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Solid Fuel Regulations Consultation
Air Quality Division
Department of the Environment, Climate and Communications
Newtown Road, Wexford Y35 AP90

Submitted by email: solidfuels@DECC.gov.ie

Thursday 1st April 2021

Re: Consultation on the Development of a new Solid Fuel Regulation for Ireland

To whom it may concern,

As CEO of CPL Industries I am very happy to participate in this consultation process by the Department of the Environment, Climate and Communications (DECC). We welcome the opportunity to respond to this consultation and provide responses to the sections of relevance to our activity and expertise.

CPL is the European leader in solid fuels producing over 300kt p.a. of low smoke fuel and c 80,000t of wood products p.a. CPL is unique in the industry possessing fuel testing laboratories to equal those of independent testing bodies and a significant R&D team.

The consultation is wide ranging covering fuels to be regulated, pollution limits for fuels, testing methods, enforcement and timing of regulations.

In summary CPL suggests the following key actions and initiatives;

i) A nationwide ban on smoky coal implemented no later than May 2022.
ii) The ban on coal forms part of the program to control all fuels on a nationwide basis to 10g/hour smoke ($Pm_{2.5}$) emissions. This includes phasing out of peat briquettes no later than May 2023, control of wood sold through retail/internet outlets by 2023 latest and all wood by 2024. Wood products with a moisture level of below 20% are shown to emit smoke of less than 10g/hour even when used on open fires and older stoves.
iii) Enforcement of these regulations is so key that its importance cannot be overstated. The current situation regarding the tax free importation of coal from Northern Ireland (estimated at 80-100kt p.a.) is significantly damaging the trading of low smoke fuel producers and law abiding merchants in the state. A national approach to banning coal across the state provides the only viable means of effective inspection and enforcement.
iv) Recommendations are made for the formation of a national testing laboratory to test fuels and enforce standards.
v) To drive consumer awareness and further aid enforcement an approved fuels scheme is recommended "EPA Approved Smokeless" which would require manufacturers to register fuels with compliant test results with a clear logo displayed prominently on all approved fuels.

vi) The regularising of emission levels for all fuels gives a level playing field for blended biomass/fossil fuels, this is important as such fuels have been shown by independent test reports to potentially reduce GHG emissions from the entire residential sector by up to 9%.

A considerable number of studies have been performed regarding emissions from wood burning. CPL has commissioned an independent report from Clean Stoves consultancy who are experts in the field. CPL have also performed their own tests using industry standard tests to provide a comparison with other fuels.

Overall CPL supports the proposed progressive policy to eradicate high smoke fuels starting with a nationwide ban on smoky coal. These high smoke fuels contribute around 50% of all $Pm_{2.5}$ pollution in Ireland. Air quality in Irish towns is poor in the winter period with pollution reached 10-20 times the EU recommended limits during evening burning.

The implementation of the actions outlined can reduce $Pm_{2.5}$ emissions from residential burning by 80%. It is important that the policy action is now urgently taken after a number of previous failures.

In recent years, a series of political commitments to introduce a nationwide smoky coal ban have been made, but since the first commitment by the then Minister for the Environment Phil Hogan in 2013, successive Governments have failed to act on those commitments. While the reach of the ban has been extended to some towns since 2013, 8 years on from the original commitment, Irish citizens not living in urban areas are, as a result of this failure, expected to continue to live and breathe in dirty air which, according to the Environmental Protection Agency (EPA), falls far below acceptable air quality and has a direct health impact on Irish citizens. A full nationwide smoky coal ban is supported by the EPA in their recent (September 2020) report *Air Quality in Ireland 2019*. The report estimated that poor air quality causes up to 1,300 premature deaths per annum in Ireland.

The European Environment Agency report, Air Quality in Europe 2020 indicates that in 2018, there were 1,300 premature mortalities linked to pollution from fine particulate matter (PM2.5) in Ireland. The same report specifies 16,200 Years of Life Lost, showing significantly earlier mortality for those deaths.

A number of related objectives can be addressed with the introduction of Solid Fuel Regulations in Ireland. They include, saving lives and improving air quality, a cost saving of €722 million, and a potential of up to 9.3% reduction in residential emissions.

Policy action is now vital linked to properly funded and structured enforcement and implementation.

In effective enforcement of these policies combined with the clear roadmap laid out for Carbon Tax will give Ireland the progressive and wide ranging fuel regulation in Europe. This will drive the development of renewable low smoke fuels which represents an excellent medium-term goal.

Finally, within this detailed submission there are a small number of sections with commercially sensitive and confidential information, which we do not wish to be released under the Freedom of Information Act 2014, the Access to Information on the Environment Regulations 2007-2014 and the Data Protection Act 2018. This is pursuant to Section 36 of the Freedom of Information Act 2014, which sets out the definition of confidential and commercially sensitive information.

Yours faithfully

[redacted]

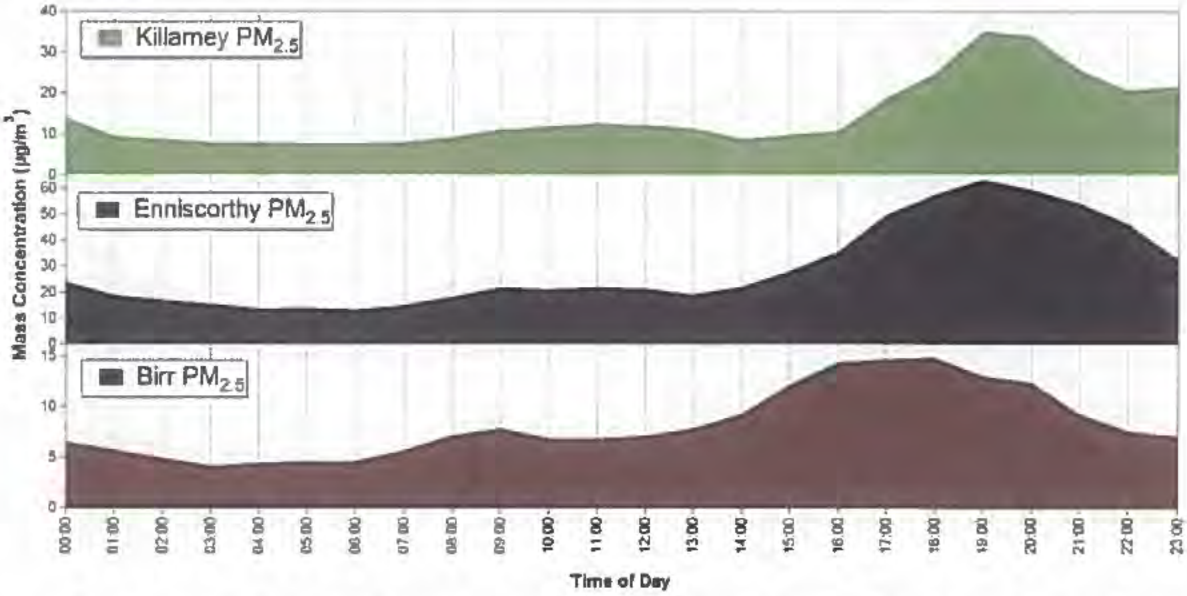
Chief Executive
CPL Industries

1) Are you in favour of a national regulation on solid fuels, and if so, why?

Yes, CPL is in favour of national regulation.

The 2017 "Cleaning our Air" document outlines that c 50% of $Pm_{2.5}$ pollution emanates from residential burning and hence is a major impact on public health. Subsequent studies most notable is the Sapphire Study by UCC showed the extent of peak exceedances in rural Irish towns.

Figure 1



While the effects of pollution from residential fuel burning are local, the scale of the problems and hence enforcement requires a national approach.

The current local approach to clean air enforcement is clearly ineffective as $Pm_{2.5}$ levels recorded within low smoke zones demonstrates. The following shows $Pm_{2.5}$, Pm_{10} and SO_2 levels in Ennis, Letterkenny, Limerick and Sligo on 25th January 2021 (further examples are shown in appendix 1).

Figure 2 - **Ennis**

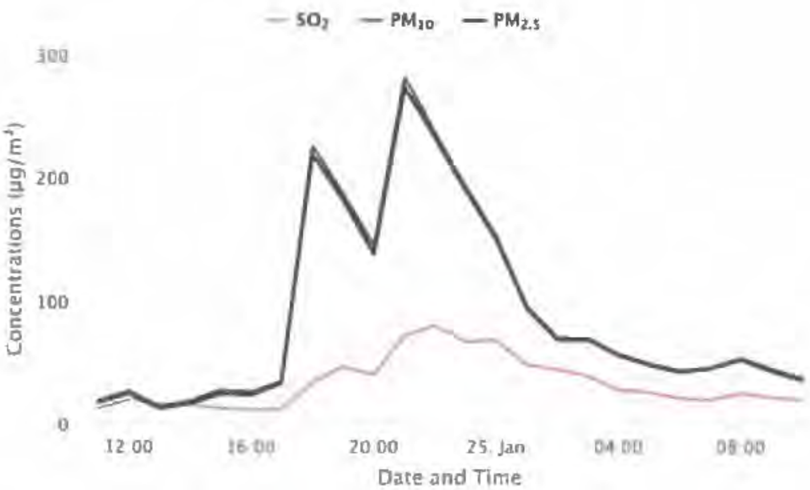


Figure 3 - **Letterkenny**

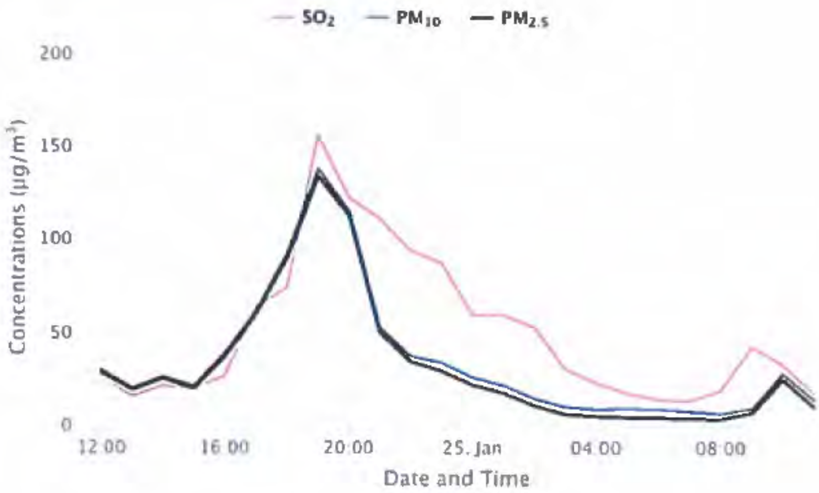


Figure 4 - **Limerick**

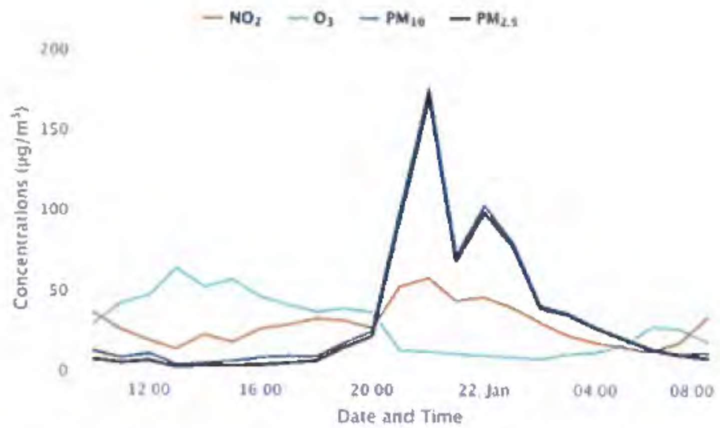
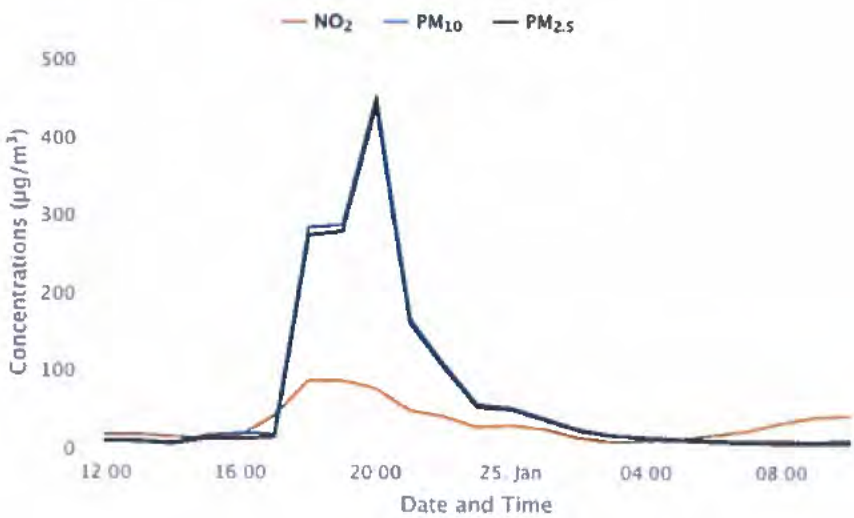


Figure 5 - **Sligo**



This situation is the result of the infeasibility of enforcing a patchwork of low smoke zones. The ability of merchants to stock smoky fuels within zones and the sale of products just outside the zones [and within the zones] makes the situation untenable.

A national ban on smoky coal will enable effective enforcement as the simple presence of coal in merchant/retailer/importer will be illegal. This is vital to provide a level playing field and properly functioning market within the state as it will largely prevent the sale of Carbon Tax free coal estimated at 80-100kt p.a. These tax free imports are putting significant pressure on the trading of law abiding merchants and low smoke fuel producers based within the state.

In terms of wood a national approach to moisture content control (should that be adopted) will again be more enforceable than a regional/low smoke zone approach as such a regional approach would have the same difficulties as currently seen with coal. Control of wood through sales channel (i.e. retailer) and/or volume of sale on a national basis will also be more enforceable than a regional approach.

In terms of the peat briquette, the centralised production is being phased out, clearly favours a national approach through removal of the CV exemption from the current regulations, which allows the briquettes to be used in low smoke zones.

It is the view of CPL that increased national regulation on solid fuels will help encourage innovation and the development of low smoke alternatives. For example, the investment in Foynes, Co. Limerick was done on the back of an earlier Government commitment to introduce a nationwide smoky coal ban. While steps by Government to introduce this nationwide smoky coal ban have been slow, CPL remain fully committed to investing in research and the development of low smoke alternatives for consumers across all markets.

This need for national regulation is supported by the EPA who have consistently warned about the consequences of poor air quality and the direct impact on individuals. A report on air quality in 2018 estimated that poor air quality caused up to 1,180 premature deaths per annum and found a strong correlation between poor air quality, as recorded by the EPA, and increased daily hospital admissions for cases of asthma related illnesses and heart failure.

The need for Solid Fuel Regulations, to address the health consequence of air pollution is well accepted. In September 2020, Minister Eamon Ryan stated *"The main health effects of air pollution include stroke, heart disease, lung cancer, and both chronic and acute respiratory diseases, including asthma. Fine particulate matter, the pollutant of most concern from domestic solid fuel burning is linked to a range of diseases. Banning smoky coal saves lives and improves health outcomes."*

Given this stark admission that there are serious health implications for those living in areas where air quality is poor, it is even more important for the Government to extend a nationwide smoky coal ban to protect everyone. This is a view supported by leading health advocacy groups such as the Asthma Society of Ireland.

In a communique issued in May 2020, the Climate and Health Alliance – made up of membership from the leading health NGOs in Ireland, called for an immediate ban on the burning of all smoky solid fuel. The Climate and Health Alliance membership include organisations representing all public health stakeholders in Ireland, from the Irish Heart Foundation, Irish Cancer Society, National Children's Hospital, Royal College of Physicians of Ireland, Safefood, Irish Medical Organisation, Irish College of General Practitioners, Royal College of Surgeons in Ireland, University College Cork (UCC) School of Public Health, Irish Doctors for the Environment, to the Association for Health Promotion Ireland.

A national approach will simplify the selection of fuels for the consumer as well as increase awareness of the requirement to use low smoke fuels. As in referenced Question 4, CPL support the introduction of an "EPA Guaranteed Low Smoke Fuel" certification scheme with clear labelling for use on all packaging. This is to assist consumers and to act as an education tool. By assisting consumer awareness, this market reaction means that these benefits can be delivered without the need for capital investment by the householder. In conjunction with using Carbon Tax as an instrument to change consumer behaviour, new regulations would encourage greater uptake in products with a significant biomass component, as is set out in the response to later questions.

2) What solid fuels should be subject to regulation and why?

It is essential that legislation covers all fuel types both from the standpoint of controlling pollution and improving air quality and to provide a level playing field for investment and manufacturers/suppliers within the market.

The regulation of all fuels is also important for consumer understanding, communication and protection. National regulation of all fuels would provide the basis for a national certification/labelling scheme to provide clarity to consumers regarding the low smoke nature of fuels.

The problems of not regulating all fuels have been show by recent issues in the DEFRA legislation in the UK. A clause in the SI provided for exempt fuels (see appendix 2 for details and analysis) which meant that some selected biomass and blended biomass fuels were exempt from all aspects of $Pm_{2.5}$ /SOx emission control. The fuels specified to be exempt included biomass such as olive logs which emit 15-20g/hr (2 x RoI limit) of $Pm_{2.5}$. It also allows blends of these fuels with low cost high sulphur pet coke materials providing a fuel that is both high smoke and high sulphur. In response to criticism and realising that such fuels were high emission DEFRA has elected not to allow such fuels to be labelled "Ready to Burn" or gain HETAS approval for use in smokeless zones. Such fuels will be able to be advertised as compliant with the latest regulations but are not approved for use in low smoke zones, evidently a basis for customer confusion.

Hence it is important that all fuels are covered by a universal smoke limit (although in the case of wood this may be enforced/measured through moisture content). This should cover all emerging biomass fuels so that Ireland ensures a trajectory towards renewable low smoke fuels. Such regulations combined with the progressive Carbon Tax now outlined will provide a Europe-leading regulatory framework for reform of the solid fuels sector.

It is imperative that the above is supported by effective enforcement.

3) What standards or specifications should/could be applied to each type of solid fuel?

This section contains commercially sensitive and confidential information, which we do not wish to be released under the Freedom of Information Act 2014, the Access to Information on the Environment Regulations 2007-2014 and the Data Protection Act 2018. This is pursuant to Section 36 of the Freedom of Information Act 2014, which sets out the definition of confidential and commercially sensitive information.

4) What do you believe are the most appropriate, implementable and enforceable regulatory approaches for each type of solid fuel?

Overall

The need for enforcement on a national basis could not be more clearly illustrated than by the current situation particularly relating to the tax free imports of coal from Northern Ireland and the sale of high sulphur manufactured fuels. These fuels are currently sold in large quantities in the Irish market and are not only significantly affecting air quality but are putting the existence of law-abiding merchants and low smoke manufacturers in jeopardy. Any further delay in the implementation of a nationwide smoky coal ban may result in the supply of low smoke fuels being restricted by the failure/withdrawal of low smoke suppliers.

For any law (or regulation) to be effective, it must be enforceable. Currently in Ireland there are flagrant breaches of the existing and limited laws relating to solid fuel. The current partial ban on smoky coal is unenforceable, and that enforcement is virtually non-existent. The paltry number of 6 fines issued in 2019 in relation to breaches of the regulations for offences relating to the marketing, sale and distribution of prohibited fuels in low-smoke zones confirms this (source EPA).

There are pockets of the country (well away from the border) where the legitimate trade simply cannot compete due to the presence of Carbon Tax free coal that has been imported principally from NI. It is damaging from a health perspective, but also from the perspective of taxes forgone and the damage to legitimate trade.

As a company CPL supplies a significant proportion of low smoke fuel to the Irish consumer and is fully aware of the scale of the non-compliance with Solid Fuel Carbon Tax (SFCT) in Ireland, arising from solid fuel smuggled across the border from Northern Ireland. We know first-hand the consequences of this on our business and see it on a daily basis in parts of the country where there is wholesale non-compliance with the law.

It has been well documented that there is little or no enforcement of the sale of bituminous coal coming from Northern Ireland. This was formally acknowledged in an admission from Minister for Finance Pascal Donohoe that the state is powerless to collect carbon tax due on solid fuel entering the Irish market from Northern Ireland. In a reply to Parliamentary question on 21st July 2020 he said, "*This means that solid fuel coming into the State from Northern Ireland is not subject to cross-border movement controls typical of harmonised excises on mineral oils, tobacco and alcohol. Revenue has no authority to stop vehicles and physically inspect loads of solid fuel. Similarly, Revenue has no authority to challenge transportation or possession of solid fuel that originated in Northern Ireland as such transportation or possession are not, in themselves, Revenue offences.*"

CPL welcome the commitment in the Programme for Government which addresses the intention to develop a multi-agency approach to clamping down on the sale of high-sulphur content fuel imported from the UK, with local authorities and the Revenue Commissioners involved. This tool is no different from the status quo where local authorities and the Revenue Commissioners already have power to seize high-sulphur content fuel imported from the UK. With an estimated 100,000 tonnes of smoky coal brought across the Northern Irish border in 2018, CPL do not have any confidence that the State is any position to stem that level of smuggling. The Minister for Finance Pascal Donohoe confirmed that not one seizure of illicit fuel supplied from Northern Ireland was achieved in 2019.

The existing legislation, the Air Pollution Act 1987 and the Environment (Misc Provisions) Act 2015 would be easier to enforce following the implementation of a nationwide smoky coal ban. The focus can then be on enforcement at point of sale, to ensure compliance with the regulations, thereby excluding the very small volume of turf that is being harvested for personal use that is not for sale.

The following outlines the regulatory approach proposed by fuel type.

Smoky Coal

The current regional low smoke zones should be replaced by a national ban. The national ban would provide a basis for regional enforcement teams to simply inspect merchants and retailers for the presence of coal. This transparency will in itself be a major deterrent to the illegal import of coal. There may be some evening deliveries and border "leakage" but the volumes of smoky coal burnt and $Pm_{2.5}$ emitted would be reduced dramatically. Only a nationwide ban can achieve this enforceability.

Manufactured Fuels

Smoke Limit

CPL recommends a 10g/hr smoke limit for all manufactured fuels. Properly performed smoke tests are time consuming and hence CPL makes the following recommendations.

a) Use of volatile levels to provide a simple low cost test that will provide guidance regarding the smoke generation with a level of 22% volatile being compatible with a 10g/hr smoke limit.
b) A levy on the sale of solid fuels (c €1 per tonne) could be used to provide a central testing laboratory (such as The State Laboratory) with full smoke testing and proximate analysis capacity.

Biomass Content

The current methodology for measuring biomass within blended fuels is considered to be entirely adequate but will require enforcement as these fuels become more significant in the Irish market.

Sulphur Limits

The enforcement of sulphur limits is again very important as the use of high sulphur raw materials reduces costs 4.5% sulphur pet coke currently costs c €110 pt compared to €150 pt for 3% sulphur and €170 pt for 1.5% sulphur materials, and hence the commercial drive will be towards higher sulphur if enforcement is not strong. High sulphur fuels are likely to be legal in Wales, Scotland until at least 2022 and Northern Ireland until 2023 and this again reinforces the need for enforcement.

Proximate testing of fuels can be quickly performed at reasonable costs and will show volatile and sulphur levels.

All of the above measures should be enforced by random testing at manufacturers, importers, merchants and retailers.

Peat/Lignite

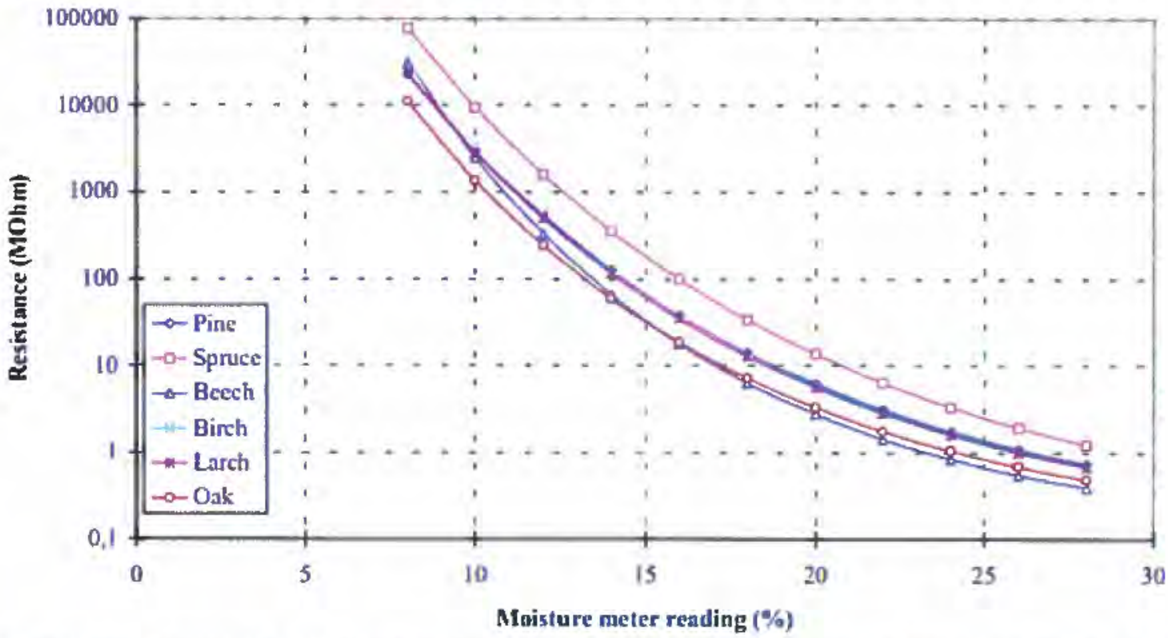
The removal of the CV exemption will remove these fuels from the market as they will exceed the 10g/hr smoke limit for manufactured fuels and have volatile levels of c 45-65%.

Wood

In line with our response to previous questions the enforcement of smoke control through moisture content represents the most practical method of enforcement.

This can be achieved by the use of moisture meters in the field. A procedure of sampling a number of bags from a given load of timber. This methodology would also involve splitting the wood such that measurements are taken (and averaged) across a selection of logs from each sample bag. The measurement of moisture levels using moisture meters and the wood size procedures are shown in appendixes 6 and 9. Moisture meters are well suited to measurement in the range of 10-25% moisture as the extent below from appendix 6 shows.

Figure 12



Resistance curves for different species of wood with moisture content measured by the same moisture meter (Forsén and Tarvainen, 2000).

Should the results for wood moisture using moisture meters be disputed the wood samples could be subject to full drying tests as outlined in (appendix 6). Such testing capability should be part of the central testing laboratory outlined above.

As outlined in the Wood Sure procedures (appendix 9) there is a need to check moisture levels at both the manufacturer/importer and the retailer as wood stored incorrectly can gain moisture in the retail environment.

