Domestic Wood Burning in Norway

Knowledge, Attitudes and Incentives

ABSTRACT

A new technology eco-label stove produces the same PM2.5 emissions in one hour as six heavy weight vehicles (EURO VI). How cognizant are Norwegians about the effects of their wood stove burning habits? This research examines the attitudes and knowledge of risks from wood stoves.

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2. Acknowledgements

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5. Introduction

Particulate matter 2,5 are very small chemical particles that make up smoke emissions from combustion. These particles result from combustion, (traffic engines, industry, wood burning, etc.) PM2.5 means the size of the particle is less than 2.5 micrometres in size (a human hair is approximately 70 micrometres(US EPA, 2016). Under exposure, humans breath them deep into lungs and they can transmit into the blood stream because of their extreme small size(US EPA, 2016). Years of well documented research have demonstrated PM2.5 increases mortality risk associated with heart and lung disease, nervous system function, low birth weight, among others (Norwegian Institute of Public Health, 2013).

This research will begin with a review of documented PM2.5 health risk followed by a closer look at Norway's wood oven use, policy and monitoring. As part of this research a questionnaire was distributed to the public to identify how cognizant users are of pollution, best burning practices, perception of health risk, and what could motivate them to change their burning habits. This work culminates in a discussion of the questionnaire results and examines how behavioural economic theory can aim planning strategies and measures at improving pm2.5 emissions considering the respondents attitudes and knowledge.

5.1. Research Question

To what extent are Norwegians knowledgeable about emissions and health risk of PM2.5 from residential heating/wood burning habits? What does this knowledge indicate about the barriers to lowering wood oven pollution?

Arguably most people love wine or cocoa beside a crackling fire, but research is proving the effects of Norwegian cultural habits more damaging than previously thought. Are local municipalities and governments taking too soft an approach to tackling the issue of domestic biomass burning emissions, and instead only concentrating efforts on traffic pollution's contribution to particulate matter?

Wood burning is a prominent source of secondary heating in Norway as acknowledged by the Norwegian Institute for Air Research (NILU), State of the Environment Norway (SOE), Norwegian Institute of Public Health (NIPH) but gets little attention even though it creates almost 60% of emissions in many cities (Lopez-Aparicio, 2019). Emissions from wood burning is based on surveys of wood use multiplied by emission factors, however Lopez and Grythe showed substantial under-estimation of wood (López-Aparicio et al., 2017). This NILU study reported wood use was four times higher that data reported (López-Aparicio et al., 2017). There can be a great deal of uncertainty for dispersion modelling when there are discrepancies from bottom-up data vs uncertain emission factors (López-Aparicio et al., 2017). Additionally, physical infrastructure to measure emissions is disproportionately allocated to road traffic(Lopez-Aparicio, 2019). Mitigation measures one-sidedly reflect the measuring tools. These mostly aim to limit traffic by license plate odd/even days, road tolls, banning diesel vehicles and increased incentives by lowered costs for electric vehicles. While official public agencies acknowledge wood oven contribution, little action has been implemented to mitigate oven emissions or to educate the public of health risks associated with oven emissions. Since 1998 Norway's main mitigation tactic is only allowing new technology oven on the market. Oven changeout schemes have been used in a few municipalities with varying incentives and results (Lopez-Aparicio & Grythe, 2019).

Ongoing bodies of evidence are shedding light on the expanding group of ailments and illness from PM2.5 pollution. These ailments do not only affect the elderly with lung and heart disease, but also affect asthmatics, children especially, and developing foetuses(Wei et al., 2019). New research in developed nations are demonstrating the increased risk and hospitalization of dementia, UTIs, kidney failure, blood poisoning (septicaemia) that accompany systemic inflammation from PM2.5 elevation(Kioumourtzoglou et al., 2016). These topics will be reviewed in section 7.1.

5.2. Context and Relevance

5.2.1. Modern wood ovens

The term referring to modern wood ovens in the Norwegian language is a misnomer and quite possibly leads users to regard them as innocuous. "Clean-burning" ovens (rent-brennende vedoven) is a misleading term. Modern technology wood ovens and even Eco-label wood ovens produce emissions. In order to provide the reader with perspective on emission quantities, on a per hour basis, a clean burning eco-label wood oven with PM2.5 emission limits of 3.1 ug/m3 has equivalent emissions to six large heavy weight vehicles (EU class IV) or 18 diesel passenger cars (Euro 6) (Monks et al., 2017). This shows how the technology of wood ovens has not kept up with the engine emission technology and accommodating legislation. For the entirety of the paper, I refer to ovens produced after 1998 as new technology ovens and those produced before 1998 as old technology ovens. If used properly, new technology ovens are capable of producing fewer particles via a second burning of gases higher up in the combustion chamber before they escape the oven flue (Seljeskog, Sevault, et al., 2017) . However, when used incorrectly for example, with smaller loads, improper air intake, inadequately seasoned wood or when left in a smouldering state, the new technology ovens can also produce high particle emissions(Seljeskog, Sevault, et al., 2017).

5.2.2. Biomass combustion

The European Commission strategy against climate change has obligated its member nations to the 20-20-20 legislation, which states 20% of total electricity consumption should be reduced, 20% energy should come from renewable sources and green has gases should be reduced by 20% by the year 2020 compared to the values of 1990 (European Commission, 2016). The World Health Organization (WHO) is worried the switch to biomass combustion, while considered renewable, the health effects of energy switching policy are not evaluated closely enough before policy adaptions are made. (Chafe et al., 2015). Many EU nations that produce energy from fossil fuels are turning to biomass combustion as a renewable source of energy for heating and governments are offering incentives to users to switch fuel types(Chafe et al., 2015).

Norway is the largest producer of oil and gas outside of the middle east. Somewhat ironically, it's energy production is almost exclusively clean hydropower due to its other natural resource, mountainous and wet landscapes of basins continuously replenished by snow and rain, which accounts for 98% of Norway's energy infrastructure (Bitto, 2017). Although Norway's power production is clean, it can be economically uncertain especially in the winter, dependent on the year's weather and basin replenishment(van Vliet et al., 2013).

The movement to limit green house gases has contributed the increase in biomass combustion. The carbon neutrality of wood fuel is not the under discussion for this paper. There is still disagreement about carbon neutrality of biomass burning and what parameters are considered in order to evaluate it as such. This will not be an argument on whether biomass combustion is renewable.

Norway banned oil burners from 2020 in all new and renovated buildings and has required the removal of oil tanks with transmission of property title (Lindberg & Magnussen, 2010). The Norwegian Water Resources and Energy Directorate (NVE) ended oil burning for heat in residential and commercial buildings to lower green house gases because of the sited PM10 emissions factors by Aasestad(Aasestad, 2008). The emission factors of PM10 were overwhelmingly dominated not by oil, gas or coal but woodburning (Aasestad, 2008).

Similarly, the UK is shifting fuel types to lower GHG and increase renewable energies. Efforts to improve air quality are being overshadowed by renewable heating. Any improvements to reduce emissions from cars based on London's low emission zones are quickly surpassed by the increase in biomass burning for heat and recreational burning. (Fuller et al., 2014)

5.2.3. Combating high particle emissions in Norway

As nations turn to biofuels as a renewable energy source the consequences of damaging emissions may result. Norway past regulation allowing only new technology ovens on the market after 1998 to combat high particle emissions from wood ovens. Even as emission impacts on human health are becoming widely published, Norway has not taken very hard steps to limit wood stoves contribution to the problem. Norway is a wealthy nation with clean hydro power resources, yet it remains steadfast to its winter heating habits regardless of research pointing to health consequences from pollution and stricter insulation regulations for lower energy requirements(Olaussen et al., 2017; Wei et al., 2019).

One of the authors premises is that households use wood ovens as a strategic buffer against high winter electricity prices. However, with battery technologies improving energy storage capabilities, soon renewable energy sources like sun and wind power will be harnessed(Fessler, 2019). This buffer will allow electricity prices to stabilize enough throughout the winter that any potential snow or rain shortages will not cause economic hardship in which loss averse users feel the need to limit risk.

5.2.4. Various degrees of emission

Ambient air quality from wood burning emissions varies greatly dependent on the density of emission sources, types of technology used, weather, and topography (Cincinelli et al., 2019). In very cold periods of inversion, the air of the upper atmosphere is heated more than the ground surface. The warmer atmospheric acts as a hat and prevents air from normally rising (Trinh et al., 2019). Air trapped close to the ground, unable to dissipate as it might normally do under warmer and less stagnant conditions contains emissions from wood ovens, traffic and industry. This weather phenomenon can happen semi-regularly in the winter months depending on the region. Periods of poor air quality in the near future can sometimes be predicted based on current air quality combined with the predicted weather forecast of temperature and wind (Trinh et al., 2019). Emissions even in small towns can deteriorate the air quality under still weather condition prevent dilution and distribution(Krecl et al., 2008).

5.2.5. Old practices versus modern challenges

Practice makes perfect. Norway's long and successful history coping with harsh winters, means a great deal of knowledge and experience has gone into learning how to cope with difficult conditions. However, Skreiberg, a Sintef researcher in the field of wood ovens and emissions has another saying, "*(Mal)practice does not make you an expert*"(Skreiberg, 2017).That which has been learned in the past for building good fires may not be good for minimizing emissions. Very old ovens with multiple levels or tiled masonry ovens heated both effectively and efficiently, maximizing wood energy and laborers efforts of manually felling trees, sawing and chopping wood by hand in preparation for long winters(Mytting, 2011; Skreiberg, 2019) Once tools became automated the task became significantly easier with less physical and time cost. The efficiency of ovens no longer held up to the standards of oven predecessors (Mytting, 2011). Newer oven technologies after the industrial revolution, particularly after WWII, lead to ovens being less energy efficient and had much higher emission output.

5.2.6. Experiences in trying to lower PM emissions

Planners and researchers around the world have tried different methods to lower PM emissions.

Australian researchers identified the university town of Arnidale that has a long history of educational best-burning campaigns and a rebate replacement scheme for cleaner burning ovens (Todd, 2003). Awareness was increased but emission levels were not affected by these tactics (Armidale-Dumaresq Council, 2003). Another emission lowering tactic that also fell short was found in both British Columbia and Nez Perce Reservation in Idaho. Findings from both change-out programs suggested that new cleaner burning ovens were not enough. In order to effectively reduce PM2.5 emission users needed technical help to operate new ovens (Allen et al., 2009; Ward et al., 2011). New wood ovens coupled with old burning behaviour sometimes resulted in increased emissions in new ovens.

5.2.7. Why wood burning demands attention

In many European cities wood burning for heat mainly happens in rural and suburban settings(López-Aparicio et al., 2017). Norwegian cities however differ from many other European cities. Lopez and her team from NILU showed in 2017, that in Oslo and neighbouring Akerhus, 62% of dwellings used wood burning(López-Aparicio et al., 2017). In Norway, air pollution isn't just a result of congested transport systems but is heavily affected by wood burning heating habits. Norway SOE states the most damaging emission to health is particulate matter and not N02 while it is still significant (Norway SOE, 2018). Urban planners in Norway need to not only consider how cities can be healthier with robust public transport systems and filtering green spaces but how the heating culture itself contributes to the general health of its residents.

The World Health Organization describes how air pollution affects particularly the bodies of very young or old. Particles as small as a molecule, when breathed in, break the barrier of lungs and enter directly into the blood stream. Systemic inflammation results as the body's system tries to fight them. Inflammation happens when exposure leads to production of inflammation proteins such as cytokines and chemokines, an immune response of messenger molecules that send white blood cells to damaged tissue. (Chafe et al., 2015) and (Turner et al., 2014).Toxic compounds lodge as a precursor to cancer. These particles inflame blood vessel which contributes to higher blood pressure and cause stroke. Particles also dislodge fat in blood vessels leading to blockages or clots that block blood to heart or brain (World Health Organization, 2018). This is our current understanding how small particulate matter (PM2.5) is detrimental to human health. New research is showing that even when particulate matter is below WHO safe air standards increased association between illness and PM2.5 is shown (Wei et al., 2019).

5.2.8. Monitoring stations

For politicians and municipalities to make educated decisions, they depend on updated and relevant data. Measuring stations is naturally an important tool. However, as I will show below, there is uncertainty in the data when it comes to PM2.5 and wood burning emissions. This is mainly due to costs, placements and ownership of measuring stations.

Norway's urban planning strategies as it relates to minimizing air pollution is self limiting as it finds itself in a catch 22 when reporting air pollution. NILU runs the web site luft kvalitet.info which is the only continuous monitoring done. NILU does this on behalf of themselves, the Norwegian Environment Agency, and the National Public Road Administration (NPRA). Air quality monitoring is divided between the environment agency, the road agency, the municipalities and industry. However, the stations are typically run by the NPRA(Lopez- Aparicio, 2019). According to Lopez from NILU, since the monitoring stations are expensive to build and run, poorer municipalities often don't have the funding to own the stations (Lopez-Aparicio, 2019). This leaves the responsibility with the NPRA. This effectively translates to monitoring stations being placed most often adjacent to main roads, limiting the information we get from the impact of residential neighbourhood plagued with wood burning in the winter resulting in some admitted uncertainties in publications (Lopez- Aparicio, 2019).

5.3. Definition of Scope

The scope of thesis will be limited to wood ovens in order to keep the discussion relevant to Norway. Limiting this discussion to wood ovens is also due to the prevalence of this technology being the dominant type used in Norwegian homes. Wood boilers and pellet ovens, both of which have considerably different emission levels than wood ovens. Additionally, discussion will be limited to developed countries such as Northern Europe, Europe, and North America. In higher income nations wood as secondary heating and decorative use is different from underdeveloped nations which use open wood fire for cooking as well as primary heat.

Norwegians regularly use wood ovens. While the NIPH and Environment agency have jointly published an extensive report which thoroughly discuss particulate matters consequences on human health it comes in a lengthily and scholarly format (Norwegian Institute of Public Health, 2013). The reports introduction itself is 20 pages long. The format is suitable for the educated population portion and intended to be useful to governments, institutions, interest groups and individuals. Educating the residential users, the layman and majority of the population is an important step to curbing wood oven use or at least informing users of the substantial actual health risks and environmental effect wood burning brings. Methods of educating and communicating PM2.5 risk to the public is outside the scope of this thesis but is integral part of changing user behaviour. Whether knowledge about the effects of PM2.5 is being spread effectively and which channels spreads is another thesis topic. This will later be touched on in the discussion chapter.

6. Theory

It is a sustainable development trend toward compact cities. Do compact cities contribute of diminished air pollution is under debate. Certain cities with topographical and weather conditions have more atmospheric stability. This lends itself to increased pollution in some winter conditions such as cold inversion. This is problematic for cities like Bergen. Green spaces directly absorb pollutants but also alter wind and temperature conditions which increases circulation and air turbulence which lends itself to dilution and dispersion (Cho & Choi, 2014).

According to the Dr. Neira, the Director of the department of Public Health, Environmental and Social determinants of Health, the number one goal of Urban planners should be health (Neira, 2018). In healthy alive cities people move around safely with access to public transport and green spaces whereas rapidly growing cities are often plagued with heavy traffic, alienation and violence which affect us mentally and physically and one of the best indicators according to Neira is the city's air quality(Neira, 2018). Susana Lopez of the Norwegian Institute for Air Research (NILU) points out the perceptions of how healthy a city becomes "crucial for the response and acceptance of implementation of policy measures "(López-Aparicio et al., 2017 p.185).

Norwegian cities however differ from many other European cities in which wood burning for heat mainly happens in rural settings. Lopez showed in 2017, that in Oslo and neighbouring

Akerhus, 62% of dwellings used wood burning (López-Aparicio et al., 2017). In Norway, air pollution isn't just a result of congested transport systems but is acutely affected by wood burning heating habits. The Norwegian Environment Agency states the most damaging emission to health is particulate matter and not N02 while it is still significant (Norwegian Environment Agency, 2018). Urban planners in Norway need to not only consider how cities can be healthier with robust public transport systems and filtering green spaces but how the heating culture itself contributes to the general health of its residents.

6.1. Behavioural Economics (behavioural change & financial incentives)

I will first present general background about behavioural economics before looking at specific biases and behavioural trends.

6.1.1. General background

How people behave in particular circumstances can be described through both psychology, economics and a good understanding of how our brains are wired. Behaviour economics is not oppositional to classic economical decision making but is a "school of thought" that considers how people think and behave in reality, outside the classroom (Samson et al., 2015). People don't behave rationally and even behave 'predictably irrationally(Frederiks et al., 2015) (Samson et al., 2015). The power of inertia. Behavioural insights reveal that people usually take the path of least resistance. In most cases, we stick to the behaviour and habits we have already developed.(Samuelson & Zeckhauser, 1988).

Adopting behavioural economics strategies to induce change is an alternative to employing new technology platforms. There is drive to direct climate change by employing new technology markets creating both new industry and jobs, for example the ongoing effort of carbon capture and storage (Terwel et al., 2009). Dependence on emergent technologies to solve climate problems often encounters feasibility issues and substantial time delays, however. While scholastic programs and government subsidies push technological advancement, resulting in billions of dollars loaned, subsidized and taxed in the effort of this new technology, the result is often failure or even corruption(Banal-Estañol et al., 2016). To little attention is devoted to the arena of the household and the sphere of individual day-to-day life as a source of significant environmental cutbacks (Dietz et al., 2009). There is also place to change peoples behaviour in favour of sustainable practice and private lifestyle (Dietz et al., 2009). Governments and business have been using behavioural economics understanding people often don't make decisions rationally according to classical economic theory but very other behave predictably irrationally based on principles of psychology and behaviour economics(Samson et al., 2015).

Behavioural economics for household finance is relevant because people choose wood ovens as an economic strategy for risk aversion of electricity prices. Government programs to loan at low or no interest to incentivize purchasing zero emissions technologies (heat pumps) relieve the burden on less robust municipalities from drawing funding for oven technologies that still pollute uncertainties. Oven technologies as a heat source that have uncertain emissions depending on user operating and knowledge and can contribute to human exposure of inhaled emissions.

6.1.2. Examining biases and behavioural trends

Examining the following biases and behavioural trends is a method of approaching behavioural change from the standpoint of policy makers who may be able to maximise change and minimize cost (Samson et al., 2015). Behavioural economic approaches are very situation specific and the following principles have been taken from researches relevant to energy use, climate change, pro-environment and health awareness (Frederiks et al., 2015).

6.1.2.1. Loss aversion:

People emphasize potential risks or unknowns of a situation rather than potential positive gains(Frederiks et al., 2015). They may focus on the financial costs (installation), physical costs(work involved), social costs(what will others think), time costs(whether it takes longer or not), functional cost(does it work in my routine)(Frederiks et al., 2015). These kinds of costs are evaluated for many types of behavioural changes, for example, choosing collective transport, installing solar panels, switching heating technology(Frederiks et al., 2015). Since Norwegian users may be loss averse, they could be worried about the potential risks of high electricity prices due to lack of snow and rain. To prepare for the unknow risk ahead they may choose to purchase 2 pallets of wood as a financial safety net. In terms of health, environment emissions, financial cost they are more prepared to accept these cons to avoid loss (high electricity prices each winter month).

6.1.2.2. Risk aversion:

people are more risk averse when the changes and are more risk seeking when faced with uncertain loss or uncertain gains

6.1.2.3. Sunk costs effect:

Once costs are laid out, people will persevere with an action rationally or irrationally in an effort to recuperate losses of all types. People who have sunk costs become overly focused on the recuperation than they do of any potential future risk or cost (Arkes & Blumer, 1985). The concept of 'recovering' cost apply in terms of effort and time not only money(Arkes & Blumer, 1985). Kahneman and Tversky cover the topic of continuing to spend money after incurring the cost in prospect theory however the psychological foundation of sunk loss and the admission of wasted was demonstrated experimentally(Kahneman & Tversky, 1977) (Arkes & Blumer, 1985). The irrational behaviour of the sunk cost effect is an increased tendency to continue on despite how reasonable to decision to do so it. Loss aversion is tied to the sunk cost effect and the general desire to not be wasteful (Arkes & Blumer, 1985). In household energy use Frederik described the concept of recuperating sunk costs, or effort and time, showing consumers who purchased electrical appliances may tend to use it more than required(Frederiks et al., 2015).

