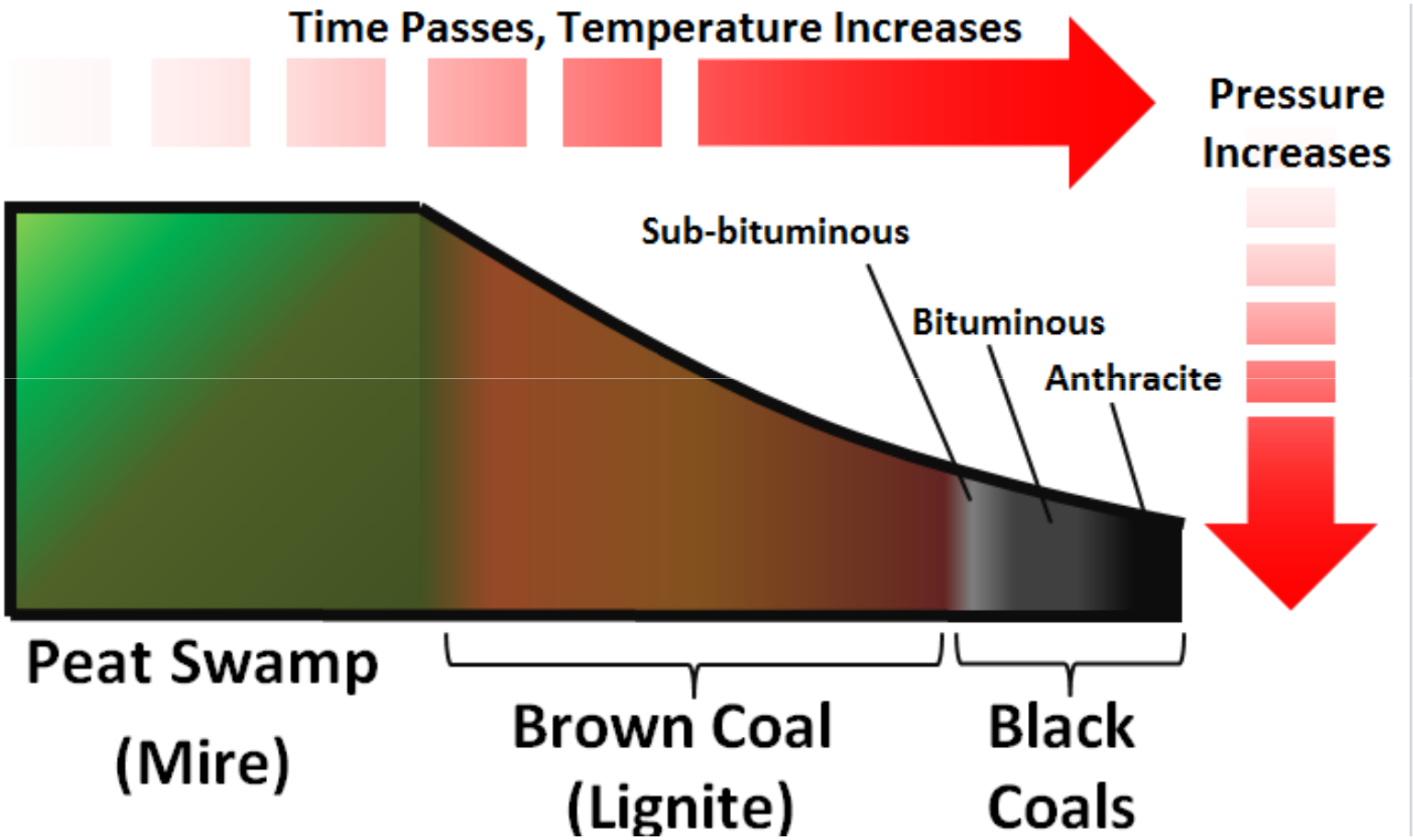
THE SEARCH FOR A COAL SUBSTITUTE

The ‘Current Climate’

A compressed history of coal….

- 360 to 290 million years ago – Carboniferous period
  - 144 – 65 million year ago – Cretaceous period
- 3490 BC - China (archaeological evidence)
- 371 – 278 BC – Greece (Theophrastus – a Greek Scientist)
- 200 AD – Romans in UK exploiting all UK coalfields
  - (except Staffordshire!)
- 1760 – Industrial Revolution
- 2022 - UK coal mining to end
- 21st Century – last coal burnt in the UK?