<u>Overall Enforcement</u>

The current enforcement methods for Swift 7 (sulphur control) and biomass content are based on the packer of the fuel being responsible for the conformity of the fuel. This has worked in the context of an industry structure based on imported fuels (particularly coal) and may still be in part appropriate as some fuels will still be imported.

Consideration should be given to the rights of the enforcement bodies to inspect fuels and production at manufacturing sites as the large majority of low smoke fuel will be supplied from within the state. This would allow the inspection of sulphur levels and volatiles on stockpiles or from production and review of manufacturing records if required. This is in line with the current enforcement methodology for biomass content.

The enforcement teams should also sample fuels from retailers to allow the inspection of imported fuels.

Wood products should also be inspected at retailers to ensure that the fuel has been stored correctly and not allowed the fuel to accumulate moisture due to its hydroscopic nature.

Product Labelling

Enforcement and public/consumer recognition could be supported through a clear certification/labelling scheme for all low smoke fuels.

The scheme proposed is based on an approved product basis. Under the system low smoke fuels would be registered on a central database and given a certification number. Each manufacturer/packer may also be given a registration number (in line with current Swift 7 registration). These registration numbers combined with a clear logo would give the consumer clear guidance regarding which fuels are low smoke and inspectors clear information on the origin of the fuel.

An example of such a scheme could be "guaranteed low smoke", the following logo has been put forward for illustrative purposes.

The logo would be required to be displayed in a specified size and location on the front of the bag to provide consumer recognition.

The regulation would allow subcontract packing under the certification number and at the responsibility of the principle manufacturers.


Homefire
THE HEART OF YOUR HOME
SUPERTHERM
SMOKELESS FUEL
CONSISTENT, EASY TO LIGHT, GENERATES A HIGH HEAT & BANKS WELL OVERNIGHT
PRODUCES UP TO 80% LESS SMOKE

5) How can a transition to less polluting fuels and more efficient heating systems be supported? (Building upon the measures already set out in the Climate Action Plan)

Firstly low smoke fuels and dried wood can be used on all appliances that are suitable for coal, peat or wet/semi-seasoned wood. Hence the rapid implementation of regulations enforcing the use of low smoke fuels and low moisture wood will support the transition to lower pollution fuels without upfront cost for the consumer.

Changing fuels is the most direct means of improving air quality through reduced emissions. Evidence from a wide range of schemes shows that consumers convert more slowly to changes in heating systems as the level of investment and change to homes is considerable (i.e. fitting of heat pumps, particularly ground source retrofit).

CPL support the fitting of stoves to homes in place of open fires and Ecodesign stoves provide efficiencies of c 85% compared to 60-65% for older stoves and 35% for open fires when used with low smoke manufactured fuel.

Proposals for scrappage schemes supporting the changing out of older appliances have not been taken forwards in England on the basis that such schemes are difficult to police and represent poor value for the State/tax payer.

The scale of the problem in relation to the energy efficiency of home heating systems and poor insulation is being addressed by the Government and the SEAI. There are however approximately one million homes in Ireland with poor insulation and inefficient heating systems. Therefore, people are using too much energy to heat their homes.

In 2017, SEAI launched the Deep Retrofit Pilot Programme to address this very problem. To date, 526 homes have completed deep retrofits under this scheme, with the average total capital cost to upgrade a home from an average BER rating of F rating to an average A3 rating is €60,229.

In relation to other home energy upgrades or retrofits, only 24,700 homes were completed in 2019. These figures are only a tiny fraction of the ambitious targets set in the Programme for Government and the Climate Action Plan. They set targets to retrofit 500,000 homes to a Building Energy Rating of B2 and to install 400,000 heat pumps in existing buildings by 2030.

While the Government has increased by 82% the allocation in capital investment for residential and community retrofit programmes (Budget 2021 provided €221.5 million), greater innovation will be required to help generate greater energy efficiency measures and to achieve significant savings in CO_2 emissions. This will come at a significant cost to the State. A viable alternative to achieving emissions reductions in the residential sector, at no cost to the state, is mandating a switch to low carbon solid fuels in homes, followed by the long-awaited smoky coal ban.

A short/medium term incentive to encourage consumers to move to low smoke 50% biomass fuels would be to offer a period of full Carbon Tax exemption on such fuels. This would make such fuels lower cost than fully fossil fuels.

As is set out in the **Ecuity Report** (appendix 4) new regulations that support a transition to low carbon solid fuels can deliver a 9.3% reduction in total residential CO_2 emissions. It is set out in the Programme for Government that a strong focus will be placed on reducing the carbon intensity of our energy mix in Ireland. New Solid Fuel Regulations and the Climate Action and Low Carbon Development (Amendment) Bill 2020 presents an opportunity to meet Ireland's 7% reduction targets, by mandating the use of smokeless ovoid fuels as an alternative to household consumption of Smoky Coal in Ireland.

The residential sector currently contributes over 28% of overall emissions, and coal represents 12% of residential heating and hot water carbon emissions. If tackled correctly through policy intervention, a transition to low carbon solid fuels could deliver a considerable portion of the overall carbon savings being sought. The first step towards achieving these targets would be the banning from sale of smoky coal, nationwide.

In the interim, significant CO_2 savings can be achieved if the solid fuel mix in Ireland moved to low smoke fuel as a first step (0.9% reduction in total residential emissions), Ovoids containing 30% biomass (5.9% reduction in total residential emissions) or Ovoids containing 50% biomass (9.3% reduction in total residential emissions).

Biomass can play a very significant role in helping to reduce CO_2 emissions in Ireland, while not penalising families and individuals who currently have solid fuel or fossil fuels as their primary heating source.

From a value for money perspective, low smoke fuels can give up to a third more heat than normal house coal and can also burn for up to 40% longer. This means that they can burn hotter for longer, meaning you need to refuel your appliance less often. Less refuelling also means that low smoke fuels can be more cost effective than your normal house coal. For an open fire, low smoke ovoid's (low smoke fuels) are marginally more expensive, but the difference in delivered energy cost between low smoke ovoid's and either standard or premium coal is in the range of 2.5 to 5.5% depending on whether it is a bulk or bag purchase. Low smokefuels are better value for money as confirmed by the SEAI. The detailed SEAI fuel comparator which looks at fuel costs and efficiency factors, shows that smokeless or low smoke ovoids are 11% cheaper to use than smoky coal https://www.seai.ie/publications/Domestic-Fuel-Cost-Comparison.pdf

The cost of heating a room for a year based on the SEAI data is as follows;

- Smokeless - Ovoid €357 [Ireland / Euro prices]
- Smoky Coal - Premium €471 [Ireland / Euro prices]

While studies all confirm that smokeless fuels represent better value than coal – produce more heat, last longer and emit far less – there is a perception that coal is cheaper. It is false economy for consumers to use coal to heat their homes and until a ban is in place a fully competitive market for low sulphur smokeless fuels will not be established.

6) What do you think is an appropriate timeframe for the implementation of a national regulation of solid fuel?

There is a clear need for differential timing in the implementation of the new regulations to differing fuels.

Smoky Coal

The discussions and policy development supporting a national ban on smoky coal are well developed having been reviewed at ministerial level since 2013. Coal is contributing c 20% of all $Pm_{2.5}$ emissions in Ireland and low smoke replacement fuels are immediately available in ample quantities from five in-state producers.

As outlined earlier, the market situation surrounding Carbon Tax free coal is very serious within the market and if not remedied rapidly could lead to the closure of key producers of low smoke fuel reducing the capacity of the industry to replace coal.

The sale of smoky coal should be banned no later than May 2022. Coal imports are usually contracted during April/May for the following winter. Hence clear communication by government during summer 2021 and the signing of a SI during autumn 2021 will be sufficient notification to the industry. Provided communication is clear and an SI is completed by early 2022 then the winter of 2021/22 should be the last for smoky coal sales in Ireland.

Although it is understood that the coal ban is likely to be part of wider policy (which is necessary to prevent legal challenge from coal suppliers outside the state) it is vital that the coal ban is expedited promptly through the SI route.

Providing the ban is on the basis of the sale and marketing of coal then this will prevent the stock piling of coal as it will not be saleable. The prohibition on the sale of coal from May 2022 will allow retailers to sell through stocks during the 2021/22 season. There may be some stock piling of coal by consumers but this is unavoidable/uncontrollable and in any case limited.

Peat Briquettes

Peat briquetted and turf peat are highly polluting fuels generating c 20% of all $Pm_{2.5}$ emissions in Ireland.

While it is reasonable to clear peat stocks (held for briquetting) the current actions by Bord na Mona of restricting supplies to the trade is prolonging the use of peat including imports of peat briquettes from Eastern Europe.

It is recommended that the peat briquette is banned no later than May 2023 giving two winter seasons to clear stocks preventing further imports or sales of highly polluting peat. Two years' notice is more than sufficient for the clearance of stocks to the Irish market and if necessary export to Eastern Europe to clear the final tonnes of stock.

The cutting of peat by those with turbary rights is understood to be exempt from the above.

Blends

All blended products should be made from entirely low smoke components from May 2023 in line with peat leaving the market. This will effectively remove lignite and other high smoke blend components.

Wood

Wood is a significant emitter of $Pm_{2.5}$ and in line with many markets the use of wood as a fuel is in rapid growth (20-25% p.a.) hence the need to control $Pm_{2.5}$ is evident.

The control of emissions from wood burning is relatively new in legislature and there are a number of differing approaches available, some of which have been explored in the UK;

i) Voluntary scheme – this was originally operated in the UK through Wood Sure. A legislative approach was adopted as retailers retained wet wood products due to the lower volumetric pricing of unseasoned wood (even though kiln dried wood represents equal value).
ii) Distribution channel/pack size – The UK legislative approach is based on pack size/delivered volume with small bags and deliveries under $2m^3$ being subject to the moisture regulation. The logic of this approach is that smaller purchase quantities will be burnt quickly and need to be at a moisture content suitable for immediate burning. Regulation and control of the retail sector through Trading Standards/inspectors using the methodologies outlined in the previous section of the report is more achievable than in the case of local deliveries of bulk timber.
iii) Complete market approach implementing moisture control across all wood irrespective of sources/pack size.

The control of wood sales through the retail sector would affect local businesses supplying the forecourt sector but would reduce $Pm_{2.5}$ emissions significantly and hence is supported with a complete ban on wood over 20% moisture introduced in 2024. While control and enforcement will be difficult for bulk woo deliveries, growing consumer awareness through the promotion of "guaranteed low smoke" schemes will help reshape market demand

Approaches ii) and iii) could be applied as a program of increasing control over a period of c 3 years. Implementation of controls on retail/internet sales (ii) above) could be applied within c 12-24 months giving local producers the time to develop kiln capacity or stock of highly seasoned wood a suitable lead time.

7. What timeframe should be applied to the inclusion of new solid fuels into legislation to allow for the necessary transition, including the phase out of existing stocks?

CPL support the same timeline as set out in question 6, whereby new Solid Fuel Regulations should be announced in mid-2021, with a clear date for their implementation, including a total ban on the sale of smoky coal by 2nd April 2022, one year from the conclusion of this current consultation process.

As outlined in the previous question.

8. Should suppliers and retailers be given a transition period to use up existing stocks of solid fuels not meeting emission standards and, if so, how long?

Implementation transition times have been outlined in answers to earlier questions.

9. Are there particular challenges in terms of the enforcement of regulations applying to solid fuel burning, and how might these be best addressed?

The need for dramatic improvements in air quality is recognised by Government, the EPA and health professionals. CPL want more action in relation to air quality, because the current partial ban on smoky coal is effectively unenforceable.

The particular challenges for effective enforcement in CPL's view can be summarised as follows;

i) The open border with Northern Ireland and the likelihood that coal and high sulphur low smoke fuels will be available for some years in N Ireland provide a high risk of importation of tax free coal and high sulphur products.
ii) There are now 5 manufacturers of low smoke fuel within the state, 3 of these are also significant importers of coal and there are further significant importers both within the state and importantly in N Ireland.
iii) Lignite and other (some high smoke) components of blends are imported through 3-4 ports and distributed to c 6-8 major packers.
iv) Kiln dried wood products are/will be produced by an increasing number of the in state producers. There will also be very significant imports (principally from Eastern Europe) through container ports to merchants, retailers and stocking locations.
v) Local suppliers of bulk wood for storage and consumption over a winter season are clearly difficult to police in terms of wood quality/moisture.
vi) Overall this complex supply chain makes enforcement challenging.

To meet these enforcement challenges the following are outline recommendations, actions and structure;

i) **Investment in a suitable regional (but centrally controlled) structure** to provide effective on the ground inspection and enforcement capability that is clear and visible to the industry.

CPL suggest a model along the lines of DECC's Waste Action Group (WAG), specifically to deal with enforcement. The Waste Action Group was established by DECC in the last year to advise them and Minister Eamon Ryan on the implementation of various aspects of the Waste Action Plan for a Circular Economy. A similar body would allow for engagement between the industry and the key state and regulatory actors including the EPA, Revenue, the Local Authorities and DECC.
There needs to be an enhanced inspection regime for fuel merchants, which is properly resourced an appropriately coordinated with all relevant state agencies and bodies, including empowering Customs to stop vehicles. In relation to compliance with the regulations in relation to specific low smoke fuels, there needs to be regular testing at manufacturers, packers and importers. There needs to sulphur and proximate testing to ascertain if fuels are over the prescribed sulphur limit or over 22% volatile. These fuels then should then be required to perform a full smoke test at an independent (or central government) laboratory.

In relation to wood fuels, there should be on-the-spot moisture testing using split log methods with moisture meters. If logs have a moisture content above 20%, they should be referred to a laboratory for full dry weight testing.

In order to ensure compliance along the supply chain, there must be a significant focus of testing at importers, with corresponding tests at merchants and retailers.

For safety, there needs to be guidance in relation to the storage and display of kiln dried wood in dry conditions.

ii) **An approved product/supplier scheme with clear product labelling** would provide confidence and clarity for consumers and traceability for inspectors and enforcement bodies.

In previous parts of this submission, CPL has outlined proposals for "EPA Guaranteed Smokeless" labelling on low smoke products. This labelling would be common to low smoke manufactured fuels, wood with 10-20% moisture content, approved blends and manufactured biomass fuels.

In addition to the clear logos on packaging the labelling would include the approval/scheme membership number of the supplier. Hence should a product not meet the specifications when tested its source is clear to the inspector.

This will require a suitable scheme to be set up (possibly using the National Standards Agency of Ireland) and suppliers would require to register their companies and products.

The registration could require submission of independent test results and quality programs or prove of adherence to quality control procedure laid out within the scheme requirements. This would clearly provide a basis for inspectors at importers, storage or production sites.

iii) **Consumer confidence/choice.** The clarity such a scheme will provide consumers should not be underestimated. A well communicated clear scheme will enable the consumer to choose low smoke fuels during transition periods and drive acceptance and usage of the fuels.

This is a substantial benefit in achieving change and eradicating high pollution fuels in sectors such as local wood deliveries where enforcement is difficult.

10. Do you have any further proposals to reduce air pollution from residential heating?

As outlined earlier changing of fuels regulation should be the fast and most urgent step to reduced $Pm_{2.5}$, GHG and SOx pollution from the residential sector.

Given the large number of open fires and older stoves in use in Ireland progressive improvement in the installed base of stoves in Ireland is required.

The results of tests by CPL shown in appendix 7 show that Ecodesign stoves reduce emissions from kiln dried wood burning by c 60% when compared to an open fire. Ecodesign stoves typically achieve c 85% efficiency reducing the fuel used by consumers and hence both $Pm_{2.5}$ and GHG emitted compared with older stoves (c 60-65% efficient) or open fires (c 35% efficient).

While Ecodesign stoves are relatively expensive, the support of the installation of such stoves may represent a more practical approach than heat pumps which require significant investment and behavioural change by the consumer.

While the Programme for Government and the Climate Action Plan cite heat pumps as a more attractive and energy efficient alternative to stoves, the fact remains that 19% of homes in Ireland rely on solid fuel, as their primary source of heat (CS) 2018). The upgraded building regulations and the Governments deep retrofit programme have resulted in a significant increase in energy efficiency due to the uptake in heat pumps, however by mandating a change in fuel can have an immediate impact on carbon emissions, $Pm_{2.5}$ emissions and savings to consumers' pockets.

As referenced elsewhere, the financial and taxation instruments available to the Government, provide a useful tool to facilitate change in behaviour by consumers. In relation to CPL's **Ecoal50 Smokeless Coal,** the Finance Bill (No.2) allows for tax relief of up to 50 % on solid fuels with biomass content of 30% or more.

This also applies to CPL's Supertherm30 range of smokeless coals and we believe that a Carbon Tax exemption for low smoke fuels such as this, can help to dramatically improve air quality standards.

This positive taxation measure means that buyers enjoy a 30% reduction in the amount of carbon tax they pay on these products. Both products emit up to 80% less smoke and 25% less Carbon Dioxide than coal, and are the first solid fuels to comply with NSAI regulations. This is a win-win situation and is an example of where national Solid Fuel Regulations can act as an incentive to industry players such as CPL to innovate, helping the environment and the pocket of consumers.

11. What performance standards, certification methods or quality schemes should/could be used to reduce air pollution caused by burning solid fuels?

CPL recommends testing to take place at manufactures and importers / distributors, to ensure compliance with the regulations.

A scheme labelling fuels as "GPA guaranteed low smoke" or similar based on fuels being approved.

Approval should be on the basis of proven independent test results showing the product meets the required smoke and sulphur standards.

The scheme could also include a quality audit approach whereby the supplying company must supply a quality control plan adherence to which (or a prescribed standard) can be checked by inspectors visiting production/operational/retail sites.

12. Would broadening the application of the 10 gram smoke per hour to all solid fuels be appropriate?

As outlined in previous sections of the consultation - CPL believes the 10g/hr smoke limit should be applied to all fuel types including wood and biomass/blended biomass fuels.

A range of measurements for use in the field for enforcement have been recommended namely volatile level for fuels (22%) and moisture content for wood (10-20%).

13. Are there any additional or different emission standards which could be applied to the broader range of fuels?

CPL considers that the primary requirement is the clear legislation of $Pm_{2.5}$ and SOx control as discussed in the report.

Subsequent to the implementation of clear legislation and enforcement of the above a number of further areas could be considered.

i) NOx – some biomass fuels (coffee log) are known to be higher in nitrogen content and hence a biomass fuel developed in the market this may need to be considered.
ii) Trace metals – fuels in future will be developed from materials such as food wastes/plant wastes etc and it will be necessary to define trace element levels that are not higher than coal/low smoke fuels that such products will replace.

The UK uses an "End of Waste" certification scheme to achieve this but it is bureaucratic and a simpler standard for trace elements would be preferable and accelerate the development of low smoke fully renewable fuels in Ireland (using Irish wastes/biomass).

14. Is it appropriate to use moisture content as a standard for the application of regulations to wood and, if so, at what limit should the moisture content be set?

As outlined in detail earlier in this submission the control of $Pm_{2.5}$ emissions from wood through moisture levels is considered a practical and scientifically sound approach.

There are other variables in the generation of $Pm_{2.5}$ from wood burning particularly oxygen availability and (related) type of appliance but these are existing variables with the usage of wet or dry wood.

It is clear that wet wood produces between 21g and 30g/hr of $Pm_{2.5}$ compared to 6-8g/hr for wood between 10-20% moisture burnt on an open fire. A scaling factor of 5 x which is seen throughout the various academic and industrial test work on whatever testing and measurement basis.

The recommended range of moisture is 10-20% as although 25% moisture wood can still produce low particulate levels a 20% limit will provide a margin of error to ensure good control of emissions.

15. What limit should be set as a cut-off point for the sale of wet wood?

a. **Bags/nets only;**
CPL support the requirement for this to be low smoke only

b. **Up to 2m3;**
CPL support the requirement for this to be low smoke only

c. **All wet wood; or**
CPL support the requirement for this to be low smoke only, except for personal use.

d. **Other:** please provide reasons or evidence to support your answer

As outlined in answers to earlier questions - CPL considers the by-sector approach to be reasonable and enforceable. Hence CPL considers that a. and b. above should be progressed as quickly as possible. This would in practice mean implementation in 12 to 24 months to provide a run in period for the trade to invest in kilns or increased seasoning capacity.

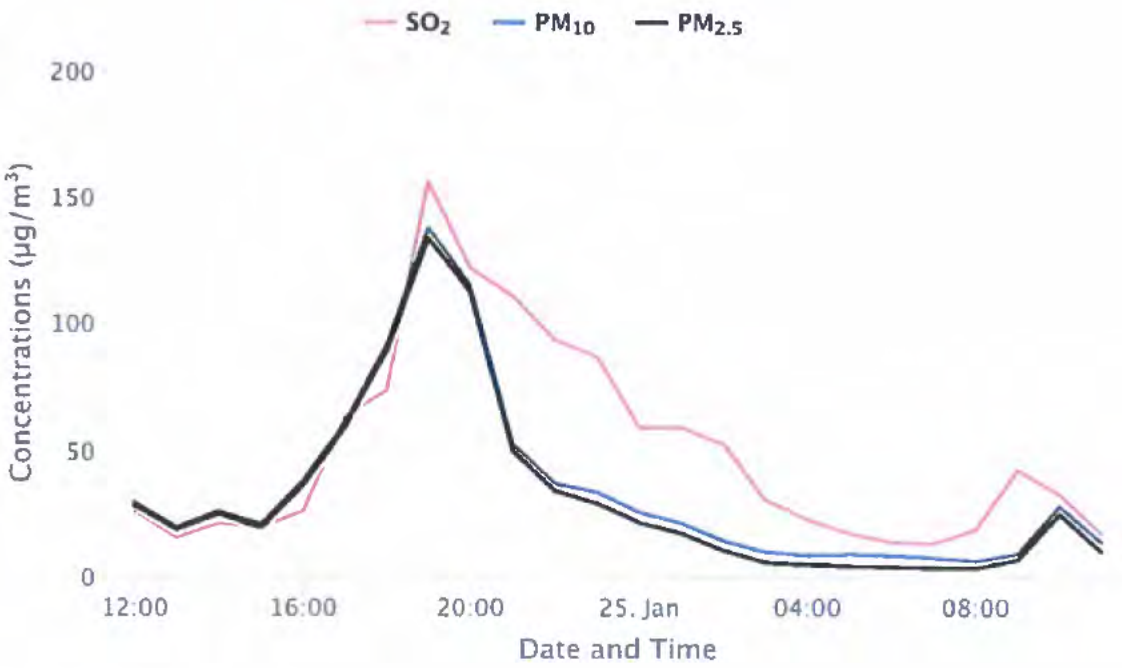
This period could be used to consult on measurement/control methodology details, the banning of all wet wood as in c. above will be difficult to enforce but will substantially reduce "wet wood" sales and should be introduced by 2024.

Such a time period will allow the public to gain acceptance of the value and performance of the dried wood products. Once established experience of other market suggests rapid growth as the consumer appreciates the c 80-100% improvement in heat output over wet wood.