6.1.2.4. Temporal discounting

Temporal discounting is the perception that something is less valuable or meaningful the further it is away, either in time or space. An example of the concept in terms of distance (spatial discounting) can be disease which is problematic primarily in other nations than one resides. These diseases may accrue less attention and concern by neighbouring nations unless it arrives in one's own region. Another well known example of temporal discounting relates to saving for retirement. Generationally speaking, younger adults may approach saving less aggressively than mature adults due to the principle of temporal discounting. Temporal discounting and delayed consequences (Frederick et al., 2002; Thaler & Benartzi, 2004). Temporal discounting is also relevant in terms of rewards or gratification. An example of such systems can be the incentive or reward for purchase an electric vehicle in Norway versus the USA. In Norway the reward is immediate upon purchase of the car. A smaller bank loan is the result of no 25% value added tax added to the purchase. In the USA the incentive comes the next year and only in the form of a tax benefit, a potentially lower tax due or greater refund received (Langbroek et al., 2016). Different commodities are discounted differently. When considering health as a commodity and discounting for potential future illness (the present value is higher today than at a future date), individuals who perceive the illness as more severe, are more like to have negative discount (Pol & Cairns, 2000).

6.1.2.5. Social norms:

People will tend to follow how others behave as guidelines or expectations of society or groups (neighbourhood) local community, for what is considered good or normal (Gregor & Lee-Archer, 2016). For example, simply mentioning and describing a social norm 'of how most people behave' "can motivate people to conformity" (herd behaviour). For example, England successfully motivated people to pay their taxes on times by simply mentioning most respondents did so in a reminder letter(Gregor & Lee-Archer, 2016). However, even though people are influenced by the attitudes and behaviour of others, different cultures don't always respond similarly. Socially normative behaviour can be very contextual. Lunn explained how successful normative messages aimed at getting UK citizens to pay taxes on time failed in Ireland as the population responded culturally with less enthusiasm (Holmes, 2018). Another conformity measure is the **bandwagon effect** in which people do or choose something because others have also. The bandwagon effect also has an economic footing as well. The more others have adopted a product, the more value it adds to the products worth as a network (Frederiks et al., 2015). An example is Norway's robust and developing network of electric vehicle charging station infrastructure.

The bandwagon effect can work in both directions. For example, there are benefits and consequences of eating less red meat to improve heart health and just as there are dangerous consequence as a result of participating in risky challenges promoted on social media. Theoretically one product or consequence of new oven technology is cleaner air due to lower emissions. The commodity of clean air (for everyone) would improve significantly if all household combustion took place in new technology ovens[1]. Likewise, if residents choose to heat with a heat pump instead of wood oven, the ambient air quality in a neighbourhood improves even more eliminating periodic episodes of poor air quality during periods of inversion.

People can switch to new technologies or transportation modes and even food choices but won't devote time, money and habits until they see those around them doing it. As people struggle to deal with uncertainty and beliefs, social evidence can be an important element propelling behaviour and technology adoption (Goldstein et al., 2008). Lack of confidence

[1] Air quality would improve providing wood consumption remained static.

can direct people to "default to the familiar" (Samuelson & Zeckhauser, 1988). "*People...tend to make social comparison and evaluate their own performance, possessions and wellbeing not in absolute terms, but relative to others*."(Frederiks et al., 2015, p. 1387). Normative behaviour nudges can have unforeseen effects. For example, when social norm feedback was sent to reduce electricity consumption amongst household users it backfired for those that consumed under the peer average. Those that used less than average compared to their neighbours began increasing their electricity use when they got feedback how they fared in comparison(Schultz et al., 2007). Perceived permission to behave like the group or norm can in fact increase undesirable behaviour.

6.1.2.6. Rewards and incentives

Rewards and incentives can be intrinsic such as equity and fairness (warm glow) but also extrinsically (incentives). The larger the incentives the greater the response(Schultz et al., 2007). Effects of extrinsic rewards (money incentives) don't last long or are inconsistent once the reward is removed(Gomez Vilchez & Thiel, 2019). For instance, people may decrease sustainable behaviour previously rewarded extrinsically once the reward no longer available unless the intrinsic reward overcompensates for the loss. Norway may find fewer people choosing to buy electric vehicles if the value added tax or road fee is reinstated for emission free cars, unless the intrinsic (fuzzy good feelings) overcompensate for the economic reward. NILU found the emission factors lowered faster in Oslo compared to municipalities not offering oven subsidy incentives, but emissions and wood use were not significantly affected by the intervention (Lopez-Aparicio & Grythe, 2019).

6.1.2.7. Trust

People use trust as a decision-making heuristic (rule of thumb) to assess risk and make cost-benefit assessment the authority's trustworthiness or experience and expertise as well as honest-ness, (integrity based trust). The effectiveness of an education/awareness campaign can be contingent on the reputation and trust of who or what disseminates the information. If the source of message seems biased, the receiver may be unconvinced(Frederiks et al., 2015; Terwel et al., 2009). Terwel concluded that citizens' trust can be dependent on organization's perceived motives. For example, citizens are more likely to trust an environmental NGO as having public interest at heart over an industrial organization who is believed to have their own organization interest at heart (Terwel et al., 2009). So, its important a trustworthy party disseminates the message if it is to be taken to heart by the intended message recipients. If any information the about health risks of oven use is passed through- health related, the impact will be greater than an environmental welfare source and vice versa.

6.1.2.8. Availability heuristic

People use this shortcut of judgements from information cognitively more available to them through personal experience. The more vivid, emotional or salient an experience is, affects its cognitive availability. The availability bias can incorrectly influence what we think about the frequency of occurrence. Accurate scientific emissions material can be complex and difficult to digest. In order to understand the implication and risks of wood oven behaviour any potential education campaign should include images that are easily understandable from compelling experience everyone can identify to. Just as nearly everyone has experienced choosing a grocery line which moves much faster than the one we are in, we also have experience being outdoors behind a bus or large truck that is spewing bad choking exhaust. How many trucks does one oven equal? Or how many trucks does one evening of heating equal?

Many times, educational campaigns fail to change societal behaviour. Tactics in Armidale Australia to improve air quality as a function of community awareness of smoke health risk is such an example(Hine et al., 2011). Researchers there did however demonstrate that education coupled with behaviour modelling and prompts elicited more responsiveness(Hine et al., 2011). If awareness was enough to motivate change, smokers knowing the health risk would easily give up their habits(Samson et al., 2015). Willingness versus awareness is pointed out by Ariely and describes how willingness is a function additionally of social norms, economics cost, behaviour preference and burden(Samson et al., 2015). An example of this could be pregnant women and drinking alcohol. Awareness is present, but additionally the cost is too high for the fetus, it is typically not socially acceptable and the burden of not drinking can be discontinued after birth.

7. Current Main Findings

7.1. Health effects of emissions from wood burning

There may be the misconception that particle emissions from burning wood are primarily organic thus are harmless both to human health and the environment. The World Health Organization however states particulate matter from wood burning should not be considered any less harmful than PM from other sources, such as vehicle exhaust, industry emissions or the burning of fossil fuels (Chafe et al., 2015). This is based on numerous epidemiological studies that link ambient PM pollution with increased hospitalizations and death(Wei et al., 2019). This section briefly describes disease vulnerabilities and pre-existing conditions linked to the effects of PM2.5 pollution, including the well document associations of respiratory and cardiovascular disease but also recent studies demonstrating the link of PM2.5 to dementia, and then briefly describes Norway's position.

The Norwegian Institute of Public Health (NIPH) promotes misinformation of risk by keeping outdated articles online that undermines the risk of wood oven emissions on human health. 'Wood Burning Ovens', a Norwegian NIPH article published in 2005 and updated in 2018 says, "*In studies where the effect of wood burning particles in ambient air are researched, the only finding is a worsening of acute asthma*."(Norwegian Institute of Public Health, 2005). Another NIPH website article "Air Pollution in Norway", describes more accurately the risks associated with PM. However it retracts its previous published estimate of lives lost each year from PM and lowers the mortality rate from 1400 to 185 for PM2.5 and PM10 is downgraded to 115(Norwegian Institute of Public Health, 2015). The retracted data is from the Global Burden of Disease Project, a worldwide study including 41 nations. Considering

NIPH's downgraded mortality estimate, PM2.5 caused more deaths in Norway than traffic deaths and murder in 2019 combined (Kripos, 2019; SSB, 2019).

As part of this research the pathology department and emergency room at the local Stavanger University Hospital was queried whether incoming cases of pulmonary or cardiac distress were registered related to poor air quality episodes. In the case of emergency room care, only immediate stabilizing care is administered before transporting patients to specialized units. The only registration made is of incoming case involving embolism or intoxification(C. Ellingsen, personal communication, March 15, 2019). Additionally, the pathology department at Stavanger University Hospital does not register reason of death from autopsy related to air quality or PM. According to a pathologist interview, Norwegian deaths per year from NIPH or SSB statistics due to air quality result from correlations and modelling data that originate from healthdata.org in Seattle, USA (C. Ellingsen, personal communication, March 15, 2019). Information posted to NIPH are numbers extracted to fit Norwegian population figures.

7.1.1. Who is adversely affected?

While many studies reveal strong morbidity related to biomass combustion in lower income nations where indoor open fire cooking is prevalent, fewer studies have focused on the health effects in higher income countries of PM2.5 emissions from biomass burning. Health effects of particulate emissions are well documented for heart and pulmonary illness, but new studies are revealing how extensive particulate matter is on human health. Rather than necessity, biomass burning is often supplemental. Biomass burning can be a financial choice, ambiance and has the perception of being renewable.

Particles as small as a molecule, when breathed in, break the barrier of lungs and enter directly into the blood stream. Systemic inflammation results as the body's system tries to fight them. Toxic compounds lodge as a precursor to cancer. These particles inflame blood vessel which contributes to higher blood pressure and can cause stroke. Particles also dislodge fat in blood vessels leading to blockages or clots that block blood to heart or brain(World Health Organization, 2018). This is our current understanding. New research is showing that even when particulate matter is below WHO safe air standards increased association between illness and PM2.5 is shown(Wei et al., 2019).

The size of the particulate matter determines how deeply into the human system it transmits and what areas of the body it can affects. Health effects of particulate matter are well documented in hundreds of epidemiological studies globally, but the medical community is still working to understand how the disease mechanisms function. Figure 1. illustrates how large PM2.5 is compared to human hair.

Children and foetuses with developing lungs are at increased risk as well as the elderly. Fetus exposed to sustained fine particulate matter are at risk for lower birth weights and being small for gestational size (Chafe et al., 2015).

Since 2013 Norwegian law has implemented regulation in order to limit second-hand smoke exposure under statutes § 25, 26, 27, 28 (Ministry of Health and Care Service, 2013) . Passive smoke is not allowed at eating or drinking establishments or with public transportation, as well as entrance to all health institutions and public buildings, schools or kindergartens, places of work (institutions and offshore excluded) (Ministry of Health and Care Service, 2013). Under this statute, children also have the right to a smoke free environment, although there is no supervision or sanctions involved(Ministry of Health and Care Service, 2013). Some children exposed to second-hand smoke suffer increased incidence of ear infections, lung infection and asthma (Fedele et al., 2016). These can present as the same symptoms children who live in homes that heat with wood ovens experience (Rokoff et al., 2017). Poor air quality as a result of residential burning is not valued similar to air quality resulting from smoking even though people spend most of their time at home. Multiple studies have documented the health results of trying to reduce the children's exposure from wood oven heating to reduce symptoms of particle exposure (Allen et al., 2009; C. W. Noonan et al., 2012; Curtis W. Noonan et al., 2017; Ward et al., 2011).

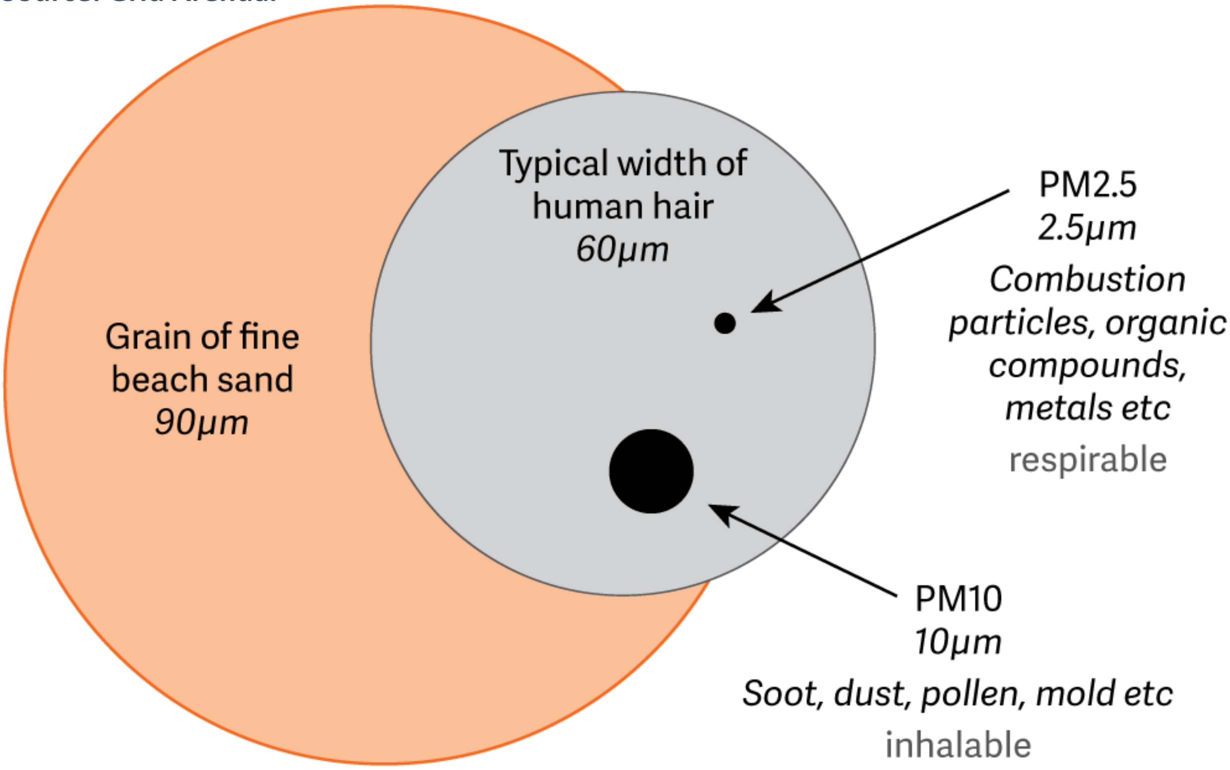
The WHO created a report in 2015 based on the need to describe the health factors as a result of the push of wood burning as a response to the need for renewable energy and climate change measures (Chafe et al., 2015). The WHO report is pertinent because the focus is on Europe and North America's habits.

As the reader can discern, between the local hospital pathology department reporting statistical data gets acquired from global sources and the FHI partly using, but partly rejecting the same data and recalculating it to reflect what they believe is a more accurate accounting, there is a level of uncertainty on how wide spread Norwegian problem is and in turn some uncertainly on the mitigation efforts to combat it.

Figure 1

*Size of Particles PM2.5 and PM10 as Compared to Human Hair and Fine Grain of Beach Sand***.**

Source: Grid Arendal

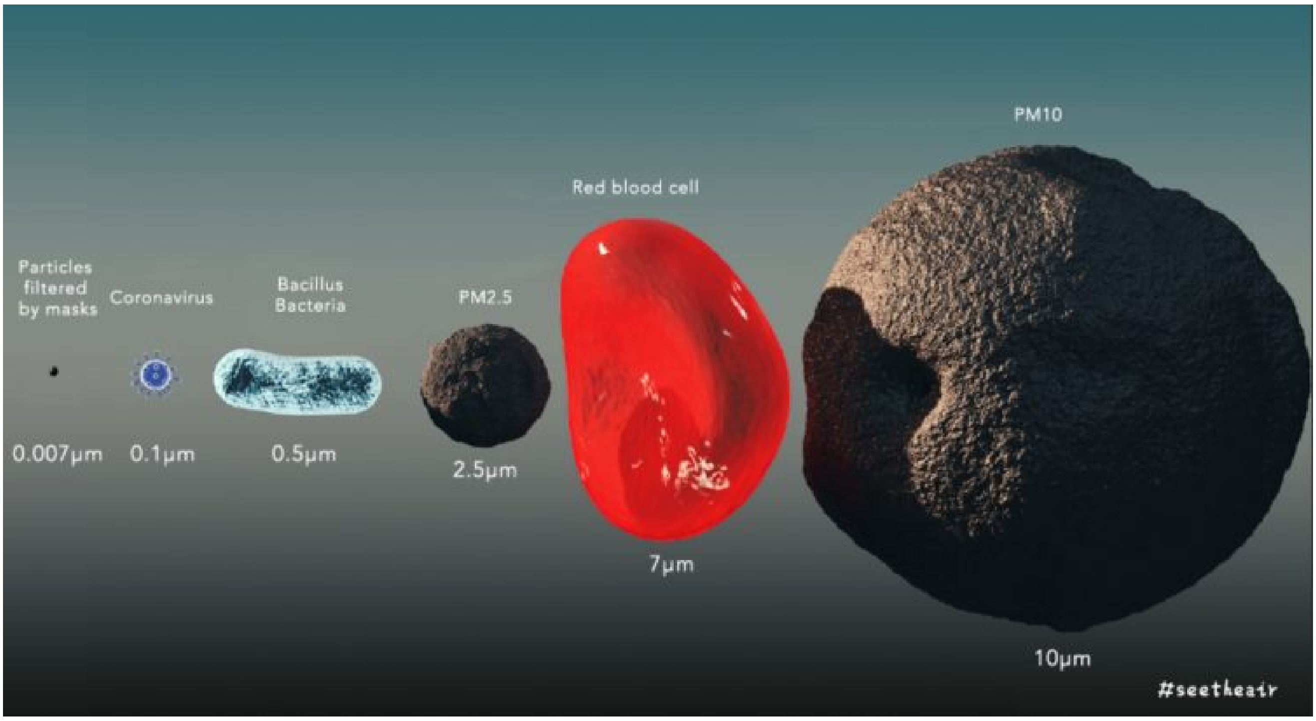


More updated information is publish through the NIPH in a report from 2013. However, this report is 163 pages long and discusses how air quality affects health quite extensively. The average laymen will go to professional groups or local authorities online, if not simply search online for accurate and reliable information. This is not the case at the NIPH.

Even though This is one of the dangers the WHO write about, the promotion of woodburning being renewable without thoroughly considering the health of particle emissions both on human health and its climate warming properties.

Figure 2

Size Comparison of Particulate Matter. Source: seetheair.wordpress



The directorate of health put out a statement saying 1 of 3 people of the population of Norway is in the vulnerable group for the COVID-19 virus. This group extra vulnerable is people with lung disease, heart disease, diabetes, low immunity, cancer, or the elderly. The people at extra risk for developing complications from COVID-19 are the same people who are documented as being at risk for adverse health effects from PM2.5, with one exception, children and developing embryos. Emissions also effects embryos growing in utero and children are also in the risk group for PM2.5 emissions. It is literally 1/3 of Norway's population is vulnerable wood burning, plus developing fosters and children. National agencies write that asthmatics/allergy suffers or people with heart and lung disease are at risk for high emissions. Initially when Covid-19 broke news people generalized that it only affected the elderly, in the same way they generalize poo air only affects asthmatics. Then people who were young and not belong to the risk group started also becoming serious ill or dying from the virus. Medical studies have proven sufferers of lung disease and heart disease are at high risk for complications due to high air pollution.