How is coal formed?



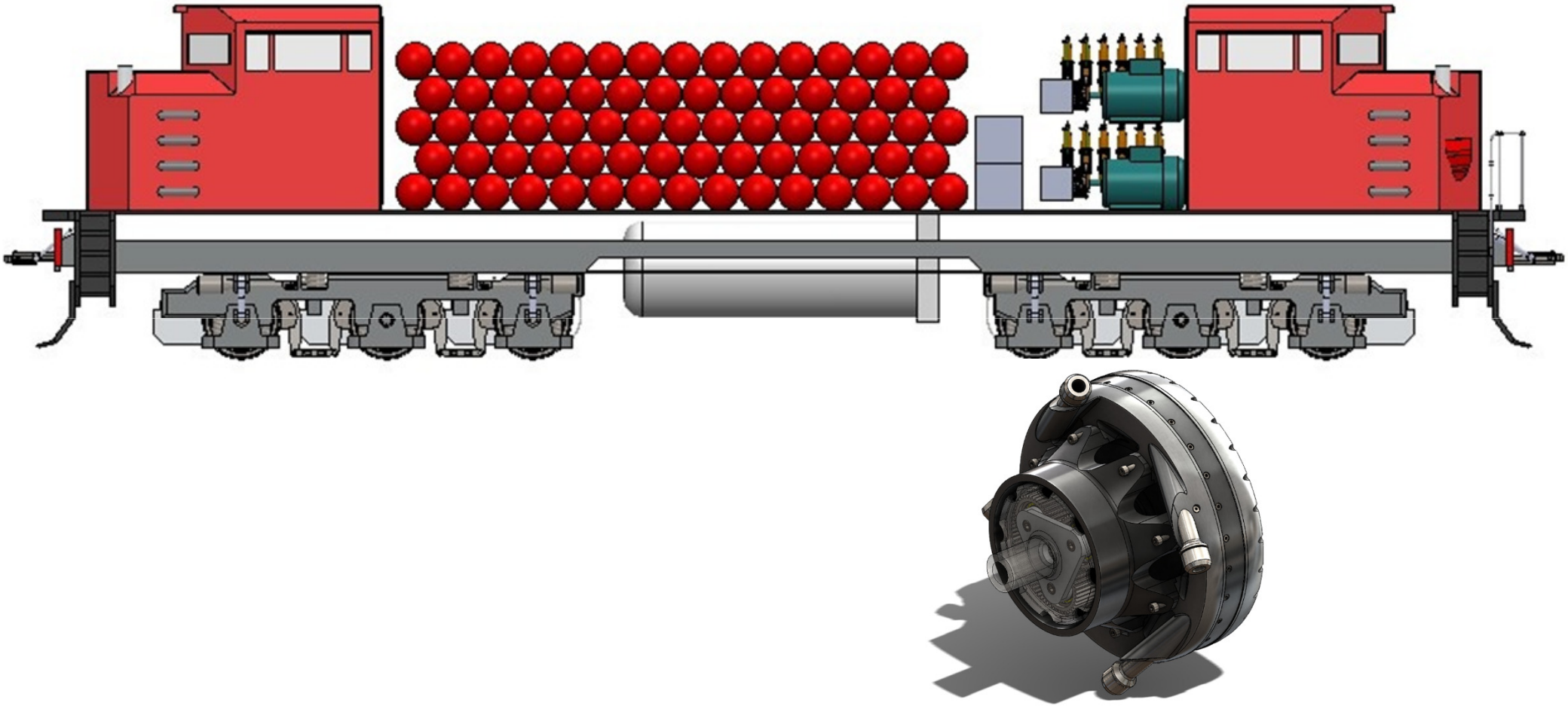
How is coal formed?

- Plant matter dies and decomposes
- Becomes buried, anaerobic bacteria decompose
- Burial and accumulation for several thousands of years, producing
- Becomes peat
- Water an other compounds decrease
- Becomes denser
- Carbon content increases
- Increasing pressure an time
  - Lignite
  - Sub bituminous coals
  - Bituminous coals
  - Anthracite

