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**PUBLIC CONSULTATION SUBMISSION
- THE DEVELOPMENT OF A NEW
SOLID FUEL REGULATION FOR
IRELAND**

FOR THE ATTENTION OF THE DEPARTMENT OF THE ENVIRONMENT, CLIMATE AND
COMMUNICATIONS

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Background

The requirement for the completion of my master's course in Energy Systems Engineering is to carry out a thesis as partial fulfilment of my degree. The objective of my project is to establish a transition strategy to greener rural homes in Ireland. I am exploring the socio-economic benefits to public health from the adoption of torrefied home heating fuels as opposed to traditional fossil fuels. It aims to highlight the negative impact associated with use of heating fuels such as peat and coal and how extensive use of torrefied fuels as a potential replacement can benefit public health and the economy. The damage costs associated with the pollutant PM_{2.5} were assessed as part of my current project. Through extensive literature review and analysis of quantitative data, damage costs appraisals were carried out on selected counties within the Midlands Region. Growing up in the Midlands and witnessing first-hand the reliance on local fossil fuels was a key indicator for my area choice. However, lack of gas network infrastructure has forced households to rely on these fossil fuels in the rural localities. Strict regulations could have the potential to create more negative attitudes towards decarbonising the residential sector as people vulnerable to fuel poverty may object to change. Instead, the public need to be informed at a simple, logical level and encouraged to part-take in energy efficiency measures through more attractive incentives based on locality, building type, social status, etc. The economic benefits from the reduction of damage costs from fossil fuel use could have the potential to enhance government funding towards retrofitting targets set out in the climate action plan.

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Introduction

This submission aims to address the questions set out on the DECC document *Consultation on the Development of a new Solid Fuel Regulation for Ireland* by reflecting on reviews of extensive research and analysis into the topic as it correlates with my master's thesis project. Potential aspects of this submission could aid with the ambition for Ireland to achieve its goal of meeting the World Health Organisations (WHO) guidelines for air quality. While the aim of this public consultation is to assess merits and procedure of regulating solid fuels nationally, more emphasis is needed to address people's attitudes towards decarbonisation of residential heating. Particularly those experiencing or vulnerable to fuel poverty. Regulations can be rules or directives set by a planning authority to achieve a certain goal. In this case restricting the use of certain fossil fuels and the potential introduction of a national smoky coal ban. Such rules can be met with objection, particularly from those in rural areas. Educating and encouraging people to switch to more cost-efficient heating fuels and methods prior to introducing new restrictions/regulations could result in less resilience towards planning authorities. Allowing informed households sufficient time and incentives to switch could prove crucial in tackling air pollution in Ireland. Throughout this submission we will see how the research conducted within the scope of my thesis could aid in the development of new regulations.

Key Literature

Studies have shown that inefficient heating systems and poorly pre-treated fossil fuels with high levels of pollutants such as PM_{2.5} are a likely cause for poor public health. Fuel poverty and fuel availability can play a huge part in this. Exposure to fuel poverty can induce many health risks to people particularly infants, who are at a 30% greater risk to health as expressed by (C Liddell, 2008). The fuel subsidy schemes currently in place are helpful, but they do not address the problem sufficiently and allow damage costs to continually affect Irish public health expenditure. 'The fuel allowance is a necessary but insufficient measure in tackling fuel poverty in Ireland' (Healy & Clinch, 2004).

However, by making people aware of the risks to family health from fuel poverty and poor fuel choices could persuade homeowners to change their attitudes and realise the potential health benefits of adopting energy efficiency measures (EEMs) at home (C Liddell & Morris, 2010). (Curtis & Pentecost, 2015) highlight that income supports are welcome but need to be

accompanied with strategic retrofit programmes that improve energy performance in fuel poor households.

The study by (Trubetskaya et al., 2021) shows the PM emissions from combustion of a range of fossil fuels in a domestic stove. It was found that torrefied biomass and low smoke/smokeless ovoids such as ecobrite, yield the lowest percentage of PM emissions. It suggests that substitution of traditional fossil fuels could produce a 63% reduction in PM_{2.5} emissions from residential space heating. Torrefaction is known to reduce PM emitted which could be a result of its pre-treatment process and physical structure of the briquette (Maxwell et al., 2020). Similar tests show that less volatile matter promotes a more efficient, longer lasting burning rates which result in less emissions such as PM_{2.5} and helps establish emission factors between the range of fossil fuels (Mitchell et al., 2016).