Appendices 1-9

Appendix 1

Letterkenny Jan 25 2021



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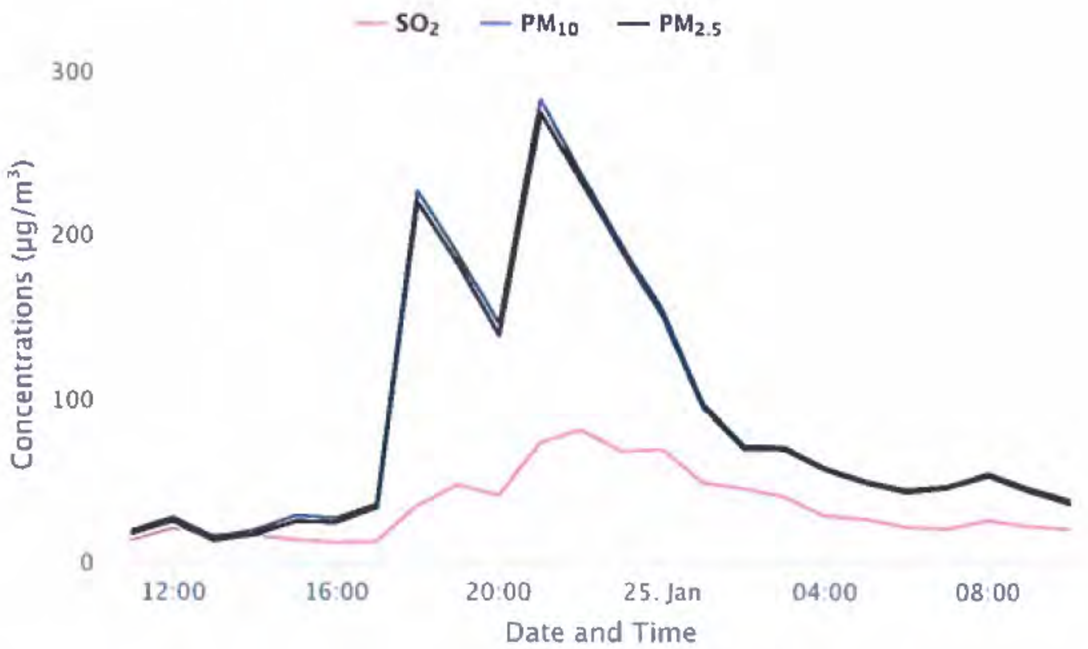

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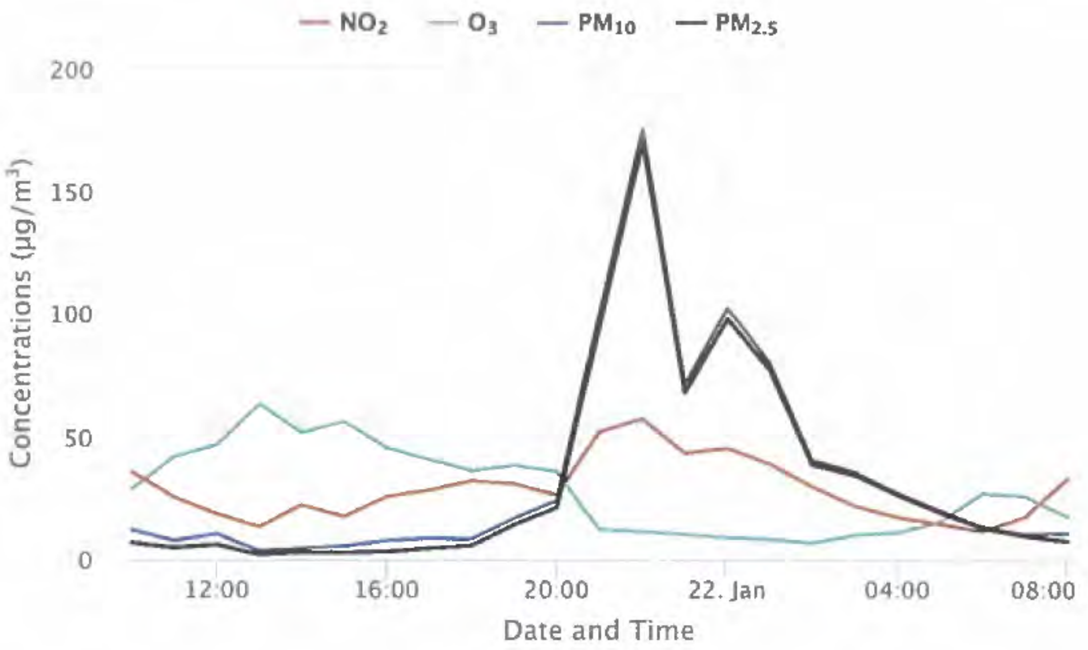
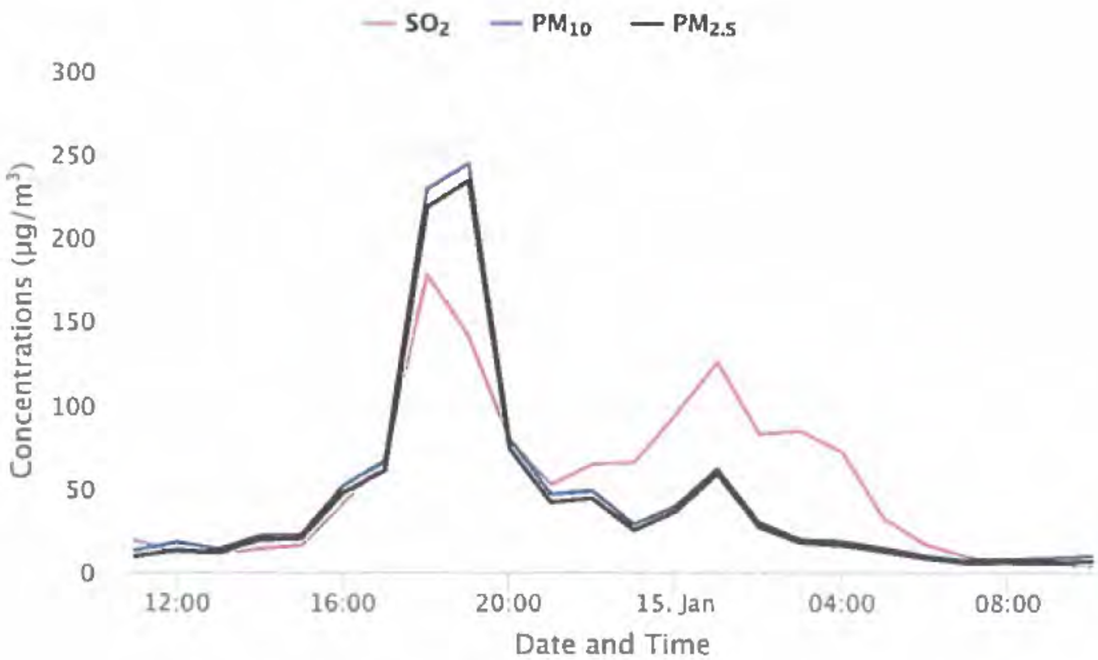


Letterkenny Jan 15 2021



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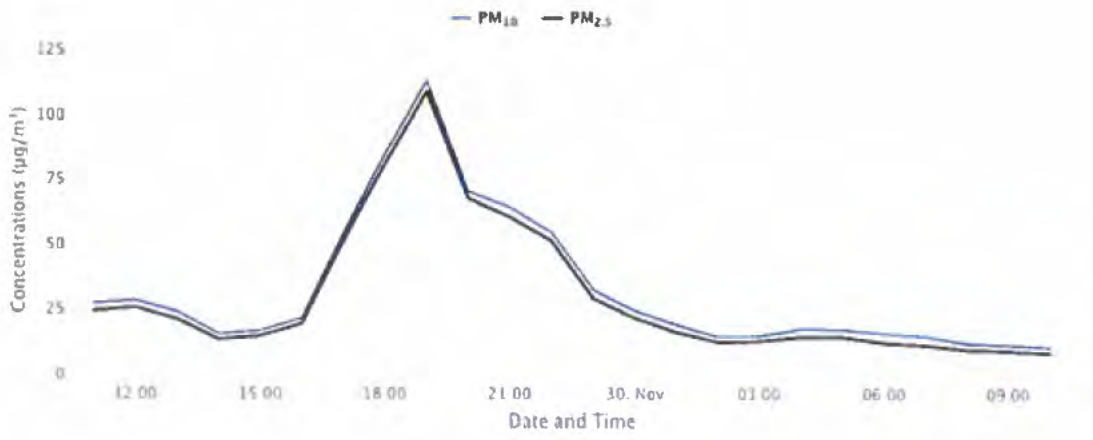
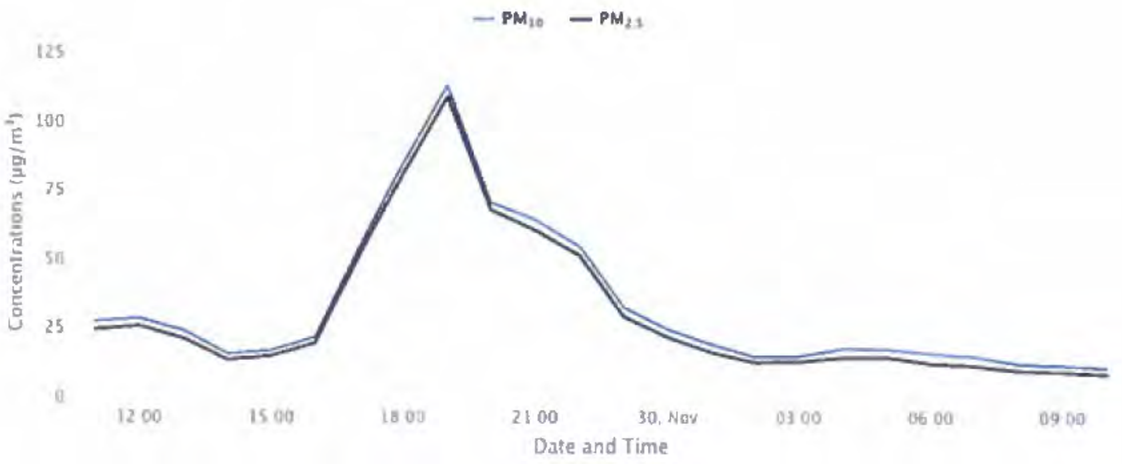
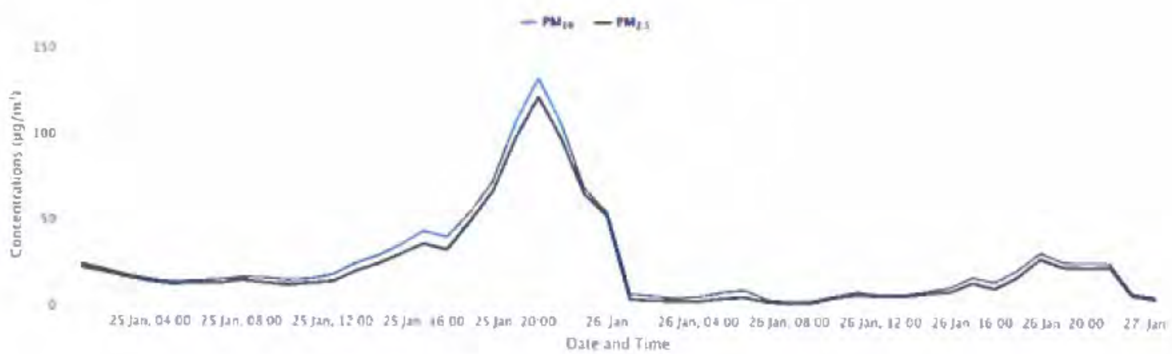


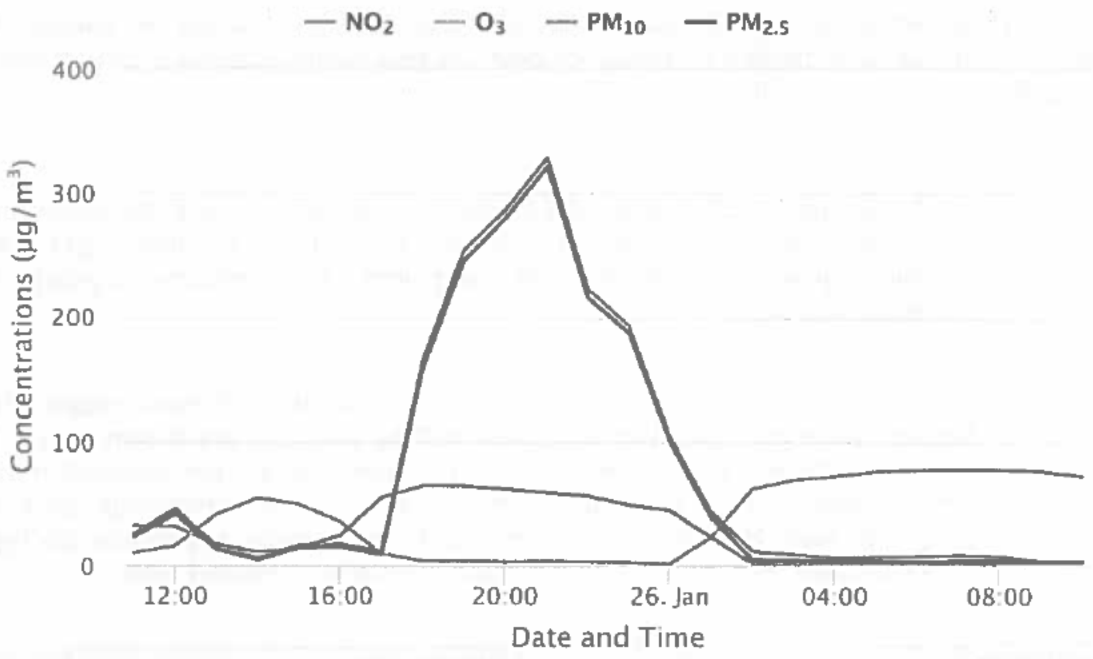
Enniscorthy



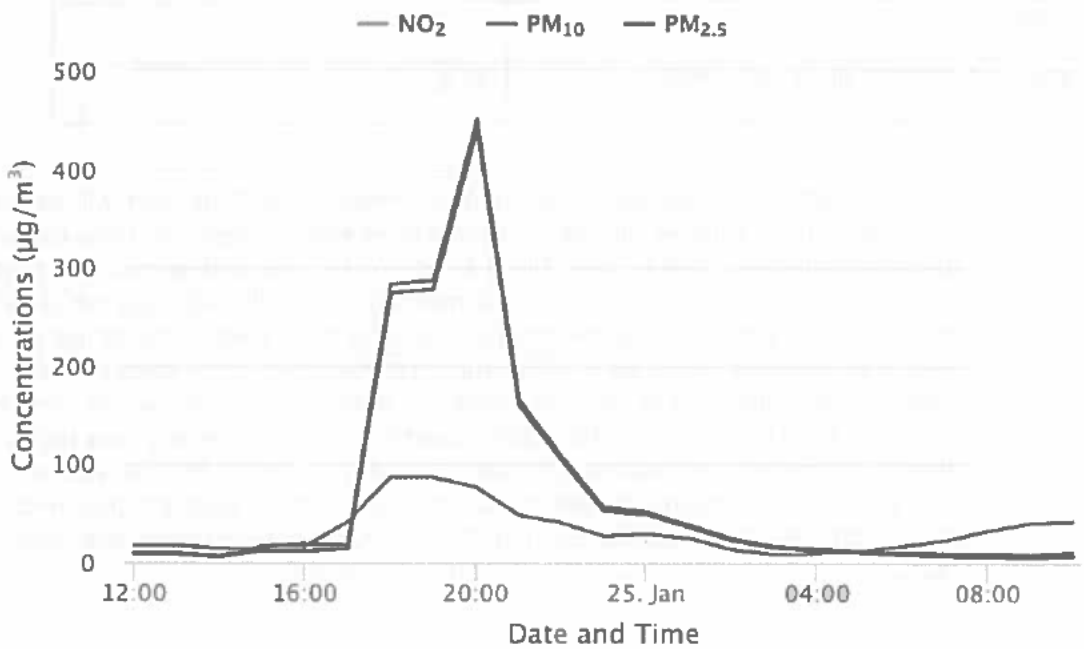
Cork



Waterford



Sligo



Appendix 2

Exempt Fuels

The UK Government's Clean Air Strategy stipulates that certain fuels will be exempt from regulation. This was unexpected and has not been subject to the extensive consultation on which the other areas of legislation draw. The following are key concerns:

i) That having developed detailed legislation to control $Pm_{2.5}$ and SO_x emissions, a complete category of high emission fuels is exempt from regulation and control, creating market distortion. $Pm_{2.5}$ emissions from olive logs/coffee logs/wine logs are equal to coal.

ii) CPL operates a fully specified fire test and smoke emission measurement facility. Tests carried out on olive cake derived products are shown below. The statutory limit is 5g/hour and hence the results indicate the potential for high $Pm_{2.5}$ emissions from such fuels. Other fuels such as coffee logs show high $Pm_{2.5}$ and high NO_x emissions. Emissions from coal are typically 20-25g/hr. This contrasts with the 5g/hour emission of smoke controlled fuels.

Briquette Blend	Smoke Test g/hour
50% olive cake / 50% smokeless fuel blend	14.5
100% olive cake	17.6
75% olive cake / 25% olive cake charcoal	34.5

iii) The exempt fuels regulation also seems limited in outlook and will exclude a range of equally renewable fuels. Exempt biomass sources for 100% renewable fuels are listed as Coffee Logs, Olive Logs, Wine Logs, whilst excluding options such as hazel nut shell, coconut shell, macadamia shell, babassu nut shells, etc which evidently meet the same criteria – coming from stocks that renew annually and from existing harvests. CPL supports food and shell-based fuels, given their renewability provenance is easier to determine than that of tree felling through FSC/PEFC type certification schemes. We believe any new regulations should outline key renewable attributes (i.e. short rotation, no damage to source tree/plant or total regrowth within 12 months). This would provide a basis of regulation that would incentivise fuels from a range of fully renewable resources, rather than a restrictive listing of prescribed sources.

iv) The part of the UK regulation dealing with blended fuels where 51% of the fuels are formed from prescribed biomass sources (composed of wheat husks, straw, miscanthus, bamboo or compressed food waste) would also be subject to the above and should be extended to include a wider range of equally renewable biomass products. The regulations include food waste but exclude plant wastes. Plant wastes can offer a fully circular and renewable solution for the provision of fuels and we believe should be included in the regulations. Advanced pyrolysis techniques can produce high performance circular fuel from green/plant waste which prevents such waste going to landfill or composting, such investments and industries are dis-incentivised by the UK regulation as drafted. The plants making such fuels can be very low or zero carbon (if renewable electricity is available or included in the plant). The circular renewable fuels produced can meet the same $Pm_{2.5}$ emissions as kiln dried wood using the same testing methods.

v) The UK regulation will potentially result in fuels that distort or defeat the intention of the legislation as a manufacturer could combine one of the listed materials (51%) with high sulphur pet coke (49%) to produce a relatively high smoke and c 3-3.5% sulphur product. The unregulated 49% could also be comprised of non FSC/PIEC wood, or indeed high smoke coal fines.

vi) The fundamental change in this area of the regulation is to seek to specify the composition of fuels rather than performance and the requirement to meet standards for emissions and sustainability. This area of the regulation was not subject to consultation at UK level, this could be improved substantially by input from Industry, NGOs, testing/certification bodies, etc. We believe that this should be removed from the UK regulation and brought forward separately following such consultation. It is an opportunity for the Scottish Government to create and implement more thorough regulations in this area to support the rapid development of innovative products and new circular and renewable fuel markets.

vii) These exempt unregulated fuels would be c £30pt (25%) lower in cost to produce than regulated 2% sulphur low smoke fuels (CPL can support this through evidenced raw material costs) and hence could gain significant market share based on the appeal of renewability. This combined with the continued presence of coal and bulk sales of wet wood may negate (or worse) any reduction in emissions from domestic burning due to the regulations.

viii) In the past week it has been announced by HETAS that the exempt fuels will not be eligible for the Ready to Burn scheme and will not have HETAS approval. The products will hence not be allowed to be burnt in smoke control areas. This presents a totally confusing picture to the consumer and will lead to these fuels being used inappropriately by consumers believing they are "doing the right thing" and using a renewable product.

Appendix 3

Raw material costs/blend and proximate analysis

Biomass	Moisture %	Ash %	Volatile %	Sulphur %
Almond shell	7.9	0.9	80.1	0.14
PKS	7.7	1.3	75.8	0.14
Pine wood	37.0	0.8	72.9	0.07
Olive cake pellets	12.3	5	74	0.30
Eucalyptus wood	30.0	1	81	0.05
Olive stones	10.7	0.5	79	0.20
Coconut shell	8.5	0.7	76.3	0.13
Peach stones	19.7	0.7	77.9	0.14
Miscanthus pellets	9.2	7.8	72.2	0.30
Grape seed	10.9	4	69.8	0.23
Coffee grinds	8.3	2.4	78.7	0.60
Oat husk	8.1	4.6	78.1	0.16
Coco Peat	13.3	10	68.1	0.03
Waste wood Coarse char	1.1	15.2	3.2	0.25
Waste wood fine char	0.7	33.9	5.5	0.30

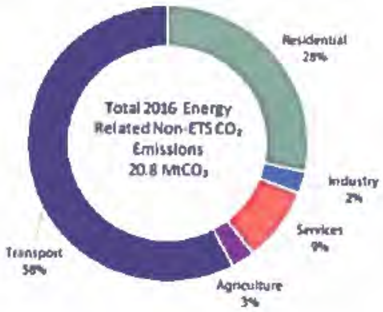
Appendix 4

Solid Fuel Regulations Consultation

Report

Domestic energy landscape

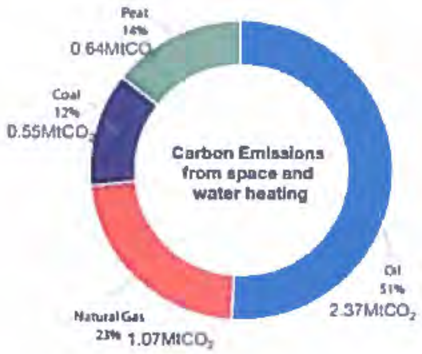
- Energy related emissions in Ireland account for 20.8MtCO_2
- The residential sector produces 28% or 5.8MtCO_2
- Residential energy consumption totalled 32 TWh in 2018
- This is approximately ¼ of total final energy consumption
- Total household energy bill cost at €3.4 billion
- Over 1.7million properties.



Source: SEAI

SOURCE OF DATA - SEAI

Domestic burning is a major contributor to residential Green House Gas



- Space and water heating together accounted for 80% household energy use 4.64MtCO_2
- Coal represents 12% of residential heating and hot water carbon emissions and if tackled correctly through policy intervention could deliver the carbon savings currently being sought.
- **Industry estimate the true size of the coal market to be double that included in SEAI reporting (only reporting figures/data supplied)**
- **If a complete coal policy intervention/ban was made savings could deliver large portions of or even exceed the reductions sought Program for Government published**

SOURCE OF DATA - SEAI

Fuel comparison

	CO_2 (in CO2/MWh)	Assumed Efficiency on Open Fire (%)	CO_2 per Effective Heat (tn/MWh)
Smoky Coal - premium	0.394	28%	1.41
Smoky Coal - standard/brown/mix	0.394	28%	1.41
Smokeless Ovoids - no biomass	0.433	37%	1.18
Smokeless Ovoids - 30-50% biomass	0.309	37%	0.85
Smokeless Ovoids - 50%+ biomass	0.226	37%	0.63

SOURCE OF DATA – The Sutherland Tables – backed by British Coal and HETAS

How big could the savings be if smokeless?

	[illegible]	Ovoids 30% Biomass	Ovoids 50% Biomass
Tonnes of Coal (all types)	380,000	380,000	380,000
Smoky Coal tonnes	212,325	212,325	212,325
Carbon emissions tonnes	693,061	693,061	693,061
Ovoids tonnes	145,825	145,825	145,825
Carbon emissions tonnes	398,350	398,350	398,350
Total Carbon Emissions	1,091,411	1,091,411	1,091,413
Total Carbon Emissions if all ovoids at each biomass %	1,038,046	747,745	554,211
Reduction in carbon emissions tonnes	53,365	343,666	537,200
Reduction in solid fuel/coal emissions %	4.9%	31.5%	49.2%
Reduction as % in Heating and Hot Water emissions (4.64MtCO$_2$)	1.2%	7.4%	11.6%
Reduction as % of total residential emissions (5.84MtCO$_2$)	0.9%	5.9%	9.3%

SOURCE OF DATA – Volumes estimated from a number of market sources

Policy Options

(1) Do Nothing
- Residential burning remains stable.
- No improvements in AQ or GHG.
- PM2.5 objectives missed

(2) Move to smokeless training
- Essential to achieve PM2.5 objectives
- Major air quality improvements
- Residential GHG emissions reduction 0.9%

Require 30% biomass
- Major air quality improvements
- Residential GHG emissions reduction 5.9%
- Emissions from residential burning fall by nearly 1/3

Require 50% Biomass
- Major air quality improvements
- Residential GHG emissions reduction 9.3%
- Emissions from residential burning nearly halved

Ireland Energy Policy Landscape

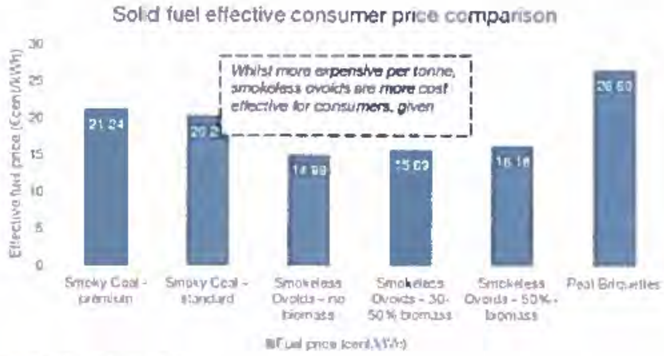
- If peat is taken into consideration this reduction could be increased. While we understand the cost of the fuel per tonne is lower due to the inefficiencies with burning it the cost to the consumer per kWh is actually larger
- Assuming just the peat briquette usage (not sod peat) is moved to the smokeless ovoid 50% biomass the addition reduction would be

1.7% reduction in residential carbon emissions

192,000 tonnes carbon for peat briquettes against 90,000 tonnes for smokeless ovoids 50% biomass given a ~102,000 tonnes Carbon emission reduction

Costs of solid fuel use

Although smokeless fuel is more expensive per tonne to buy it is lower cost per effective unit of energy than smoky coal and peat briquettes as its more efficient when burnt

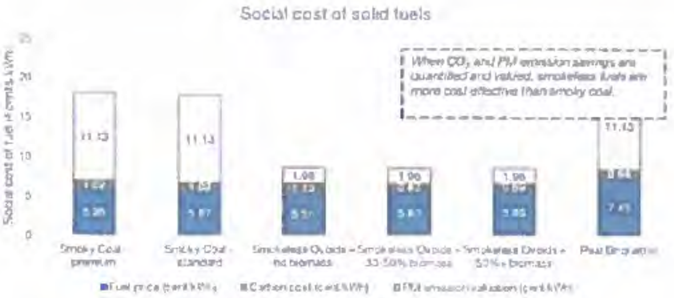


SOURCE OF DATA - SEAI

- **The following chart compares the *delivered* fuel price of smoky coal and peat briquettes with smokeless solid fuel – taking account of the energy efficiency of the heating system.**
- **Smokeless fuel is marginally more expensive than smoky coal in terms of fuel price per tonne, but owing to energy efficiency benefits, the delivered cost of energy is lower for smokeless ovoids.**
- **The delivered cost of smokeless ovoids at 16 €cents/kWh is the lowest solid fuel price per kWh of delivered heat for the consumer.**

Social cost of solid fuel

When carbon and air pollution emission savings are quantified and valued, smokeless fuels are most cost effective



The socialised premium of smoky coal over smokeless is ~€722million (1805GWh)

*Damage cost estimate taken from Ricardo [illegible]

- **The Irish Government could for example value the emission savings generated by switching to cleaner fuels.**
- **In respect of carbon emissions, the Irish Government has set a carbon price in other sectors (€26/tCO_2). Applying the same cost of carbon to the emission savings generated by switching to smokeless fuel with biomass, carbon costs reduce from 3.7 €cents/kWh with coal to close to 1.6 €cents/kWh with smokeless ovoids.**
- **The air quality impact is potentially greater. Poor air quality causes over 1,100 premature deaths per year in Ireland. Here, PM_{10} emissions are reduced substantially (82%) by switching to smokeless fuel. Monetising the environmental, health and wellbeing benefits of reduced air pollution using a damage cost estimate*, the social cost of particulate matter pollution can be decreased from 40 €cents/kWh to 5 €cents/kWh.**

Appendix 5

Heavy Metals in Solid Fuels

Materials Tested

The materials tested were high volatile Columbian coal, Welsh anthracites, two high sulphur pet cokes circa 5-6% sulphur and a low sulphur pet coke circa 1.2% sulphur.

The Columbian coal represents a high quality house coal which therefore acts as a standard for the coals being burnt in the home (lower quality Scottish coals are also consumed).

Anthracite is burnt as a boiler fuel but also used as a major component of smokeless solid fuels.

Petcokes are used as near 100% of the raw material component of non-authorised non HETAS approved solid fuels. These products are increasingly used to replace housecoal but their use is poorly policed. Low sulphur petcoke represents an alternative petcoke sometimes used to mitigate very excessive levels of sulphur though the high cost significantly limits its use in solid fuels.

Results in Summary

The Table attached shows the results for heavy metal content of the various cols and fuels in mg/kg. Results were obtained using an XRF analyser that achieves measurement to 0.01%. The work was carried out by Birmingham University Chemical Engineering Dept on behalf of CPL. When using XRF the results have to apportioned on the basis of the carbon content of the material as carbon is transparent to XRF scanner. The table data has been proportioned in this way and the fixed carbon content for each product is indicated at the top of each column. These carbon values are averages for each product taken from routine testing carried at Imminmgham Briquetting Works over a number of years. Looking at the data there is as expected a good correlation between heavy metals in the coals and the smokeless fuels as the coals are blended to produce the finished fuel and the binders used have very low if any heavy metal content. There is also a good correlation with the data collected by the EA for their report which is included in the final column. The report from August 2016 Report – SC130040/R9 Version 2 Material Comparators for End of Waste Decisions - Materials for Fuels: Coal analysed 20 coal samples (including anthracites and house coals) sourced in the UK from retail and industrial outlets. The analysis used was different using LE I metals (ICP-OES) 01 – digestion block aqua regia extracted under reflux; determined by inductively coupled plasma optical emission spectrometry (ICP-OES).