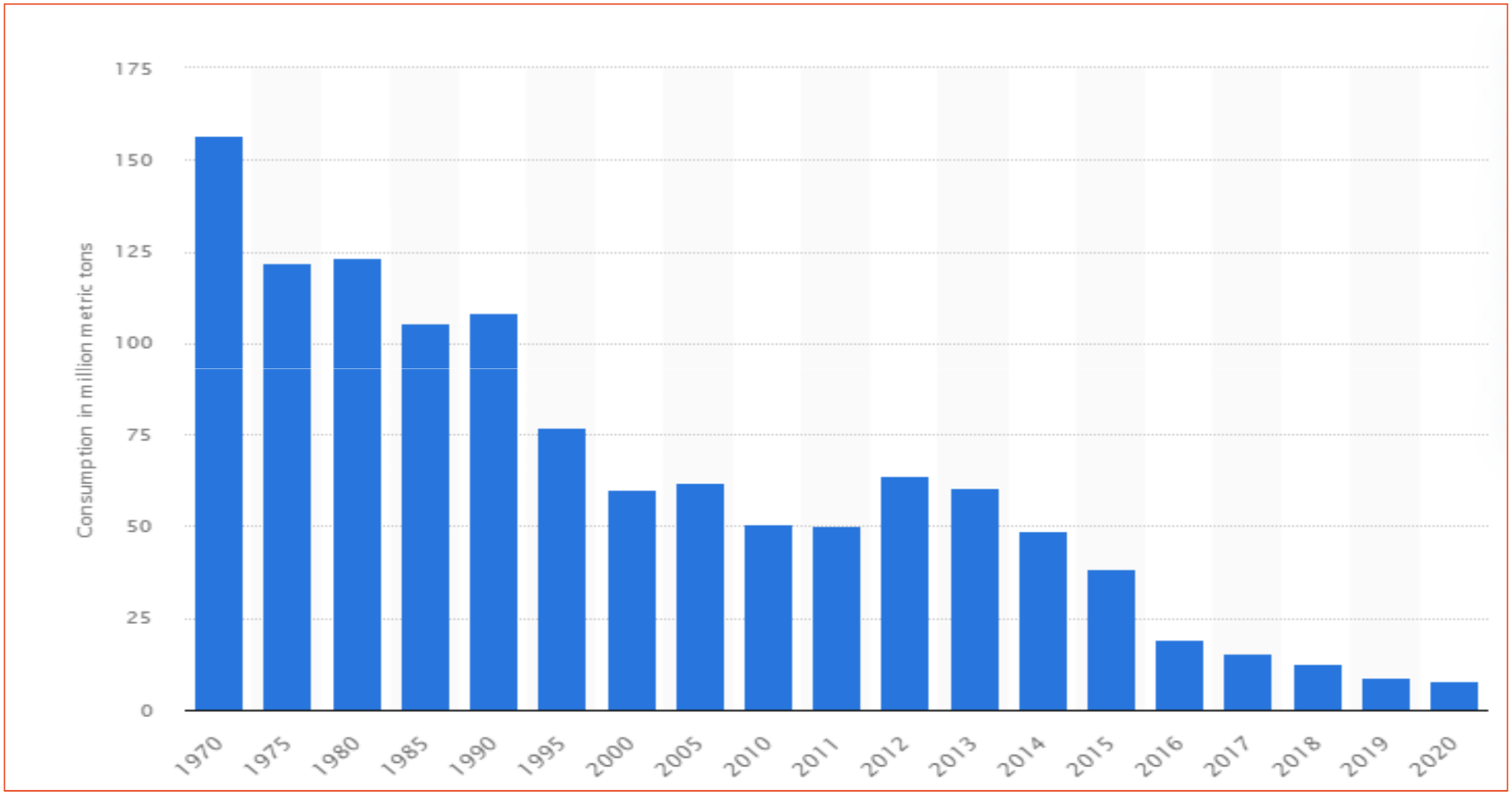
Coal and the Steam Locomotive

- 21/02/1804 – First recorded steam railway locomotive journey
  - Richard Trevithick's Penydarren locomotive
- 27/09/1825 – Stockton and Darlington Railway opened
  - For the transport of coal
- Steam locomotive development continued based on fossil fuels
  - Ended industrial service still hauling coal

Without coal, where would have development lead?