Numerous epidemiological studies for all over the world show associations between PM levels of PM in ambient air with increased hospitalization and death, the clearest association is between PM 2.5 (Norwegian Institute of Public Health, 2013). Increased exposure to PM worsens the disease but also shows exposure may actually initiate the diseases development (Chafe et al., 2015).

Although wood burning combustion particles are organic in nature it does not mean they are less harmful. PAH (polycyclic aromatic hydrocarbons) are common in the combustion on oil, gas, coal and wood. They are known to be carcinogenic to humans and awareness/education about the source and effects of PAH should be improved (Abdel-Shafy & Mansour, 2016). PAH levels are over 100 times higher in wood burning particles, comparable to diesel particles (Norwegian Institute of Public Health, 2013). There is a clear difference in the physical and chemical qualities of particles from wood burning versus particles from vehicles.

7.1.2. Heart:

Scientists believe inflammation in the cardiovascular system is sparked by exposure to particle pollution. This is because PM2.5 particles are smaller than the size of a blood cell which is between 6-8 µg in size. Breathing in particles this size are able to transmit through the walls of the lungs and into the blood stream (World Health Organization, 2018b). Cardiovascular disease, including blood pressure and stroke, is worsened by exposure to particulate matter 2.5. Ischemic heart disease, or reduced blood flow to the heart by a narrowing of the arteries (including heart attack) is also affected. Smoke inhalation from wood burning when combined with intermittent exercise showed that an increase in heart rate and acute increase in major artery stiffness (Unosson et al., 2013).

One of the first studies to compare wood oven regulation on ambient PM2.5 pollution and adult health is the American San Joaquin Valley study. After years of poor ambient air quality in the region, regulation (Rule 4901) was put into place that banned the use of wood ovens during days or weeks of poor air quality forecasts (about 65µg/m^3). Hospitalizations of patients over 65 years for cardiovascular disease, ischemic heart disease and COPD decreased approximately 50% during this same period, while for adults between 45-65, hospitalization was only slightly decreased. "*Among those aged 65 years and older, Rule 4901 was estimated to prevent 7%, 8%, and 5% of CVD cases, and 16%, 17%, and 13% of IHD cases*"(Yap & Garcia, 2015, p4). Interestingly, the affects on elderly with COPD was least affected(Yap & Garcia, 2015).

Most recently, a 2019 study of the entire Medicare Claim database by the Harvard Chan Medical School demonstrated new associations beyond the typical cardio and pulmonary diseases of increased hospital admission and increased days in the hospital with each 1µg/m3^3. Septicaemias (systemic wide blood infection), acute renal failure, urinary tract infections and disorders of the fluid and electrolytes are some of the newly identified associations to increased pm2.5 (Wei et al., 2019).

7.1.3. Lung:

Breathing in particulate matter leads to inflammation which is central to development and worsening of lung diseases such as asthma, COPD and lung cancer(Norwegian Institute of Public Health, 2015). According to the World Health Organization's fact sheet on ambient air pollution, larger PM10 particles are inhaled and deposited in the lungs while smaller PM2.5

particles are so small they transmit through the lung walls and enter into the blood stream(World Health Organization, 2018b).

7.1.4. Dementia:

A study particularly relevant to the Norwegian status quo was done in neighbouring Sweden. Unlike other more distant European nations, the cultural and climate similarities allow similar assumed conditions comparable across borders between Norway and Sweden. The Swedish longitudinal study compared the incidence of dementia and Alzheimer's over 15 years combined with modelled PM2.5 pollutions(Oudin et al., 2018). GIS mapping enabled the researchers to differentiate the associated risk of dementia with high resolution modelling between residents that lived in each of the two distinct scenarios; residents that lived along heavy traffic roadways versus more isolated wood burning residential areas(Oudin et al., 2018). There was a significantly higher risk of dementia in participants that lived in areas of the city with the highest quartile of pm2.5 pollution(Oudin et al., 2018).

7.1.5. Children and Babies

Etiologic mechanisms leading to gestational diabetes and preeclampsia are uncertain, but systemic inflammation may be a contributing factor (Sibai et al. 2005; Wellen and Hotamisligil 2005). Both experimental and observational evidence indicates that exposure to air pollution, particularly ultrafine particles, induces oxidative stress and consequently inflammation (reviewed by Terzano et al. 2010). Recognition that indoor air pollution from solid fuel use is a potential source of significant health risks to children is relatively new, but second-hand smoke has been recognized as a factor in children's health (Chafe et al., 2015).

7.1.6. What do the different agencies say?

Environment.no(Norway SOE, 2018) lays out that PM is the most detrimental air pollutant to health while NO2 is also significant. They discuss it's roll in respiratory disease and cardiovascular incidents. They do not yet describe that the smallest particles actually transmit directly into the blood system (World Health Organization, 2018a) and the latest research points out several other health illness associated with high PM 2.5 such as kidney failure and sepsis (Wei et al., 2019).

In Helsinki 29% of residences use wood ovens for heating and in suburbs as much as 66% of residences rely on wood burning to supplement heating.

However, the World Health Organization, (WHO) reports in areas which residential heating by wood combustion is common, it is not only the smaller 2.5 particles but particles up in size of PM10 which is found in relatively high concentrations. This is important because when examining emissions levels of PM, background stations only stand out as areas of high pollution when considering particle size up to 10 nanometers. This translates into residential areas with heavy wood oven burning for heating, but that have little traffic as compared to road station monitor data, are burning wood very inefficiently producing both large (PM10) and small (PM2.5) particle emissions. Graphs representing data of PM2.5 emissions behave similarly between road monitoring stations and background monitoring stations. Graphs representing emission data of particle size from 2.5 up to 10 behave significantly between the two kinds of stations.

Averaging times: FHI discusses how to meaningfully look at measurements of pollutions levels and these are down in terms of averages over time (Norwegian Institute of Public Health, 2013). But yearly averages are poor ways to decipher the health affect. Traffic is a constant which change little except for summer months as it relates to holiday travel of the majority of Norwegian society. Pollutions from wood burning is significant in the winter months. Watering emissions out in a yearly time frame gives a disproportionate view of air quality strictly in winter and its accompanying health effects for vulnerable citizens.

7.2. Air Quality

7.2.1. Outdoor Air Quality

Studies have shown the measurements of wood burning emissions in residential neighbourhoods result in emission levels of PM2.5 to be similar to vehicle emissions in congested street canyons of larger cities(Glasius et al., 2006). Sentence about emissions from cars and trucks to understand how this is possible. A residential wood burning study in Denmark showed the volume of biomass particulate matter to mirror that of a busy Copenhagen street canyon of 70,000 vehicles daily (Glasius et al., 2006).

Emissions from biomass come from many sources but all emission have similar chemical makeup regardless of which source they come. This research will focus on emissions in the residential sphere coming from burning of wood in wood ovens, open or closed, and fireplaces, open or closed. The reader should however understand there is no fundamental difference in the makeup in the composition or effect based on source. Emission sources from biomass or wood are; power stations that burn wood to generate electricity, agricultural burning of fields and farm waste, waste burning of wood or landscape greenery, bonfires, forest fires (both purposeful as forest management and accidental or arson) and lastly as this paper will focus on emissions from fireplaces and ovens for residential heating (Monks et al., 2017).

Incompletely burned particles and gases form wood burning emissions. The gases are elements such as carbon monoxide (CO), carbon dioxide (CO_2), nitrogen oxide (NO), and the less familiar volatile organic compounds (VOCs) and polyaromatic hydrocarbons(PAHs) (Monks et al., 2017). VOCs can come from hundred of sources, including wood smoke and wood burning ovens. They are organic compounds which alone are dangerous but can also combine in the air with NO and form other dangerous pollutants like ozone (American Lung Association, 2020). PAHs are incompletely burned organic particles that are cancer provoking and can bind to PM. PAHs come from industry, traffic, and burning wood(Norwegian Institute of Public Health, 2013). According to NIPH 2013 report on health effects from pollution, 40% of PAHs come from industry, 34% from wood burning and 11% from traffic (Norwegian Institute of Public Health, 2013). The particle makeup of the wood burning emissions or PM is complex and dependent on multiple factors; moisture, burn rate, temperature, type of wood, construction and shape of burn box, dimensions of flue and air supply and air mixing (Monks et al., 2017; Seljeskog, Sevault, et al., 2017).

Particulate matter is categorized by size of microns or micrometres. PM2.5 refers to all particles 2.5 micrometres or smaller and are considered fine particles. PM10 are course particles and vary in size from 10 micrometres to 2.5 micrometres in size, while ultrafine particles are categorized as PM0.1(Norwegian Institute of Public Health, 2013). Fine and ultrafine particulate goes deep into the lungs and can transmit into the bloodstream. Larger particles remain or dissolve in the lungs. They can come from natural or manmade sources, from forest fires to vehicle exhaust. A persons exposure to PM2.5 and biomass combustion from different phases of the combustion; start up, full burning, and burnout or smoulder (Chafe et al., 2015). While ambient exposure is considered to be higher in denser urban settings, Missoula university demonstrated the extraordinarily high (600) short-time indoor exposures of PM2.5 in rural settings(Semmens et al., 2015).

Fine and ultra fine particles are more associated with combustion, and coarse particles are typical made mechanically, i.e. road and tire breakdown(Norwegian Institute of Public Health, 2013). NIPH acknowledges wood burning is a substantial PM source but reports that most urban PM comes from traffic, road dust and diesel exhaust(Norwegian Institute of Public Health, 2013). However, due to the disproportionate emissions reduction development between the oven and vehicle industry this assumption calls for further investigation (Monks et al., 2017). Additionally, the ambiguity of actual vs. test oven emissions, air quality modelling resolution technologies, as well as examining sources and effects of small vs larger particles and distances also sheds light on need for closure resolution modelling(Goodkind et al., 2019; López-Aparicio et al., 2017; Seljeskog, Goile, et al., 2017). For all of these reasons Norway should reassess their unbalanced approached of air pollution focused on cars and the slow switch to new technology ovens.

Black carbon is a particle component of biomass burning. Black carbon, or elemental carbon, in layman terms is soot and is a term used to described that it is light absorbing carbon (Seljeskog et al., 2013). Black carbon from residential burning, forest fires and fossil fuels plays an important role in climate change and glacier melting(Seljeskog et al., 2013; Stohl et al., 2013). The source of black carbon emissions are decreasing overall, transport emissions are reducing but residential burning is increasing into 2030 (Chafe et al., 2015).

7.2.2. Indoor Air Quality

The cold northern climate requires Norwegian homes be tightly insulated against moderate to bitter winter weather. 1. Energy house rating 2.Infiltration of ambient air pollution into homes adding to poor indoor air quality is less concerning than the potential of ovens themselves leaking with poor draft or faulty pipe connections(Chafe et al., 2015). The second factor influencing indoor air pollution is infiltration of outdoor ambient air into the home.

Energy performance certificates in Norway began in 2010 and were initially meant to incentivize homeowners increase housing energy efficiency use. Policymakers believed in energy transparency and the better a house energy rating, the more the home would sell for on the market. Homeowners, in theory, would pay more for a better insulted and better energy rated house. This turned out not to the be the case as discussed by (Olaussen et al., 2017) in a NTNU study. Only houses that were geographically located in higher prices areas before the rating scheme began in 2010 continued to sell for at higher prices (Olaussen et al., 2017). The rating system did not have the intended affect.

Although numerous studies document poor air quality related to indoor combustion in rural China, India or Africa, the combustion use, emission exposure and building types are not comparable to northern European burning technology or residential conditions. Indoor emissions from biomass combustion in northern Europe typically result from leaking ovens, pipes, or connectors, improper pressure, too much draft (leaving the door open) or not enough draft (Ricardo Luis Carvalho et al., 2014). These can factors can be a result of both technical and/or user operational faults (Semmens et al., 2015).

Semmens estimated that 70% of indoor particles were a result of indoor emissions escape pointing out the relevance for targeting measures to improve air quality with proper fittings, seals and ventilation (Semmens et al., 2015).

There are several relevant studies examining air quality as a resulting of changing from old wood stove technology to new wood stove technology. A study on the Nez Perce reservation changed out oven technology types for families with children suffering from asthma and demonstrated lower indoor concentration of PM2.5 in 2/3 of homes by 36% (Ward et al., 2011). 1/3 had worse air quality and initial education and operation training strategies needed to be repeated for successful outcome(Ward et al., 2011). Another American study aimed at improving conditions for child asthmatics demonstrated an improvement in measured air quality by 67% as a result of using HEPA filters but no improvement from changing oven technology(Curtis W. Noonan et al., 2017). Neither the air filter or stove technology interventions improved reported quality-of-life(Curtis W. Noonan et al., 2017). A northern European study demonstrated in order to improve indoor air quality by upgrading oven technology, user interaction with the combustion chamber and the proper air inlet from exterior sources is crucial(Jalava et al., 2010). If the temperature of the combustion box is too low a reflux of exhaust results that worsens air quality(Jalava et al., 2010).

Gustafson reported the PAH levels to be 3-5 times higher in Swedish homes with wood burning appliances compared to those without. While Gustafson reported lower PAH levels outdoor than indoors, conflicting findings were reported by Vicente (Gustafson et al., 2008). Vincente's study focused on PAH concentrations between homes with open fireplaces versus closed wood stoves and found that indoor levels were higher than outdoors (Vicente et al., 2020). The largest concentrations were found during ignition and reloading phases but Vicente found PAH levels negligible in closed stove devices but lifetime cancer risk was exceeded with levels exhibited from open fireplaces (Vicente et al., 2020).

A study relevant and interesting study from north western US and Alaska introduced factors associated with increase or decreased PM2.5 levels in the home, perhaps the most important being the income level(Semmens et al., 2015). Supporting the premise that people choose to burn wood in order to buffer economic hardships associated with fluctuating electricity prices. Factors which increased PM2.5 were1. No other supplemental heating.2, burning candles or incense, 3. Opening a window, 4. 1% higher humidity inside than outside. Interestingly seasoning the wood for 2 years resulted in pm2.5 levels that were reduced by 25%(Semmens et al., 2015). The most alarming finding was that all of the homes in the study at some point in the measuring had pm2.5 levels over 600ug/m3(Semmens et al., 2015). While researchers of this project found a high association between higher PM concentrations with open windows and doors, resulting in the theory that high concentrations are causing people to air out their homes. Alternatively, opening windows and doors could instead be a result of overheating, or as Seljeskog and Skreiberg refer to flattening out the heat release curve(Seljeskog, Sevault, et al., 2017) and in turn affecting the natural draft or house pressure and associated emissions(Skreiberg O. & Seljeskog M., 2018).

7.3. Mitigation tactics

7.4. Norway's approach to mitigating wood oven emissions.

Norway's environmental agency, environment.no (Miljøstatus), reports, *"On cold winter days, wood burning can be the largest local contributor to bad air in cities and dense areas." "På kalde dager om vinteren kan vedfyring være det største lokale bidraget til dårlig luft i byer og tettsteder»*(Miljødirektorat, 2019). Their website's local air pollution front page however strictly emphasizes traffic's contribution. These agencies give lip service to the problem of air pollution from wood ovens but don't actually employ any mitigation tactics other than eventually switching out technology ovens for new ones. It seems that the agencies have not actually decided which source is the greatest contributor of pollution because the English platform for miljødirektorat is environment.no and they state as a headline, "*Road traffic the dominant source of local air pollution"* (Norway SOE, 2018). Mixed messages are being spread. The measuring stations and air modelling done in Norway emphasizes traffic contribution. Whether or not it is traffic or wood ovens polluting the air to the largest degree is beside the point. The message being delivered to residents is ambiguous, but the actions to alleviate the problem are not. Efforts are directed to limit traffic.

WHO report states change out programs are inconclusive about changing air quality. HEPA filters have shown ability to change indoor air quality. Educational campaigns identified barriers to reducing smoke was poor operation and lack og knowledge (this is too cut and paste…needs different wording). Education campaign have only limited success. Awareness doesn't change behaviour. (Hine). The perception of wood burning needs altering as has been done with cigarette smoking. Now hygge or cosy comfort and warmth can be the reasons people decide based on feelings instead of knowledge of risk(Chafe et al., 2015).

7.4.1. Stavanger

To help mitigate air quality, especially near Stavanger centre, the municipality has an incentive program since 2018 for changing out old technology ovens for new technology ovens. Up to half of the price of the oven and installation up to 5000nok are subsidized. Old ovens are delivered to the installer/dealer and the new oven installation is registered with fire brigade. The program is financed through tax on studded winter tires which destroy the asphalt and allows for a maximum of 1000 houses to be financed. The program effectively serves two purposes, limiting studded tires and incentivizing new ovens. The municipality oven refund webpage includes a link to the fire brigade with advice on proper burning to minimize emissions and links to an effective 90 second video describes proper ignition burning material, ignition method, and how to optimize draft pressure in the house. An important message is delivered early in the video; "*if you burn correctly*, a new wood oven is an environmentally and economic friendly heat source." An improvement could be including the link earlier on the municipals oven page to increase the chance people view it in case they don't navigate further to the fire brigade page.

Stavanger states the important goals for climate and environment are reducing emissions, ensuring fish are safe to eat, clean air for everyone, and protection for plant and animals to increase diversity(Vareide et al., 2018). In critical periods the municipality and national road agency will undertake extra measures such as more frequent road cleaning or spraying a chemical binding agent to the roads which keeps the particles from recirculating in the air(Vareide et al., 2018). Additionally, a third air monitoring station (Schancheholen)was introduced to monitor traffic emissions associated with new road development recently finished in 2019 (Vareide et al., 2018).There has been a successful national effort to increase the proportion of electric vehicles as in March 2020 over 400,000 electric and hybrid vehicle were registered in Norway(Norwegian Electric Vehicle Association, 2020). Lip service is given to changing out diesel engines for Euro6/VI technology and is meant to lower particle emissions, but until EU law is changed, banning the sale or import of diesel vehicles is not legal(Kovacs, 2019). Numerous road taxes, vehicle value taxes and road toll fees are all methods aimed at curbing emissions from vehicles, however little mitigation effort is directed at ovens which have much higher comparable emissions than vehicle.

7.4.2. Oslo

Oslo has an oven refund program which is funded by the Climate and Energy Fund. Financial support is greatest if the dwelling is located within ring 3 at 6000 NOK and is limited to 1500 outside of ring 3. While Stavanger supports installation cost, Oslo limits funds to the 50% of the oven cost and pre-approval must be received before any work or purchases begin to qualify for the subsidy.

Starting in 2016, Oslo strengthened guidelines to ensure good air quality. Outdoor burning is not allowed unless grilling or using an outside oven with clean wood or coal and only if it is not bothersome to people nearby(Regulation on Burning Garbage, Oslo, 2015).

Certain neighbourhoods in Oslo, near the centre are densely built and tend to use ovens but that the value limits aren't met just because of wood ovens so the focus has been directed at roads and exhaust. In winter periods when conditions can be worse, a solution of magnesium chloride is used but this is not at the direction of the municipality but instead decide by the road crew. In theory, the road crew will inform the municipality when this process is done. Continuous road cleaning ensures the same road is cleaned every 14 days.

Since 2017, Oslo has been open to the ban of diesel vehicles on days of bad air quality due to excessive NOx emissions as part of a preparedness plan but to date hasn't used this tactic yet(Å. Løseth, personal communication, March 5, 2020). It does not have a similar plan for pm2.5. Oslo has had several video campaigns promoting correct firing habits on Facebook page of fire brigade. The fire brigade gives out brochures when they check chimenys.