Establishing sufficient appraisal systems could prove to be very beneficial for estimating damage costs to public health. By doing so, it could allow planning authorities to assess the cost-benefit of retrofitting and torrefied fuel transition schemes. The British Department for Environment, Food and Rural Affairs (DEFRA) hired Ricardo Energy & Environment to update damage costs to air pollution in the UK with the objective of providing an air pollutant dispersion model. Changes in PM_{2.5} emissions were captured using pollution climate mapping (PCM) (REE, 2019). An interesting report by (Wenger et al., 2020) shown analysis PM_{2.5} dispersion and highlights Midlands towns such as Birr are at risk of higher PM_{2.5} exposure due to vast amounts of peat burning for residential space heating. The guidebook produced by (EnvEcon, 2015) along with other studies by (Dey et al., 2018a) could aid in the calculation of Irelands damage costs.

The end of goal of achieving 400,000 dwellings retrofitted to the highest standard with heat pumps by 2030 appears optimistic and without a planned transition strategy these numbers will not be not achieved as currently not enough households are being retrofitted (Uidhir et al., 2020). The climate action plans vision for scaling up to over 50,000 retrofits annually from 2024 is subject to many obstacles such as postponed payback periods highlighted in the study by (Beagon et al., 2018) and simplifying the decarbonisation strategy and support schemes for the residential sector (Brown et al., 2019). It may take longer than expected to reach these targets which suggests alternative ways of reducing carbon emissions and air pollutions need to be assessed.

Response to Consultation Questions

The following consultation questions provided are subjective and will be answered based on my informed opinion, research, and findings to date. Any questions that may be beyond the scope of my studies may not be answered fully. Any additional comments outside the questions posed will be in the discussion & conclusion section.

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

Yes, I would be in favour of some additional regulations on solid fuels as I am continuously learning of the damage to health caused by pollutants such as PM_{2.5}. While the damage is not immediate, it does pose a threat of premature death and respiratory diseases which could hinder quality of life in years to come (Environmental Protection Agency, 2020; Mitchell et al., 2016).

However, a number of people may resist/object to regulations regarding their fossil fuels, a suggestion would be to provide and advertise to the general public more infographics detailing the negatives effects of burning fossil fuels that have the high potential to emit PM_{2.5}. An expansion on the infographic at the start of the 2019 Air quality report for example could give the public a simplified idea of the affects but needs to include measures to combat it (Environmental Protection Agency, 2020).

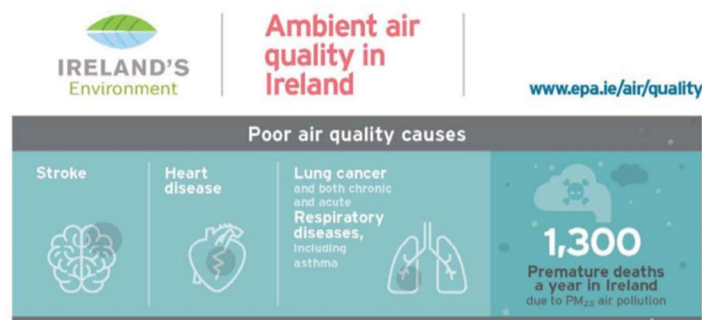


Figure 1: EPA Ambient air quality Infographic.

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

All smoky coals should be regulated as these produce high emissions of CO₂ and harmful pollutants. An imported fuel like has a much larger carbon footprint due to its delivery into Ireland. However, border counties will be exposed to fuel smuggling if strict regulations come in. This will be very difficult to monitor but generous incentives should be put in place to encourage homeowners to produce torrefied fuels instead of smuggling illegal fuels into the country.

High levels of PM_{2.5} can be found in both peat and coal fuel products in Ireland. (Trubetskaya et al., 2021) shows that a substitution of these fossil fuels could reduce PM_{2.5} emissions by over 60%. Eradicating wet wood, peat and smoky coal by adopting pre-treated biomass products could significantly reduce air pollution. However, as peat/turf cutting has been a traditional method of home heating for many years, an instant ban should not be implemented and a phasing out approach adopted instead.