Coal Consumption in the UK 1970 - 2020



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 will close by 2022
- Heritage railways are now importing coal resulting increased carbon emissions
- Research underway to investigate lower CO_2 fuels

Current UK Heritage Coal Situation

- HRA working with UK and devolved governments
  - Exemptions from Environment Act and Clean Air Act and
    - For continued use of coal in heritage environments
- Remaining stocks of UK Coal available
- Imports available
  - Hargreaves Ltd
  - Coal Products Ltd
  - Heritage Railway Association

Typical Locomotive Combustion Conditions

- Designed for lump coal burnt on grate
  - CV values between 27.85 and 30.00 gJ/tonne
  - Density @ 1.2 to 1.6 kg/m^3
- Typical conditions at high rates of work
  - Firing rates – 679 to 1360 kg/hr
  - Boiler pressures – 9.65 to 17.24 barg
  - Firebox Temperatures – 1090 to 1242 ^oC
  - Steam rates - .796 to 2.77 kg/s
  - Flue gas flows - 1.69 - 4.41 kg/s
  - Superheated steam temperatures – 340 to 374 ^oC
- Pressure Differentials
  - 10 to 46 mBar (4 – 18 inches of water)

Typical Combustion Conditions

- Under high rates of working, up to 50% of fuel can be lost
- High rates of air-flow through the firebox
  - Flue gas velocities up to 42.2 m/sec (94 mph) at exit from tube bundle
- Smaller / lighter fuel particles lifted off the firebed and ejected through the chimney
- Gas producer combustion system (GPCS) reduces losses, but very few locomotives are fitted with it

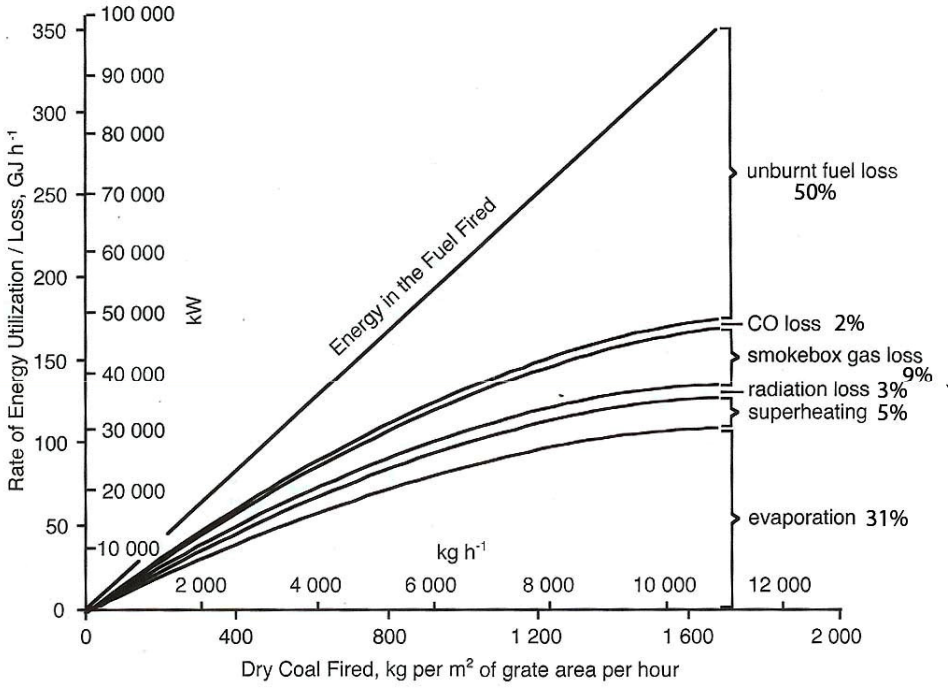


Fig. 21

Pennsylvania Railroad M1-a Class 4-8-2:
Energy Utilized by and Lost from the Boiler versus Coal Firing Rate

Source : Brand C. A., The Locomotive Boiler, Transactions of the American Society of Mechanical Engineers, 1939. Note the extremely high power input to the boiler: at the maximum firing rate energy was being *lost* from the boiler at the staggering rate of 62 000 kW.

The *Ideal* Alternative 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
- Can use current distribution system
- No capital expenditure by the user
- No additional waste handling
- ***A profitable market for a supplier***
- ***Sustainable fuel***

Sustainable?