There are two potential portals to log complaints about air quality complaints or issues. The first is the city notification alert (bymelding) where city repairs or broken functions can be reported and then followed up on by specific districts of the city and the second and more appropriate is Branntips.no. This is a new broadly used national online service that allows reporting questionable conditions that may hinder fire safety (blocked exits, poor wiring, construction, individuals putting others fire safety in danger (Oslo Fire and Rescue Service, n.d.). Individuals can inform the local fire brigade via a centralized reporting platform that forwards to the correct municipality, with the location of fire safety concern, images can be uploaded and the local brigade is dispatched (Oslo Fire and Rescue Service, n.d.). This platform could be used if outdoor firing is happening under summer burning bans or if material dangerous to health (painted or treated wood) is burned.

Oslo is one of 5 municipalities active in a pilot program research, iFlink, involving microsensors and citizen engagement to improve air quality awareness and increase knowledge. The project aims to combine low cost micro sensors with traditional monitoring stations to link open big data of local environments to create more detailed information than currently available (Castell, n.d.). The microsensors improve model output by assimilating the data of sensor observations into the model (Castell, n.d.).

Public oven subsidy

Since 1998 Oslo has subsidized the purchase of new technology ovens and in 21 years used 39 million kroners towards that goal. As of 2018, Oslo reports that 11000 stoves were installed as part of the ordinance and since 2005 there has been a 5% decrease of PM2.5 emissions(Lopez-Aparicio & Grythe, 2019). NILU studied the effects of Oslo's public subsidy program to change out old oven for new ovens compared to municipalities without a similar offer. They looked at how the subsidy affected 1. emissions, 2. wood use, 3 emission factors. NILU found no systematic emissions difference over time between municipalities offering pant (change-out) schemes versus those with no scheme(Lopez-Aparicio & Grythe, 2019). The emission factors were reduced earlier over time in Oslo, which can be a result of the pant scheme, but this eventually happened with other non-participating municipalities(Lopez-Aparicio & Grythe, 2019). From studied municipalities, Oslo had the lowest yearly emission reduction and lowest reduction in wood use(Lopez-Aparicio & Grythe, 2019). NILU points out the importance of not increasing wood use when changing technologies and they explain the possible increase either because people switched from oil burning to wood or people chose to burn more(Lopez-Aparicio & Grythe, 2019). In conclusion, the authors found the gains of cleaner burning were counteracted by increased wood use(Lopez-Aparicio & Grythe, 2019).

7.4.3. Bergen

Bergen started offering oven change out subsidies in 2010 with 7 million kroner, 2 million in 2016 and committed an extra 50 million kroner in 2017 to the oven change out scheme. This money came from the city's distributable reserve fund (*149/17 Bergen City Council*, 2017). No other oven measures are described in contingency or assessment plans other than the changeout program until 2021, when all old stoves are to be banned(Bergen City Council, 2016; Høiskar et al., 2017).

Due to a long inversion period in the winter of 2010, a continency plan for high air pollution was developed(Bergen City Council, 2016). The city council concluded decisions would prioritize health and authority would be given to the crisis management team of the city government. The team could be assisted by all or part of the contingency council consisting of 12 separate agencies and departments, including; Directorate for Public Roads(NPRA), Hordaland Council, Meteorological Institute, Police, Port Authority and City of Bergen(Bergen City Council, 2016). The City Council measures include health tips and information dispersal, removing ships from port, reducing PM dispersal from roads, alternate-day road driving, time differentiated tolls as well as differentiation based on emissions(Bergen City Council, 2016). Additionally, low or zero emission zones are under discussion awaiting approval. Bergen City Council acknowledges the necessity of proactive measures to effectively prevent episodes of high pollution using 5-day forecasts from the meteorological institute but there are no measure directed limiting oven use in their action matric for handling high air pollution(Bergen City Council, 2016).

There is disagreement on why air quality in Bergen has improved. The politicians within the city council believe the integrated measures have contributed to the reduction(Røren & Mæland, 2018). These measures include more people driving electric and hybrid cars, commuting on public transport, fewer diesel vehicles on the road ways and cleaner wood burning overs(Røren & Mæland, 2018). Researcher Wolf-Grosse on the other hand believes it's the weather that has contributed most to fewer days with poor air quality from emissions, specifically heavy rains(Røren & Mæland, 2018).

Politicians are sceptical to implementing the ban on all dirty-burning wood ovens and think restricting oven use to areas of Bergen that suffer bad air quality should be enough. Wolf-Grosse agrees and described the situation in Bergen being very dependent on the local topographical it is situated in but his recent research suggest as well that the climate situation as far as Greenland affects the climate that results in bad weather resulting in poor air quality (Wolf-Grosse et al., 2017). Wolfs research shows certain areas in Bergen result in a cumulative affect on the air down wind in Bergen while other areas, the emissions really only affect that small specific region(Wolf-Grosse et al., 2017).

The action assessment for improving air quality in Bergen lists road traffic, the port of Bergen and exceedances of NO2 as the contributors to emissions. It is odd they don't give a section to wood burning as a source of emission, but they do use clean wood burning ovens as a measure to improve air quality. Wood burning is given a separate section as a contributor and the documents states wood burning accounts for 25% of emissions and roads and traffic only account for 15% of the emissions in Bergen. However, the documents stipulate the road emissions probably contribute more because the emissions on ground based at the level of traffic

7.5. Monitoring stations

EU legislation today requires a minimum 1 sample monitor point for ever 100,000 km2(European Parliment, 2008). Norway has approximately 380,000km2. The EU requirement of 1 monitor per 100,000km2 would require Norway to have nearly 4 stations. Stavanger alone has 3 monitoring stations, although these are all in the city centre. Norway's Environment Agency states; average air quality indicators can not be transferred to the rest of country. Measurement indicators only qualify the situation where the measurement stations. This is problematic because Goodkind's damage estimates of human health impacts report the towns which suffer the greatest impact from air pollution are between 40,000 and 60,000 residents(Goodkind et al., 2019). EU regulation stipulates the air monitoring stations are based on population size. NILU researchers have pointed out that Norway's small population and generally small town size limits expensive monitoring stations(Lopez-Aparicio, 2019) . Small local municipalities are at a disadvantage to correctly represent air quality unless they rely on uncertain modelling with far too large resolution grids to accurately reflect local conditions(López-Aparicio et al., 2017) .

Table 1

Bergen, Norway Monitoring Station PM2.5 Values

Bergen, Norway All values are PM2.5 | μg/m³					
Period	Year	Danmarks plass	Loddefjord	Rolland, Åsane	Klosterhaugen
Entire year	2019	6,71	5,34	4,22	5,87
winter	2019	7,67	5,54	4,01	6,07
spike	2019	15,46	6,58	3,46	9,68
Entire year	2018	7,23	5,48	4,20	6,09
winter	2018	7,67	5,55	3,73	6,31
spike	2018	10,11	6,46	4,19	8,43
Entire year	2017	6,72	4,70	3,29	5,19
winter	2017	7,15	5,47	3,59	*
spike	2017	8,19	8,13	4,33	*

Note. Danmarks Plass and Loddefjord are city centre monitoring locations. Rolland and Klosterhaugen are background monitoring stations.

Bergen's assessment of PM2.5 concentrations in city centres are described as well below the legal limit and near or just above the national targets of PM2.5(8 μg/m³) (Høiskar et al., 2017).

The spike months show concentrations values exceed the national target levels og PM2.5 (8 µg/m³) for all three years shown. During 2019 the legal limit of 15 was passed as well as the national and health target levels of PM2.5 (8 µg/m³).

Table 2

Oslo, Norway Monitoring Station PM2.5 Values

Oslo, Norway All values are PM2.5 | µg/m³					
Period	Year	E6 Alna senter	Rv 4, Aker sykehus	Sofienbergparken	Bryn skole
entire year	2019	9,17	5,75	7,59	8,30
winter	2019	10,62	6,37	8,41	10,09
spike	2019 Jan	15,95	8,53	12,54	15,57
entire year	2018	10,29	8,46	9,63	12,18
winter	2018	12,83	9,25	10,42	12,18
spike	2018 Dec	13,74	8,01	10,22	12,41
entire year	2017	12,90	6,88	8,51	
winter	2017	12,90	8,84	11,31	
spike	2017 Jan	12,69		16,54	

Table 3

Stavanger, Norway Monitoring Station PM2.5 Values

Stavanger, Norway All values are PM2.5 | µg/m³				
Period	Year	Kannik	Schancheholen	Våland
entire year	2019	7,61	8,47	7,10
winter	2019	8,27	9,37	7,85
spike	2019 Feb	12,95	14,41	13,04
entire year	2018	8,37	8,05	7,37
winter	2018	9,49	9,14	8,09
spike	2018 Nov	12,27	12,19	10,05
year	2017	7,31	*	5,98
winter	2017	9,05	*	6,97
spike	2017 Dec	9,59	*	8,56

Note. Bergen PM2.5 Value: showing yearly average, winter average and highest value month average. Winter months are defined at Jan-Mar & Oct-Dec.* Klosterhaugen monitoring station was installed in November of 2017.

7.5.1. Late night spikes

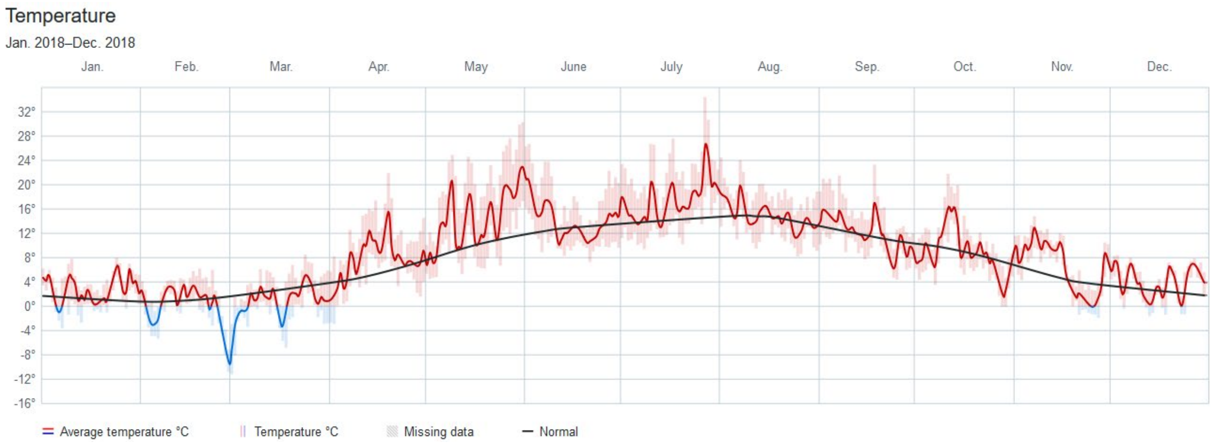
Krecl's study in Northern Sweden documents and explains the late-night spike effect and the differences in particle size as activities are differentiated. During the week, particle concentrations are highest in morning but smaller in size (traffic) and weekend peak concentrations happen late evening with large diameter particles.(Krecl et al., 2008). This supports NIPH that the primary source of PM2.5 particles is traffic exhaust. This leads to questions regarding the particle size profile of emissions from old technology stoves versus new technology stoves. The ratio of old to new oven technology has shifted certainly since Krecl's publication and could reflect different particle concentrations and diameters under the current ratio scenario. More research should be done to understand how Norwegian burning habits influence the size and concentrations of emissions as the Swedish study did not discern between the two types of combustions technology.

7.5.2. Roadside versus background monitoring stations

This section will discuss how monitoring stations differ depending on whether they are designated as roadside stations or background station only when particulate size from PM10 down to PM2.5 is considered. NIPH describes particles resulting from combustion as fine (PM2.5) to ultrafine (PM0.1) and particles mechanically generated are coarse(PM10).

Figure 3

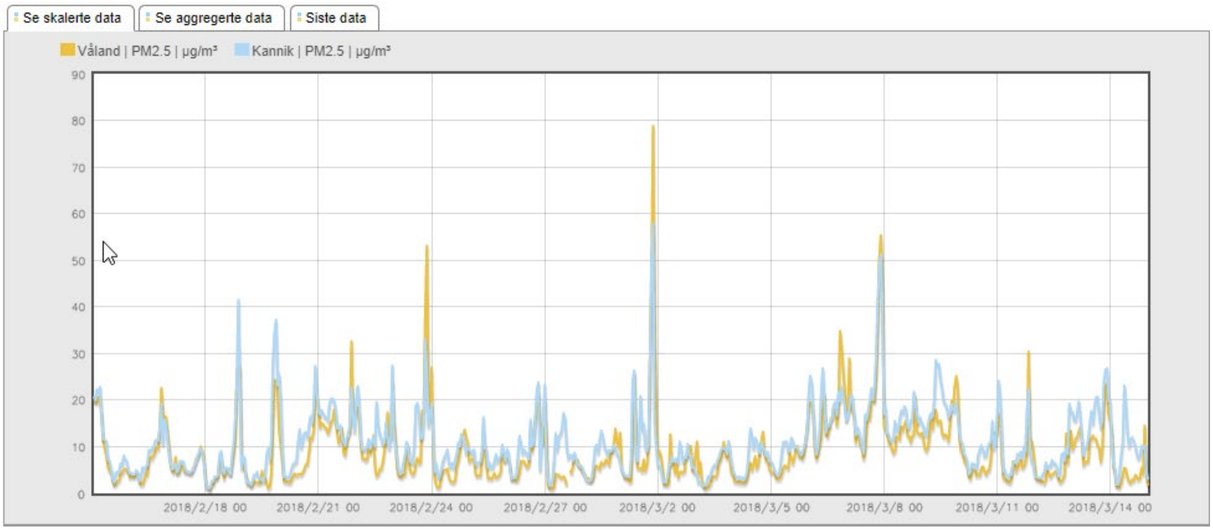
Temperature Data for 2018 from www.yr.no



Note. This graph shows the time frame when temperature was below freezing in Feb/Mar of 2018 when data is shown in the following figures. From yr.no, 2020 (https://www.yr.no/en/statistics)

Figure 4

PM2.5 Concentration in Stavanger (Feb 15-Mar 15, 2018) from https://www.luftkvalitet.info

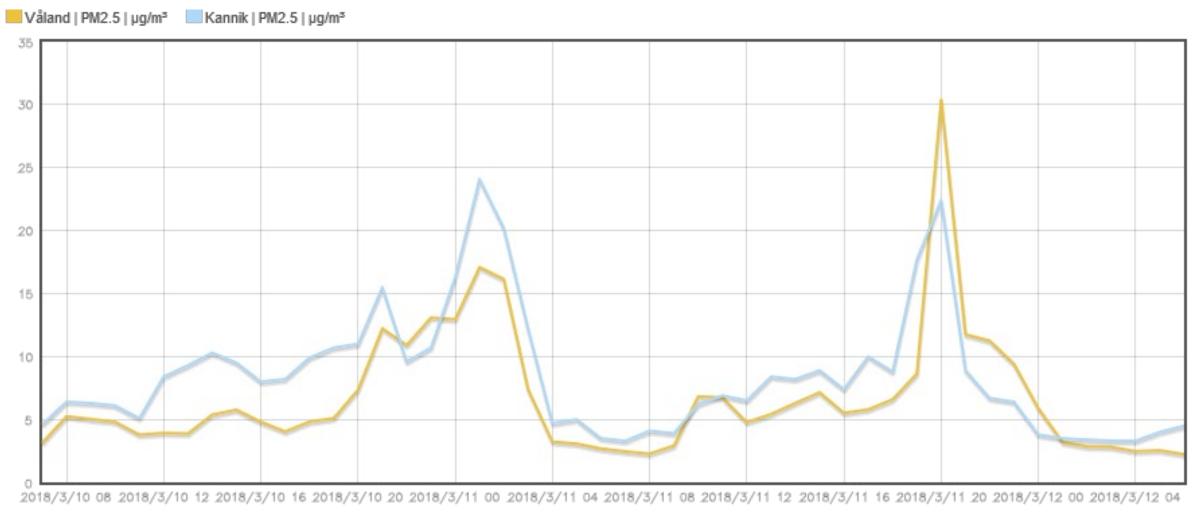


Note. The graph shows PM2.5 concentrations levels in Stavanger at Våland and Kannik monitoring stations between February 15 and March 15, 2018. Luftkvalitet.info database. Copyright NILU.

Figure 5 is one example of several data snapshots pulled out from NILU database in February and March 2018. Several similar data samples showed the same phenomena but with very slight variations in time. All demonstrated the same points I mean to bring to the readers attention, and I will discuss these with just one image. Våland is a background monitoring station in a dense residential neighbourhood near the centre of Stavanger and Kannik is a street side monitoring station meant capture PM2.5 concentrations of traffic also in the centre of Stavanger. Despite the stations measuring particle emission from different sources, they both behave very similar to one another. The following figure shows concentration peaks at 23:30 and again the following day at about 20:00. This type of pattern repeated itself on several days. The concentration values on the following image were between 17µg/m³and 30 µg/m³. However, on days with colder weather (between -11 and +1 Celsius) the concentrations were as high as 50 µg/m³ at Kannik and 80 µg/m³ at Våland, these also being typically in the evening or late night. These larger late-night spikes occur where there is little to no traffic on the roads, this especially being the case in the Våland neighbourhood. Due to little traffic and dense residences we can assume the PM2.5 spikes may be a result of wood stove burning.

Figure 5

PM2.5 Concentrations March 10th and 11th, 2018. Stavanger

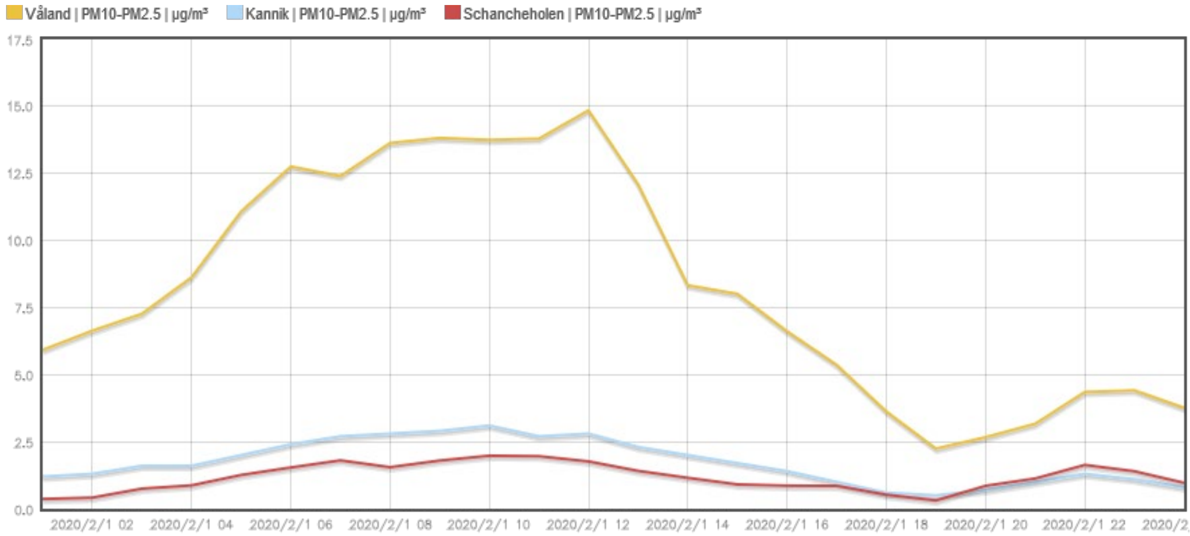


Note. This graph shows concentration peaks at 23:30 and 20:00. Våland (background residential station). Kannik (roadside station) www.luftkvalitet.no, Copyright NILU.