Arsenic and Mercury

In our analysis neither was found at a detectable level. In the EA report all analyses for mercury was reported as below the limit of detection 0.2 mg/kg. Arsenic in the coal was reported in a range 3 – 6 mg/kg. Although this was below the LOD in our XRF work, the experienced testing staff at Birmingham University expressed the clear opinion that arsenic and mercury were not present in the samples to a level of any significance.

Lead

In terms of lead content using XRF it was detected in only one of the petcoke samples at a level of 38 mg/kg. In the EA report over the range of tested coals Lead was detected in all samples with a mean content of 13 mg/kg. Using XRF there were no detectable levels in either smokeless fuels.

Nickel and Vanadium

The coals showed levels of nickel and vanadium similar to the results from the EA report (6 mg/kg Ni and 38 mg/kg V) with anthracite having slightly elevated levels of nickel (23 – 45 mg/kg).

Analysis of the petcoke samples shows a high content of nickel and vanadium content in the fuel compared to the other coals and to the EA comparator. The high sulphur petcoke samples are reasonably consistent in terms of nickel (Ni) and vanadium (V) content showing levels of 327 – 386 mg/kg for Ni and 548 – 647 mg/kg for vanadium.

The sample of low sulphur petcoke does appear (based on one sample) to have slightly lower levels of nickel at 379 mg/kg and particularly vanadium at 265 mg/kg.

The two CPL products show slightly elevated levels (58 – 66 mg/kg Ni) and (79 – 92 mg/kg V) due to the circa 10 – 15% petcoke used in the blending to reduce ash and increase reactivity in the product.

The particular issue with petcoke is the very low ash contents. CPL carried out some ash heavy metals analysis as part the investigation and the results indicated that after combustion the Nickel and Vanadium remained in the ash. With ash contents typically less than 1% the concentration effect gave results as high as 50,000 mg/kg Nickel and 118,000 mg/kg Vanadium. It is reported that the nickel and vanadium contents derive from the catalyst used to aid cracking of the very heavy oil distillate which is processed to produce the very last high fractions and the solid petcoke.

Brief Summary

The heavy metals content of coals, anthracites and solid fuels using anthracites as a major constituent are very similar. The CPL products Homefire and Phurnacite show slightly elevated levels of vanadium and nickel due to the inclusion of c 15% petcoke. This results in relatively low results of c0.1-0.15% for the metals in the product but would result in over 1% vanadium in the ash.

The major issue is that those fuels made from circa 100% petcoke are in most cases produced using very high sulphur material (circa 5%) due to its low price. This results in excessive levels of sulphur oxides during combustion and at circa 0.05% nickel/vanadium within the petcoke briquette and 5-10% in the ash.

Possible regulatory options to control petcoke in solid fuels include the national prohibition of fuels with sulphur content above circa 1.5 -2% or restrictions regarding the maximum petcoke content of fuels. Either of these would lead to significant reductions in Nickel and Vanadium in the ash of solid fuels.

To illustrate the effect of the high price differential between high sulphur petcoke and low sulphur petcoke also attached are 6 blend formulation sheets which are used by CPL to assess the cost of various input raw materials blends. The six sheets show 3 blend formulations for CPL's premium smokeless open fire product Homefire and 3 for a generic 100% petcoke briquette. For Homefire the blends are for decreasing sulphur contents 2% , 1.5% and 1% and for petcoke the blends are a current 100% high sulphur petcoke briquette and the additions of low sulphur petcoke to get that product below 2% and 1.5% overall sulphur.

The formulations show the current delivered prices experienced by CPL and the blend calculations show the resulting proximate analysis of the proposed product and its cost of production. It clearly indicates that for a smokeless fuel such as Homefire, which is predominantly anthracite to maintain a low particulate emission, a stepwise reduction in total sulphur in cost terms is relatively neutral but would result in a higher ash, less reactive fuel for the final customer. For the 100% petcoke briquette the cost of even achieving the current smoke control area limit of 2% sulphur would result in 70% increase in raw material cost up by £61 / tn. This is not commercially viable so a reduction in the overall sulphur content will severely disadvantage the production of these products.

	Columbian Fines Typical of UK Housecoal	Columbian Singles Typical of UK Housecoal	High Ash Anthracite Welsh Anthracite	Low Ash Anthracite Welsh Anthracite	High Sulphur Pet Coke Russia Typical Mid - High Sul PC
Ash %	3.0	2.7	12.0	5.5	0.7
Fixed Carbon %	80.3	80.9	76.6	87.4	89.6
Formula	mg/kg Coal Actual	mg/kg Coal Actual	mg/kg Coal Actual	mg/kg Coal Actual	mg/kg Coal Actual
Si	369	455	1274	1748	159
Al	187	195	472	1024	54
Fe	1114	980	459	2264	622
Ca	233	253	380	271	514
Ti	40	42	128	167	
Ba			64	112	
Sr	37	21		79	15
Mg	18	16			
Na					
Pb					
Cu			11	31	
Ni	7	6	23	45	386
Zn	10		12	29	11
V			8	17	647
Mn	7		9	28	
Mo	25	32	17	45	46
As			6	12	
Hg					
Co					

Appendix 6

Moisture matters:

The impact of wood fuel moisture content on emissions

CLEANSTOVE consultants

Customer:

This work has been prepared for CPL Distribution Limited by Clean Stove Consultants Ltd.

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Date:

March 2021

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Executive summary

Residential solid fuel burning can be a significant contributor to ambient air pollution, particularly where older inefficient appliances are used with smoky fuels such as coal, peat and wet wood.

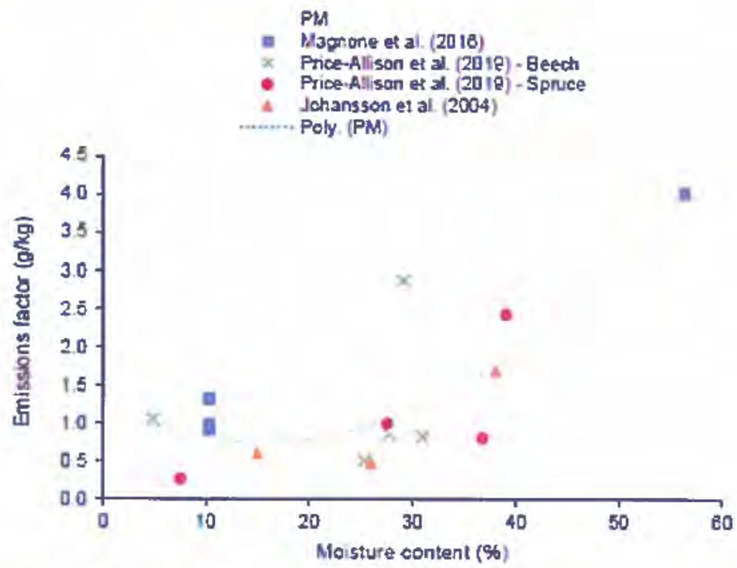
The aim of this report is to assess the impact of wood fuel moisture content on combustion efficiency and emissions, with a focus on particulate matter (PM).

Freshly felled wood logs maybe contain more than half their weight in moisture which when burned, must be evaporated from the fuel before the combustible fraction of the fuel can be burned. This takes a significant amount of energy out of the fire, thereby reducing the temperature and combustion efficiency and increasing emissions.

Seasoning of wood logs can reduce moisture content to 25% or below, but the time this takes can vary according to how the logs are stored and what the ambient weather conditions are. Additionally, the hygroscopic nature of wood means that stored wood will absorb moisture from its surroundings in wet or humid conditions. To be sure of a fuel with consistent dry quality and moisture content below 20%, it is recommended to use kiln dried logs. This has added benefits for the consumer by increasing the fuel heat value per unit weight. The calorific value of the kiln dried wood above (10% MC) is 81% higher than wet wood (45% MC).

Moisture content also has a considerable effect on efficiency. Higher moisture content lowers the temperature in the combustion chamber and promotes incomplete combustion leading to a drop in thermal efficiency from 80% for a stove burning dry wood to 50% for a stove burning wet wood. The result of this drop in efficiency is an increase in pollutant emissions, principally soot (particulate matter), carbon monoxide (CO) and other volatile organic compounds (VOCs).

The relationship between particulate emissions and moisture is parabolic, as shown below. Considerable PM emissions reductions (c.2x) can be achieved by switching from wet wood to dry wood, with a minimum between 15-20% moisture.



Burning extremely dry logs (5-10% MC) can result in higher PM emissions compared to logs at 15-20% MC. The reason for this is that moisture has an inhibiting effect on the rate of devolatilisation and without this, the fuel can burn very quickly using up the available air supply and producing more soot. The degree to which this happens is dependent on stove design and efficiency; more modern appliances with careful air control (e.g. secondary or tertiary air supplies) show less of an increase than older stoves or open fires.

In addition to a reduction in total emissions of particulate matter, carbon monoxide and methane, there is also a reduction in particle toxicity when burning dry wood over wet. This is because PM produced from the burning of wet wood contains significantly more organic material and PAH which are associated with higher rates of lung cell toxicity and mutagenicity. The burning of dry wood allows for more complete combustion of the fuel into carbon dioxide and water, as well as PM with a lower organic content.

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1. Introduction

Domestic burning in appliances such as open fires and solid fuel stoves are thought to be a significant contributor to ambient air pollution. This is particularly the case where older inefficient appliances are used, or where smoky fuels such as coal, peat and wet wood are being burnt. Domestic burning has recently come under increased scrutiny in the UK due to the UK Clean Air Strategy published in January 2019 suggesting that "increase in burning solid fuels in our homes is having an impact on our air quality and now makes up the single largest contributor to our national PM emissions at 38%". Although evidence suggests the accuracy of this figure is questionable (Mitchell et al., 2019), actions to reduce any of the potential emissions of PM from domestic burning is imperative.

Whilst modern eco-design stoves have shown to have significantly lower emissions than older more inefficient appliances, replacing or retrofitting these older appliances on a large scale is challenging. Instead, emission reductions can be more readily achieved by ensuring cleaner fuels are burnt, such as suitably dried wood. This is due to wet wood containing as much as 50% or above of water by weight, all of which has to be evaporated from the fuel before combustion can occur. This requires large amounts of energy to be extracted from the fire, resulting in lower combustion temperatures, reduced thermal efficiencies and increased emissions. The marked improvement of emissions seen when burning dry wood has led to the UK government banning the sale of wet wood and bagged coal.

Despite widespread evidence suggesting that dry wood has significantly lower emissions than wet wood, a detailed review of the emission reductions achievable has yet to be done. The aim of this report is to rectify this knowledge gap, by reviewing available literature to assess the impact of wood fuel moisture content on combustion efficiency and emissions, with a particular focus on particulate matter.

2. Moisture in wood

2.1 The moisture content of wood

On felling a tree, two distinct areas in the wood will be noticeable; the darker inner area termed heartwood, and the lighter outer area close to the bark known as sapwood. Although not physiologically active, the heartwood provides mechanical support to the tree and potential long-term resistance to pathogens (Plomion et al, 2001). Alternatively, the sapwood forms the living part of the wood and is primarily responsible for transport of water and sap around the tree, as well as storing resources. During the growing season, new layers of sapwood will be added to the tree, increasing its diameter. Correspondingly, inner portions of sapwood die and convert to heartwood, becoming infiltrated with gums, resins and other material in doing so.

Freshly cut 'green' wood contains significant quantities of water, often accounting for over half of the mass of the wood. This moisture exists in two forms; free moisture and bound moisture. Free moisture relates to that contained in the pores and vessels of the wood, whereas bound moisture relates to moisture chemically bound within the cells themselves (Phillips, 2018). Heartwood therefore consists only of the latter type of moisture whilst sapwood contains both types. Consequently, in softwoods, the amount of moisture in the sapwood is usually greater than that of the heartwood, although, for hardwoods this distinction is less noticeable (Simpson and TenWolde, 1999). Average values of moisture for freshly cut hardwood and softwood species and by heartwood or sapwood can be seen in Appendix 1.

The amount of moisture in wood is known as the moisture content (MC). This MC is conventionally measured as a percentage of either the dry or wet weight of the wood, termed dry and wet basis respectively:

$$\textit{Moisture content, dry basis}\ (\%) = \frac{\textit{Weight of water in wood}}{\textit{Weight of totally dry wood}} \times 100$$

$$\textit{Moisture content, wet basis}\ (\%) = \frac{\textit{Weight of water in wood}}{\textit{Weight of wet wood}} \times 100$$

As shown in Appendix 1, the MC of fresh cut wood regularly exceeds 100-150% on a dry basis (50-60% moisture on a wet basis), therefore representing a significant mass of the wood. Although moisture content is typically reported by the forestry industry on a dry basis, within the fuel industry a wet basis is more common, therefore this definition is used throughout the remainder of this report unless otherwise specified. A conversion from dry basis to wet basis can be calculated using:

$$Moisture\ content, wet\ basis\ (\%) = \left(\frac{Moisture\ content\ dry\ basis}{100 + Moisture\ content\ dry\ basis}\right) \times 100$$

Considering 50-60% of freshly cut wood by weight is moisture, this therefore means that a 1kg freshly cut log contains around one pint of water. A common misconception among consumers faced deciding between a cheaper and heavier bag of unseasoned wood, compared to a lighter and more expensive dried bag of wood of the same size, would be that the former is better value for money. In fact however, the reality is the consumer is actually buying more water, not more useable firewood. This is primarily one of the reasons firewood is sold by the volume instead of weight.

Figure 1: There is approximately 1 pint of water 1kg of freshly cut wood (HETAS, 2018)

The large amount of water present within freshly cut wood has important implications for the subsequent transport and use of the wood. As the majority of uses for wood require it to be dry, the transport of wet wood wastes energy by shipping this mass of water. To counteract this, freshly felled wood is often naturally dried, a process known as seasoning.

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2.2 Seasoning

Freshly felled wood first requires delimbing, before removal of bark and being stacked into piles for seasoning. The seasoning process allows for the natural drying of the free moisture in the wood until only the bound moisture remains, a condition known as the fibre saturation point. Typical fibre saturation points of wood average about 30% moisture content on a dry basis (23% wet basis), although this may vary by several percentage points depending on the individual species (Simpson and TenWolde, 1999).

The hygroscopic nature of wood means moisture levels may increase or decrease depending on the relative humidity (RH) of the surround air. As such, the seasoning time depends on many factors such as the weather conditions, ambient temperature, log size, season in which it was felled and storage conditions such as the presence of cover. As such, in hot summer months, wood logs may rapidly lose water, particularly in the outer layers. However, in winter months, moisture loss may be minimal as shown in Figure 2.

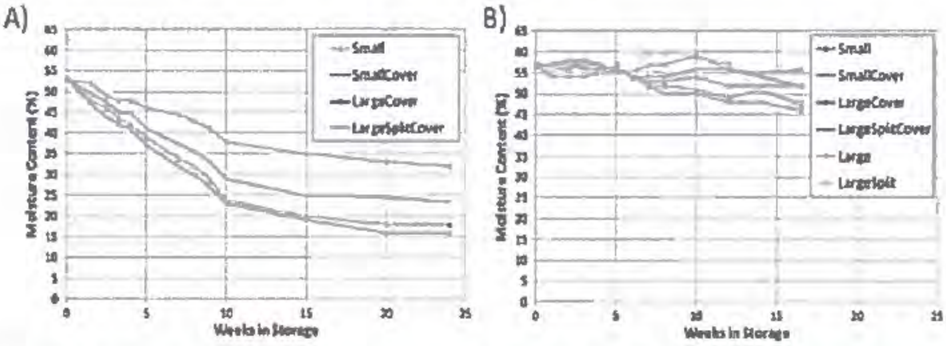


Figure 2: Estimated wood moisture content of radiata pine logs in New Zealand during A) summer months and B) winter months. Adapted from Visser et. al. [4]

To add further complication to the required seasoning conditions of wood, different species are known to season at different rates. For example, Nord-Larsen et al. (2011) found that Norway spruce rapidly reduced its moisture content down to *ca.* 20% in a matter of few months (Figure 3). As such, trees felled in early summer could be sufficiently dry by the start of the heating season in October. In contrast, the deciduous species such as Oak and Sycamore, whilst having lower initial moisture contents, also took longer to dry. Consequently, felling during the summer months would not provide sufficient time for the log to dry out before the heating season. These logs would also need to be covered to avoid large increases in moisture content during the winter months.

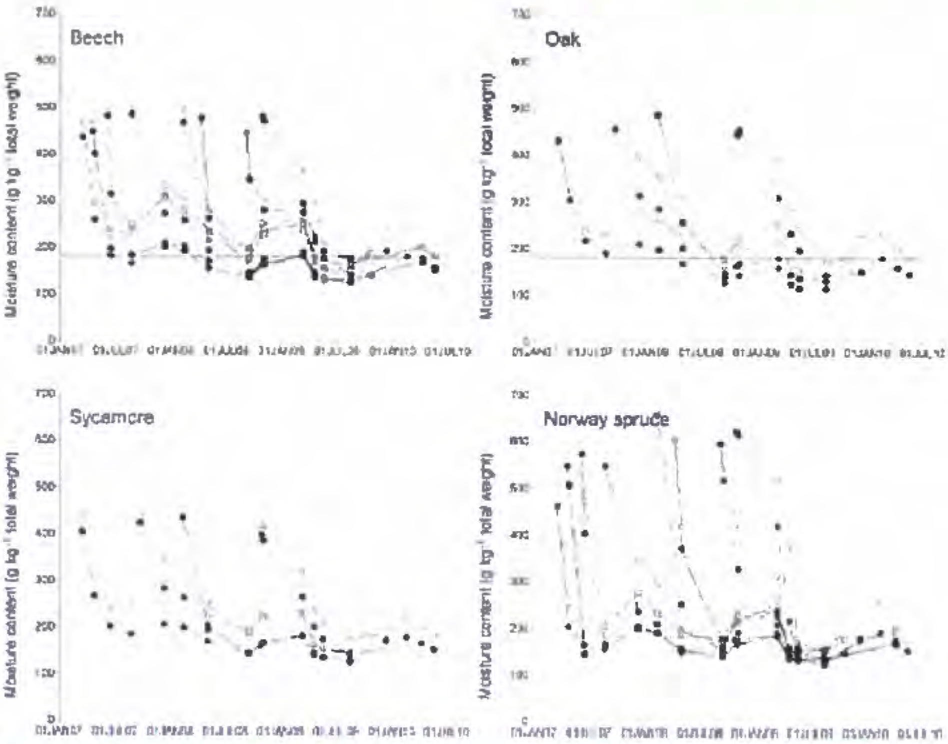


Figure 3. Drying rates of wood logs from different species (Nord-Larsen et al., 2011)

The major drawback to natural seasoning of wood is the considerable time that it takes for moisture levels to reduce to the fibre saturation point. As shown in Figure 3 this can take as little as 3 months for species such as Norway spruce, ranging up to almost two years for other deciduous species. This uncertainty in drying times makes it difficult for people to make judgements on how long they should leave wood to season, whilst further confusion is added due to inaccuracies in domestic moisture meters, as discussed more in section 2.4.

Generalising the above, a period of 3 – 12 months is typical for wood seasoning (Rogge et al., 1998, Burnet et al., 1986), although the Defra Burn Better campaign recommend a minimum of at least 12 months (Defra, 2021). Despite this advice, Wöhler et al., (2016) found via a questionnaire across 16 European countries that a quarter of people store undried raw logs for less than this period, with this increasing to 51% for undried ready firewood (i.e. chopped and cut but not dried).

2.3 Kiln drying

Kiln dried wood can be an attractive alternative to natural seasoning due it being ready to burn and having a degree of assurance in regards to the moisture content, usually measuring in at between 10-20%. This lower moisture content, below that of the fibre saturation point, translates into higher combustion efficiencies and lower emissions, as discussed further in section 3Error! Reference source not found.. Despite this, kiln dried wood stored improperly n wet conditions will inevitably increase in moisture content as it equilibrates with the environment. Therefore efforts should be made to ideally store kiln dried wood in dry, low humidity conditions such as indoors.

The kiln drying process relies on controlling a number of critical factors important for reducing the moisture content down to satisfactory levels. Significant research has been conducted in this field, although this is primarily focussed around the lumber industry and the ability to inhibit the formation of defects during drying such as warping (Kuznetsoc *et al.*, 2021). As much of this research is not as relevant for firewood, it will not be discussed further.

The control mechanisms used in the kiln drying of wood include:

1. Relative humidity of the air
2. Drying temperature
3. Drying time
4. Air circulation

Although many different types of kilns exist, the most common type is that of a conventional steam-heated kiln (Simpson, 1991). This steam is generated from a boiler fired on either natural gas, oil or waste wood. Aside from conventional steam kilns, alternative kilns types include that of dehumidification kilns, vacuum kilns and solar kilns (Bond and Espinoza, 2016). Wood drying kilns typically operate in batch processes (compartment kilns) but can also be of continuous form (progressive kilns).The temperatures of operation is dependent on the species being dried, quality required and final use, however, hardwoods are usually dried at up to ~80 °C whilst softwoods have a higher temperature of ~100 °C or above (Simpson, 1991). Drying times also vary depending on the specific conditions, but in order to reach less than 20% moisture, usually require a number of days as shown in Figure 4.

Kiln drying of firewood clearly has an inherent energy penalty compared to natural air seasoning. Energy is required to heat the wood, raise the temperature of the surrounding air, evaporate the water and accommodate for any losses in the system. Approximately 50% of this energy is associated with the evaporation of water from the wood due to the high latent heat of vaporisation of water of ~2.2 MJ/kg (Shottafer and Shuler, 1974). This energy requirement is particularly important if the wood dried in kilns powered by fossil fuels, thereby causing a net increase in carbon emissions. However, these emissions need to be balanced against the emissions that would be released from transporting the extra mass in the wood in the form of water, as well as the additional emissions from burning the wood at a higher moisture content and associated reduction in combustion efficiency for wet wood. Likewise, the energy required by the kiln to evaporate the water in the wood is not avoided by using non-kiln dried wood, with the stove instead having to provide this energy through the burning of more fuel.

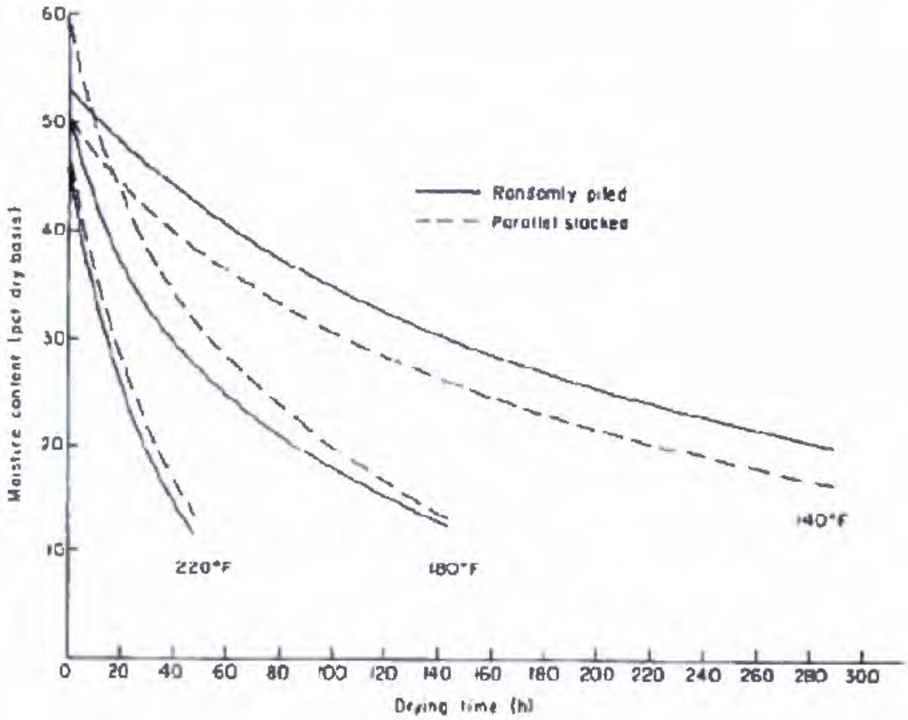


Figure 4: Drying time of split oak firewood at three different temperatures with wood stacked parallel to airflow (dashed lines) and randomly (solid lines) piled (Simpson, *et al.*, 1987.)

2.4 How moisture content is determined

Integral to understanding the impact of moisture on domestic burning efficiencies and emissions is the ability to accurately measure the moisture content in the wood. The British Standard - BS EN ISO 18134 for determination of moisture content in solid biofuels is composed of three parts:

Part 1. Total moisture - reference method (BS EN ISO 18134-1:2015)
Part 2. Total moisture - simplified method (BS EN ISO 18134-2:2015)
Part 3. Moisture in general analysis sample (BS EN ISO 18134-1:2015)

These standardised approaches rely on the oven dry method to report the moisture content on a wet basis. This method dries the biomass in an oven at 105 °C until a constant mass is achieved. The moisture content is then calculated from the loss in mass of the sample, with corrections for buoyancy effects (in part 1 only). It should be noted that the oven drying method also leads to the release of volatile compounds during the drying process which would count towards the overall mass loss.

In contrast, the ASTM standard for measuring moisture content is that of ASTM D4442-20. The primary approach of this standard is similar to that of the BS EN ISO 18134 whereby the wood is dried in an oven at 103°C until the mass loss of a 3-hour period fluctuates less than that sensitivity of the balance. As before the change in measured mass can then be used to calculate the moisture content in the wood.

The above oven-drying methods are intended for use within the forestry industry as they can provide accurate results regardless of moisture content. The drawbacks to this method however are the need for dedicated vented ovens and the time taken to complete the test, typically around 24 hours or longer (Govett et al., 2010). Microwave ovens offer an alternate to measuring moisture content in much quicker times of approximately 15 minutes (see ASTM E1358-97), however these are generally only considered suitable for occasional spot testing rather than being the primary method for determining moisture content. This is due to the inability for the microwave technique to measure multiple samples at once and the considerable risk of sample combustion, therefore requiring continual monitoring (Govett et al., 2010).

Alternate methods such as via distillation (AWPA A6) can also be used to determine the moisture content of wood, however, these are designed for treated wood containing at least 5 grams of wood to one gram of oil. As such these are not relevant for firewood and therefore will not be discussed further.

The methods described above are generally suitable to the forestry industry requiring high accuracy but are not practically suitable for domestic users wishing to check the moisture content of their firewood. Moisture meters offer a common solution to this by allowing simple, portable, and quick measurements of the moisture content. Available to purchase at a reasonable price, this meters have therefore become the common approach used in households.