UK 'green' biomass sourced from forests with 150 year old trees

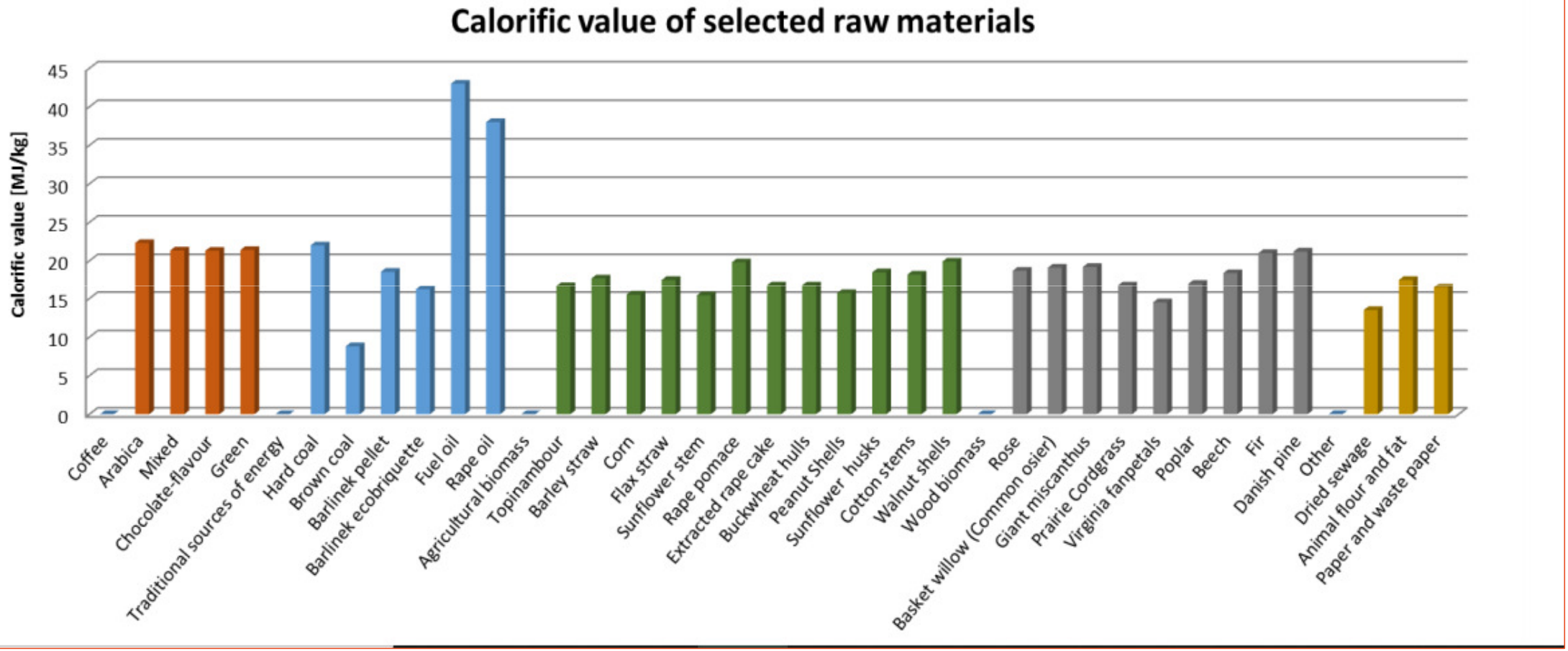
Calls for subsidies for industry to be halted

Trees which take over a century to regrow are being used to supply a new generation of "green" British power plants subsidised by tax breaks intended to stop climate change, the Daily Telegraph can reveal.

The Telegraph found Drax, which runs the UK's biggest biomass operation, is sourcing some of its wood pellets from forests in Russia that could take up to 150 years to regrow, five times longer than we have to meet our net zero target.

Campaign against bio-fuels

Comparative Calorific Values



Current Solid Fuel Alternatives

- University of Minnesota Bio-Coal
  - At prototype plant level
  - Tested in the USA
- Coal Products Limited
  - Ecoal 50
    - 50% Crushed Olive Stones
    - 50% Coal Dust
- N+P Subcoal
  - ‘Waste of the Waste’ derived fuel

Bure Valley Trials

11/6/21 & 14/6/21

Background

Three sample fuels were compared with steam coal to assist the Bure Valley Railway, BVR, at trials held on the 11/06/21 and 14/06/21 as follows:-

- The steam coal used as a baseline comparator was Ffos-y-fran bituminous steam coal
- The three sample fuels in briquette form supplied by Coal Products Ltd, CPL, were:-
  - Ecoal50
  - Brite Flame
  - Homefire Ovals

BVR Trials – No 6 Bickling Hall

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Ffos-y-fran – Aylsham Underpass