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

In new regulation solid fuels should be standardised by their emission factors. All manufacturers and distributors should only sell products that have a PM emission factor below a certain threshold. To reduce black carbon emissions, only low-smoke/smokeless coal ovoids and other fuels that are approved by a quality assurance specialist should be for commercial sale in Ireland.

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

- **For Coal:** Country wide ban on smoky coal as there are plenty of other options for heating fuel that have similar heat outputs. While costs may be higher for some households, incentives should be given to encourage use of smokeless fuels. Revenue for incentives could be generated from savings in damage costs reduction by use of less emitting fuels. Fuel allowances should be restricted to only be available on purchases of greener solid fuels such as low smoke ovoids.
- **For wet wood:** Ban the commercial sale of all wet wood over a moisture content of 20%. Provision of drying techniques and methods for people cutting their own wood privately showing the benefit of kiln-drying and torrefaction.
- **For Peat:** A phased shutdown over a number of years should be implemented. Turf cutting still holds a traditional value in the Midlands and the introduction of an instant ban could cause outrage among the community. Especially at areas with little to no gas connections. My suggestion would be to first educate these people that peat/turf is harmful to their health and the environment and will inevitably run out. I believe the creation of strong, incentive schemes for people to voluntarily cease turf cutting on their lands should be introduced. By encouraging people to make their own choice to move away to solid fuels it allows for a much smoother transition. It is key that the decarbonisation strategy is simplified for the general public (Brown et al., 2019).

5) How can a transition to less polluting fuels and more efficient heating systems be supported?

Throughout my master's project, I have been quantifying the damage costs savings from eradicating solid fuel use in the Midlands region. Analysis on the widespread substitution of torrefied fuels such as Ecobrite showed that millions of euros could be saved each year on damage costs to public health from the reduction of PM_{2.5}. Using these savings, investments into housing retrofits and more efficient fuels can be achieved. Educating the public on the benefits of less polluting fuels can also increase uptake. By having low-cost BER audits as highlighted by (Uidhir et al., 2020), homeowners can establish what characteristics of the household can adopt the most energy efficient retrofits and yield the best return on investment while utilising the available grants (Collins & Curtis, 2017).

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

The timeframe must correlate with the retrofitting timeframe. If the target of 500,00 household retrofits is met by 2030, then need for fossil fuel demand will go down making regulations much easier to implement. However, if retrofit installation experiences setbacks due to lack of infrastructure and tradesmen, then people subjected to fuel poverty should be allowed more time to fuel switch. Sale of wet wood over moisture content of 20% should be banned within the year. Smoky coal should be phased out over the course of the next 3 years to allow for stocks to be used up, banning the use of it in all towns with populations over 5,000 this year. While peat production from turf cutting should be given a longer period due to land rights and peoples heritage.

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?

New solid fuels such as torrefied products should be included as soon as possible. These products must overlap with the existing solid fuels to allow people to transition. Once coal use is finished, these manufactured ovoids could work as a perfect substitute with little to no additional requirements. Advertising of new solid fuel products must also be included to inform people of the benefits to air pollution and energy outputs prior to banning traditional fuels.

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?

Yes, I believe any fuels purchased by suppliers prior to new regulations should be given a chance to sell their stock or be reimbursed by the government. 2/3 years would allow everyone to sell their stock. Any fuels not meeting standards and purchased/imported by suppliers after regulations should be penalised to dishearten future endeavours.

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

Enforcement of regulations with regards to solid fuel burning poses many challenges as it is unfeasible to monitor what every household is burning. A suggestion would be to install more air monitoring equipment in smaller towns/villages to assess the PM levels in the ambient air. If levels are too high, local fuel suppliers could be investigated with regards to sales to see if they are complying with new regulations. However, fuel smuggling may also occur in some areas particularly border counties which will be difficult to account for.