By far the most popular type of handheld moisture meters is that of a conductance (or resistance) meter. These work by making electrical contact with the wood at two points and measuring the conductance across the wood between these contact points. This conductance is related to the electrical resistance of the material using Ohm's law. A determination of the moisture content is possible from this reading due to the resistance of a material having an inverse relationship with moisture content. Simply put, as the moisture content of the wood decreases, the resistance increases. At low moisture contents this relationship is particularly sensitive, with the resistance increasing by a factor of 10 million from fibre-saturation point (~23% MC wet-basis) down to oven dry conditions (~6% MC wet-basis). In contrast, increasing the moisture content from the fibre saturation point up to the maximum free water content, only decreases the resistance by a factor of 50 or less (James, 1963). As such, conductive moisture metres are best suited to reading moisture contents between the 6% - 23% range on a wet-basis, whereas anything above this range is generally not accurate and should only be qualitatively described as 'above 23%' (Govett et al., 2010). The sensitivity of resistance to moisture content is clearly demonstrated in Figure 5 below, noting the y-axis of resistance is of logarithmic form.

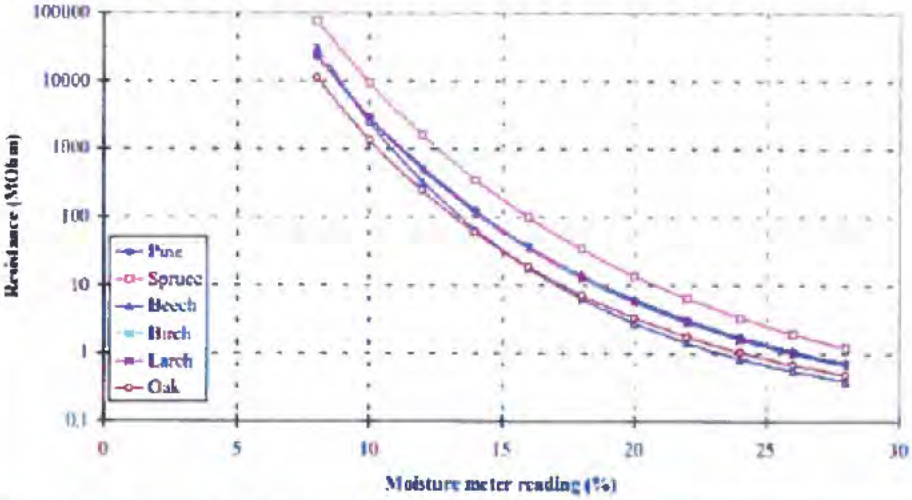


Figure 5: Resistance curves for different species of wood with moisture content measured by the same moisture meter (Forsén and Tarvainen, 2000).

In addition to this optimum range, moisture meters are affected by a number of other parameters. For example, the electrical resistance of wood decreases with increasing wood temperature, with this approximately halving for every 10°C increase of temperature (James, 1963). Likewise, the resistance of wood parallel to the grain is also roughly half of that perpendicular to the grain, may vary if chemical treatments have been applied, can differ depending on the part of the wood being measured, and also changes with species (James, 1963). This variation by species is demonstrated in Figure 5, with values of resistance varying as much as by a factor of 10 between species for a given moisture content.

The sensitivity of resistance by all of the aforementioned parameters means that calibration is essential for moisture meters. This calibration should be done based on a piece of wood dried according to the standardised over-drying method, with care taken to avoid potential errors based on aspects such as temperature (Forsén and Tarvainen, 2000). Nevertheless, even a top of the range, well calibrated moisture meter with options to correct based on species and temperature, can give erroneous results if used incorrectly. To avoid such user error, HETAS (2018) recommends users take at least three samples from a log pile, split the logs down the centre, and take at a minimum of six readings from the sample, ensuring to only measure across the grain, before averaging these readings. However, other common issues may arise if battery levels are allowed to get low or the moisture meter is not reporting the basis it operates on. This latter point can particularly cause confusion if moisture meters designed for the construction industry report on a dry basis instead of the more common wet-basis for firewood. For instance, if the user does not understand the distinction between the two types of basis, a wood log with a relatively acceptable moisture content of 23% on a wet-basis would be reported as 30% MC on a dry-basis, a value that is perhaps unsatisfactory for a consumer, despite the measurements reporting the same moisture content.

2.5 Impact of moisture content on fuel properties

All the above discussion on the background, drying, and measurement of moisture content in wood is important because of the impact this moisture has on its properties when used as a fuel. However, moisture content also has important practical implications prior to its use as a fuel. For example, for freshly cut wood, the moisture content on a wet basis can be 50-60% or above. As such, over half of the mass of the material is water that offers no energy to the combustion process but is still required to be transported. Drying this wood, even by simple techniques such as seasoning, can remove much of this water without significantly impacting the volume of the wood itself. This causes the bulk density of the wood to decrease (i.e. less mass per volume), and the energy density to increase (i.e. more energy per volume), as shown in Figure 6 for both hardwood and softwoods.

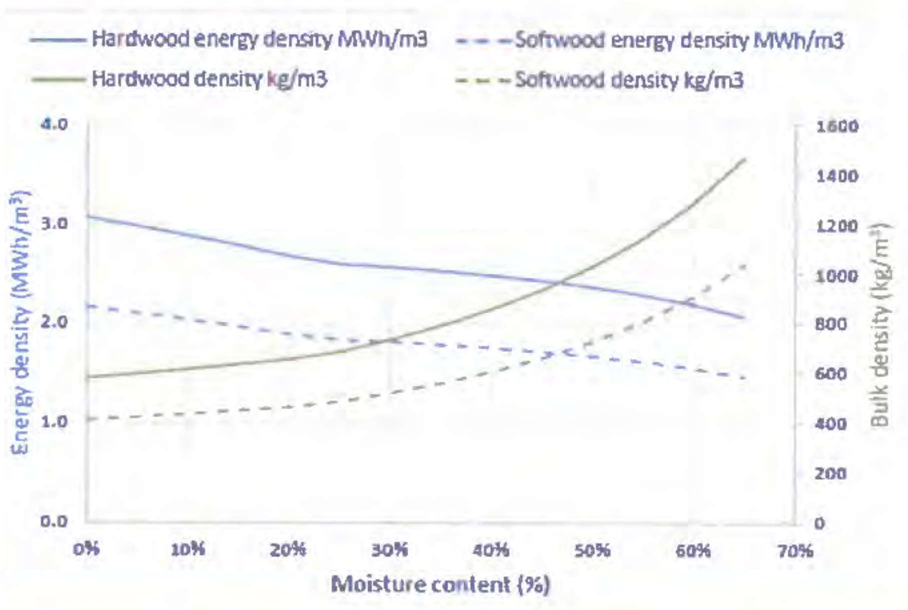


Figure 6: Impact of wood moisture content on energy density and bulk density. Data source: Forest Research (2013)

The impact that the drying of wood has on the transportation emissions is dependent on many factors such as the transportation distance, initial moisture content, level of drying and transportation vehicle. However, given the fact that wood resources are often located in remote locations and have low energy densities compared to other fuels such as coal or oil, the transportation element is often important. For example, Talbot and Suadicani (2006) reported the most important controllable factor in determining transport efficiency is that of the moisture content. This is confirmed by Sosa et al. (2015), who modelled the potential supply of wood to three peat power plants in Ireland based on different moisture contents. It was found that by allowing the wood to season to at least 40% MC, a reduction of 10% in the fleet size would be needed and higher energy would be delivered per truckload. Overall, higher moisture contents increase the weight and cost of transport, can lead to higher demands of fuel in terms of volume, and therefore increased the number of shipments needed.

In regards to the impact of moisture content on the combustion properties, as seen in the graph of Figure 7, an increase in moisture content causes a linear decrease in the net calorific value (NCV) of the fuel (i.e. the energy output assuming moisture stays in the gaseous phase). At moisture contents of between 10-20% this can be over 4 KWh/kg, whereas for green wood around 60% moisture content, this can more than half to less than 2 KWh/kg (Forest Research, 2013).

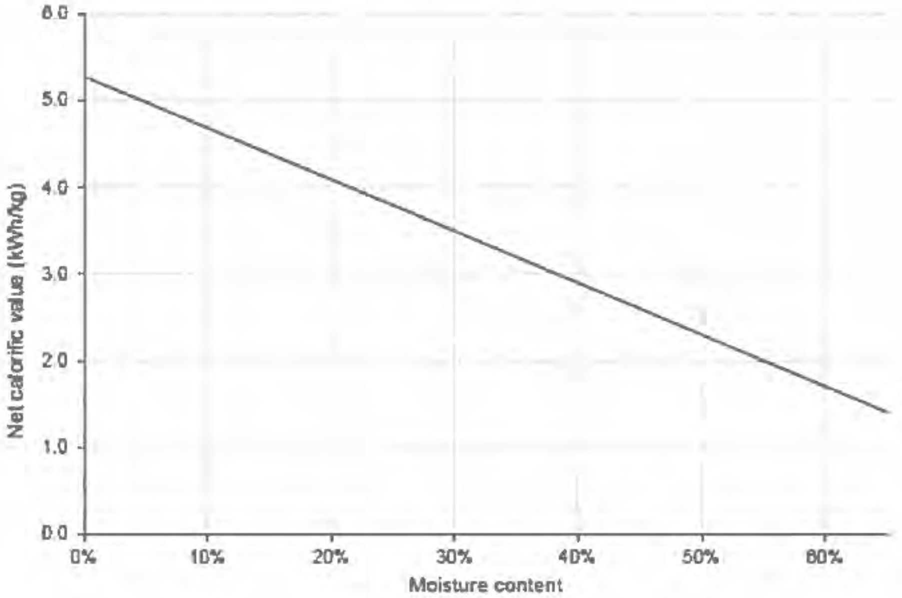


Figure 7. Impact of wood moisture content on net calorific value. Data source: Forest Research (2013)

The large variation in net calorific value of the fuel with moisture content is due to the combustion process first requiring any moisture in the wood to be evaporated before combustion can begin. The high value of latent heat of vaporisation of water (~2.2 MJ/kg water) consumes much of the energy to simply evaporate this water, with this vapour being emitted in the flue gases. The addition of wet logs to a stove therefore decreases the combustion efficiency, requiring more logs to reach the same heat output.

Likewise, the addition of wet wood to a stove reduces the combustion temperature which in turn may result in incomplete combustion of the fuel. As before this reduces the combustion efficiency due to potentially combustible products being emitted in the flue gas, but can also result in these emissions recondensing within the flue, leading to corrosion or blockages in the flue from the accretion of material (Forest Research, 2013). Incomplete combustion in the stove is also responsible for higher emissions of particulate matter and other hazardous emissions. These aspects are discussed in greater detail within the following section of this report.

3. The impact of moisture content on combustion and emissions

3.1 Impact on combustion

Wood fuel moisture content plays a key role in the combustion process. When a log is added to a bed of kindling or a pre-lit fire, the first fundamental stage is to dry the biomass and to raise its temperature to the point of ignition. A moisture content that is too high can inhibit this process and delay the subsequent phases of combustion, as shown in Figure 8.

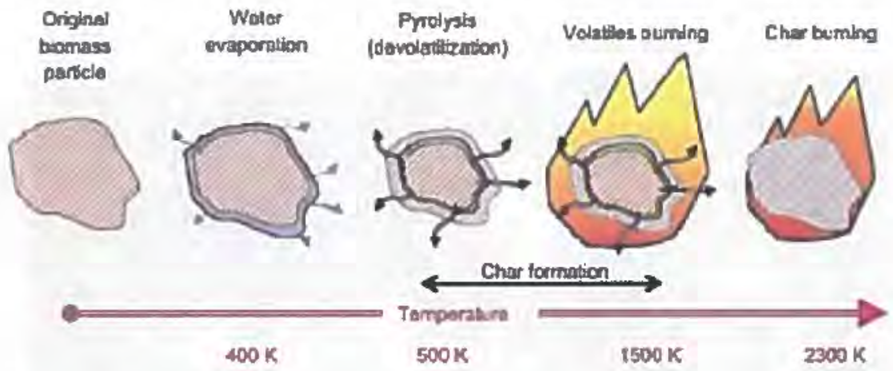


Figure 8. The stages of wood combustion. Source: Piriou et al. (2013)

Although some of these phases can occur simultaneously, particularly for larger pieces of fuel, the rate of release of volatiles (or pyrolysis) is slowed significantly by high moisture levels. During this first key stage of drying and ignition, small pieces of biomass ignite while larger pieces undergo radiative heating. Water contained within the wood must overcome the latent heat of vaporisation and be out-gassed, which requires more energy per kilogram of wet fuel than dry fuel.

These steps are intrinsically linked and being the first key stage, water evaporation and moisture content have a major bearing on combustion efficiency. The duration of each step is influenced by the particle moisture content, volatile content and the nature of the char, as well as several other external conditions including:

- Log size
- Thermal conductivity

- Porosity and surface area
- Heat capacity
- Density

The duration of the first low temperature phase has been shown to increase with increasing moisture content (Koppmann et al., 2005). As the temperature of the bed increases, the main chemical constituents of the wood begin to thermally break down and this releases highly volatile organic vapours. Under ideal conditions, these gases and vapours ignite and fully combust into carbon dioxide (CO_2) and water (H_2O), and we see a yellow-orange flame. However, high moisture content can inhibit this, as shown in Figure 9.

Figure 9. Different burning conditions for dry and wet fuel.

Higher moisture content lowers the temperature in the combustion chamber and promotes incomplete combustion, the products of which are soot (particulate matter), carbon monoxide (CO) and other volatile organic compounds (VOCs).

The three main chemical constituents of biomass are cellulose, hemicellulose and lignin. Under ideal burning conditions with dry fuel, these thermally breakdown in a predictable way based on the temperature of the fuel bed. During devolatilisation, large quantities of highly volatile organics are released, including aromatics and ethers, and the decomposition of hemicellulose and lignin gives rise to methanol, aldehydes and formic and acetic acids (Koppmann et al., 2005). As the temperature increases to over 250 °C the vast majority of the fuel is thermally decomposed and aromatic compounds such as benzene, toluene and phenols are emitted (Elsasser et al., 2013). Most of these species are destroyed in the flame when dry fuel is used, but the flame inhibiting effect of adding a wet log can lead to slippage of these compounds into the flue gas, negatively affecting air quality.

As well as affecting the energy density of the fuel, moisture content also affects the specific heat capacity. Heat capacity is defined as the amount of energy needed to increase in temperature of one kilogram of a material by one degree. In order to reach ignition temperature, a cold wood log added to a fire needs to take energy out of the existing bed in order to evaporate the moisture contained in the log. As such, wet wood has a higher heat capacity than dry wood and is the sum of the heat capacity of the dry wood and that of water, plus an additional adjustment factor that accounts for the additional energy in the wood–water bond (Simpson and TenWolde, 1999). The effect of this is shown in Figure 10.

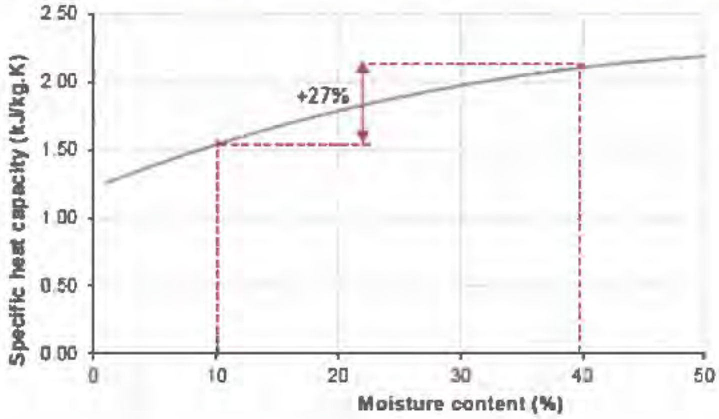


Figure 10. The impact of moisture content on specific heat capacity of wood

As shown, the specific heat capacity of wet wood at 40% moisture content is 27% higher than that of kiln dried wood at 10% MC. That is to say that when added to a fire, it will take 27% more energy to raise the temperature of wet wood to the point of ignition compared to dry wood. This reduces heat output and combustion efficiency.

3.2 Impact on efficiency

Burning high moisture content fuel has a dramatic effect on overall thermal efficiency. The effect is more pronounced in domestic heating stoves than larger commercial boilers due to fuel inhomogeneity and user error. In fact, some wood chip boilers are carefully designed to operate with wood chip fuel with a moisture content of more than 30%. Manually fired stoves on the other hand, perform optimally with wood logs below 20% moisture content.

A simple indicator of combustion efficiency is the ratio of CO_2 to CO in the flue gases of a wood burning appliance. Purvis et al. (2000) observed a considerably higher CO_2/CO ratio of 40.3 for dry wood (17% MC) compared with a ratio of 22.2 burning wetter wood (34% MC).

The European standard measure of thermal efficiency in stoves, according to EN 13240:2001 and EN 16510-1:2018, is by difference:

$$\eta = 100 - (q_a + q_b + q_r)$$

Where q_a is the thermal heat losses in the flue gas, q_b is the chemical heat losses in the flue gas, and q_r is the heat losses due to combustible constituents in the residue.

Depending on the age and type of stove, very dry fuel tends to lead to higher thermal heat losses in the flue gas due to very rapid thermal breakdown and devolatilisation. The presence of some moisture (up to 20%) can slow this rate but high moisture levels lead to incomplete combustion and large increases in the chemical heat losses in the flue gas. The impact on overall efficiency is shown in Figure 11.

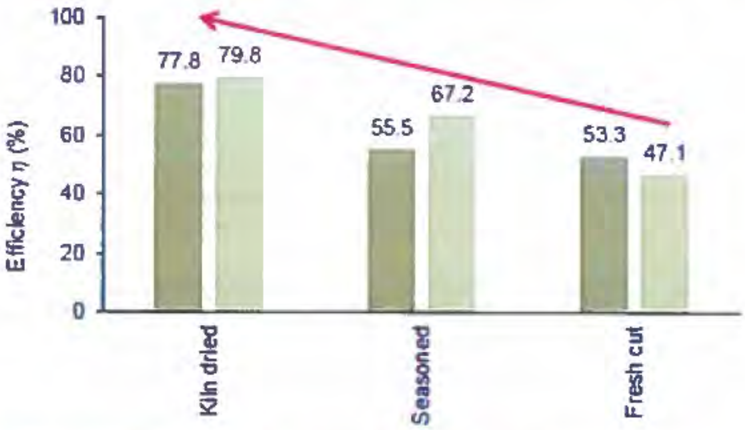


Figure 11. Thermal efficiency for kiln dried, seasoned and fresh cut beech logs burned in a stove. Data source: Price-Allison et al. (2020) / University of Leeds.

Reduced efficiency means that more fuel must be burned in order to achieve the same heat output. As shown in Figure 12, Dzurenda and Banski (2019) found that 48% more wet fuel (40% MC) needed to be burned to achieve the same heat output as dry fuel (20% MC).

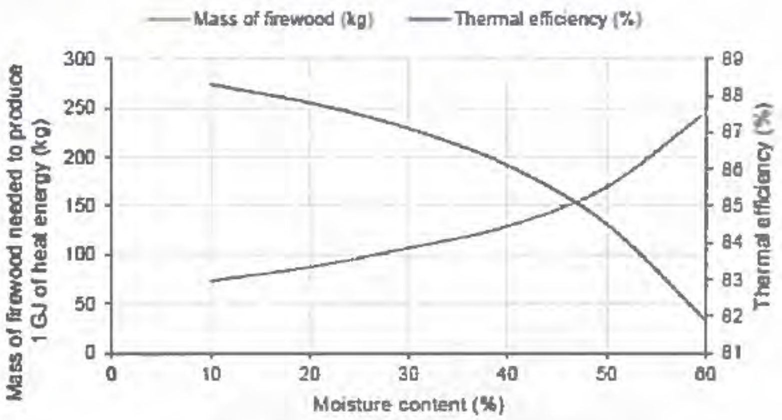


Figure 12. Influence of moisture content on fuel requirements and energy efficiency. Data source: Dzurenda and Banski (2019)

Orang and Tran (2015) found that bed temperature had a large effect on combustion of high moisture fuels. It was found that fuel containing 40% moisture could still ignite and burn readily at 800 °C, but took a much longer time to ignite at 500 °C and did not ignite at all at 400 °C. There is some impact of the type of wood burned, particularly hardwood versus softwood because of the differences in density and thermal conductivity. However, the impact is relatively small in comparison to the impact of variables that principally effect burning rate, temperature and air supply.

3.3 Impact on particulate emissions

3.3.1 Impact on particulate formation, composition and toxicology

Particulate matter (PM) is a mixture of solid and liquid phase particles with various morphologies and compositions that are suspended in a flue gas or in the atmosphere. PM is often classified into two key categories from an air quality and emissions perspective; particles smaller than 10 micrometres (PM_{10}), and smaller than 2.5 micrometres ($PM_{2.5}$).

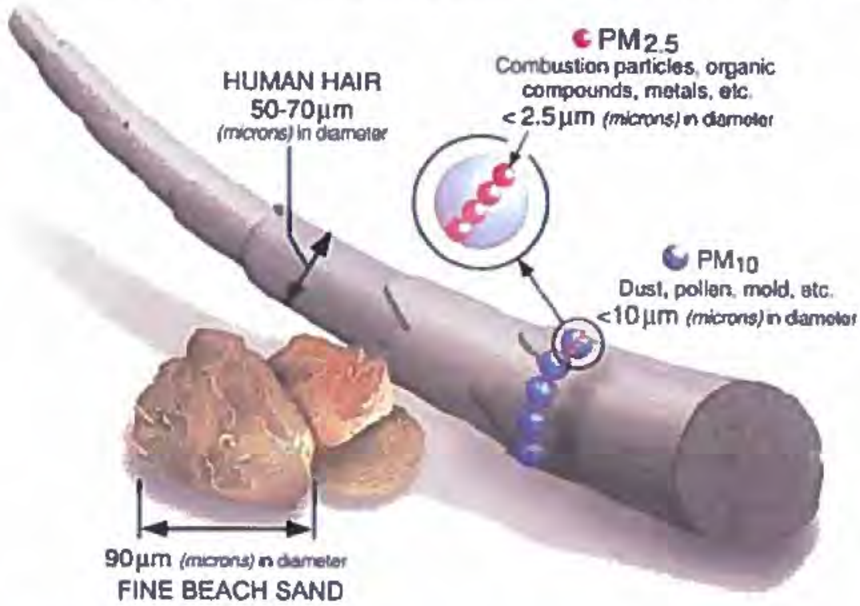


Figure 13. Size comparison of PM10 and PM2.5. Source: USEPA (2020)

Wood burning $PM_{2.5}$ is a mixture of inorganic ash and soot with adsorbed organic species such as polycyclic aromatic hydrocarbons (PAH). The lower the bed temperature and the more inefficient the combustion, the greater the level of organics and tars adsorbed to the surface of particles. This acts as a carrier for trace amounts of carcinogens such as PAHs directly into the lungs.

More efficient burning of biomass, such as in automated pellet stoves or boilers, leads to higher relative levels of ash inorganics such as KCl in the particulate matter, as well as a reduction in the total mass of particles (Uski et al., 2014). So by switching from wet fuel to dry fuel, the benefits are two-fold in that total $PM_{2.5}$ mass is reduced, but also those particles remaining are less harmful to health.

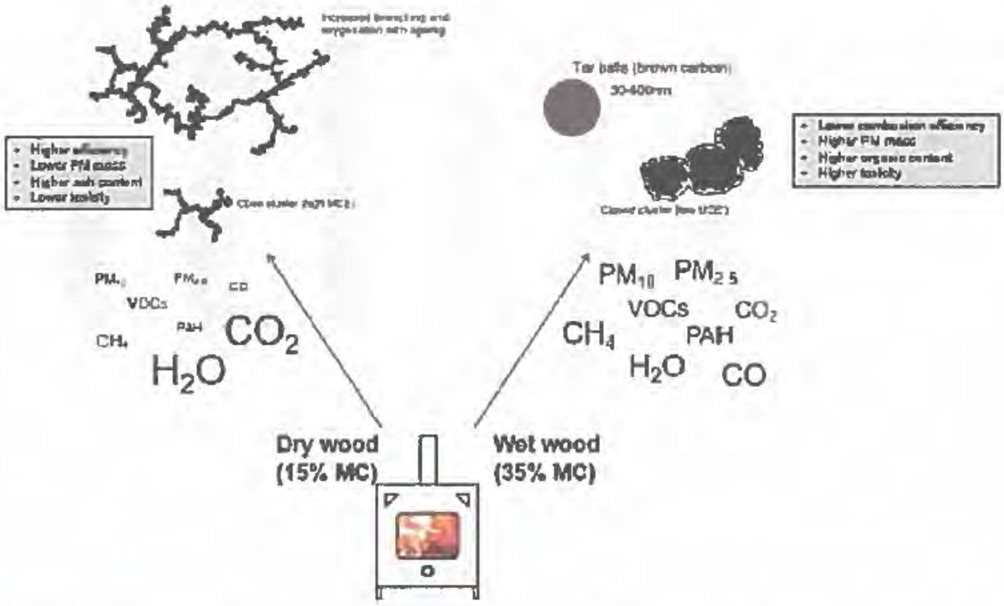


Figure 14. Differences in the structure of PM2.5 emitted by dry and wet wood. Adapted from Mitchell (2017).

As described above, adding fuel with a high moisture content has a major impact on combustion temperatures and efficiency. This in turns changes the chemistry of the thermochemical conversion of the fuel to release heat energy.

High moisture content fuel promotes inefficient low temperature combustion (250 – 500 °C) where methane, aldehydes, methanol, furanes and aromatic compounds such as polycyclic aromatic hydrocarbons (PAH) and phenols are emitted. This process is known as pyrolysis and the products are semi-volatiles which are very tarry and sticky in nature. It is chiefly this that leads to higher particulate matter emissions from burning wet wood.

Organic carbon (OC) and Brown carbon (BrC) have been the subject of a lot of research in recent years due to its light absorbing and scattering properties (Laskin et al., 2015; Lin et al., 2016; Adachi et al., 2019). Increased brown carbon emissions and formation have been linked to lower temperature inefficient combustion, such as that observed when burning wet wood (Chen and Bond, 2010). Price-Allison et al. (2020) observed a dramatic different in particulate organic content, as shown in Figure 15.