ECoal50 – Aylsham Underpass

Slow Motion of Exhaust

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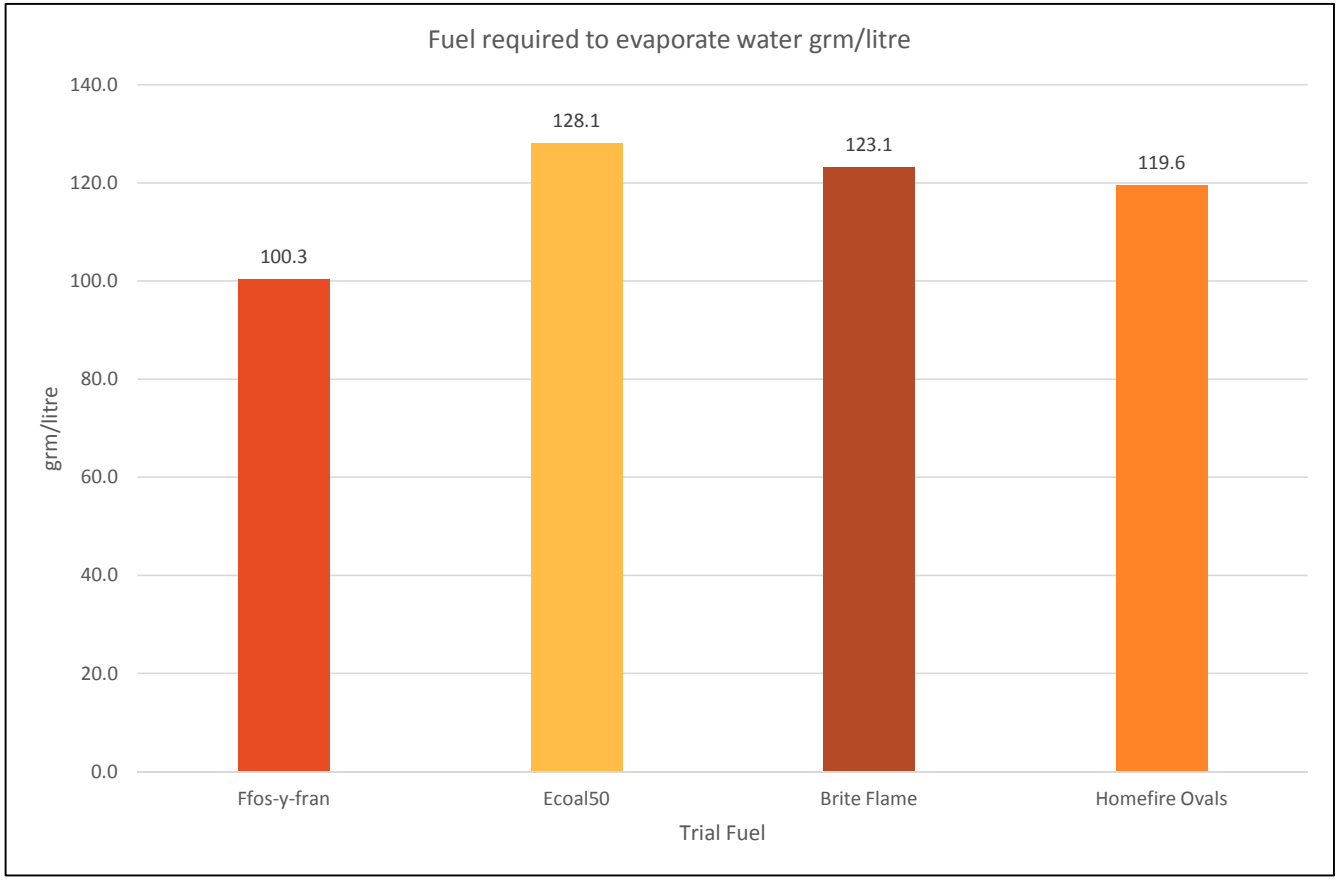
Fuel required for evaporation