Figure 6 and 7 data snapshots from February 2020. They display slightly coarser PM which is between 2.5 and 10 micrometres in size. Shown is both midweek and weekend examples. It is interesting to see when looking at medium size particles, Våland monitoring station, which reflects background use such as wood oven emissions, not traffic emissions, begins to differentiate itself from the other two roadside monitoring stations, Kannik and Schancheholen. Figure 10 shows roadside station concentration values at the Kannik and Schancheholen remain low regardless of time of time day because it is a weekend and commuting traffic should be reduced. Våland station shows elevated concentrations from early morning until evening. This could mean that wood ovens are burning particles incompletely producing different size particles depending on oven technology. However, another theory for why the stations show different concentration levels could be smaller roads located in in the residential background station area are not maintained in the same fashion as the main roads. This difference could be reflecting recirculating dispersion particles from road surfaces. Main roads are treated with magnesium chloride when necessary to keep dust and particles from recirculating with traffic disturbance. However, the literature from study of particles size and concentration in northern Sweden supports wood ovens as the source(Krecl et al., 2008).

Figure 6

Stavanger Monitoring Station - February 2nd, 2020 (Sunday)

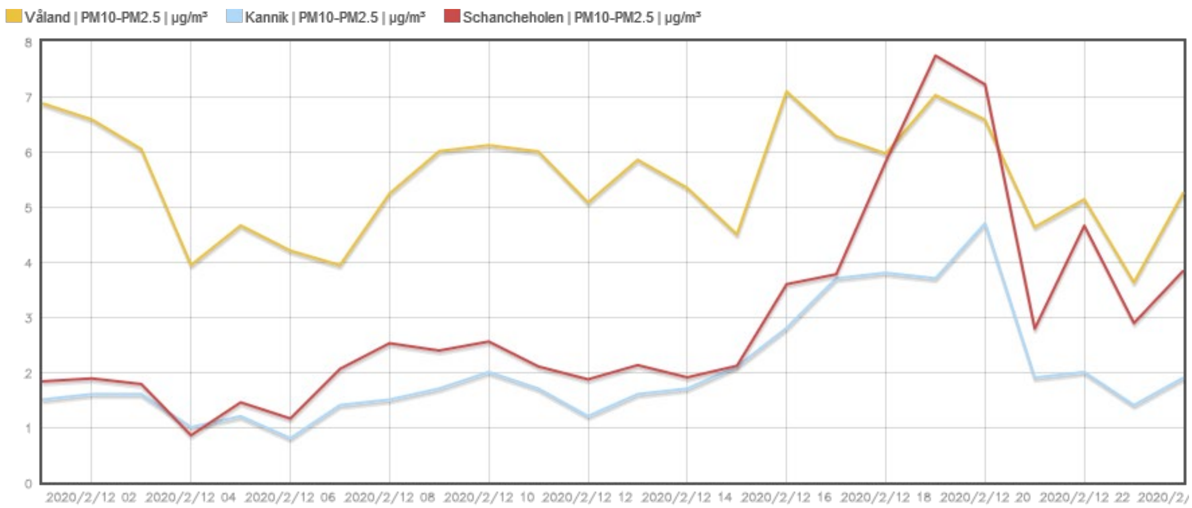


Note. This graph shows the roadside monitoring stations with lower values than the background Våland station. www.luftkvalitet.no, Copyright NILU.

Figure 7 shows Stavanger monitoring stations on a weekday. Although the values are not particularly elevated you can see the background station still exhibits an overall higher concentration and peaks are at midnight and 16:00 and 19:00. The two roadside stations, Kannik and Schancheholen have lower concentrations and show one major peak between 18:00-20:00.

Figure 7

Stavanger Monitoring Station - February 12th, 2020 (Wednesday)



Note. The graph demonstrates the roadside stations have lower concentrations than the background residential station (Våland). www.luftkvalitet.no, Copyright NILU.

7.6. Are new technology ovens the solution?

The specific way Norwegians use wood ovens, late night smouldering, is especially detrimental for the environment, even when using clean burning ovens. The NIPH describes three categories of burning depending on the quality of combustion. One type of Norwegian burning behaviour is so typical culturally (Skreiberg O. & Seljeskog M., 2018) that the term smouldering flames in the Norwegian version of the article is translated as “night burning” or “nattfyring”(Norwegian Institute of Public Health, 2005). Is there new evidence that air quality values spike very late at night or early morning?

The habit of turning dampers down at night to keep the oven burning slower and longer in the night happens everywhere. In some places like Chile, it is to save money on wood while elsewhere done to preserve the house’s warmth for morning. This type of combustion is smouldering, a way of burning that makes the wood last longer but increases emission significantly, damaging the air quality and peoples health (Ruiz-Tagle & Schueftan, 2019). When the dampers are left open, with freer air flow, the wood is burned quicker but cleaner (Ruiz-Tagle & Schueftan, 2019).

The Norwegian mitigation strategy has been to replace older higher emissions ovens with more complete burning ovens that reduces emissions by burning gases with second or third additional air-intakes. This is a strategy that takes time due to the life cycle of a oven and the significant cost of replacement. A limited number of Norwegian municipalities have tried to escalate the rate of old wood oven replacement with new technology ovens by offering financial incentives to lower the cost of purchasing and installing new ovens. Cities like Bergen, Oslo, and Stavanger have implemented such ‘pant’ or refund schemes. Some smaller municipalities have also offered similar programs. These programs vary in money output and limited number of ovens each year. Funding comes from different sources. For example, Stavanger funds its oven exchange program with fees from cars that use studded winter tires contributing to road breakdown and larger particulate matter that recirculates from road traffic(Aamdal & Klausen, 2019).

While Norway’s overreaching tactic is to slowly convert its old technology ovens to the new technology type. It has paid out extensive funds in such programs. Research has exposed several weaknesses to this strategy. The problem with oven technology is how long a cast iron’s life is. A well made cast iron oven can last as long as 40-50 years (Mytting, 2011). Only the most recent and best ovens emit very little emission particles.

Maximum emission standards allowed for Norway from 1998 10g/kg, Denmark is 5g/kg (2015) and the voluntary Nordic Swan Ecolabel is 2g/kg (2017-2019) (Seljeskog, Sevault, et al., 2017).

7.6.1. Oven Design

Williams et. Al (2012) suggests wood ovens with larger oven chambers allows for better mixing which results in less emissions. However, Skreiborg (2017) points out that larger heavier ovens often come with larger glass surfaces. If these larges ovens were to be were fired with smaller wood loads, emissions could be higher because combustion temperature would be lower due to heat storage in the larger oven and losing greater heat through the larger surface area of glass(Skreiberg O. & Seljeskog M., 2018). Additionally, modern house construction is regulated with higher envelope insulation and requires ovens with smaller heat outputs and a flatter rate of heat release (Skreiberg O. & Seljeskog M., 2018). Otherwise better insulated houses are overwhelmed with heat.

The cockle oven is an old-fashioned masonry oven of substantial mass that stores the heat energy in soap stone, brick or ceramic materials. The heat of the oven is released at a lower more constant rate. After the oven combustion has stopped it can heat the area for 6 to 36 hours. Modern ovens typically reach their heat output suddenly and rooms overheat, resulting in users opening doors or windows to cool off the space. Sintef researchers have written about potentially mitigating the problematic heat release profile of ovens (space overheating) especially problematic in newer low energy residences which require ovens with lower heat output by using stone mass to capture and store heat for slow release, similar to the centuries old technology of masonry ovens or tile oven (Ricardo Luis Carvalho et al., 2014).

7.6.2. Efficiency

Older wood ovens, pre-1998 were given the efficiency rating of approx. 50%. However newer Sintef research has shown the efficiency of old ovens to be substantially higher than previously rated, approximately 67% and 65% (Seljeskog, Goile, et al., 2017). New technology ovens based on lab experiments have found new wood ovens not to be substantially better, with a rate of 72% and 69% (Seljeskog, Goile, et al., 2017). In order to achieve a higher energy efficiency, approx. 90%, wood ovens are run at a lower load resulting in higher emissions(Skreiberg O. & Seljeskog M., 2018). Selkjeskog further demonstrates emission factors for oven technologies are quite different based on the loading of the oven, whether partial or nominal load (Seljeskog, Goile, et al., 2017). Skreiberg of Sintef describes nominal loading which means the firebox of the oven should not be filled more than 25% with wood to ensure adequate air supply and draft up the chimney pipe(Skreiberg, 2016).

7.6.3. Emissions

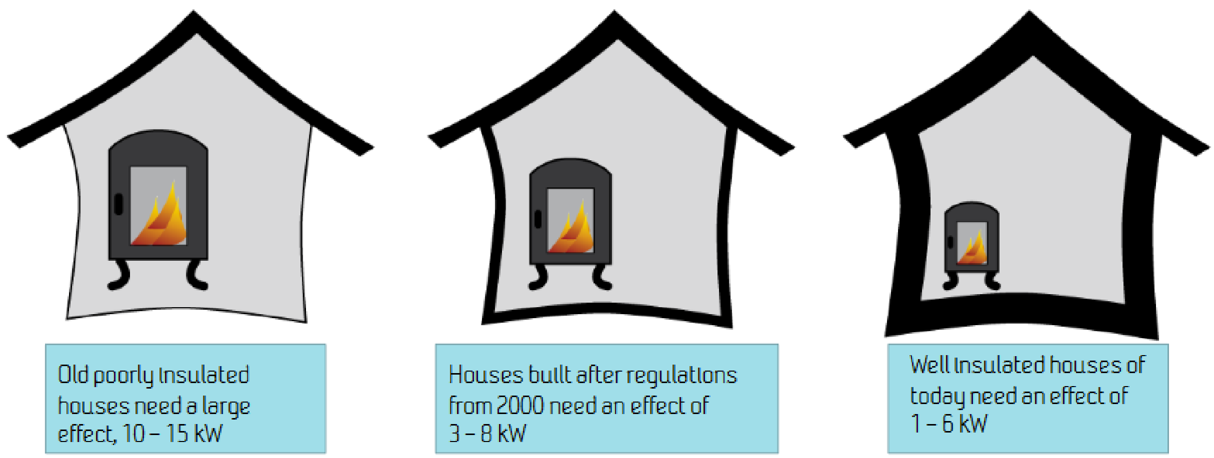
Uniformity of emission testing would make comparison among peer nations clearer(Skreiberg O. & Seljeskog M., 2018). Emission testing is not done using the same unit values. Norway measures emissions in terms of grams of PM per kilogram wood (g/kg), while other northern European nations uses micrograms per cubic meter ($\mu g/m^3$) (Levander & Svante, 2014). In North America, both the USA and Canada measure emissions in terms of grams/hour. This clouds the issue of regulation robustness and comparison of standards. This said, a benefit to the Norwegian testing method is calculating a weighted PM level of four different wood loads which ensures a oven is not approved that performs well on a full load but not partial loads or vice versa(Skreiberg O. & Seljeskog M., 2018) .

Norway's mitigation tactic has been to eventually replace older less efficient wood ovens with modern technology wood ovens. The problem with oven technology is how long a cast iron oven is its long life. A well made cast iron oven can last as long as 40-50 years (Mytting, 2011). Only the most recent and best ovens emit very little emission particles (Skreiberg O. & Seljeskog M., 2018). Norway passed regulation introducing the standard for wood ovens (NS 3058) to emit no more than 10g/kg wood (Skreiberg O. & Seljeskog M., 2018). Norway has not lowered oven particle emission standard in over 20 years. The Nordic Ecolabel has a voluntary swan label in which the following emission standards must be met in order to market under the Nordic Swan ecolabel. Between 2014-2017: 6g/kg and between 2017-2019 5g/kg(Nordic Swan Ecolabel, 2019). Although encouraged by the improvements in state of the art wood oven technology, and the swan label, the Norwegian government has not yet lowered its emissions level from the 1998 level (Skreiberg O. & Seljeskog M., 2018).

7.6.4. Smaller households

Figure 8

The future of wood firing in Norway. Different heating needs based on type and insulation of house. Source: Sintef, Skreiberg, Ø, (2017)



Regulation in Norway has mandated new construction to be low energy. Ovens in low energy houses must produce less heat overall or capable of storing the heat for later use or distribute to other areas of the house (Ricardo Luis Carvalho et al., 2014). Ovens that produce less heat however burn less efficiently and ovens that are energy efficient often only do so at low load which results in higher emissions(Skreiberg O. & Seljeskog M., 2018). Caravalhos study comparing building type(old and poorly insulated versus modern tightly insulted) showed no difference with the amount of wood used (Ricardo Luis Carvalho et al., 2014).

7.6.5. User knowledge

“Years of (mal)practice, does not make you an expert.” Øyvind Skreiberg, Sintef, 2017

Australian researchers identified the university town of Arnidale which had a long history of educational best-burning campaigns and a rebate replacement scheme for cleaner burning ovens (Todd, 2003). Awareness was increased but emission levels were not affected by these tactics (Armidale-Dumaresq Council, 2003). Another emission lowering tactic that fell short was found in both British Columbia and Nez Perce Reservation in Idaho. Findings from both change out programs suggested that new technology ovens were not enough. In order to effectively reduce PM2.5 emission users needed technical help to operate new ovens (Allen et al., 2009; Ward et al., 2011). New wood ovens coupled with old burning behaviour sometimes resulted in increased emissions in new ovens.

Lighting a fire, the proper way:

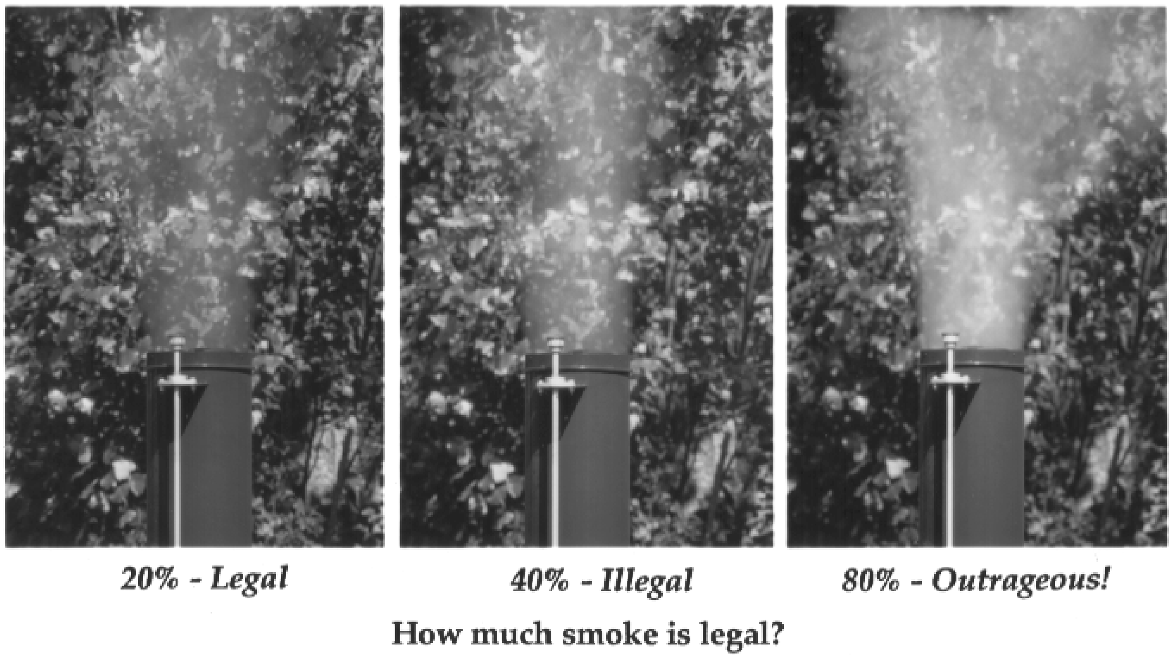
The beginning phase of lighting a fire releases many particles. During the ignition phase smoke is visible exiting the chimney or flue. This is when gas particles are not hot enough to be completely burned and instead form visible particles that are emitted. When flame in visible in the fire chamber, it shows volatile gases burning, which makes up 80% of the fuel in wood (Burn Right, 2018a). If the fire is not hot enough the gases are still released but not completely burned. These will stick to the inside of the chimney, risk chimney fire, or be emitted out of the chimney as smoke or particulate pollution (Burn Right, 2018a). When a fire is lit properly this phase shouldn’t last more than 10-15 minutes. Puget Sound Clean Air allow complaints to filed for fireplaces where visible smoke of a density/opacity more than 20% is visible more than 6 minutes. Regulation 1, Section.9.11 Detriment to person or property:

a) *“It shall be unlawful for any person to cause or allow the emission of any air contaminant in sufficient quantities and of such characteristics and duration as is, or I likely to be, injurious to human health, plan or animal life, or property , or which unreasonably interferes with the enjoyment of like and property.”* (Regulation-I-Section-911, 2004, p. 5)

Purchasing an oven with too high wattage creates too much heat for a space results in overheating (Ricardo L. Carvalho et al., 2013). Most likely, the user will lower the air flow to limit the fire resulting in poor fuel efficiency and increased pollution(Burn Right, 2018b).

Figure 9

Legal and illegal chimney smoke, Source: Washington State Department of Ecology,



Methods of lighting the wood oven or fireplace. The top down method, putting kindling and smaller wood pieces on top of larger blocks of wood is the preferred method to reduce emissions during the ignition phase of burning (Slejeskog, 2016). This phase can produce a lot of smoke (particle emission) while the fire is become hot enough to burn efficient and clean. The opposite method, bottom up, of placing small kindling on the bottom and larger blocks of wood on the top. This method can tend to produce more soot and ash. If you light the wood from below the heat will cause gases to rise from the colder wood above, however there is not enough flames to burn the up the gases that form particles before they escape out the flue (Norwegian Institute of Public Health, 2005).

Fachinger, et. al's study demonstrates what factors are important for the user to be aware of to minimize emissions when using a wood oven. The type of wood (hard or soft) did result in compositional makeup of the particles but not the amount of emissions(Fachinger et al., 2017). Researchers at Umea University examined typical wood species used in Nordic ovens and found the most import factor to reduce emissions was the burn rate regardless of the species of wood(Nyström et al., 2017). Additional research from the same university examined the effect of wood type on PAHs and found a correlation specifically between Pine at a high burn rate and Spruce at a nominal burn rate(Avagyan et al., 2016) . Overall small, or very dry wood pieces and excessive air results in faster combustion which resulted in a shorter time in the burn chamber and enhances particles escaping up the flue(Fachinger et al., 2017). Additionally, fire starters, if not wood, lead to much higher emissions because of incomplete combustion when they burn at a much lower temperature(Fachinger et al., 2017)a.

The importance of user knowledge both to protect household health and outdoor emission was shown by Finnish researchers demonstrating how important combustions conditions are. They compared normal combustion versus smoulder combustion emissions and found toxically significant properties between the two groups(Jalava et al., 2010). Smouldering combustion showed much higher inflammatory and cytotoxic (cell toxicity) properties(Jalava et al., 2010).

8. Questionnaire

8.1. Motivation and objectives

The motivation for this questionnaire is to better understand what types of barriers are in place to lower emissions from the wood oven user's standpoint. The objectives are to understand the reasons people use ovens for heating, identify how knowledgeable users are about environmental effects of biomass combustion, and lastly, identify how knowledgeable users are about health risks from biomass emissions. This study contributes to understanding of how people use their wood ovens, what their reasons are for doing so and in turn design effective policy to mitigate environmental and health risk for biomass emissions.