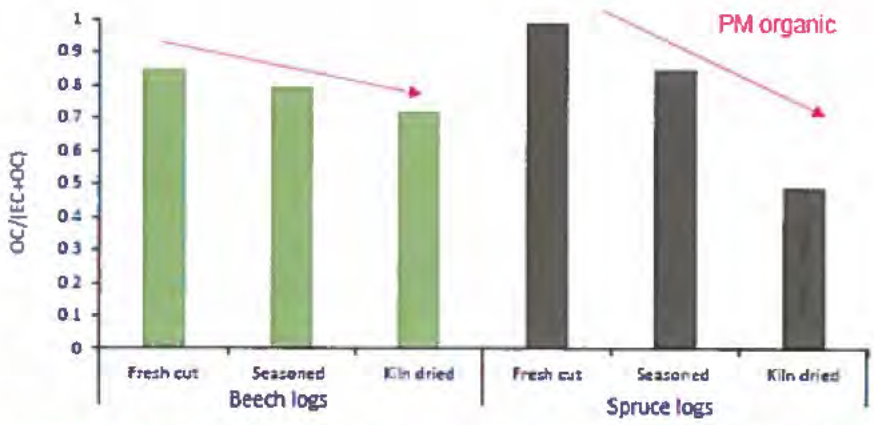


Figure 15. Reduction in particulate matter organic content for fresh cut, seasoned and kiln dried wood. Data source: Price-Allison et al. (2020).

The evidence shows that significantly more organic carbon is emitted from fresh cut logs compared to kiln dried logs. The ratio or organic carbon to total carbon reduces from 0.98 to 0.49 for spruce logs. This is important because the organic fraction of particulate matter contains phenols and PAHs, which are known to be harmful to health.

The increase in toxicity is driven by the higher surface area of particles and higher organic content, which contains carcinogenic and mutangeic PAH. Chomanee et al. (2009) showed a higher mass fraction of 4 - 6 ring PAH for dry wood and more 2 - 3 ring species for wet wood. Marabini et al. (2017) showed that increased presence of pyrolysis products (organic carbon) leads to increase cell damage and inflammatory response. Both Uski et al. (2014) and Dilger et al. (2016) found that wood smoke PM induced dose dependent DNA damage in the human lung cells, and that PAH was the major contributor to toxicity. One study went so far as to measure to effect of exposure to PM from different combustion conditions on laboratory mice (Gibbs-Flournoy et al., 2018). It found that the highest lung injury was associated with smoke from the most inefficient burning, due to exposure to hazardous air toxicants (e.g., 1,3-butadiene, toluene, benzene, acrolein) in association with the greatest number of particles, and particles with the highest percentage organic carbon.

Poor burning conditions induced through the burning of high moisture fuels therefore results in higher toxicity of particles, due to changes in their size and composition. The differences between PM generated from dry and wet wood are visible via electron microscopy, as shown in Figure 16. As well as being browner in colour, the burning of wet wood also produces slightly larger particles, up to 140 nm in diameter (Chakrabarty et al., 2006).

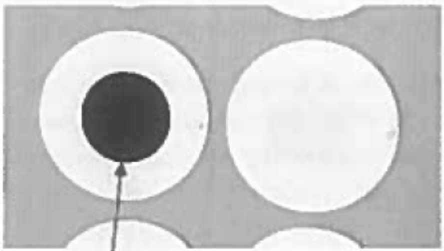
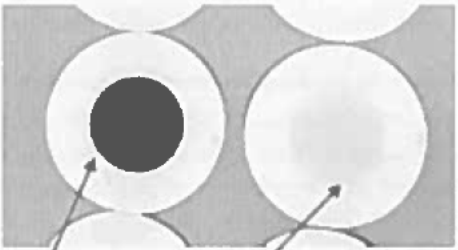
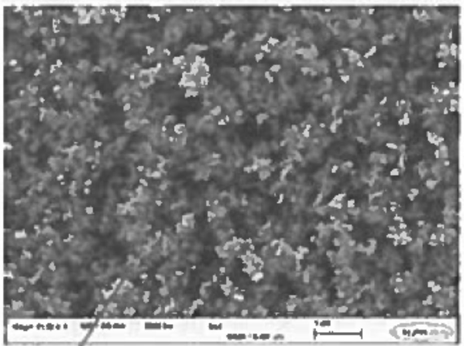
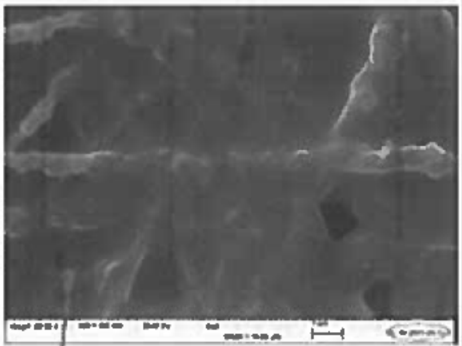
Dry wood (15% moisture)	Wet wood (35% moisture)
Particulate matter sample:  Higher black carbon	Particulate matter sample:  Higher brown carbon More condensable material on second filter
Electron microscope image:  Chains of soot particles	Electron microscope image:  Smear of tarry organic material on filter
Particulate content: • Low organic (brown) carbon • Very high elemental (black) carbon • Lower PAH and oxygenated PAH content • Lower toxicity	Particulate content: • High organic (brown) carbon • Lower elemental (black) carbon but more OC adsorbed to particle surface • High PAH and oxygenated PAH content • Higher toxicity

Figure 16. Comparison of particulate matter from dry wood versus wet wood. Data source: Mitchell (2017).

The burning of wet wood can result in smouldering of the fuel bed, which visibly produces large amounts of smoke and brown carbon material.

3.3.2 Impact on emissions factors

A number of studies have revealed increasing particulate matter and $PM_{2.5}$ emissions factors with wood fuel moisture content. For example, Butcher and Sorenson (1979) found that PM emissions from oak at 42.4% moisture were up to 10 times higher than oak at 9% moisture.

However, significant differences in experimental design do not facilitate fair comparison of results. Some studies burn fuel in simple open fires whilst others use simple stoves or modern biomass boilers. There is very limited evidence of the impact of the variance in moisture content on emissions from modern Ecodesign stoves. Despite this, the fundamental changes to combustion conditions with varying moisture content apply to most types of appliance, with the exception of wood chip boilers which are purpose-designed to burn high moisture fuel (30% MC).

Focussing on residential log wood stoves, a literature review has been carried out. Fachinger et al. (2017) compared the emissions from 11 different hardwood species and 4 different softwood species in a 6 kW log wood stove. It was found that fuels with highest moisture contents had the highest emission factors of particulate organics, suggesting a strong impact of this fuel property on PM-related emission factors. There was also higher repeatability with more consistent and homogenous fuels, notably briquettes and pellets.

Chomanee et al. (2009) compared particulate matter and PAH emissions from wood at three different high-level moisture contents (27.2%, 41.1% and 42.4%), using a simple wood burning oven arrangement. It found that both PM and PAH emissions increased by a factor of two when burning 42.4% MC fuel compared to 27.2% MC fuel. The PAH concentration was found to exhibit a non-linear dependence on smoke particle concentration, underscoring the significance of wood moisture content and burning period with respect to both physical and chemical characteristics of smoke particles.

Table 1: Comparison of PM and PAH emissions from wood at varying moisture contents Source: Chomanee et al. (2009).

Moisture content (dry basis)	Moisture content (wet basis)	Highest PM concentration (mg/m^3)	Highest PAH concentration ($\mu g/m^3$)
37.4%	27.2%	23.4	60.6
73.6%	42.4%	47.6 (+103%)	118.1 (+95%)

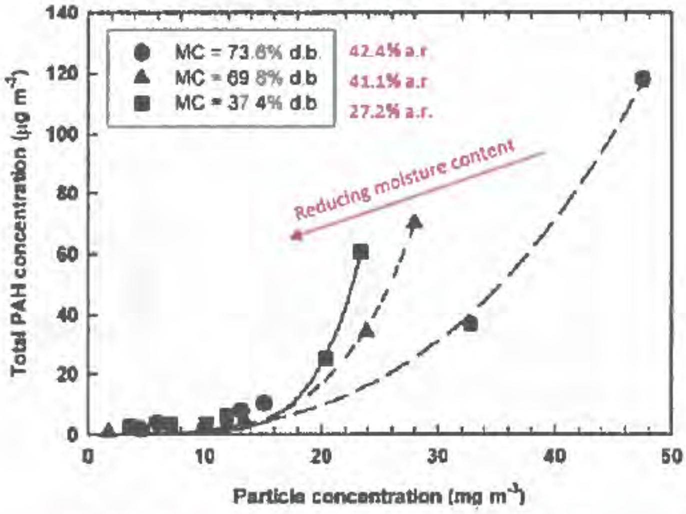


Figure 17. Impact of fuel moisture content on PM and PAH concentrations. Source: Chomanee et al. (2009).

Shen et al. (2013) burned poplar wood logs of varying moisture contents in a conventional solid fuel cooking stove. Results showed that emissions of PM, OC and PAH all increased with increasing moisture content, with statistically significant correlation coefficients of 0.910 – 0.992 ($p < 0.05$). The results are shown in Figure 18.

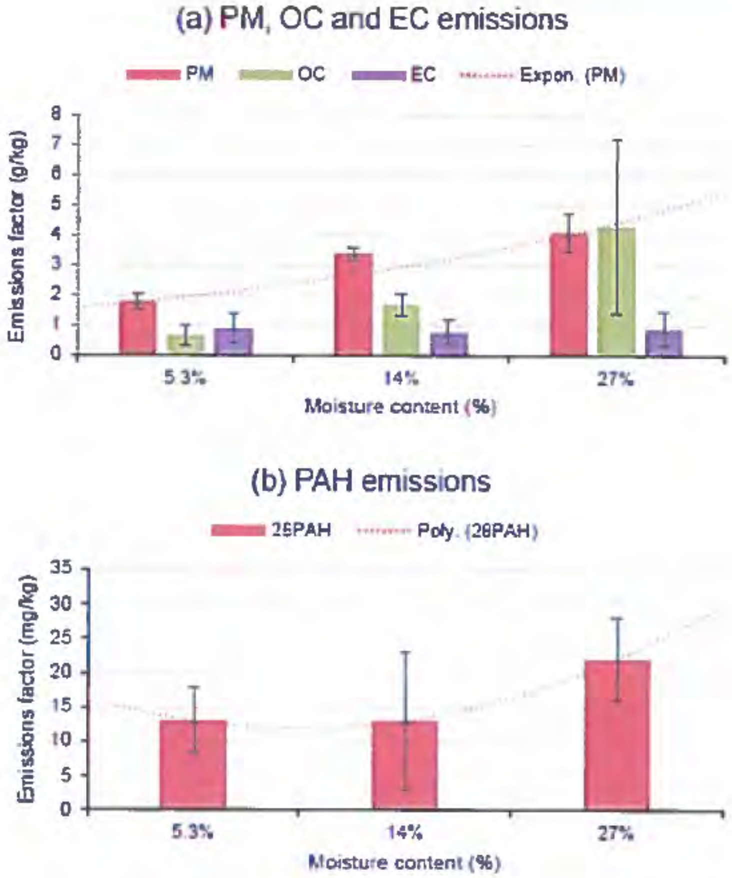


Figure 18. Particulate matter, organic carbon, elemental carbon and PAH emissions factors at varying log moisture contents. Data source: Shen et al. (2013).

Compared to wood at 14% moisture, emission factors for fuel at 27% MC were 21% higher for PM, but the emissions of OC were 153% higher and PAH were 69% higher. This was mainly due to reductions in combustion temperature and efficiency. The study also found that there was a change in the particle size distribution of emitted PM, with higher moisture fuel leading to greater emissions of fine $PM_{2.5}$.

Johansson et al. (2004) burned wood logs with three different moisture contents (15%, 26% and 38%) in a modern (for the time) log boiler. The results are summarised in Figure 19.

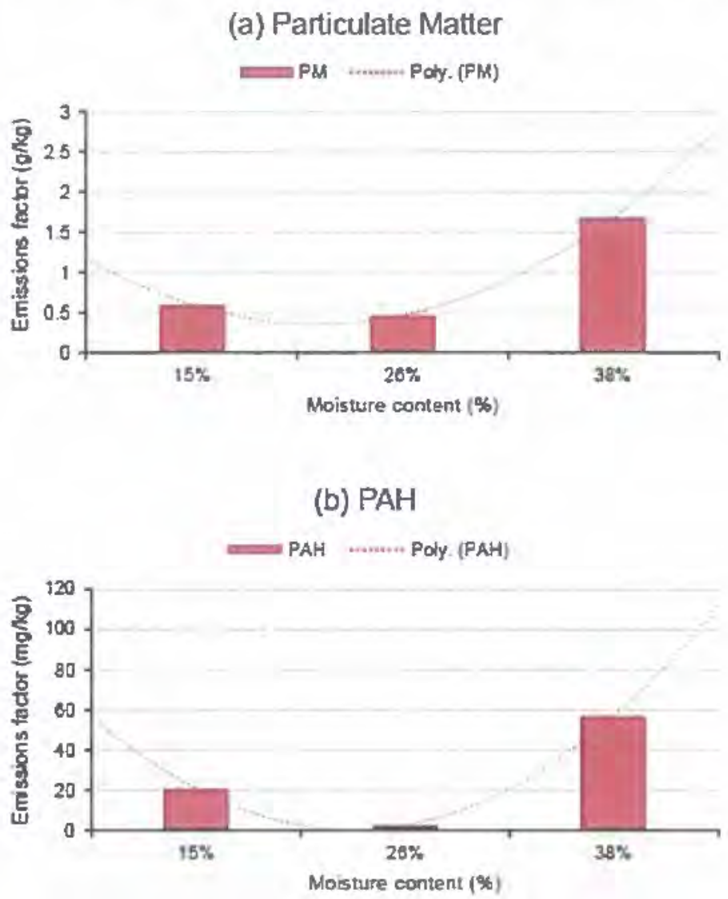


Figure 19. Particulate matter and PAH emissions at varying log moisture contents. Data source: Johansson et al. (2004).

Compared to wood at 15% MC, the study found that wood at 38% MC emitted 178% more particulate matter and 173% more PAH. The relationship appeared to be parabolic, with emissions factors increasing for drier fuel. The low can be seen to be around 20% moisture, which is the design condition for many log-fired appliances.

Fernandes et al. (2011) observed a linear relationship of increasing PM emissions with moisture content. However, the maximum moisture content reported was less than 16% indicating that all fuels used in the study were extensively seasoned or kiln dried.

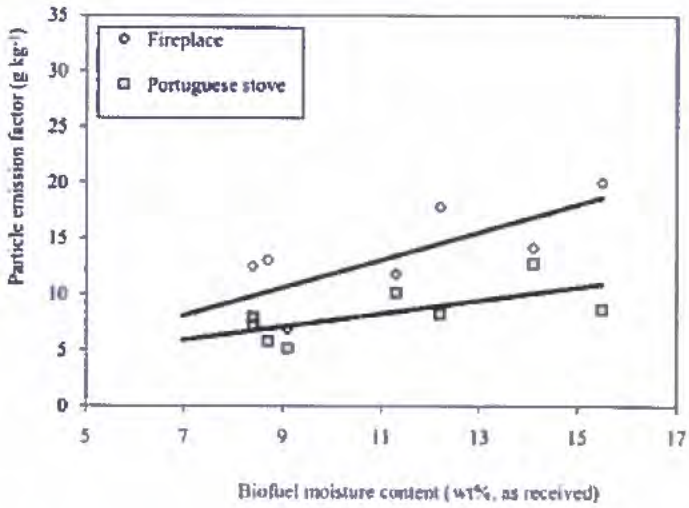


Figure 20. Relationship between PM emissions factor and moisture content for dry Portuguese fuels according to Fernandes et al. (2011).

Purvis et al. (2000) burned multiple fuels in three types of US fireplaces, focussing mainly on relatively wet oak (34% MC dry basis, 25% MC wet basis). The results showed that wood moisture content plays a major role in determining the quantity of emissions produced, with emissions dropping by nearly half for 15% MC fuel compared to 25% MC fuel. It was found that combustion efficiency, wood moisture, and dilution tunnel gas temperature, are interrelated and affect the particle size distribution. The authors postulated that combustion efficiency is more important than wood moisture alone, but it is not possible to separate the two effects.

Yuntenwi et al. (2008) found that extremely dry or over-wet fuel inhibits combustion efficiency and increases PM emissions when burning wood in cookstoves and open fires. The results are shown in Figure 21.

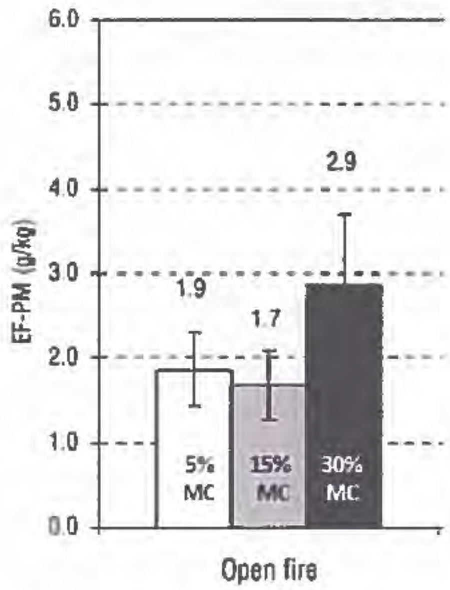


Figure 21.PM emissions factors for low, medium and high moisture content wood burned in an open fire according to Yuntenwi et al. (2008).

Magnone et al. (2016) compared the combustion and emissions performance of very dry oak (10.3% MC) and very wet oak (56.3% MC) logs in a typical heating stove. It was found that the wet wood emitted 3.7x more particulate matter than dry wood. Moreover, 5x more organic carbon was emitted which reflects the dramatic difference in burning conditions between the two wood types.

A recent study by Price-Allison et al. (2019) compared the emissions of fresh cut, seasoned, and kiln dried hardwood and softwood. It found that moisture content has a key influence on fuel mass burning rate. Higher moisture content increases the burning time, but other fuel properties also affect the time taken for the fuel to burn. Hardwood has a significantly higher density (beech 721 kg/m³, spruce 450 kg/m³), and the thermal conductivity of beech is about three times that of spruce.

Moisture content was also found to affect the temperature of the fuel bed and flue gas, whereby kiln dried beech had an initial flue gas temperature of 620 °C declining to about 150 °C at the end of the smouldering phase. In contrast, fresh cut beech has an initial temperature of about 325 °C declining to the same final temperature, 150 °C. As a result of the reduction in temperature and combustion efficiency, there is an increase in PM emissions. Compared to kiln dried spruce (7.1% MC), the PM emissions factor for fresh cut spruce (42.9%) was a factor of 6 times higher.

The authors noted the difficulty in igniting very wet wood due to the drop in temperature and energy barrier in evaporating large volumes of embedded moisture. It was concluded that although complex, the relationship between PM emissions factor and moisture content is typically parabolic as shown in Figure 22.

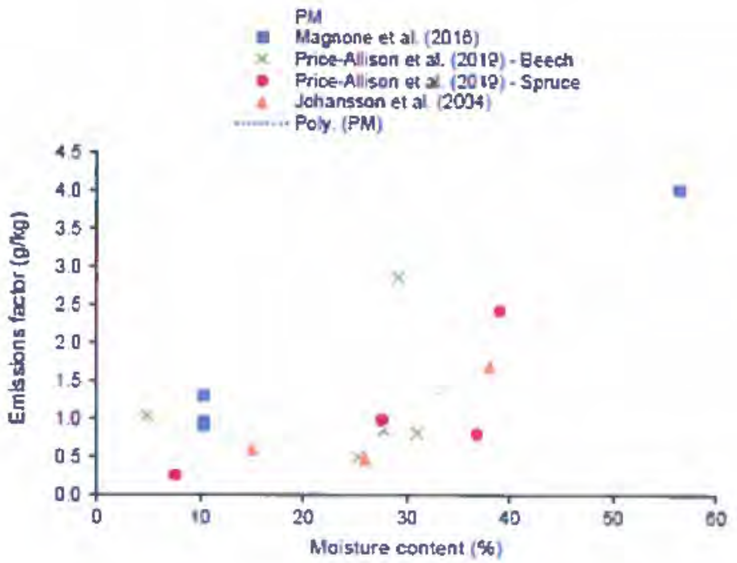


Figure 22. Parabolic relationship of wood moisture versus PM emissions factor. Adapted from Price-Allison et al. (2019).

The reason for this is that high MC promotes low temperature combustion (250 – 500 °C) where methane, aldehydes, methanol, furanes and aromatic compounds such as benzene, toluene, ethyl benzene and phenol are emitted. The duration of this low temperature phase increases with increasing moisture content (Koppmann et al., 2005). Conversely, extremely low MC promotes rapid devolatilisation and vapour combustion which promotes the formation of elemental carbon (soot) particles in greater mass (Burnet et al., 1986). The rapid burn rate induces an oxygen deprived atmosphere, leading to incomplete combustion and higher particle emissions (Rogge et al., 1998). The parabolic relationship was first observed in Shelton (1979).

3.3.3 Wet wood emissions factor testing and reporting

It should be noted that not all results presented in the previous section are directly comparable due to variations between studies. Normally, in order to assess the impact of a fuel variable such as moisture content on another variable such as PM emissions, a number of other variables must be fixed. These include operational variables as well as measurement techniques, which vary between studies:

Operational variables	Measurement variables

• Type of stove or appliance
• Age of stove or appliance
• Air supply setting
• Induced draught
• Ignition method
• Fuel type (e.g. wood species)
• Fuel dimensions (e.g. logs / pellets / chips)
	• Particulate measurement technique (e.g. dilution tunnel or DINplus type heated filter)
	• Reporting units i.e. mass of PM per unit:
	  o Fuel mass (kg)
	  o Time (hour)
	  o Fuel energy (MJ or kWh)

For example, Magnone et al. (2006) used a Koem wood stove (model KW-1731) following the US test protocol EPA Method 5H whereas Price-Allison et al. (2019) used a 5 kW Waterford Stanley Oisin multifuel stove with a dilution tunnel and a Dekati PM_{10} impactor. It should be noted that the academic studies often attempt to simulate 'real world' conditions which look at emissions over the whole fuel cycle, including ignition, flaming (or near steady-state) and smouldering (char burnout). It is important to include these phases in 'real world' testing because emissions vary significantly with time. For example, in the char burn phase there is still significant heat output but very little PM emissions and very high CO emissions. Similarly, in the ignition phase there can be extremely high and unpredictable PM emissions as fuel ignition is highly variable from a cold start, particularly in the case of wet wood.

In order to overcome these issues and harmonise test conditions for fuels and appliances, a number of test standards have been created. These are summarised in Figure 23. As shown, even within standard test methods there is significant variation in the design set up for stoves and fuels. Some peer-reviewed academic studies have attempted to align their test procedures with their local standard (e.g. in the USA, Australia/NZ, UK and Europe) but there may still be variation from standard conditions in non-accredited laboratories.

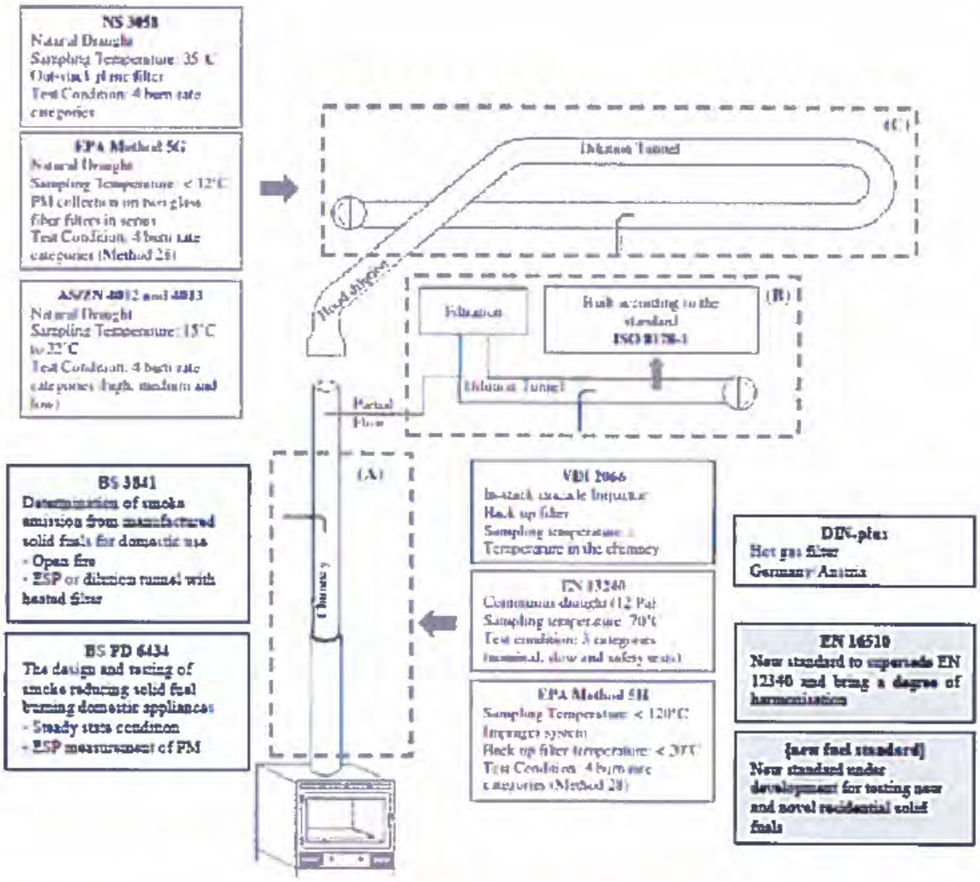


Figure 23. Test standards and procedures for solid fuels and heating appliances. Expanded from Vicente and Alves (2018).

In 2012, New Zealand's NIWA published a report comparing 'real world' emissions from the in-situ testing of wood burning stoves in New Zealand homes. The study found the same parabolic relationship between fuel moisture content and PM emissions as shown in Figure 24. The shape of the curve and the scale of the axes can be significantly different where older stoves and open fires are used (blue) compared to more modern stoves (red).

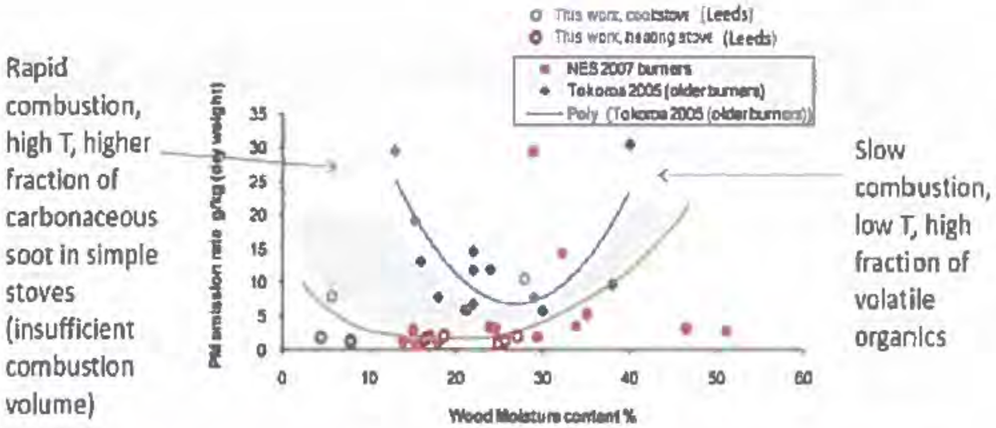


Figure 24. Impact of wood moisture content on PM emissions from different types of appliances from in-situ testing. Source: Wilton and Bluett (2012), Jones et al. (2019).