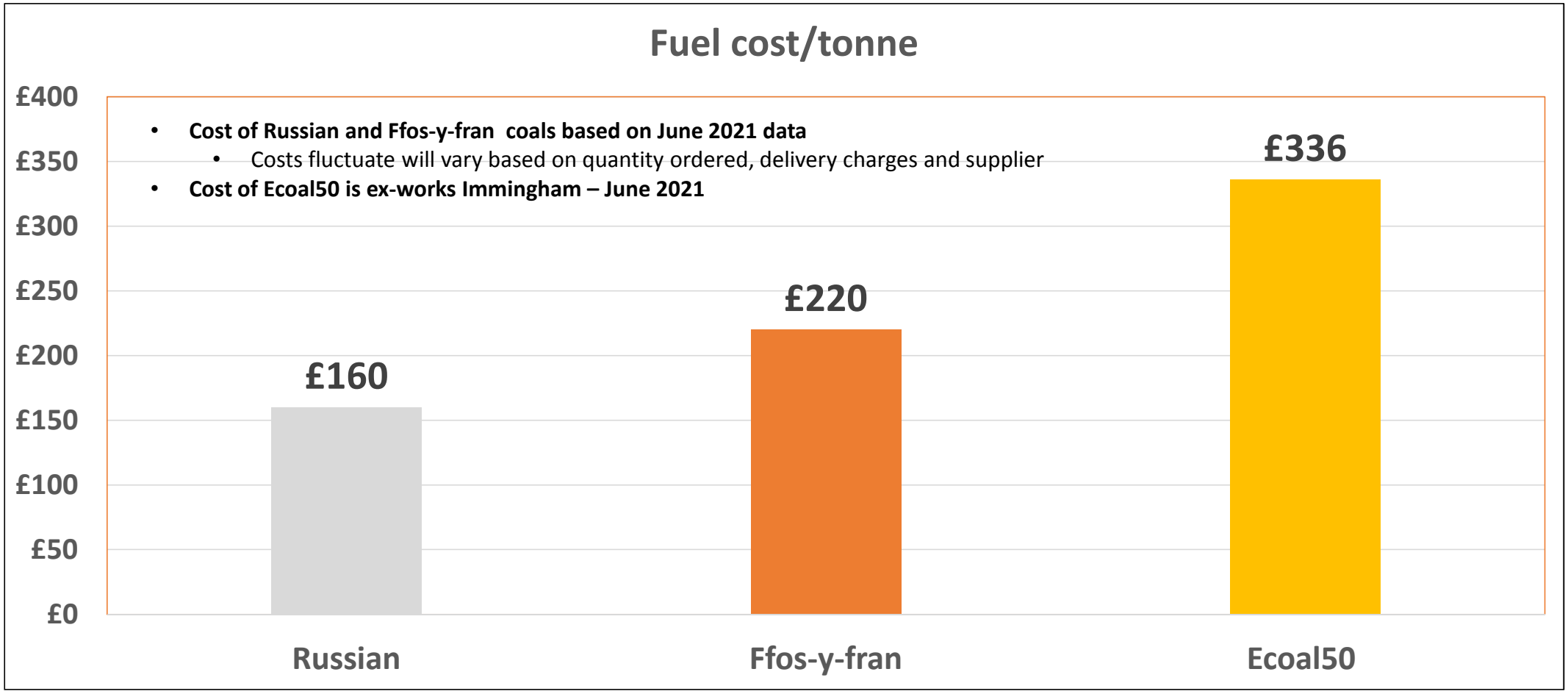
The three sample fuels were compared with Ffos-y-fran coal to assess the quantity of fuel required by weight to evaporate a litre of water



Qualitative assessment of locomotive steaming

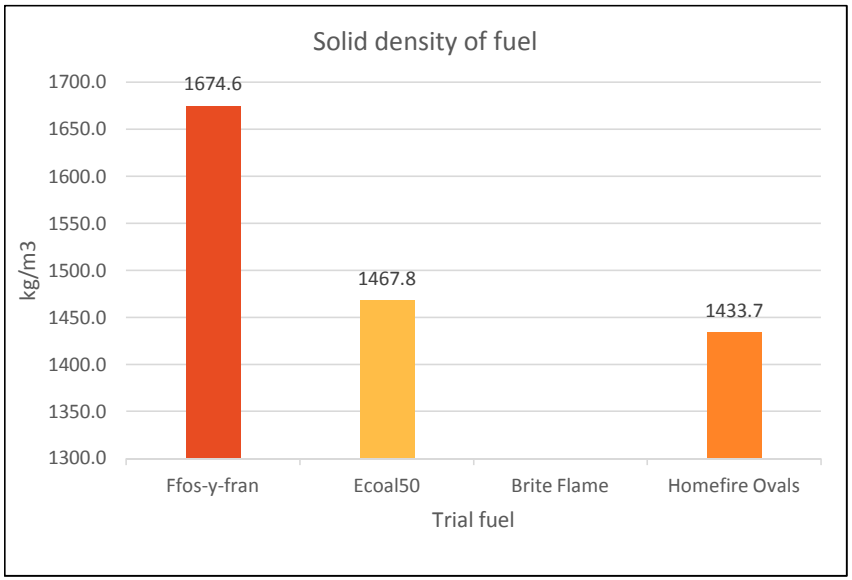
The three sample fuels were compared on a qualitative basis by observation of locomotive steaming performance