*10) Do you have any further proposals to reduce air pollution from residential heating?
(Underlined in conclusion):*

- **Provision of free/low-cost BER energy audits for households to gain an understanding of their energy losses and where returns on investments can be more evident as mentioned above in Question 5.**
- **More incentives/information for installation of Eco design stoves to replace traditional open fireplaces.**
- **Creating an education platform to highlight the dangers of air pollution and teaching young people methods in combating and protecting themselves from harmful emissions.**
- **Educating Tradesmen and Building Suppliers about the retrofitting targets, materials, costs, etc. Create more employment as a result.**

- **Development of community alert schemes, providing simple infographics for public distribution. Synchronise with community initiatives like ‘Tidy Towns’ as mentioned in Question 11.**

- **Invest further into government research in the socio-economic benefits from the reduction of damage costs by air pollutants. Exploring potential revenue savings to be used as further investment into the decarbonisation strategy as reflected in the Discussion.**

- **A simplified version of the decarbonisation strategy making objectives and support schemes more understandable for everyone. With revised support packages based on location, social status, exposure to fuel poverty, etc (Brown et al., 2019).**

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

Installing more air quality monitoring technology in most towns could provide essential data for how towns are performing with regards to their air quality management. Rewards schemes could be implemented similar to the ‘Tidy Towns’ initiative where towns of exceptional air quality or huge improvements in air quality could be honoured for their performance. Towns could be awarded certification and funding to further improvements. Any commercially sold solid fuel should be certified by a quality assurance specialist such as HETAS.

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

I do not feel broadening the application to 10g smoke per hour would be appropriate until sufficient time and opportunity is given to those who require retrofits particularly those requiring new stoves. As studies of PM_{2.5} are mainly carried out in controlled environments and eco design stoves, it is unfair to assume the amount of PM_{2.5} would be the same for older stoves and fireplaces and would more than likely be much greater due to the inefficient burning methods (Trubetskaya et al., 2021).

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

Based on the guidebook by (EnvEcon, 2015), damage costs from each pollutant should be assessed and studies on solid fuels emissions should be researched further. However, I believe that focusing on CO₂ and PM_{2.5} emission reduction would reap the greater benefit and could be easier to simplify for the general public.

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?

While my studies have not involved the use of wood for domestic space heating, a standard moisture content should be set in the regulations. By having a maximum moisture content of 20% or below with an approved mark from HETAS or another quality assurance specialist, this would allow for the sale of a more efficient fuel.

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

All wet wood should be banned for commercial sale as it is an inefficient source of heating and contains high level of volatile matter. Kiln-dried, small sticks or logs in nets should remain for sale as long as sufficient drying measures are taken prior to distribution and an approval mark in place.

Discussion

My current research aims to explore the benefits from the reduction of PM_{2.5} both from a public health and economic point of view. For example, County Offaly has the highest percentage of peat solid fuel use in the country and equates for 11.44% of all peat burned domestically (CSO, 2016). By totally substituting all peat fuels (sod and briquette) for a torrefied fuels such as Ecobrite, it could yield a saving of approximately 38 tonnes of PM_{2.5} per annum from Offaly homes based on (Trubetskaya et al., 2021) emission factors.

Using the marginal damage cost guidebook by (EnvEcon, 2015) and applying inflation rate calculations a total damage cost saving for County Offaly could potentially range up to €928,528 per annum. The range represents primary PM_{2.5} emissions in Rural Ireland to Urban Medium locations of greater than 15,000 people using conservative values for damage cost per tonne. My initial research findings suggest a mean damage cost saving of €598,509 per annum. Another appraisal model for damage costs used by (Dey et al., 2018b; DTTAS, Department of Transport, 2016) suggests this saving could even range up to €1,792,808 per annum as seen in table 1.

Table 1: Damage Costs Savings from reduction of 38 tonnes of PM_{2.5} from County Offaly's residential sector.

Appraisal Model	Damage Cost Savings Range (per Annum) (€)	Mean Damage Cost Savings (per Annum) (€)	Mean Damage Cost Savings by 2025 (€)	Mean Damage Cost Savings by 2030 (€)
EnvEcon:	€268,490 - €928,528	€598,509	€2,094,782	€5,087,329
Dey / DTTAS:	€624,269 - €1,792,808	€1,208,539	€4,229,884	€10,272,576

**The cost variance in the models highlights the need for more research into damage cost appraisals from air pollutants as mentioned in Q10.*

However, by carrying out effective retrofitting programmes, further savings from damage costs will also be attained due to less fuel energy required to adequately heat the home, showing the significance of Climate Action Plan.