There is a notable difference in scale, which is likely due to differences in the type of testing procedure and measurement equipment used. Also apparent is the far greater increase in emissions factors for very dry fuels in the older burners (blue). This is due to the simplicity of older stoves and lack of control over air supply and burning conditions. The same is true of open fires. The increase in PM emissions at very low moisture contents may be offset by the use of modern Ecodesign stoves with highly controlled air flow and secondary/tertiary air inlets. This is controlled in pellet stoves and larger systems by a lambda sensor which can be used to vary air supply and fuel feed rate.

Reporting units

Reporting units can also significantly affect the comparison of emissions factors between dry and wet wood. The standard unit used in this work is grams of particulate matter per kilogram of fuel (g/kg), but others use grams per unit fuel energy (MJ or kWh) or grams per hour. This can complicate comparisons because wet wood has a much lower energy content per kilogram and also a significantly lower burning rate.

For a typical 5 kW heating stove, Price-Allison et al. (2019) found average burning rates for kiln dried fuel were closed to 2.0 kg/hour compared to 1.5 kg/hour for seasoned logs and 1.2 kg/hour for fresh cut logs. Using this and typical CV values, emissions factors can be compared in different units as shown in Table 2.

Table 2. Comparison of wet wood emissions factors in different reporting units.

	Kiln dry	Seasoned	Fresh cut
Moisture content (ar basis)	10-15%	20-25%	35-40%
CV (MJ/kg)	16.6	14.0	10.8
Typical PM (g/kg)	0.78	0.86	1.74
Typical PM (mg/MJ)	47.0	61.4	161.1
Scaling factor (PM emissions compared to kiln dry fuel)	1	1.3	3.5

Arguably the most appropriate unit for reporting PM emissions is mg/MJ since 1 kilogram of wet wood contains significantly less energy than dry wood, and also it has a much lower burn rate meaning that more fuel must be burned in an hour to achieve the same heat output. For comparison, the PM emissions limit for RHI eligible biomass boilers is 30 mg/MJ.

Industrial emissions measurements

In the UK and Ireland, PM emissions limits for fuels and appliances are set under the Clean Air Act at 5 g/hour (UK) and 10 g/hour (Ireland). When the fuels are tested by industry, the test must conform to BS 3841 and the laboratory must be accredited. In order to maintain the benchmarks and allow for fair comparison, the fuels are tested with several reloads of the fire but within an output range which represents the typical real world use of the fire. This inherently means that these measurements will be higher than many of those done in academic settings which include the char burnout phase.

The hourly emissions figures are hugely dependent on sampling period and burn rate and can be as high as 21.1 g/hour for wet wood (40% MC) compared to 3.2 g/hour for dry wood (KIWA Gastec, 2015). This equates to a scaling factor of 6.5.

3.4 Impact on other emissions

In addition to impacting on particulate emissions, wood fuel moisture content also affects the emissions of other gaseous pollutants such as carbon monoxide (CO), formaldehyde, benzene and methane. Polycyclic aromatic hydrocarbons (PAH) emissions maybe be gaseous or bound within the particulate fraction, and the impact of moisture content on this is discussed in the preceding section.

Carbon monoxide is one of the most well-known products of incomplete combustion. Johansson et al. (2004) found CO emissions for wet wood (38% MC) were 2.9x higher than dry wood (15% MC). By promoting incomplete combustion, the burning of wet wood also releases organic gases in greater concentrations than dry wood, as shown in Figure 25.

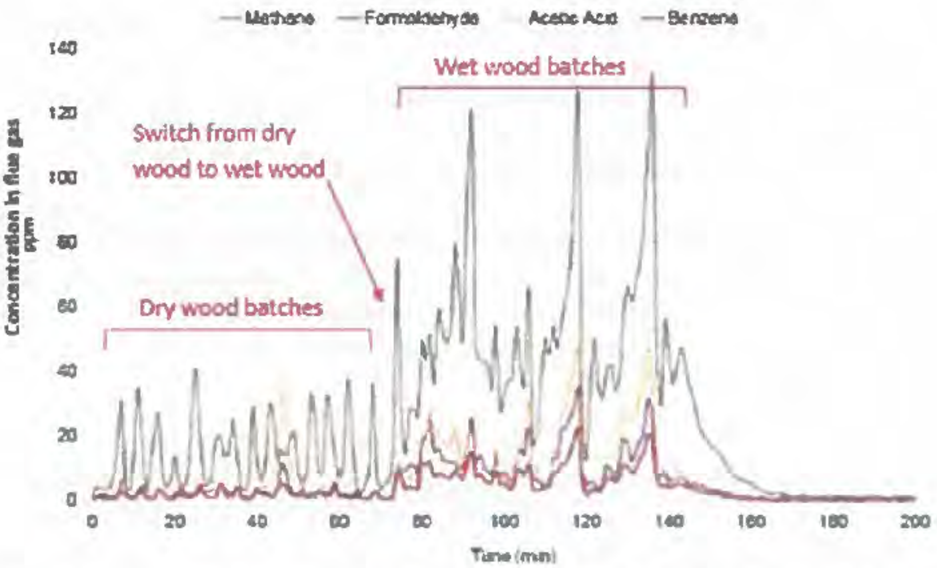


Figure 25. Variation of gas pollutant concentrations versus time for dry wood and wet wood. Source: Mitchell et al. (2020).

As shown, the concentration of all pollutants increased when wet wood was added. Perhaps the most dramatic increase was in methane emissions, which is often overlooked in emissions studies. Price-Allison et al. (2019) recorded an increase in methane emissions of a factor of 10 times for wet beech logs (36.4% MC) compared to kiln dried beech logs (4% MC). This is significant as methane is a potent greenhouse gas, with a global warming potential of 28. Exposure to other emissions such as benzene and formaldehyde is linked to adverse health effects and by switching to dry wood, emissions and therefore exposure can be reduced.

4. Conclusions

Moisture in wood

- Freshly cut wood can be 50 - 60% moisture by weight, therefore having large implications on subsequent transport and combustion if not dried.
- Seasoning of wood typically reduces moisture contents from 50 - 60% down to 23% depending on the species.
- Moisture contents of seasoned wood can fluctuate between 15 - 30% depending on conditions such as humidity and storage method.
- For assurance of a consistent low moisture content, kiln drying is recommended.
- Moisture contents can be measured using standard methods, however, for simplicity are typically measured in domestic settings by moisture meters. These are sensitive between 6% - 23% moisture content and require calibration and correct user operation (e.g. repeated measurement on split wood) to avoid errors.
- The calorific value of kiln dried wood (10% MC) is 81% higher than that of wet wood (45% MC).

Impact on combustion

- Lighting wet wood on stoves increases the duration of the initial low temperature phase due to the water contained having to overcome the latent heat of vaporisation before combustion can begin.
- Wet wood (40% MC) added to an established fire requires 27% more energy to raise the temperature of the wood compared to dry logs at 10% MC due to the higher specific heat capacity of wet logs.

Impact of efficiency

- Higher moisture contents lower the temperature in the combustion chamber leading to incomplete combustion. This can cause drops in thermal efficiency from 80% for a stove burning kiln dried wood down to 50% for a stove burning fresh cut wood.
- Due to the reduced thermal efficiency when burning wet wood, as much as 48% more wet fuel may be required to achieve the same thermal output as dry fuel.

Impact on particulate emissions

- The toxicity of particulate matter released when burning wet wood is higher than that when burning dry wood. This is due to the ratio of organic carbon to total carbon being much higher for fresh cut or seasoned logs compared to kiln dried logs. This organic carbon contains phenols and PAHs, which are well known to be harmful to health.

- Particulate matter emissions factors on a wright basis (g/kg) can be halved by switching from wet wood to dry wood with a moisture content between 15 - 20%.
- On an energy basis, PM emission factors (mg/MJ) can be 3 - 4 times higher for fresh cut wood compared to kiln dried wood.
- Burning extremely dry logs (5 - 10% MC) can result in small increases in particulate emissions due to there being a lack of moisture to supress the devolitisation rate. This leads to rapid combustion that uses up all the available air supply. This increase more pronounced in older stoves and open fires due to lack of air control.

Impact on other emissions

- Wood fuel moisture increases the emissions of other pollutants, for example CO emission for wet wood are 2.9 times higher than for dry wood due to incomplete combustion.
- Incomplete combustion associated with wet wood releases a range of toxic gases such as PAH, formaldehyde and benzene.
- Methane emissions can be as much as 10 times higher for wet logs compared to kiln dried logs. This is important for climate change due to methane being a potent greenhouse gas with a global warming 28 times that of carbon dioxide.

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6. Appendices

6.1 Appendix 1 - Average moisture content of green wood by species

Table 3 Average moisture content of green wood by species (Simpson and TenWolde, 1999)

Species	Moisture content[a] (%)		Species	Moisture content[a] (%)	
	Heartwood	Sapwood		Heartwood	Sapwood
Hardwoods			**Softwoods**		
Alder, red	—	97	Baldcypress	121	171
Apple	81	74	Cedar, eastern red	33	—
Ash, black	95	—	Cedar, incense	40	213
Ash, green	—	58	Cedar, Port-Orford	50	98
Ash, white	46	44	Cedar, western red	58	249
Aspen	95	113	Cedar, yellow	32	166
Basswood, American	81	133	Douglas-fir, coast type	37	115
Beech, American	55	72	Fir, balsam	88	173
Birch, paper	89	72	Fir, grand	91	136
Birch, sweet	75	70	Fir, noble	34	115
Birch, yellow	74	72	Fir, Pacific silver	55	164
Cherry, black	58		Fir, white	98	160
Chestnut, American	120		Hemlock, eastern	97	119
Cottonwood	162	146	Hemlock, western	85	170
Elm, American	95	92	Larch, western	54	119
Elm, cedar	66	61	Pine, loblolly	33	110
Elm, rock	44	57	Pine, lodgepole	41	120
Hackberry	61	65	Pine, longleaf	31	106
Hickory, bitternut	80	54	Pine, ponderosa	40	148
Hickory, mockernut	70	52	Pine, red	32	134
Hickory, pignut	71	49	Pine, shortleaf	32	122
Hickory, red	69	52	Pine, sugar	98	219
Hickory, sand	68	50	Pine, western white	62	148
Hickory, water	97	62	Redwood, old growth	86	210
Magnolia	80	104	Spruce, black	52	113
Maple, silver	58	97	Spruce, Engelmann	51	173
Maple, sugar	65	72	Spruce, Sitka	41	142
Oak, California black	76	75	Tamarack	49	—
Oak, northern red	80	69			
Oak, southern red	83	75			
Oak, water	81	81			
Oak, white	64	78			
Oak, willow	82	74			
Sweetgum	79	137			
Sycamore, American	114	130			
Tupelo, black	87	115			
Tupelo, swamp	101	108			
Tupelo, water	150	116			
Walnut, black	90	73			
Yellow-poplar	83	106			

[a]Based on weight when ovendry.

Appendix 7

CONFIDENTIAL

Appendix 8

Report on CPL Wood Combustion Testing

Introduction

CPL have a combustion testing facility at their Immingham Site that has the necessary fire settings and testing equipment to carry out solid fuel efficiency and flue gas emissions rates to both Open Fire BS 3841 and Closed Appliance/Stove EN 16510. CPL also has independent data from KiwaGastec and BSRIA the two main test houses in the UK. The following is a summary of recent test work on kiln dried and unseasoned wood and a comparison with independent results.

Open Fires

The current standard for emissions from open fires is BS 3841 which is used by the UK government as the particulate emission test for authorisation of solid fuels for use in smoke control areas. The testing standard is based on an ignition phase and then 2 or 3 refuels with the measurement starting after the ignition phase and ending when the fire drops below a pre-set heat output.

The UK limit for authorisation is a particulate emission of less than 5 g/hr.

Although generally used for mineral fuels BS 3841 part 2 allows for the testing of low calorific value fuels such as wood.

CPL recently tested kiln dried wood with the following results

Particulate Emission	Av Heat Output	Burning rate
g/hr		kg/hr
5.2 - 6.5	1.55 - 1.86	3.3 - 3.8
Av. 5.9	Av 1.74	Av 3.49

The wood tested was 9 – 13 % moisture.

There are no truly comparable results for wet/unseasoned wood as the material does not combust easily and the testing methodology has to be altered significantly to get any data. However recently HETAS asked KiwaGastec to carry out testing with an external energy input to keep the fire going and reported these results

Particulate Emission	Av Heat Output	Burning rate
g/hr	kW	kg/hr
21.1	0.91	2.4

The wood moistures were 30 – 40 %.

Typical values for smokeless fuel would be

Particulate Emission	Av Heat Output	Burning rate
g/hr	kW	kg/hr
4.3	1.95	0.93

From a residential user perspective the main issue is the useful output from the fire in terms of heating room. The comparison on this basis would be the particulate emission at a reference useful heat output in grams of particulate per hour. The following table illustrates the comparative particulate emission for the three fuels at a representative output of 2 kW.

	Particulate Emission	Av Heat Output	Particulates Emission@ 2 kW
	g/hr	kW	g/hr
Smokeless Fuel	4.3	1.95	4.41
Kiln Dried Wood	5.9	1.74	6.78
Unseasoned Wood	21.1	0.91	46.37

Closed Appliances / Stoves

The current UK closed appliance fuel testing standard is EN 16510. In this test combustion efficiency and emissions are measured when the appliance is at nominal/rated output over relatively short time spans (1 hour) with the whole apparatus on a balance to calculate burning rate. The particulate emission measurement is carried using similar equipment to the BS 3841 analysis.

Because of the higher efficiency of closed appliances it is possible to compare kiln dried and unseasoned wood. The following results were taken from a modern EcoDesign stove (Charlton+Jenrick Fireline) in CPL's facility

	Particulate Emission	Total Heat Output	Burning rate
	g/hr	kW	kg/hr
Kiln Dried Wood	2.3	5.3	1.3
Unseasoned Wood	8.0	3.3	2.1

The moistures were 11.2 % kiln dried and 35 % unseasoned.

CPL also have independent data from work of a similar nature on an older Waterford Stanley Oisin dry stove where the average particulate emission was 11.7 g/hr with wood circa 13% moisture indicating a wide range of performance between older and new stoves. This data is backed up by work carried out by the Stove Industry Alliance in the UK indicating an overall 80% improvement in particulate reduction in new EcoDesign stoves versus older models.

There is little independent data regarding unseasoned wood on stoves as most stove manufacturers do not recommend its use and the standards both for appliance and fuel testing require dried wood.

Typical values for smokeless fuel on a modern stove based on CPL data would be

Particulate Emission	Av Heat Output	Burning rate
g/hr	kW	kg/hr
2.3	5.0	0.7

Cost in Use

The efficiency of combustion is related to both the appliance and the fuel. On behalf of HETAS working for DEFRA an approved fuel and appliance testing house (BSRIA) carried out a series of trials to establish the cost per useful output for a number of wood types and 2 mineral smokeless fuels. The report was published in February 2020 and the table below lists the results 4 differing wood types and moisture contents and the 2 smokeless fuels in the report. The table below shows the efficiency and cost on three different devices referred to as an Open Fire, Old Stove and Modern Stove.

As with the KiwaGastec work on wet wood the BSRIA report identifies that to carry out the work the two highest moisture woods the appliances had a further heating input to maintain combustion.

Fuel		Appliance		
		Open Fire	Old Stove	New Stove
Smokeless (MF1) manufactured mineral fuel	Efficiency	41%	68%	82%
Moisture As Fired 12.40%	Cost/Useful Output £/kWhr	£0.15	£0.09	£0.08
Low cost smokeless (MF2) manufactured mineral fuel	Efficiency	38%	62%	83%
Moisture As Fired 10.70%	Cost/Useful Output £/kWhr	£0.15	£0.10	£0.07
Kiln dried wood logs (Beech)	Efficiency	27%	65%	75%
Moisture As Fired 15.30%	Cost/Useful Output £/kWhr	£0.49	£0.19	£0.17
Seasoned wood logs (Beech)	Efficiency	29%	62%	71%
Moisture As Fired 15.00%	Cost/Useful Output £/kWhr	£0.41	£0.19	£0.17
Wet wood logs (Ash)	Efficiency	7%	46%	53%
Moisture As Fired 29.12%	Cost/Useful Output £/kWhr	£1.22	£0.19	£0.17
Wet wood logs (Beech)	Efficiency	6%	18%	8%
Moisture As Fired 39.06%	Cost/Useful Output £/kWhr	£1.74	£0.61	£1.31

The wet wood on all appliances produced reduced efficiencies against the other fuels and this was particularly marked on open fires where the efficiencies were in single figures. In these cases the fires would be producing significantly high pollution levels whilst actually giving virtually no appreciable heat output.

The work demonstrated that a move to drier wood and low smoke fuels would provide a cost reduction to all users although the effect is more marginal on the most up to date stoves. However most manufacturers of new stoves will only recommend the use of dry wood.

Appendix 9

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READY
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HETAS Technical Bulletin #9

READY to BURN Special Edition

February 2018

Welcome to a special edition HETAS Technical Bulletin, in conjunction with Woodsure and its Ready to Burn dry wood fuel scheme. With challenging press and media questioning what actual environmental effects burning logs & wood briquettes have we felt it right to bring together information of how the solid fuel & wood-burning sector along with modern stove manufacturers are reducing environmental impact, helping our industry to be part of the solution not part of the problem.

This publication will help give ways to explain the issues to those who have concerns and to show how we in our industry, installers, chimney sweeps, servicing businesses, manufacturers & retailers work together to reduce environmental impact. This bulletin documents evidence of our joint efforts which has resulted in highly publicised support from Defra. The ultimate message is for consumers to burn clean dry fuel in modern clean burning appliances but for those who are not buying new stoves or replacing old ones, the dry clean wood fuel message alone will have clear environmental benefits.

\- Bruce Allen, CEO

If you have comments we would be pleased to hear from you: hello@hetas.co.uk

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CONTENTS

Air Quality in the UK - How Solid Fuel, Wood & Biomass can be Part of the Solution

Bruce Allen, CEO of HETAS and Chairman of Woodsure on work undertaken by Defra, Woodsure & HETAS to highlight and combat air pollution in cities.

The Issues.

Recent press attention has highlighted growing evidence of very small particulate emissions caused by burning fuels like diesel, coal, biomass and log wood-fuel – but also from tyre wear and brake dust. These particles known as PM2.5 & PM10's are tiny air born particles of 2.5 to 10 microns in size and they can cause damage to health as they are small enough to be breathed in to the lungs.

Defra has looked at much research and data on air quality and concluded that:

"Tackling air pollution is a priority for this Government. Clean air is one of the most basic requirements of a healthy environment for us all to live, work, and bring up families".

Improving Consumer Understanding

Use of open fires & wood-burning stoves has risen in popularity in recent years. There has been an increase in the number of queries or complaints from residents about smoke (particulates).

This increase is an indicator that we are seeing more emissions from wood/biomass burning and a subsequent increase in air pollution in built up areas. Domestic wood & coal burning are said to be the single largest contributors to harmful PM emissions in some cities, comprising over 30% in London at one point in 2015. It is believed that the part attributed to home appliances is made up mainly from poor fuel on open fires & old stoves. This compares to emissions from industrial combustion (17%) and road transport (13%). Tiny particles in smoke can cause a range of health impacts such as breathing problems and exacerbating asthma as well as contributing to other health conditions.

Get a pollution forecast for your area at:
https://uk-air.defra.gov.uk

Local Authorities are the regulators for domestic biomass under the Clean Air Act 1993 and play a vital role in helping to improve air quality in their local areas by ensuring that residents are informed about legislative requirements and the environmental and health impacts associated with poor burning practices. Defra calls on their assistance in raising awareness.

Defra has issued a guide: "We all breathe the same air" which is available for consumers. This has been produced in association with chimney sweeps and provides clear advice on the procedures to follow when lighting a stove to minimise smoke emissions.

This guide can be found at:
https://goo.gl/7N7eYz

Government will be developing a Clean Air Strategy which will be published for consultation in 2018 setting out how we will work towards our international commitments as well as continuing to deliver air quality improvements in the UK

What action has Defra already taken?

As part of Defra's commitment to improving the UK's air quality and cutting harmful emissions they have been working with industry sectors on a proactive strategy to help reduce emissions.

This strategy already includes:

The launch of Woodsure's 'Ready to Burn' brand by wood fuel suppliers, promoting the sale & use of good quality dry wood, which has lower emissions than wet wood. Ready to Burn is mentioned in Defra guidance (pictured): **www.woodsure.co.uk/gov-guidance**

The stove industry launch last year of the Ecodesign Ready brand which enables consumers to identify which stoves are tested to the high emissions standards of the Ecodesign Directive due to be introduced in 2022.

Work to improve consumer information e.g. development of information leaflets and consumer advice at point of sale.

Working on a series of informative animations based on the information in the practical guide.

An Industry View

For many in our sector, it's hard to imagine that solid fuel appliances could possibly be responsible for large enough quantities of particulates to cause problems – but scientists can see from chemicals in the atmosphere that at some times of the year and on some days like cold Sunday afternoons, the combustion of wood can become a real problem in some of our cities.

Many will straight away proclaim that most of our major cities are smoke control areas so how could they be polluted like this? Surely only authorised smokeless mineral fuels or wood burnt in appropriate Defra exempted appliances is allowed?! This would surely limit particulate emissions greatly. It is true that sticking to the rules would make a massive positive difference.

Unfortunately use of poor fuels, open fires and old stoves causes much of this unwanted pollution (along with bonfires and other fires used to burn waste – often illegally). continued...

The Charnwood Country 4 is one of the many HETAS listed Defra Exempt stoves

_ "An Industry View" continued

Over the years we have repeatedly discussed enforcement of the Clean Air requirements and despite much effort we are forced to conclude that the legislation is incredibly challenging to enforce in its current format.

Whilst some Local Authorities have taken action, enforcement is not common. Government will look at future legislation but at this time we have to push for other remedies. For this reason, the particulate emissions issue becomes one that our industry can affect greatly and where we must rely heavily on educating users to buy the right fuel and burn it properly; wherever possible in newer, clean burning appliances.

The rest of the document gives more detail so that you can understand the issues in more depth and can present the right arguments ensuring that our industry is part of the solution not part of the problem.

Benefits of dry wood over wet wood

ADVICE TO CUSTOMERS

BENEFITS OF DRY WOOD OVER WET WOOD:

It may sound obvious that wood fuel should be dry before you attempt to burn it, but it is not normally obvious when wood fuel is actually ready to burn.

A living tree or recently felled tree can contain over 60% moisture dependant on the tree species. If the tree is cut into fire wood and sold to a customer it may look perfectly good to place straight on to the fire. But a 1kg freshly cut log could contain around 500-600ml of water i.e. around one pint of water.

With that knowledge it's obvious that trying to burn a wet log is not sensible. Before you can benefit from the energy released from a log the fire has to evaporate and boil off a pint of water, so instead of benefiting from the full amount of available heat energy into the room, much of the energy is being used to drive off the moisture turning it to steam.

BRIQUETTES ARE A GREAT OPTION FOR DRY, READY TO BURN FUEL WITH AN AVERAGE 10% - 12% MOISTURE CONTENT

Following this logic it may be assumed the drier the wood the better, and wood with zero moisture would be best? But this logic doesn't apply especially in wood burning stoves. A small amount of moisture is beneficial and the standard that appliance manufacturers work to allows for wood fuel between 12% - 20% moisture content (on a wet basis). This small amount of moisture moderates the combustion process and liberates the right amount of heat energy to the room in accordance with the appliance design. Wood that is too dry can burn quickly and ferociously dragging in large volumes of excess air which cool flue gases and can increase particulate emissions.

Within the specified parameters not only will you get more useful heat from Ready to Burn wood fuel, but you will also benefit in other ways. Ready to Burn wood reduces maintenance needs and keeps chimney liners in better condition (as long as there are no long periods of slumbering).

... "Benefits of Dry Wood Over Wet Wood" continued...

When faced with 2 similar sized bags of wood fuel where one is cheaper, heavier, unseasoned wood, psychologically the cheaper heavier bag may appear better value. But you will get more useful heat from the lighter, drier **"Ready to Burn"** wood, and produce a cleaner burn with less smoke and emissions. **Ready to Burn** wood fuel is likely to give you more value for money and more heat output for the same volume of wood.

How can I find Ready to Burn fuel?

Look for the **Ready to Burn** logo. Or if you are unsure and in the absence of a moisture meter look for radial cracks and loose bark. Knock two logs together, if you hear a dull thud it's likely the wood is still too moist.

www.readytoburn.org

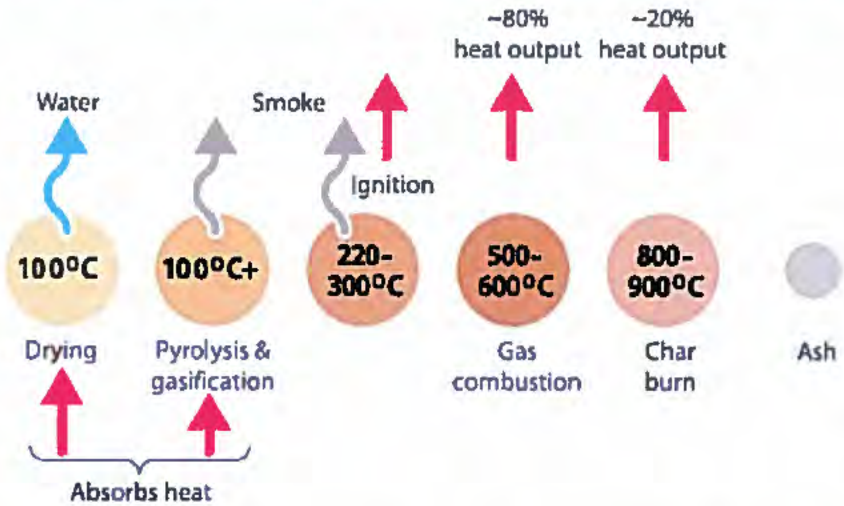
Technical Information supporting use of drier wood

Andrew Hopton, Director of Woodsure and HETAS consultant explains the science behind wood burning.

What is the ideal moisture for my wood fuel?

There are a number of values that are often quoted for the ideal moisture content of wood fuel, and figures of less than 25% and less than 20% moisture are probably the most common values stated. There has been a great deal of recent scientific work done on the combustion of dry and wet wood so we are better informed than ever.