8.2. Method of survey

The survey was attempted to be distributed nationally. All municipalities were sent emails with links inviting them to participate and share the questionnaire by letting residents of their municipality respond. Additionally, the link to the questionnaire was posted on Facebook pages that were designated as "Friends of a *particular region*" The questionnaire was designed using Microsoft forms, and respondents answered the survey using tablets, smart phones or computers. The survey focused nationally, one anyone who's municipality posted a link to our survey on the municipality page or by placing a short introduction and a link to the questionnaire on Facebook social media site that were generic site to people of a geographical location. For example, "Friends of Trondheim". Questions were selected around three main themes. 1) How and why people used wood ovens 2) Knowledge about risks and environment effects from Pm2.5 from ovens 3). Possible motivators to alter burning behaviour.

8.3. Survey Distribution

The questionnaire was distributed using social media (Facebook)and municipalities via online communication, similar to a crowd-source study pollution perception in the Oslo region (López-Aparicio et al., 2017). Stakeholder or special intertest groups were avoided to avoid bias from the respondent group. The link to the questionnaire was only open to accept responses for a 14-day period. Dissemination of the link to our questionnaire form used the online networking service Facebook or directly on the municipality's website or the municipality's Facebook page. The distribution was supported by a short text/description of Bergen's decision to ban old technology wood ovens from being used after Jan 2021. The following text was included as a suggested hook to spark interest and participation.

> *Are wood ovens damaging?*
>
> *Using wood ovens is a hot topic in some places in Norway. This is exciting because it touches something deep in the Norwegian character.*
> *Certain municipalities offer a public subsidy to exchange your old oven for a new one. Bergen has taken it a step further and adopted a ban against old polluting ovens starting in 2021.*

A student at UIS has put focus on this theme in masters thesis research and has made a questionnaire to find out what most people think on the matter.
What is the opinion of our residents?

Contribute your viewpoint and participate in the query that you find here: http://tinyurl.com/vedfyring-no.

Municipalities either posted only the link to the questionnaire form with the description of the survey or they included the short text about Bergen's decision. Without prompting, several municipalities also chose to independently include their own image to include with the description of the survey. The image chosen reflects the municipality's individual bias on the matter (or that of the individual responsible for making the post). For example, one municipality included an image of a modern oven in a sleek living room setting while another county chose to include an image of an old-fashioned oven in a rustic cabin setting. 11 municipalities chose to publish on their Facebook page and 4 of these same municipalities included it directly on their municipality's official web page as well. The link was additionally posted on thirty open Facebook municipality websites, such as "Friends of Alta municipality".

8.4. Participation and survey sample

1429 individual responses were collected in a 14-day period (2019) with purposive maximum variation sampling. The survey used closed questions that were 'likert-type' with both 'forced choice' and 'check all that apply'. 13% of the respondents were between the ages of 18-30, 74.7% were between the ages of 30-59 years of age, and 12,4 % were 60 years of age or older. A weakness in the distribution of the questionnaire may have resulted in excluding older portions of the population who may not be active on social media. Additionally, as this was an opt-in online questionnaire, promoted through public municipality websites and municipal Facebook pages, there is no way to be sure it is actually representative of Norway's general population.

Feedback was only received from municipalities who considers biomass emissions an important topic or by individuals responsible for bulletin board publication think similarly. Reliability of response could be uncertain because it was an opt-in survey, potentially only attracting respondents who feel strongly one way or another about environmental pollutions, or health effects from emissions or people who are considering purchasing a new oven.

8.5. Considerations

Norway has several climate zones that can challenge homogenous reasons for burning behaviour. It has milder and wet southern coastal regions, colder more severe inland regions and the upper third of the country lies above the artic circle. Thus, comparing burning behaviour on a national level is not as ideal as doing so regionally.

8.6. Results and Discussion

In the following sections I will look at and discuss results from the query.

8.6.1. Oven usage

The majority of all respondents had the possibility for combustion at their residence. Only 5% of the 1429 questionnaire respondents had neither an oven nor fireplace. 73% of the respondents had a wood oven at their residence and 8% had a fireplace. 14% of respondents had both an oven and fireplace.

The user groups can be categorized into "*regular users*" (every day, 3-4 times per week or 1-2 times per week), "*very occasional users*" used the oven a few times a month or only on special occasions and lastly, "*never users*". For the purpose of categorizing use, the assumption was regular users depend on the combustion source as a primary or secondary heat source while the very occasional users' purpose was instead decoration or enjoyment. Decorative use for instance can be described as using the oven with an occasional glass of wine on the weekend, for a special gathering or to create a special atmosphere or ambiance in the home. There is some uncertainty whether the respondents who select using 1-2 times per week and a few-times-a-month are using the oven for heating purposes or for decoration or some practical combination of the two. Although 95% of the respondents reported having an oven or fireplace for heating, 4% of those respondents were "never" users, meaning 9% of the questionnaire respondents refrain from burning. 13% of respondents were "very occasional" users and 83% of respondents are regular users.

NILU found the emission factors lowered faster in Oslo compared to municipalities not offering oven subsidy incentives, but emissions and wood use were not significantly affected by the intervention (Lopez-Aparicio & Grythe, 2019)

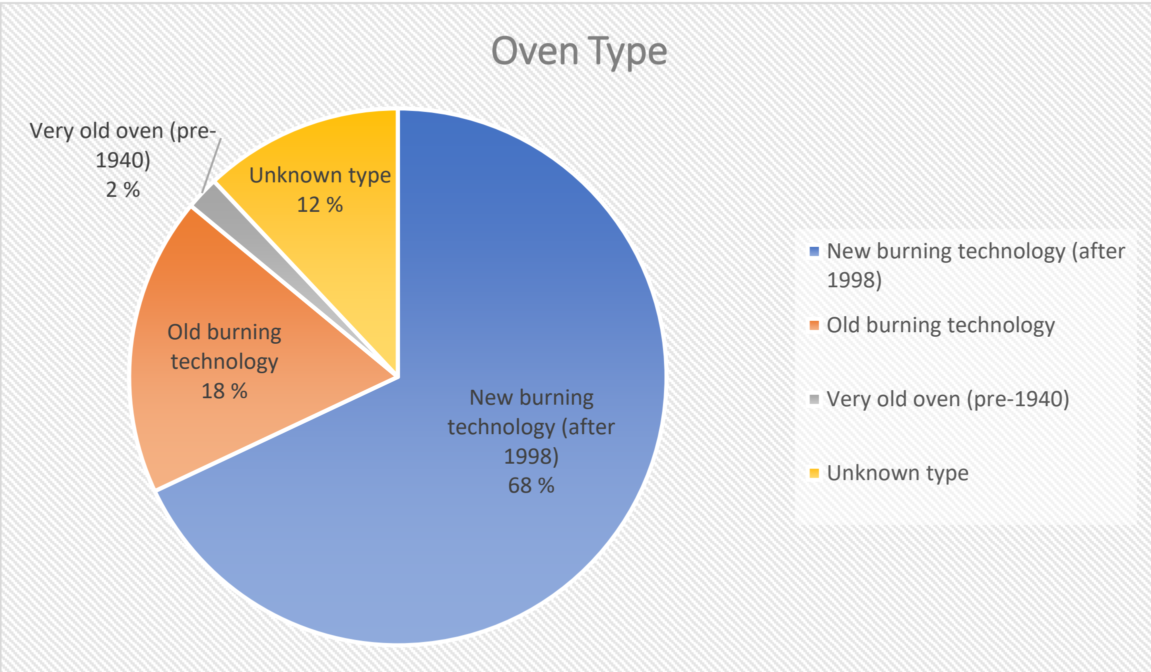
In order to decrease uncertainty around percent of old and new wood ovens installed and used, the local fire brigades should be asked to accumulate this information as part of regular bi-yearly chimney sweep/safety check and report it centrally in order to have an accurate emissions inventory. Alternatively, this information could be required as part of the census occurring each decade.

8.6.2. Type of combustion technology

68% of wood ovens owned had new burning technology (after 1998) & 18% were not old burning technology. 2% of respondents had very old ovens from before 1940 which functionally can behave as new technology ovens due to the ability to burn gases at several levels, lowering the emission amount exported out the chimney (Skreiberg, 2019). The remainder of respondents (12%) did not know the age of their oven or whether it was old or new burning technology.

Figure 10

Oven Technology Type



Note. This chart demonstrates the percentage of respondents that own each oven type**.**

8.6.3. Awareness of mitigation

It was assumed that most respondents were not aware of mitigation efforts to reduce pollution from wood ovens because the mitigation effort on air pollution in Norway has focused on traffic contribution. 65% of the respondents were not aware that some municipalities offer pant to incentive people to switch to new burning wood oven technology. It could be that the topic of oven pollution is being communicated to residents of municipalities that offer the subsidy. In order to discover if oven emissions were on the respondents' radar, they were asked if they were aware of Bergen's decision to ban old technology ovens in 2021. 81% of the respondents did not know that after January 1st, 2021 only new technology ovens can be used in Bergen municipality.

I want to know if people who don't have or use ovens are aware of wood oven politics…if they know about panting schemes. Is the topic on the common man's radar or not? Is the topic only being communicated toward residents of municipalities that offer pant?

8.6.4. Time of year

Figure 11

Frequency of Oven Use

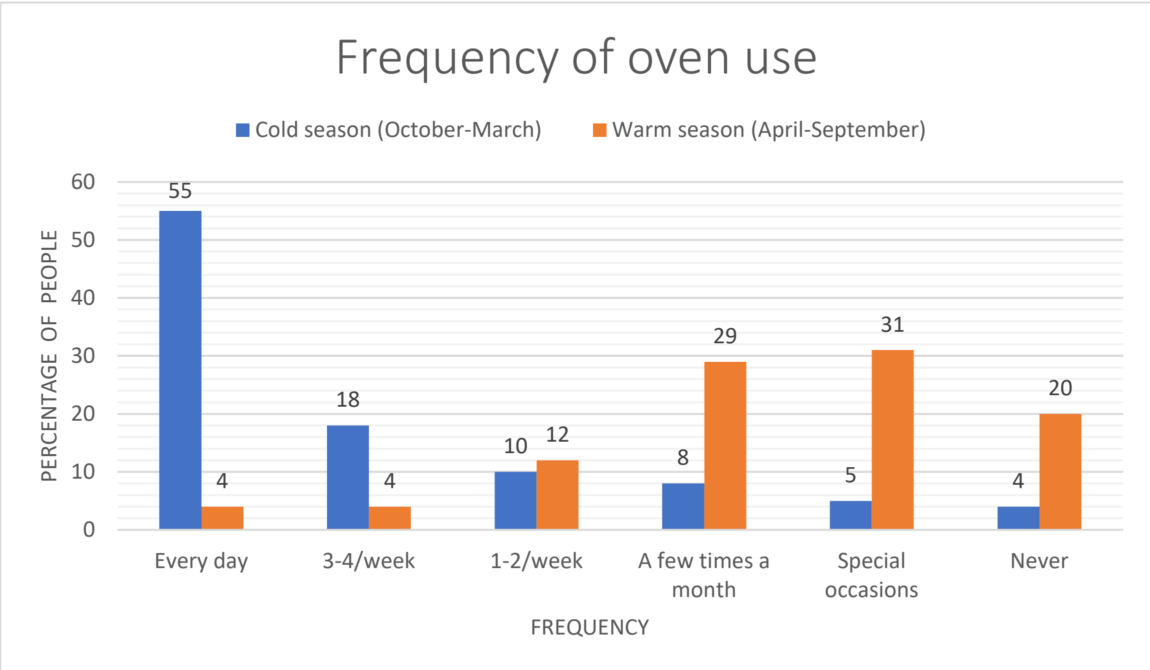
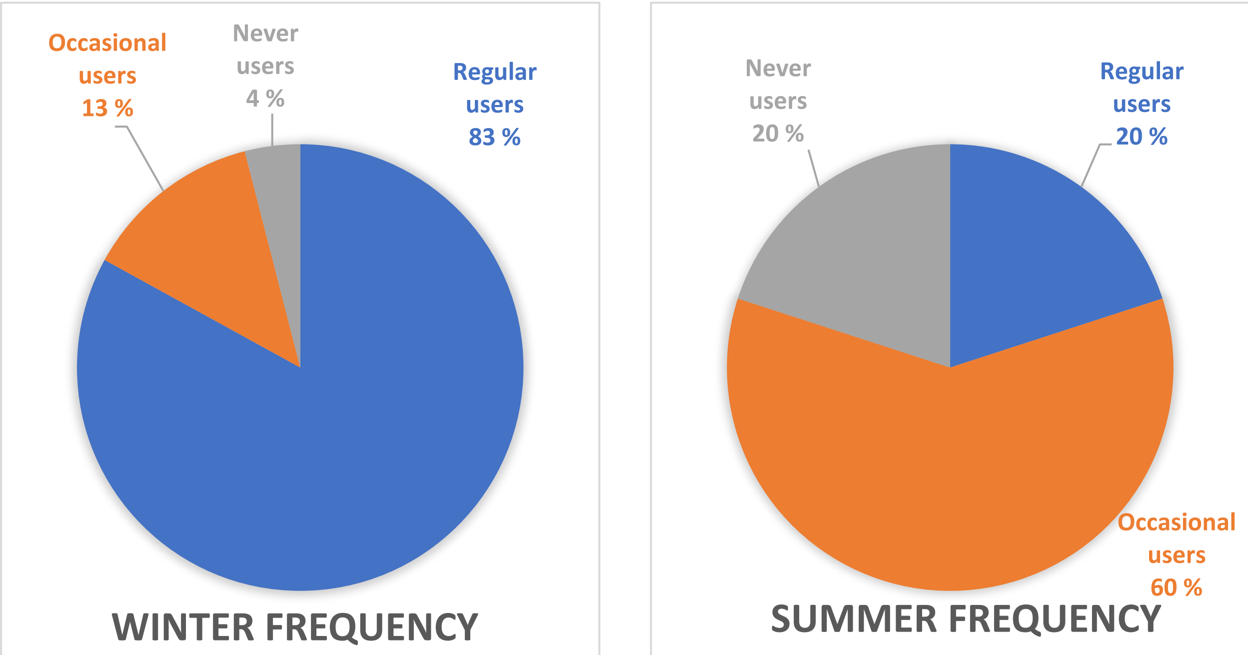


Figure 12

Frequency of Oven Use Dependent on Season: Winter/Summer

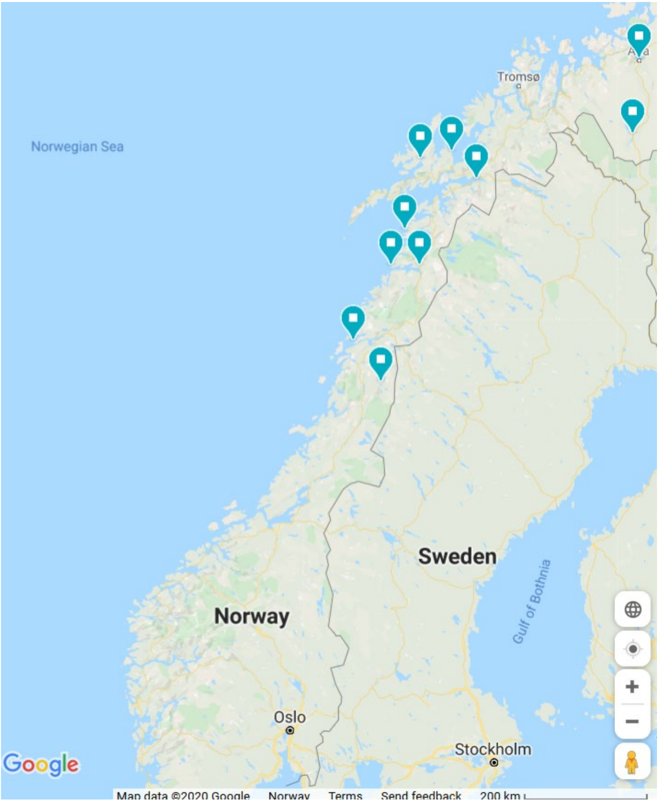


Note. User groups have been combined to create regular, occasional or never status.

The frequency of oven use was divided into two seasons or time of year. The cold season was defined as October through March and the warm season from April until September. As expected, the frequency of oven use was inverted when examining the summer period. During the warmer half of the year, 20% of respondents were "regular users", 60% were "very occasional users" and 20% were "never-users. It might be expected that northern countries such as Norway with colder climates require heating in the summer period. However, the finding that 20% of respondents used the oven regularly during the summer months is startling. The assumption was made that everyday summer users must be residents of the colder northern half of the country; however, this was not the case. Examining the respondent's municipality of residence that used ovens every day during the summer months, showed only 10% of these were in the northern half of Norway (located above the city of Stjørdal, on the 63° latitude). See Figure 13. This finding made it difficult to draw any conclusions based on geographical location. The municipalities that had many regular summer users (everyday, or 3-4 times per week) and had the largest number of respondents were located in especially rural locations, and typically were in the eastern inland portion of the country. 78% of everyday summer users reported that their wood oven or fireplace was their primary source of heat. These respondents were located in northern Norway, middle Norway south of Trondelag and in-land in rural locations outside of the Oslo area. Of 42 users that used a oven for their primary heat source, and reported using it every day during the summer, 26 were new technology ovens.

Figure 13

Northern Summer Oven Users



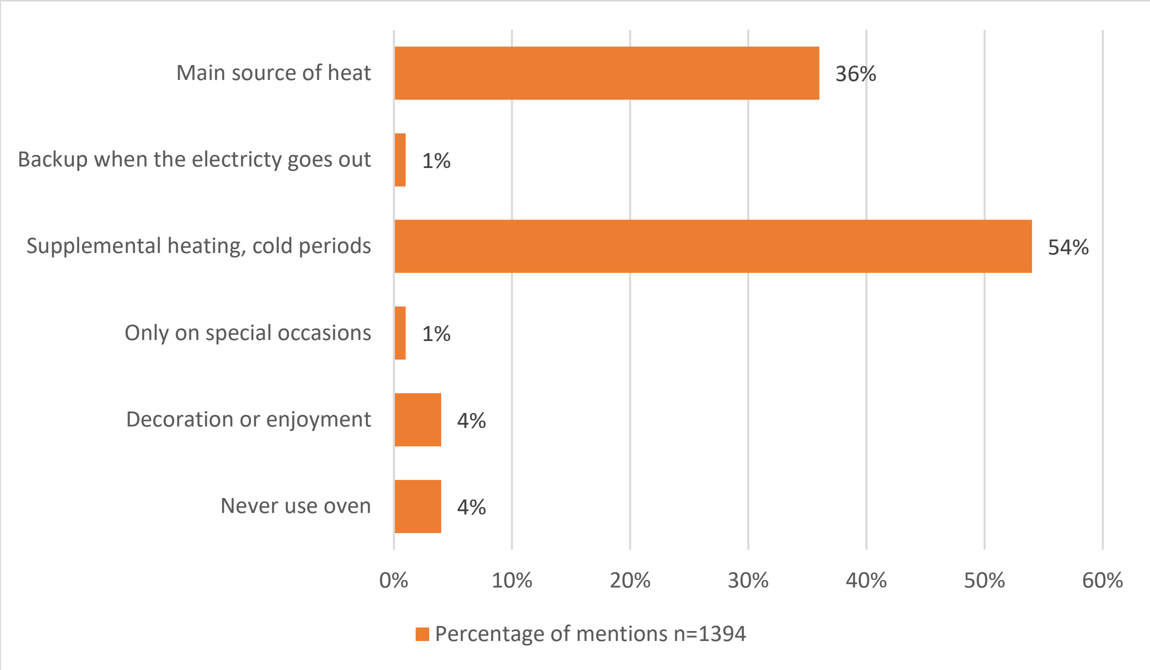
Based on the significant climatic variations it is more appropriate for burning regulation to be locally mandated, dependent on climate, population density and local topographical conditions.