Educating people about the benefits of torrefied fuels and eco-friendly practises should be a prime, initial objective within the new regulations and updated climate action plans. Substitution to transition fuels could play a huge role in maintaining funding to reach the ambitious retrofit targets by 2030 and future targets in 2050.

Without the sufficient number of tradesmen and infrastructure in place to carry out the cost optimal retrofitting programme, the yearly targets for retrofits are likely overestimated. This reflects the importance of immediate action on solid fuel substitution to reduce emissions and improve air quality immediately at relevantly inexpensive costs.

Conclusion

This public consultation submission addresses all the questions set out in the development document using knowledge gained from extensive literature review and research into the topics of damage costs from solid fuels and socio-economic benefits from torrefied fuels. By developing new solid fuel regulations for Ireland, air quality and general public health will vastly improve.

However, the strong opinion from this submission is to endorse and encourage the use of cleaner fuels whilst slowly restricting use of traditional solid fuels so that a smooth, just transition can occur. Emphasis on the following key points should be of main interest/concern from this submission:

- **Education** – Informing young people about the effects harmful air pollutants like PM_{2.5} has on both public health and the environment. Classes could be introduced explaining the impacts and promote awareness to achieve a greener Ireland. Local community groups could have information evenings to help educate and promote community engagement in tackling air pollution.
- **Ban** – Strict regulations on imports of all smoky coal and sale of wet wood with high moisture content to come into effect by end of this year. All remaining stocks to be sold off in areas of sparse population. Consideration of a collaborative effort with Northern Ireland to reduce the risk of fuel smuggling.
- **Community Engagement** – Installation of air quality monitoring equipment in all small towns to allow for more involvement at local level. Provision of award schemes for efforts involving reduction of the community's air pollution.
- **Funding** – for retrofitting to subject to house location, type, lack of gas network infrastructure and social status, etc.
- **Free/Low-Cost BER energy audit** – Nearly half the housing stock in Ireland does not have a BER graded rating which could help scale the problem more accurately and show homeowners the cost-benefit from housing retrofits.
- **Fuel Transition/Phasing out of Existing Solid fuels** – Traditional fuels such as turf may need more time for people to adjust. More incentives are required to encourage to switch solid fuel type while they wait for a retrofit and heat pump installation.
- **More Research** – Further research into damage costs from air pollutants should be looked at with regards to spatial analysis to gain a more accurate representation of PM_{2.5} dispersion and its socio-economic cost.

Appendix:

Consultation Questions

1. Are you in favour of a national regulation on solid fuels, and if so, why?
2. What solid fuels should be subject to regulation and why?
3. What standards or specifications should/could be applied to each type of solid fuel?
4. What do you believe are the most appropriate, implementable and enforceable regulatory approaches for each type of solid fuel?
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)
6. What do you think is an appropriate timeframe for the implementation of a national regulation of solid fuel?
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?
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?
9. Are there particular challenges in terms of the enforcement of regulations applying to solid fuel burning, and how might these be best addressed?
10. Do you have any further proposals to reduce air pollution from residential heating?
11. What performance standards, certification methods or quality schemes should/could be used to reduce air pollution caused by burning solid fuels?
12. Would broadening the application of the 10 gram smoke per hour to all solid fuels be appropriate?
13. Are there any additional or different emission standards which could be applied to the broader range of fuels?
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?
15. What limit should be set as a cut-off point for the sale of wet wood?
 - Bags/nets only;
 - Up to 2m³;
 - All wet wood; or
 - Other- please provide reasons or evidence to support your answer.