When wood is burnt it goes through the following process:



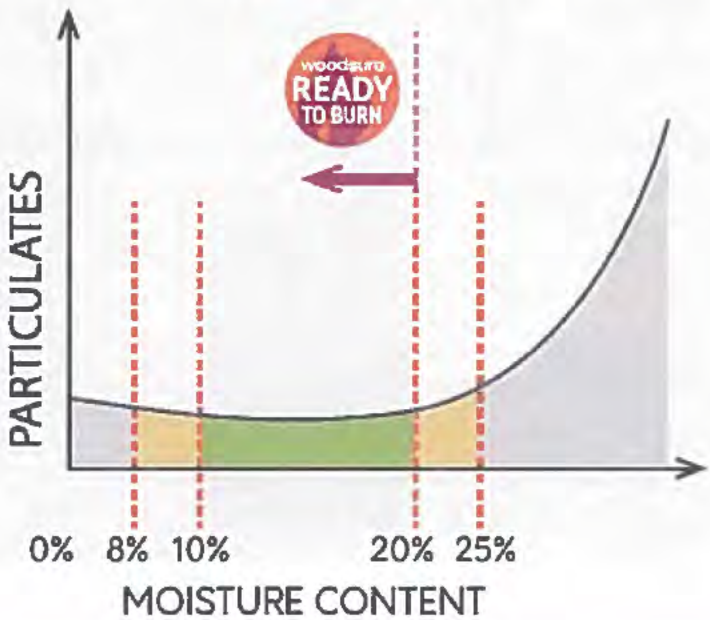
When an established fire is reloaded with logs the existing embers will first need to evaporate and boil off any moisture in the newly loaded logs. The assumption that 'drier the better' would tend to support this first stage of the combustion process, but a small amount of moisture provides a controlled burn rate at this stage in the combustion process.

"Technical Information Supporting Use of Drier Wood" cont...

Wood burning stoves are designed to meet established manufacturing standards to release the maximum heat efficiency from the fuel, and the appliance standard for stoves defines test fuel at a moisture value of 16%±4%. This amount of moisture in the wood fuel moderates the combustion process and liberates the designed amount of heat energy to the room.

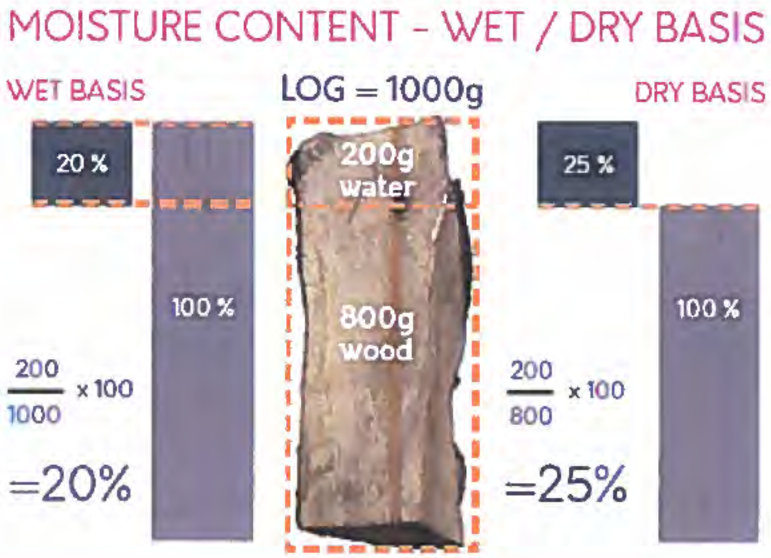
With the established stove testing standards and other information that we have managed to collect from various pieces of testing results and academic research, we have established that the 10% to 20% moisture range for wood fuel burnt in wood burning stoves is likely to be the optimum range to get the most useful heat, with minimal emissions.

Woodsure and HETAS have agreed from research that the benefit of drier logs starts at about 25% moisture content. The **Ready to Burn** scheme sets an upper limit of 20% to ensure that the real benefits can be realised. It is also understood that briquettes (and pellets) will have a moisture content from 8% - 12% and generally burn very cleanly. Very low moisture fuel can lead to an initial rapid burn and problems with the amount of oxygen available, so it is not necessary to strive for absolute dryness. But any appliance burning log wood fuel will benefit when the wood fuel is dried to between 8% to 25% in place of wet or freshly cut logs or waste wood. The research we have seen can be summarised in the following graph:



Moisture Readings

Moisture content is measured in 2 ways, Wet basis is the normally accepted value used for wood fuel and used by Woodsure, but please be aware that some moisture meters have duel use for construction and may be reading on a dry basis.



Heat Energy

The potential energy that can be released from burning wood is typically known as calorific value (CV). Most wood species have a similar calorific value of about 4kWh per Kg for **Ready to Burn** fuel. The actual heat released in combustion relates to the efficiency of the stove and the quality of the fuel used. Modern stoves can now achieve 80% efficiency if the wood fuel is **Ready to Burn**. If the fuel is 'wet' with a high moisture level (>20%) a lot of heat energy will be used to drive off the excess moisture before you appreciate the useful heat energy to the room from the wood.

Burning wet fuel on open fires can provide little or no heat benefit to a room, can tar up a chimney and create smoke and high emission levels.

In all cases burning dry wood fuel on any appliance is better than burning wet wood. Modern efficient stoves will provide the most benefit.

Naturally seasoned or kiln dried wood

There are two usual ways of drying wood fuel:

- **Naturally seasoned ~ A traditional way, but can take up to two years to get below 20% moisture (depending on the drying method and conditions), ready for use.**
- **Kiln dried ~ Forced dried using heat, changing unseasoned wood to Ready to Burn in a matter of days; significantly shortening the drying process.**

Naturally seasoned is where wood fuel is cut to length, split & allowed to dry naturally. Logs are stored in well ventilated, covered stores. From freshly felled to **Ready to Burn**, naturally seasoned wood can take up to 2 years to dry sufficiently although experienced experts can accelerate this with well managed stores & methods.

To kiln dry requires a large oven where prepared wood fuel is dried at temperatures of around 60°C over a number of days until a moisture content of typically <20% is achieved.

From a pile, stack or bulk delivery select a number of random samples: at least 3 but the more the better.

Take logs from different locations outside or a representative sample.

For long logs, cut a section out of its centre using a chainsaw.

Helen Bentley-Fox, Director of Woodsure on the best method to test moisture levels of wood fuel

A moisture meter can give a good indication of moisture if you follow this procedure:

FIREWOOD MOISTURE PIN METER METHOD

2

Take the samples and split the log down the centre with an axe.

3

Measure moisture content on this fresh face by pressing the pin meter's pins into the centre of the log **across the grain**.

Record a number of measurements along the centre of each split log. Measure moisture content in this way for at least 6 readings from the sample then **calculate the average:**

$$\text{AVERAGE} = \frac{\text{SUM OF ALL READINGS}}{\text{NUMBER OF READINGS TAKEN}}$$

Record this as the timber's average moisture content.

Controls

* Make sure your pin meter can be set for type of timber & possibly ambient temperature and set the reading / moisture content on a wet basis (many pin meters are for use in the construction industry and may have options to set to measure walls for example).
* Measure moisture on the cut surface as centrally as you can and as quickly as possible as the moisture content can change very quickly.
* Make sure you take a representative sample from throughout the load, choosing logs from the middle of the pile as well as the surface.

Make sure the pin meter is in good condition.

Smoke control areas, fuels and appliances

Brian Bailey, Senior Product Evaluation Officer at HETAS on government Smoke Control regulations

The great London smog (1952) is estimated to have directly caused the deaths of some 4,000 people and indirectly led to the deaths of a further 8,000 people in the ensuing months. The Government responded by introducing The Clean Air Act in 1956. The act enforced a number of measures to reduce air pollution. In particular it empowered local authorities to establish Smoke Control Areas in certain towns and cities. This restricted the use of fuels for heating households so that only smokeless (authorised) fuels were permitted such as cleaner solid fuels, electricity & gas. These measures proved very effective at reducing smoke pollution and gases such as Sulphur Dioxide.

The focus of the legislation is the emission of smoke from chimneys and includes domestic premises as well as commercial and industrial facilities. If a chimney emits 'dark smoke' this is an offence and whoever owns the chimney is guilty of the offence. There are of course ways to comply with the requirements; for householders this means either burning only authorised smokeless fuels or using an exempted appliance with one of the fuels that particular appliance is exempted for use with. There is a Statutory Instrument listing the appliances with the fuels that each is exempted for use with.

*** If you are in a smoke control area look for stoves that have the Defra exempt logo in The HETAS Guide to Approved Solid Fuel, Wood and Biomass Products & Services. Search for a solid fuel appliance or product at hetas.co.uk**

Look out for the Defra exempt logo in The HETAS Guide

DEFRA EXEMPT


The "Stockton 5" Defra Exempt stove - courtesy of Stovax

So in the case of a domestic home owner accused of emitting dark smoke; if you could prove that this was inadvertently emitted whilst burning a smokeless fuel (an authorised fuel) or that you were burning a fuel that was not an authorised fuel but on an exempted appliance designed to burn the specified fuel then you should not be found guilty of the offence.

The Government Department for Environment, Food and Rural Affairs (Defra) maintains a list of all Authorised Fuels and Exempted Appliances. Only those fuels or those appliances that are listed are legally entitled to be classed as such. View the list at: **https://www.gov.uk/smoke-control-area-rules**

Most generic wood based fuels including natural wood logs, wood chips and compressed wood pellets are not authorised fuels. In order to burn these fuels in a designated smoke control area the appliance on which it is burned must be an exempt appliance listed on the Defra website and the exemption must be for burning the specific fuel type. The appliance manufacturer's instructions will also provide further details about the specifications of the fuel to be burned and this will almost always include details about its required moisture content.

For the burning of authorised fuels it is necessary that the appliance on which it is burned is designed to burn the fuel however this appliance does not need to be listed by Defra and can be a generic designed appliance recommended by the manufacturer for burning the generic fuel type, often described as smokeless fuel. In such cases it is the fuel itself that must be listed by Defra to ensure that it is an authorised fuel.

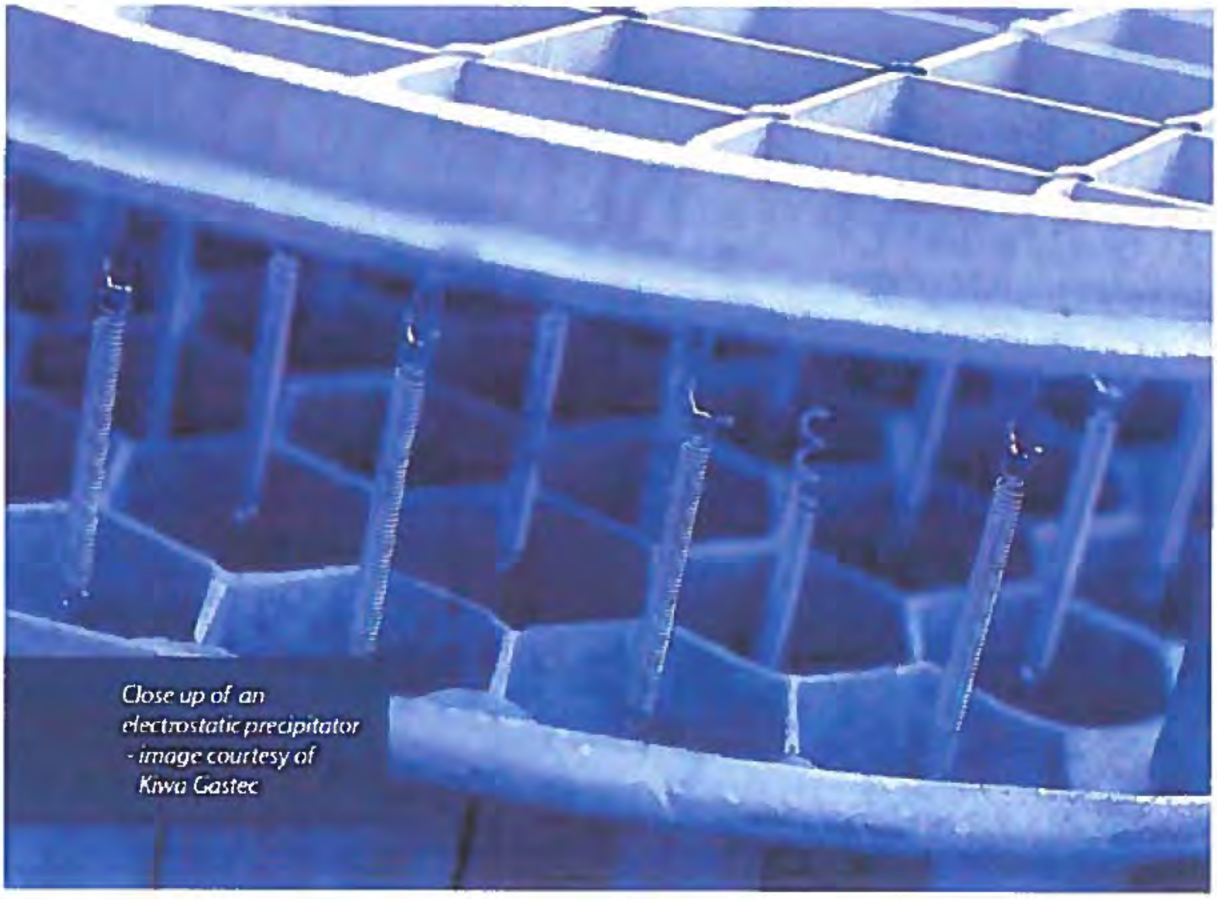
As we move towards the next decade, there are some uncertainties including Brexit and future test methods accepted by individual nations. There is new European legislation coming in 2020 (for boilers) and 2022 (for stoves). This is the Ecodesign legislation. We are not yet sure which rules will apply in the UK although it seems sensible that to some extent they fit in with the EU Regulations to avoid unnecessary barriers to trade.

HETAS & Woodsure
Supporting Industry

Calvin May, Technical Standards Manager on the difficulties of enforcing the Clean Air legislation.

Air quality continues to be of the highest importance to the solid fuel and biomass industry. One of HETAS's objectives is "to improve the quality, efficiency and safety of appliances, fuels, associated equipment and installation & maintenance services". Both HETAS and Woodsure have been working closely with Defra (Department Environment, Food and Rural Affairs), in support of the governments clean air strategy to reduce overall emissions and significantly improve air quality through the use approved dry wood fuels, promotion of highly efficient clean burning appliances and a consumer focus on applicable guidance to correctly operate the appliance to achieve maximum efficiency and cleanliness in operation.

HETAS and Woodsure make great efforts to communicate with Government and other stakeholders making them aware that our industry is operating in innovative ways that contribute to improved air quality. We have strong working relationships at both government department level and with a wide range of stakeholders. Through these relationships we are able to engage in discussions about future legislation and to influence it in positive ways. HETAS and Woodsure attend a wide number of industry technical groups, and are involved in advising and consultations about air quality issues. We are able to call on our understanding of our sector to ensure the industry is seen as part of the solution, and not part of the problem as some press releases claim.


Close up of an electrostatic precipitator - image courtesy of Kiwa Gastec

As with all service industries, there are many very technical areas of work that go in to various stages of the supply chain. Innovation is present through the setting of manufacturing standards right through to appliance design, manufacture, installation and fuel production. Each part of the jig-saw contributing something to what are now highly engineered and effective pieces of heating equipment. In order to demonstrate that appliances, fuels and other heating equipment complies with laws and regulations the standards are the basis of measurement.

This is one of the areas where HETAS plays a pivotal role in the development and updating of the standards. HETAS currently chairs the BSI national UK mirror committee RHE/28, whose main responsibilities include development of applicable appliance, installation, fuel and associated equipment standards and codes of practice, thus ensuring any future requirements are clear, robust and realistic, whilst at the same time promoting a safe and efficient environment for installers, retailers, manufacturers and most importantly the consumer.

...continued on next page


Image appliance testing facility - courtesy of Kiwa Gastec

The mirror committee is supported by a number of sub-committees and stakeholder groups, who use the opportunity to share a wide level of technical expertise, experience and knowledge, and use this to drive discussions and action in areas of identified issue and resolution. Fuel quality, appliance test methodology, air quality and installation best practices are to name but a few of the consultations currently taking place, working in close partnership with industry recognised organisations such as Woodsure, Kiwa Gastec, BSRIA as well as manufacturer associations such as the SIA, HWA and the BFCMA.

Along with these industry stakeholder groups, HETAS leads the HETAS Technical Committee, an open technical forum where matters of importance are discussed with actions and resolutions to problems being proposed. This includes research projects and some testing work which explore and provide evidence to back-up any suggested amendments or improvements on safety within national legislation and the Building Regulations, as well as development of alternative installation practice approaches that can be used in the absence of any other standards e.g. for new and innovative products not yet covered by statutory guidelines.

HETAS has been heavily involved in the development of new installation standards for solid fuel appliances in the form of a revision to BS8303, as well as implemented alternative guidance for installation of dedicated external air supply appliances, which include risk assessment and commissioning processes to ensure the installation is safe and compliant.

There are still a wide variety of technical projects under consideration and development, however all these activities play a key role in ensuring the future of the solid fuel industry puts safety and efficiency first, and plays its part in supporting government air quality initiatives as well as continued promotion of quality fuels, appliances and services.

The Benefits of Ecodesign Appliances

Calvin May, Technical Standards Manager, points out the many benefits of opting for a greener appliance.

With the impending Ecodesign Regulations coming in to force in Europe in January 2020 for independent boilers and January 2022 for room-heater stoves, it is important for installers, retailers, specifiers and consumers to understand what the changes will mean and how the relevant sectors can support renewable, decarbonisation and clean air strategies and targets. The overall aim is to promote more energy efficient appliances and use of quality wood fuels to lower emissions and improve air quality.

HETAS and Woodsure have been working with industry, Defra and other Government departments to support a pragmatic but effective transition to the new Ecodesign regulations. Initiatives like the Eco-Design Ready appliances, Eco-design Compliant and Defra Exempt appliances are all great weapons in fighting against pollution from emissions. We all want to breathe clean air and we all want to offer customers an option to burn solid fuels, wood, biomass cleanly and efficiently into the future. This means we must aim to reduce the emissions of particulate matter (PM) i.e. organic gaseous compounds (OGC), carbon monoxide (CO), nitrogen oxides (NOx) (and for some fuels sulphur). Older stoves and open fires are the worst polluters.

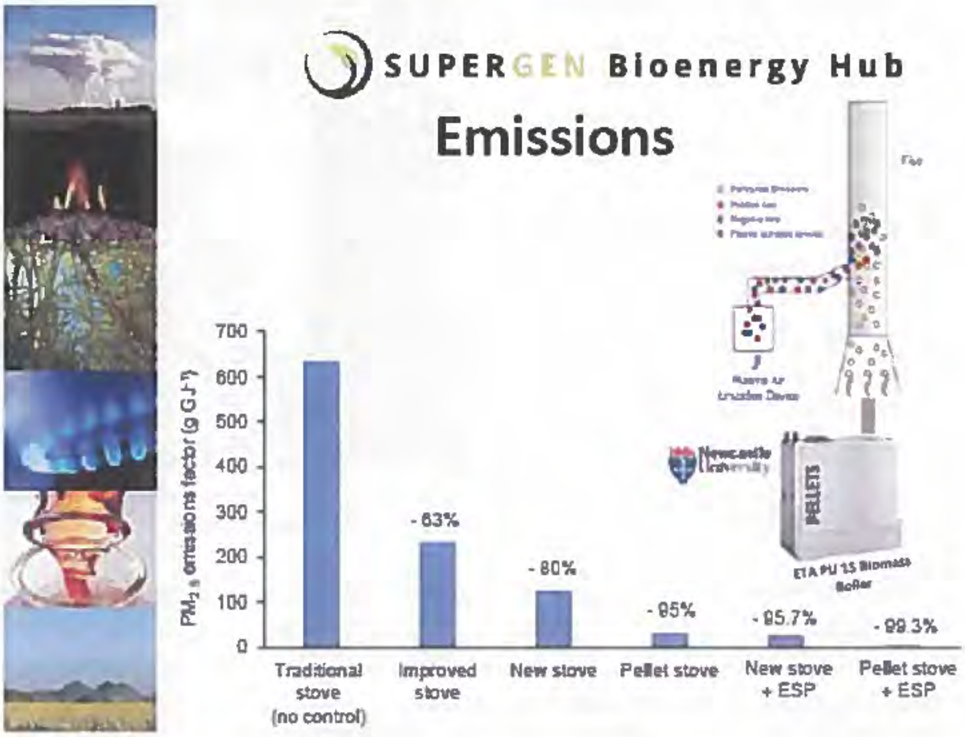
...continued on next page

*The Defra exempt icon in the HETAS Guide (top left) The SIA run an EcoDesign Ready scheme. Search for an SIA EcoDesign Ready product at: **hetas.co.uk** (top right)*

For the very best future mitigation of effects from solid fuel emissions we should discuss new cleaner appliances with consumers and hope to persuade them to modernise and have a hand in protecting the environment.

HETAS and Woodsure are working with Defra, the Forestry Commission and others to find ways to reduce environmental impact. We are also grateful for information shared with us by Scientists at Manchester, Newcastle and Leeds Universities where they are researching wood burning as part of the Supergen project.

The Supergen research project at Manchester, Newcastle and Leeds Universities found that more modern appliances burning the right fuels reduce particulate emissions drastically as shown in the following diagram:



This is part of the evidence that shows this industry can be part of the air quality solution rather than part of the problem. Open fires and old, uncontrolled stoves are much less effective than newer clean burning stoves, not only in terms of particulate emissions but also in cost effective and efficient use of fuel.

Appliance and property considerations

Calvin May, Technical Standards Manager, explains the key points to think about when buying your appliance.

Typically older properties built before the 1960s used open fires fuelled by mineral fuels. These may have been the primary heat source for the dwelling and therefore in very regular use. The most efficient open fired appliances achieved around 50% gross efficiency but most were less efficient at around 35%.

In comparison, a modern closed room-heater which meets Ecodesign efficiency requirements can achieve a gross efficiency as high as 80%. This ultimately means an increase in the heat passed to the room where the appliance is installed. This increases consumer comfort & reduces running costs for the fuel being burnt.

The Supergen findings show very clearly that old appliances emit larger volumes of particulates and new clean-burn appliances much fewer. When we introduce the issue of poor fuel the evidence is equally as compelling.

The Vogue Small T Eco; an SIA EcoDesign Ready woodburner - image courtesy of Stovax

There has been laboratory testing of particulate emissions from an open fire burning wet wood and then dry wood. Tests revealed that burning wet wood produces four to five times the weight of particulates than burning dry wood in a similar open fire. So even in the oldest and most inefficient appliances burning the right fuel can make a huge difference reducing particulate emissions and reducing environmental impact.

Modern appliances are highly engineered, clean, efficient and effective heating appliances. Engineers and designers have been very successful in increasing efficiency and reducing emissions. There are significant improvements over appliances from on the market as little as 5-10 years ago. ...continued on next page

Ecodesign legislation will bring about mandatory requirements to design and test products against maximum limits for OGC's and NOx values. Maximum levels of CO emitted will also decrease dramatically, with more stringent limits in place. Figures recently published show that newly designed appliances can produce 90% less emissions than those appliances sold on the market over 20 years ago e.g. in comparison with open fires burning poor fuels.

The Skye 5 Store Stand SIA Ecodesign Ready appliance. Courtesy of Charnwood

Many HETAS approved stoves are already verified as being "Ecodesign Ready" through a Stove Industry Alliance initiative, which means they already meet some of the fundamental requirements of the Ecodesign legislation. Those manufacturers are already choosing to produce products that meet emission and efficiency requirements 5 years before they are enforceable. As we move towards the implementation of Ecodesign legislation the HETAS listing of appliances in the Guide and on the web site will allow manufacturers to demonstrate full compliance with the legislation. The industry is therefore making great strides in ensuring boilers and room-heater stoves support current and future government clean air strategy and objectives.

As well as success with room-heater stoves, a large number of independent biomass boilers sold on the UK market today have already been verified as meeting these Ecodesign emission and efficiency limits more than two years early. HETAS has been working closely with the independent boiler sector to introduce a new HETAS Ecodesign compliance scheme, which promotes those appliances as meeting Ecodesign, as well as other legislation such as the UK Building Regulations, CPR and Energy Labelling regulations. Those appliances on the register will have listed against them a new certification mark to allow consumers, designers and specifiers to make a more informed choice about the product being used, knowing that the product is in compliance with all national legislation before purchase.

In order to protect the reputation of our sector it is important for installers, retailers, manufacturers and other relevant bodies to promote the use of appliances that meet Ecodesign requirements early.
Further information can be found on the HETAS website at:
www.hetas.co.uk or by speaking to HETAS helpline on 01684 278194

Consumers' Questions & Answers

Q. Will stoves be banned?
A. Despite some sensationalism in newspapers there is no suggestion that stoves will be banned

Q. Will I have to change my old stove for a new one?
A. There are no plans to require anyone to do so. If your appliance is an old open fire or an old stove it is very much worth considering a change as a new one will be much more efficient and cleaner to use with dry Ready to Burn fuel.

Q. Can I burn clean dry wood in a smoke control area?
A. Only in a Defra exempted appliance which lists wood logs as an allowed fuel.

Q. Can I burn waste wood like old fence posts etc?
A. Never burn waste woods with chemicals, paints or treatments – this waste is always more polluting and can contain more hazardous emissions than clean dry wood fuel.

Q. Can I still use coal & mineral fuels?
A. Yes in some cases. In a smoke control area you must burn an authorised smokeless fuel. Outside smoke control areas, whilst the guidance is less strict, it is always better to burn clean dry wood or smokeless fuels. This way you protect your appliance and chimney, get better efficiency and heat, and protect the environment more.

Q. How do I get both the best appliance & greatly reduce environmental impact?
A. The best choice is always burning clean dry wood-fuel in a modern appliance. You get best value from your fuel and reduce environmental impact.

Q. Is seasoned wood as good as kiln dried?
A. Yes very much so. The key is to use Ready to Burn wood which always have a moisture content of up to 20% moisture.

Q. Are heat-logs & briquettes OK?
A. Yes, again very much so. Look for the Ready to Burn logo and the heat-logs will be clean & dry; Ready to Burn.

Q. What about burning other forms of compacted fuels?
A. We strongly recommend checking if they are made from clean dry wood to be sure about what you are burning. Some of these compressed fuels contain contaminates and waste that cause damage to appliances & flues and increase polluting emissions.

Q. Are modern appliances that much better than old ones?
A. Yes very much so. A modern clean burn appliance burning Ready to Burn wood fuel can be seen to reduce particulate emissions by 80% compared to old appliances burning wet wood.

Q. Do I need to get my stove serviced?
A. Yes, it is important to get chimneys swept and appliances serviced. HETAS operate a list of service companies which are searchable at www.hetas.co.uk There is an approved chimney sweep scheme operated in partnership with the Association of Professional and Independent Chimney Sweeps (APICS), The Guild of Master Chimney Sweeps (GoMCS) and the National Association of Chimney Sweeps (NACS).

READY to BURN Special Edition

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