8.6.5. Purpose of oven use

In order to understand behaviour barriers to reducing oven emissions, it is important to understand use-frequency, the reasons why people like to use ovens and how people use them in terms of practicality or recreation.

Figure 14

Purpose of Oven Use



Note. The majority of oven use if for heating purpose, not decoration.

The kinds of ovens people have in their homes can be a result of their perception of oven emissions as well as the perception of their own contribution to the problem of air pollution. In Norway, since 1998 only new technology ovens are sold but the motivation to purchase and install a new oven before the life cycle has run out and instead use an oven that still technically functions could be from lack of information about oven emissions. Information about air pollution sources and the mitigation techniques imposed on locally to curb emissions sends both direct and indirect messages about acceptable polluting behaviour. Disseminating information about health risks from wood ovens both from outdoor and indoor pollution as well as environmental impact on climate damage has taken second or third place to traffic contributions in Norway (Miljødirektorat, 2019; Norwegian Institute of Public Health, 2013). The fact that only one percent of respondents use it as backup when electricity goes out could reflect on the Norwegian electricity grid's stability even under harsh winder storm conditions.

8.6.5.1. Primary heating source:

A significant query finding is 36% of respondents said their oven or fireplace was their main source of heating. Within that module, 16% had old technology ovens, 71% had new technology ovens, 3% had very old or pre-1940 oven and 10% of this group did not know the technology or age of their oven. A very favourable finding is such a large percentage of the primary heat users have new technology ovens. On the other hand, over a third of the respondents, living in such a developed nation use combustion as the main heat source. 23% of these reported having houses that are poorly insulated.

8.6.5.2. *Supplemental heating:*

Of the people who use their ovens as supplemental heating, the makeup of oven technology was similar to those that use it for primary heating: 20% were old technology ovens, 67% were new technology ovens, 2% very old oven (pre-1940), and 11% did not know the technology or age of their oven.

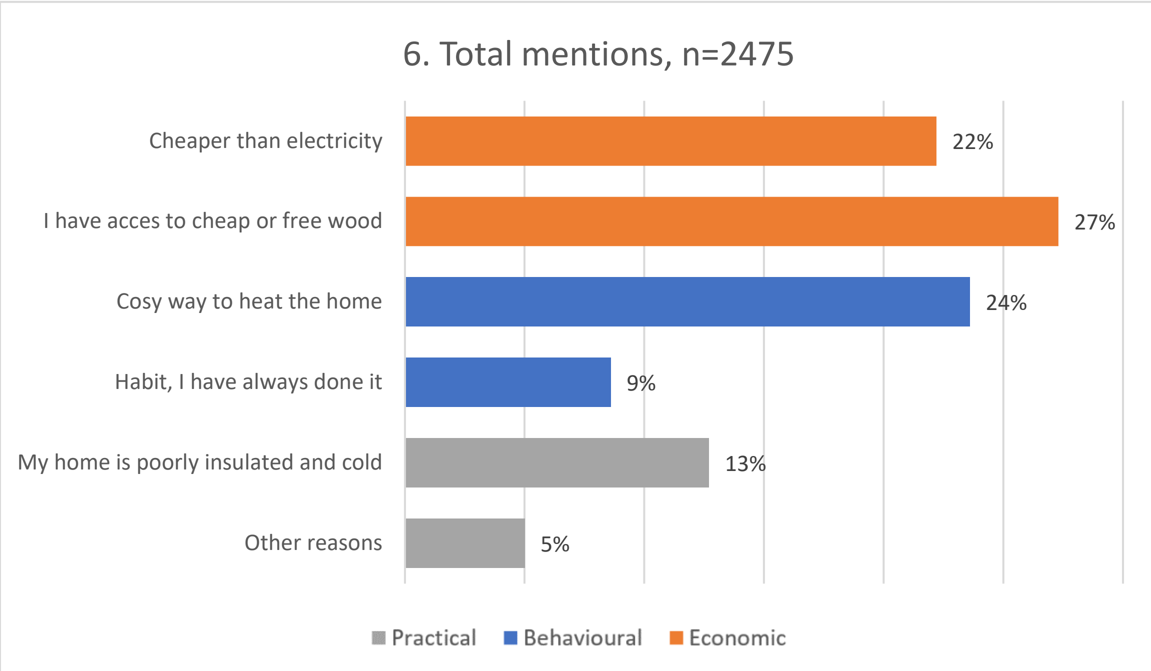
It is interesting to look at the type of technology the people who never use their oven have in order to see if the behaviour choice to burn or not reflects on the technology oven they have. 13% of never users had old technology ovens, 40% had new technology ovens, 45% did not know the oven type, and none of the never users had ovens from before 1940. Although 40% of the never-users had new technology ovens, it's important to point out the ovens could be as much as 22 years old.

8.6.6. Why respondents use wood oven

The reasons why people use their wood oven was broken down into three categories; economic, technical/practical, or behavioural.

Figure 15

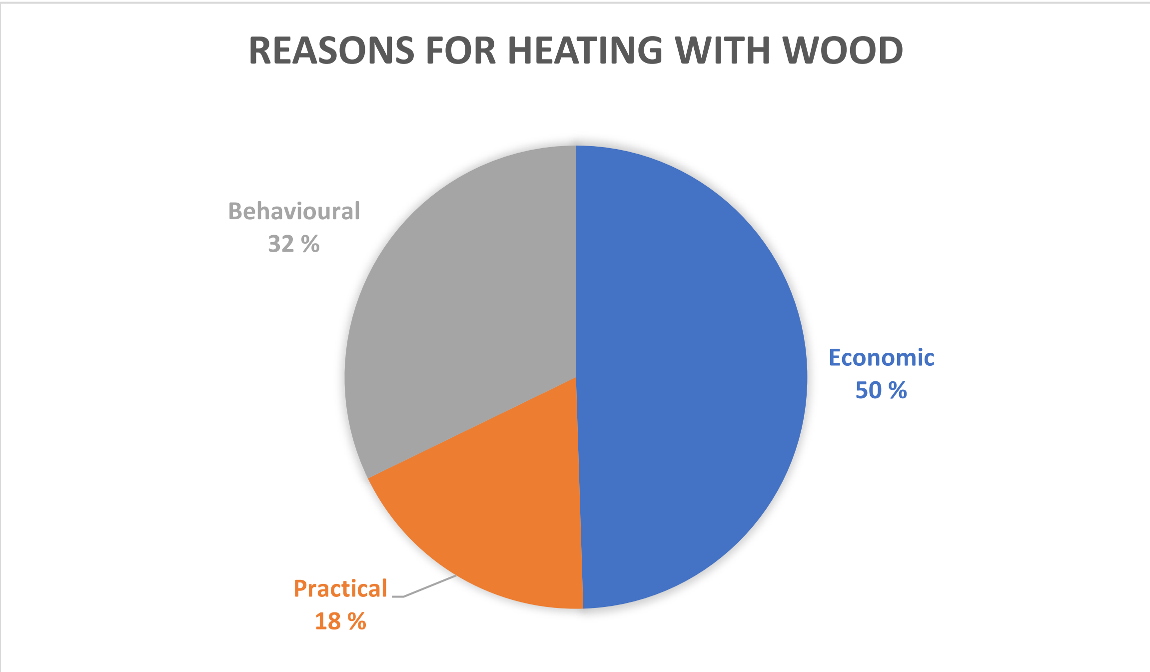
Why Respondents Use Combustion



49% of the mentions were for economic reasons; that it was either cheaper than electricity or because they had access to cheap or free wood. There is future potential for this group to be eliminated when electricity storage is optimised to save electricity overages from truly renewable sources (Fessler, 2019). In turn, we can assume that the reasons why people use ovens translates into a particular strategy directed at limiting their combustion behaviour. Respondents that heat with ovens for economic reasons may not be similarly motivated as those who burn for practical or behavioural reasons. People may use mental accounting and assume that buying two or three pallets of wood for the winter at about 1200 kroners a piece is still less costly than 2 or 3 stiff winter electricity bills.

Figure 16

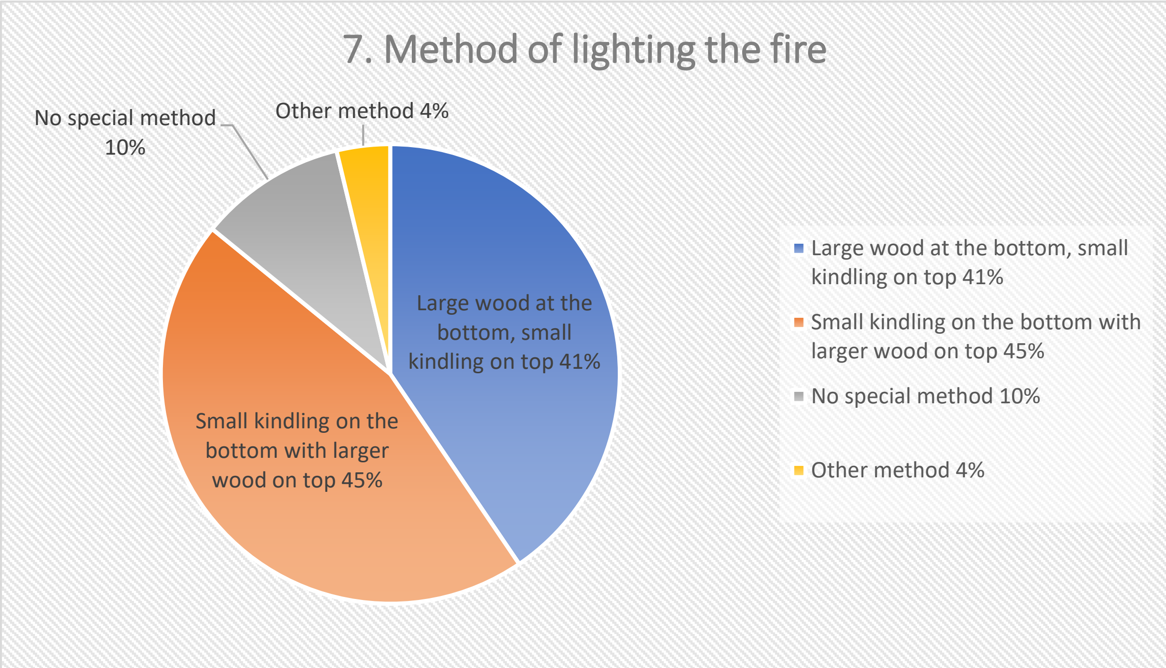
Reasons for Heating with Wood



It could be argued the method you use to start a fire is reflected on where or who you

Figure 17

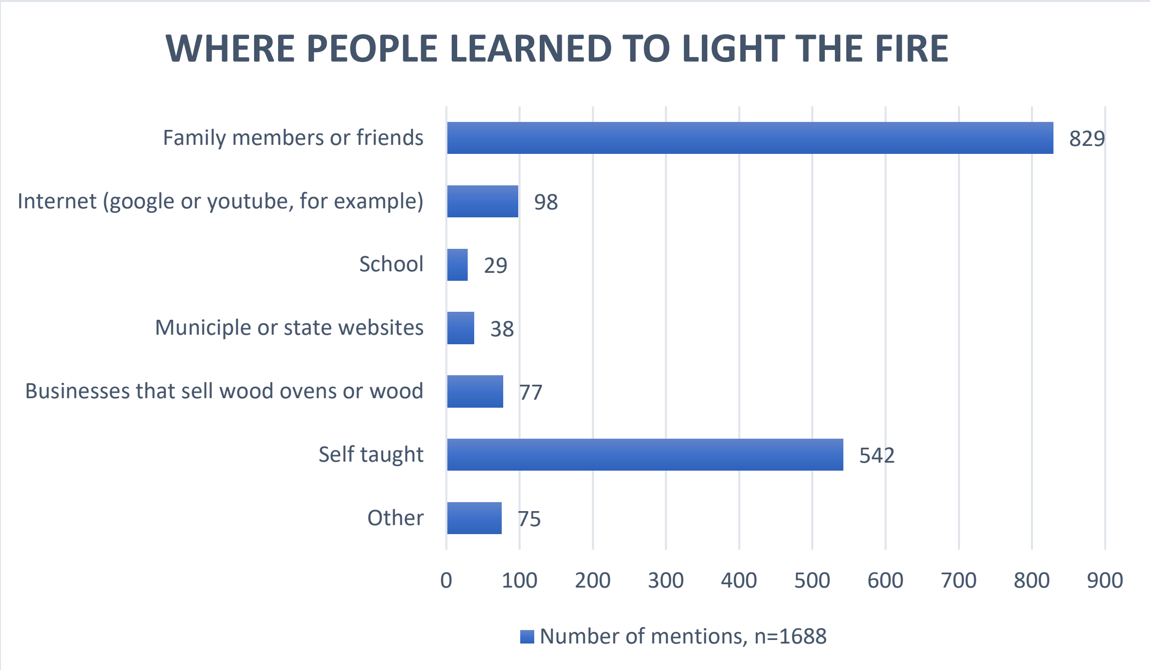
Method of Fire Lighting



learned it from. Since such a large percentage of respondents learned it from family or friends it is interesting to see if this reflects best-practices recommended by NIPH to minimize emissions from heated but not burned particles emitted from the flue.

Figure 18

Source of Learned Lighting Method



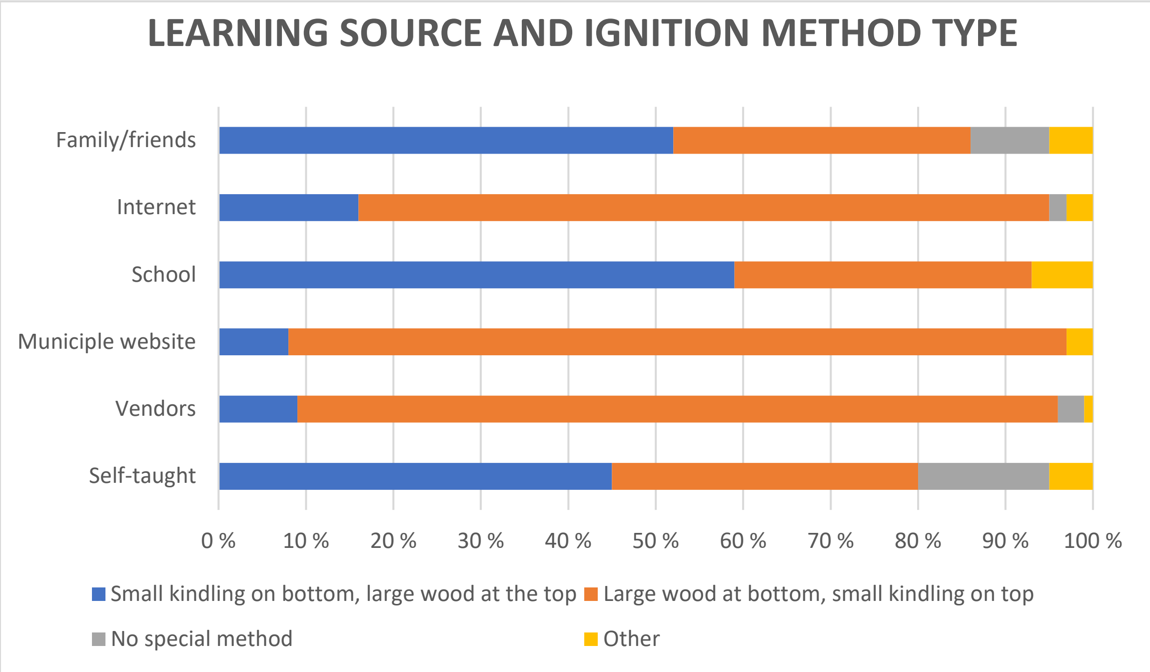
Source of Learned Lighting Method

The majority of respondents (49%) learned how to set and light a fire from their family or friends, but results show that who or where one learned the method from can demonstrate which method is likely used. See Figure 18. Respondents were first queried which method they used to set and light the fire, followed by where they learned the method. As Rogers demonstrated new technology adopters are more likely to search out information and use the preferred lighting method (Rogers, 1995). Consequently, if the respondent learned from the internet, a municipal site or business vendor, they probably use the best practices method of "top-down". The best practices method minimizes emissions during the ignition phase of combustion (Norwegian Institute of Public Health, 2005). Unfortunately, only a small number of respondents learned from either the internet, municipal web sites or a vendor, see Figure 19. If the respondent learned from family and friends, the chance is roughly 50-50 whether they use the bottom-up or top-down method. An intervention technique to educate should be directed at the family/friends group and the self taught for proper fire building technique.

The two largest groups of respondents either learned from friends and family(49%) or were self taught (32%). Contrary to Rogers theory on new adopters of technology, the respondents that used internet (6%) and municipal or state website sources (2%) were not younger. A limitation of the questionnaire was not asking education level. Few respondents demonstrated the attributes of early adaptors of innovation (seeking information out online or by vendors)(Rogers, 1995).

Figure 19

Lighting Method Based on Source of Learning



8.6.7. Health and considerations

Respondents may have a low awareness of oven emission having health implications. Unless the reader is asthmatic or has chronic lung disease it may come as a shock that using a wood stove is harmful at all. 21% of the respondents reported have a vulnerable person in the household, with the largest percentage being, lungs diseases followed by young children or babies. One possibility could be people may perceive heart disease and heart risk more severely than a child with recurrent lung infections thus discount it negatively and are more likely to alter their burning behaviour(Pol & Cairns, 2000). Risk taking decreases when the stakes are high and when the losses are perceived to be small people take or accept more risk. The group of respondents who seem most risk averse are those with heart conditions.