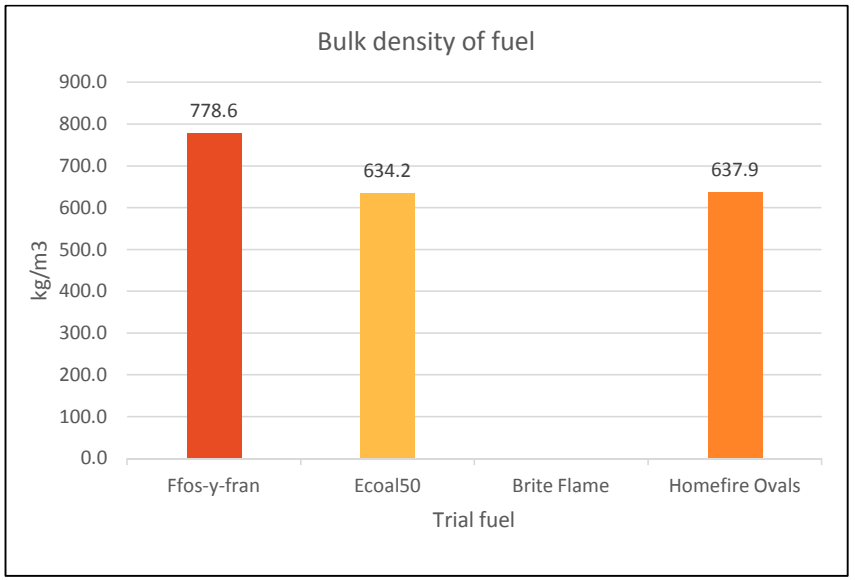
Cost Comparisons



Fuel densities

The bulk and solid densities of the three sample fuels and Ffos-y-fran coal were determined by testing as follows:-





It was not possible to determine the densities of ‘Brite Flame’ as all of the fuel sample was used in the trial

Maximum combustion rate

The maximum combustion rate is to be determined from the thermal modelling of the locomotive boiler and the smokebox vacuum traces when available. However an interim 'Ball Park Guesstimate' for steam coal is shown below based on the following assumptions:-

- Standby losses of 5%
- Locomotive pulling for 50% of running time
- A maximum combustion rate of 50% above the calculated average

This suggests a modest maximum combustion rate of around 240 kg/m²/hr or 50 lb/ft²/hr

Grate area m2	0.373
Grate are ft2	4.0
Total fuel used kg	45.7
Stand-by losses @5%	2.3
Run round time mins	15.0
Running time mins	90.0
Loco pulling mins	45.0
Standby losses kg/hr	1.3
Average consumption when pulling kg/hr	59.2
Assuming max combustion rate when pulling say is 50% above average kg/hr	88.8
Max combustion rate kg/m2/hr	238.1
Max combustion rate lb/ft2/hr	48.8

Summary conclusions

Ecoal 50 is the best of the test fuels based on the results of the tests which conclude that under BVR operating conditions :-

- Ecoal 50 is capable of matching the steaming performance of Ffos-y-fran steam coal
- The consumption of Ecoal 50 is around 28% greater than steam coal by weight
- Solid and bulk densities are less than steam coal and may increase the incidence of spark throwing at higher, as yet untested, combustion rates
- Around twice the amount of smokebox char was produced
- A thicker firebed was required as the particle diameter was greater than steam coal
- There was no clinker and ash + char in the ashpan was reduced
- No unpleasant odours from the exhaust were detected by the test observers

This fuel has environmental benefits as coal content is reduced with 50% of the product understood to be derived from organic sources including olive husks

What next?

- ‘Burn in’ at the SMR on Sunday
  - Ecoal 50
  - N&P Fuel
  - Ffos-y-fran
- Feedback to CPL – 23/9/21
  - Discuss a way forward
    - Higher firing rates
    - Standard Gauge
  - Feedback to N+P - TBC