References

- Beagon, P., Boland, F., & O'Donnell, J. (2018). Quantitative evaluation of deep retrofitted social housing using metered gas data. *Energy and Buildings*, *170*, 242–256. <https://doi.org/10.1016/j.enbuild.2018.04.022>
- Brown, D., Sorrell, S., & Kivimaa, P. (2019). Worth the risk? An evaluation of alternative finance mechanisms for residential retrofit. *Energy Policy*, *128*(December 2018), 418–430. <https://doi.org/10.1016/j.enpol.2018.12.033>
- Collins, M., & Curtis, J. (2017). An examination of the abandonment of applications for energy efficiency retrofit grants in Ireland. *Energy Policy*, *100*(October 2016), 260–270. <https://doi.org/10.1016/j.enpol.2016.10.030>
- CSO. (2016). *Census of Population 2016*.
- Curtis, J., & Pentecost, A. (2015). Household fuel expenditure and residential building energy efficiency ratings in Ireland. *Energy Policy*, *76*, 57–65. <https://doi.org/10.1016/j.enpol.2014.10.010>
- Dey, S., Caulfield, B., & Ghosh, B. (2018a). Potential health and economic benefits of banning diesel traffic in Dublin, Ireland. *Journal of Transport and Health*, *10*(November 2017), 156–166. <https://doi.org/10.1016/j.jth.2018.04.006>
- Dey, S., Caulfield, B., & Ghosh, B. (2018b). Potential health and economic benefits of banning diesel traffic in Dublin, Ireland. *Journal of Transport and Health*, *10*(June), 156–166. <https://doi.org/10.1016/j.jth.2018.04.006>
- DTTAS, Department of Transport, T. and S. of I. (2016). *Common Appraisal Framework for Transport Projects and Programmes*. 2016(March), 93.
- EnvEcon. (2015). *Marginal Damage Valuations for Air Pollutants in Ireland*.
- Environmental Protection Agency. (2020). Air Quality in Ireland 2019. *Environmental Protection Agency, (EPA)*, 32. <https://www.epa.ie/pubs/reports/air/quality/Air Quality In Ireland 2018.pdf>
- Healy, J. D., & Clinch, J. P. (2004). 04/02182 Quantifying the severity of fuel poverty, its relationship with poor housing and reasons for non-investment in energy-saving measures in Ireland. *Fuel and Energy Abstracts*, *45*(4), 299. [https://doi.org/10.1016/s0140-6701\(04\)94769-8](https://doi.org/10.1016/s0140-6701(04)94769-8)
- Liddell, C. (2008). The impact of Fuel Poverty on Children. *Save the Children*, 20.
- Liddell, Christine, & Morris, C. (2010). Fuel poverty and human health: A review of recent evidence. *Energy Policy*, *38*(6), 2987–2997. <https://doi.org/10.1016/j.enpol.2010.01.037>
- Maxwell, D., Gudka, B. A., Jones, J. M., & Williams, A. (2020). Emissions from the combustion of torrefied and raw biomass fuels in a domestic heating stove. *Fuel Processing Technology*, *199*(October 2019), 106266. <https://doi.org/10.1016/j.fuproc.2019.106266>
- Mitchell, E. J. S., Lea-Langton, A. R., Jones, J. M., Williams, A., Layden, P., & Johnson, R. (2016). The impact of fuel properties on the emissions from the combustion of biomass and other solid fuels in a fixed bed domestic stove. *Fuel Processing Technology*, *142*, 115–123. <https://doi.org/10.1016/j.fuproc.2015.09.031>
- REE, (Ricardo Energy & Environment). (2019). *Air Quality damage cost update 2019*. ED 59323(2.0), 122.
- Trubetskaya, A., Lin, C., Ovadnevaite, J., Ceburnis, D., Dowd, C. O., Leahy, J. J., Monaghan, R. F. D., Johnson, R., Layden, P., & Smith, W. (2021). *Study of Emissions from Domestic Solid-Fuel Stove Combustion in Ireland*. <https://doi.org/10.1021/acs.energyfuels.0c04148>
- Uidhir, T. Mac, Rogan, F., Collins, M., Curtis, J., & Gallachóir, B. P. Ó. (2020). Improving energy savings from a residential retrofit policy: A new model to inform better retrofit decisions. *Energy and Buildings*, *209*. <https://doi.org/10.1016/j.enbuild.2019.109656>
- Wenger, A. J., Arndt, J., Buckley, P., Hellebust, S., McGillicuddy, E., Connor, I. O., Sodeau, J., & Wilson, E. (n.d.). *Source Apportionment of Particulate Matter in Urban and Rural Residential Areas of Ireland (SAPPHIRE)* (Issue 318).