Figure 20

Household Members Vulnerable to Air Pollution

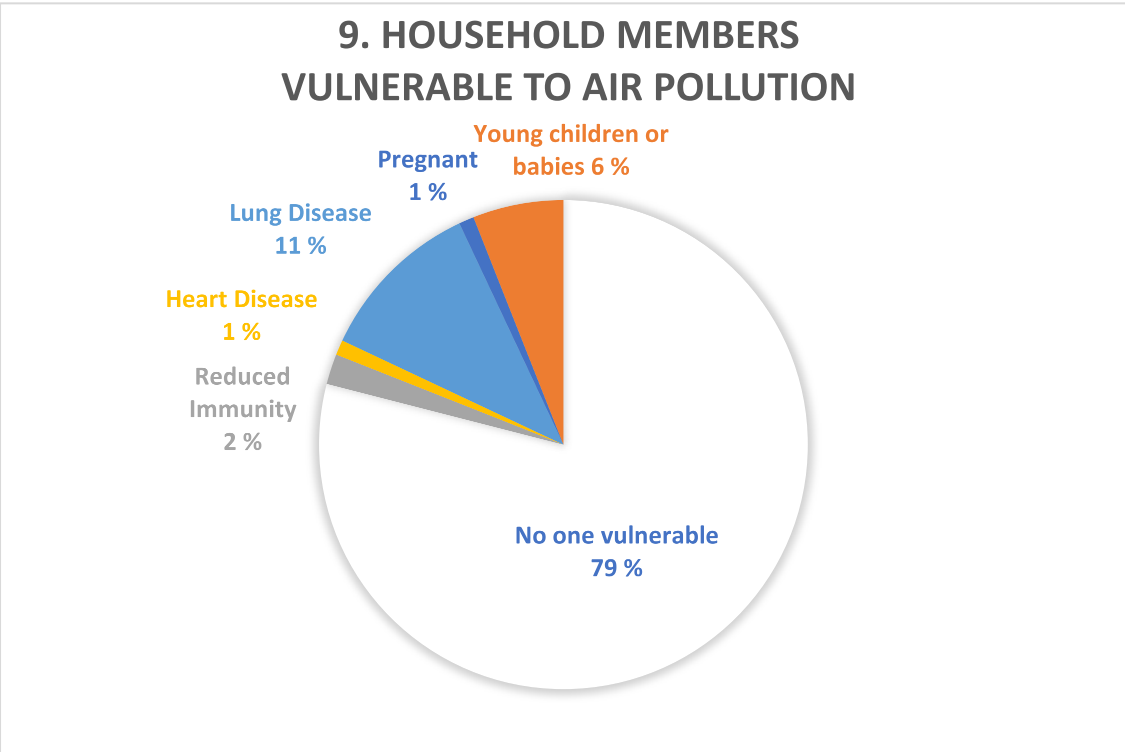
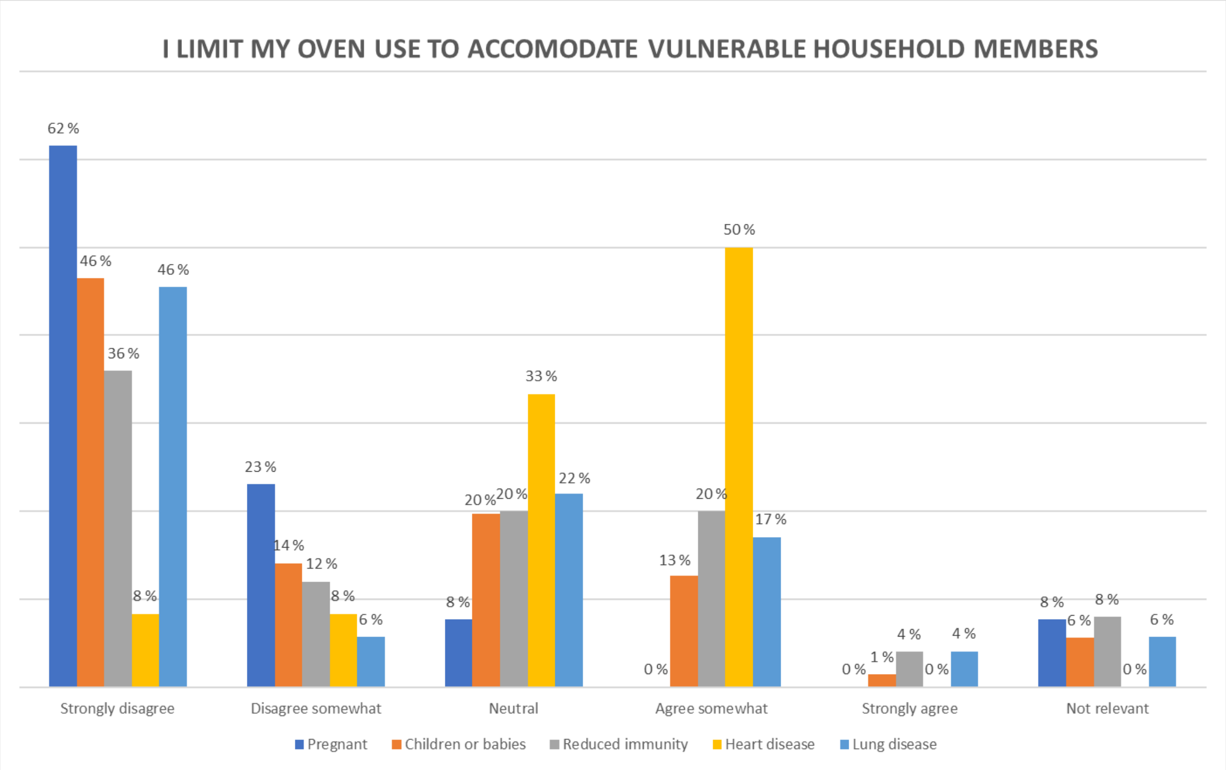


Figure 21

Limiting wood burning accommodating vulnerable household members



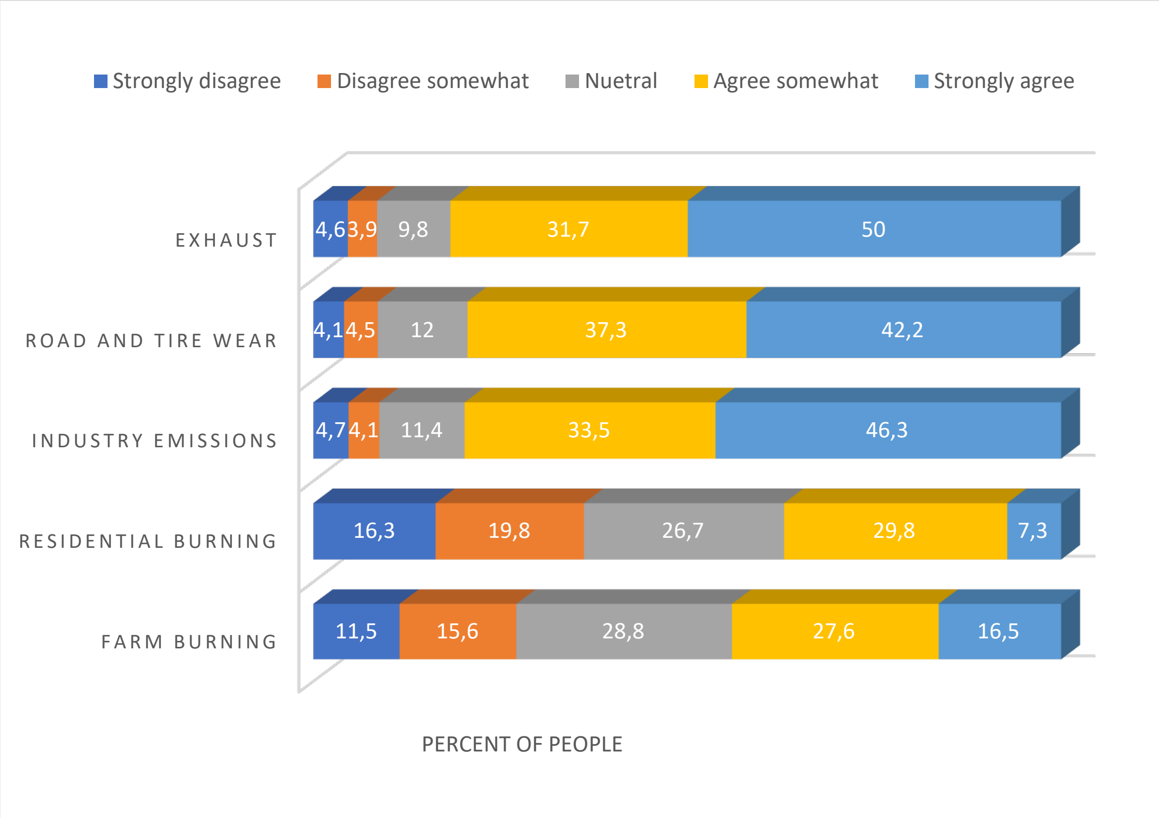
Note: when a respondent checked for having two or more different categories of vulnerable household members, all of the marked groups come out equally on this graph, since the respondent could only answer this question once (no matter how many in her/his household there were within the risk groups. None the less, trends are clearly visible.

Bothersome wood oven emissions:

The NIPH reports that air quality in Norwegian cities is at levels that emissions can normally cause bothersome symptoms (Norwegian Institute of Public Health, 2013). However very few query respondents reported pollution from wood burning as a problem in their neighbourhood. Nearly 70% of respondents said they were never bothered. 25% reported being very rarely bothered. This could result from living rurally with a low concentration fraction. *A small group (2%) said wood burning pollution was a problem daily or a few times a week in the cold season*. A closer look at the 2% revealed there were multiple respondents From Alta, Ås and Randaberg. Alta and Ås had relatively high number of respondents. It is up for conjecture on why respondents were not bothered by pollution, but the descriptive wording used in the questionnaire of symptoms could be too harsh and reflect very high pollution which is not often typical of Norway's air quality. Using less descriptive adjectives and leaving room for the respondent's own interpretation of bothersome symptoms could have resulted in a different frequency response. Additionally, the times oven combustion emissions are highest outdoors, as a study by the University of Montana reported, is from 10pm to 2am at night (Semmens et al., 2015). Symptoms would not typically be reported because very few people are active outside at these hours.

Figure 22

Factors that Contribute Most to Air Pollution

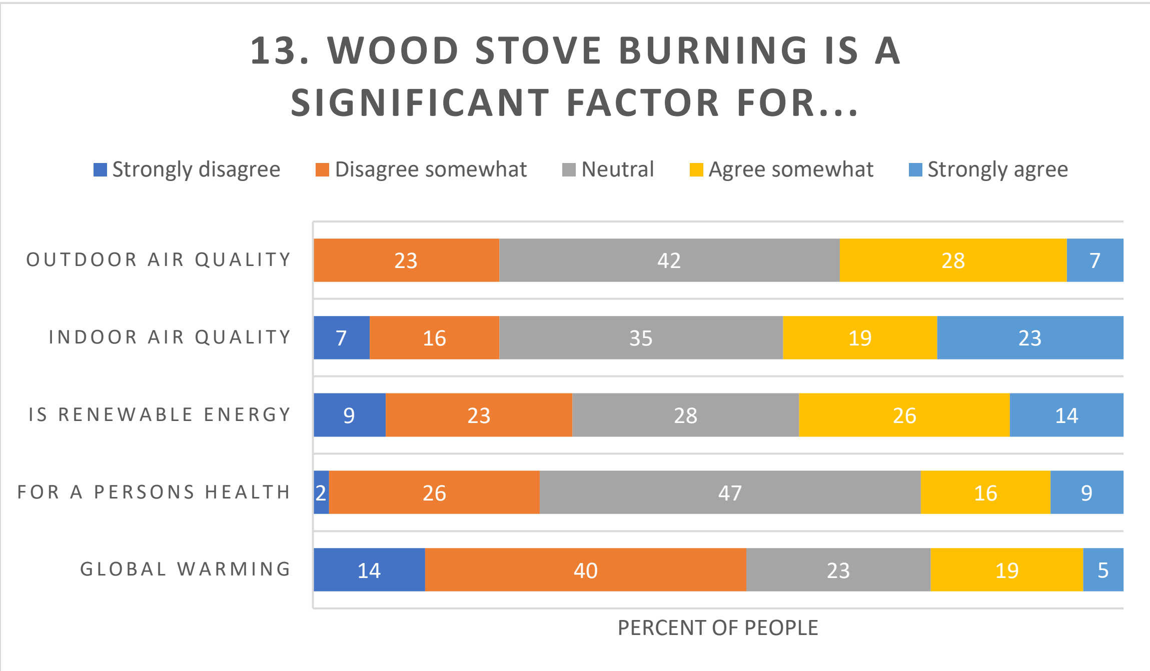


López-Aparicio et al., 2017A crowdsourcing study supported by a public participation GIS tool was designed and carried out in two Norwegian regions. The aim was to improve the knowledge about emissions from wood burning for residential heating in urban areas based on the collection of citizens' localized insights. We focus on three main issues: 1) type of dwelling and residential heating source; 2) wood consumption and type of wood appliances; and 3) citizens' perception of the urban environment. Our study shows the importance of wood burning for residential heating, and of the resulted particle emissions, in Norwegian urban areas. Citizens' localized insights on environmental perception highlight the areas in the city that require particular attention as part of clean air strategies. Information about environmental perception is combined with existing environmental data showing certain correlation. The results support the urban environmental management based on co-benefit approaches, achieving several outcomes from a single policy measure. Measures to reduce urban air pollution will have a positive impact on the citizens' environmental perception, and therefore on their quality of life, in addition to reducing the negative consequences of air pollution on human health. The characterization of residential heating by fuelwood is still a challenging activity. Our study shows the potential of a crowdsourcing method as means for bottom-up approaches designed to increase our knowledge on human activities at urban scale that result on emissions (López-Aparicio et al., 2017).

Oslo subsidy results: Since the results of Oslo's oven subsidy program showed only meagre results, it can be suggested that moneys could be alternatively used to fund microsensor networks to more accurately reflect real time wood emissions in dense residential places. This may provide greater certainty on local contributions demonstrating a larger response of emission mitigation resulting from ovens instead of only traffic. Additionally, if the network was partially crowd sourced, public awareness of wood combustion contribution to air quality and health risk might be augmented.

Figure 23

Wood Oven Burning is a Significant Factor

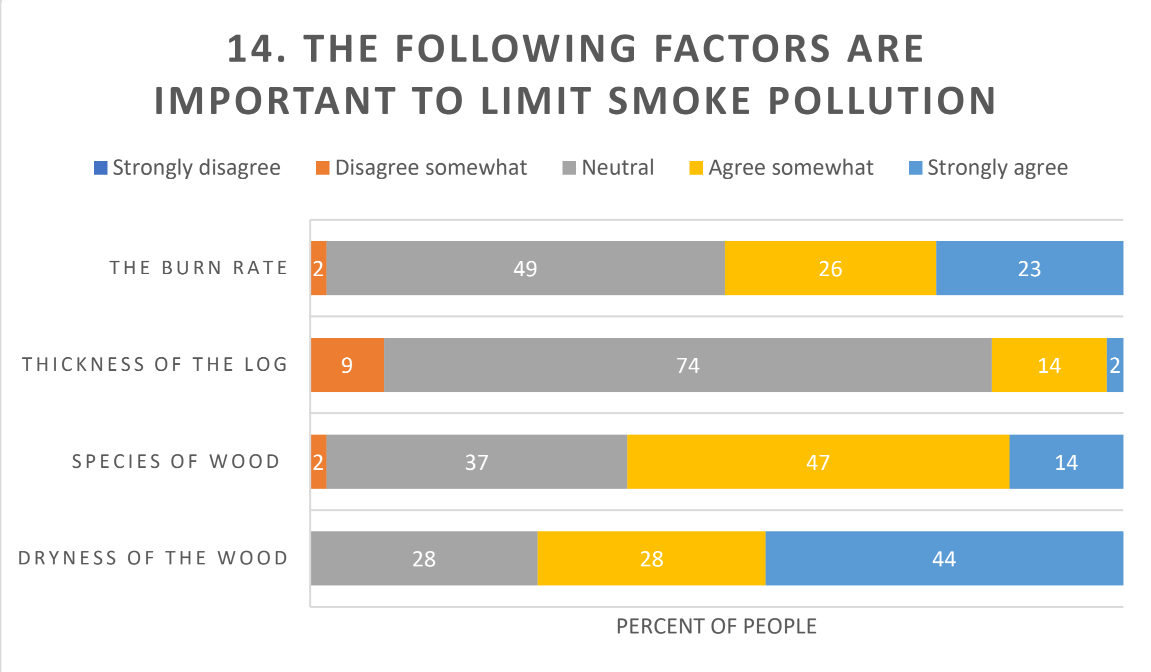


While 35% of respondents think oven smoke is significant for outdoor air quality, a greater percentage (42%), believe it is significant for indoor air quality. There is some discrepancy between the belief that its bad for indoor air quality and its risk for health. Only 25% agreed using a wood stove is significant on health.

There is the perception that

Figure 24

Factors limiting smoke pollution

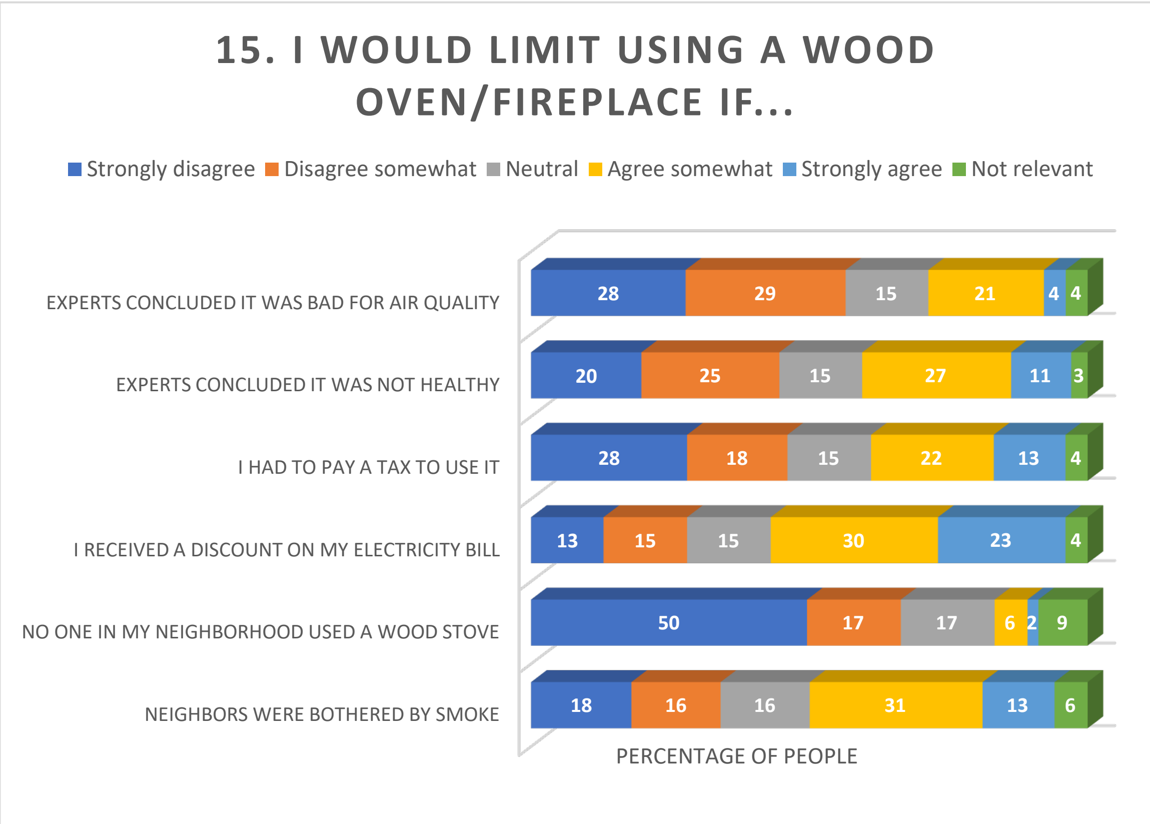


Respondent awareness of factors contributing to oven emissions varied. This was the only question resulting in no strong disagreement and had very little partial disagreement. This could be the result of two phenomenon. First, a general awareness that all burning leads to pollution and recognition that users' operational knowledge is effectual. A possible exception to this thinking could be the burn rate. Potentially, naive users may believe the burn rate is simply a function of the ovens properties and not a result of operational habits. Secondly, while other questions focus on opinion and attitude, this alternatively measures technical burning technique. In turn, out of social acceptance, respondents might be less willing to answer in a manner that demonstrates lack of knowledge.

Most respondents clearly demonstrated understanding the importance of wood dryness (Seljeskog, Sevault, et al., 2017). Respondents demonstrated species is an important factor in oven emissions. While a great quantity of research has been done about emission composition, limited studies have investigated how species affects emissions. Respondents may think species is important, but research has determined wood species says little about emission quantity. As described in the emission section 7.6.3 several studies review the makeup of emissions but species of wood is not significant for emissions (Fachinger et al., 2017; Nyström et al., 2017). Species however was a significant factor for PAHs content. (Avagyan et al., 2016). Experts agree and report the burn rate is the most important factor to effect emissions. Almost 50% of respondents either strongly agreed or somewhat agreed, and the other 50% were neutral on the matter. Since this module reflected factors that oven users have significant control over, there is a strong need to disseminate pertinent 6information through education/information campaigns relating to burn rate. Repetitive visual prompts hung on oven door handles as used by Ruiz-Tagle and Schueftan could serve to remind oven users the importance of controllable factors as discussed in user knowledge section 7.6.5 (Ruiz-Tagle & Schueftan, 2019).

Figure 25

Factors to Limit Oven or Fireplace Use



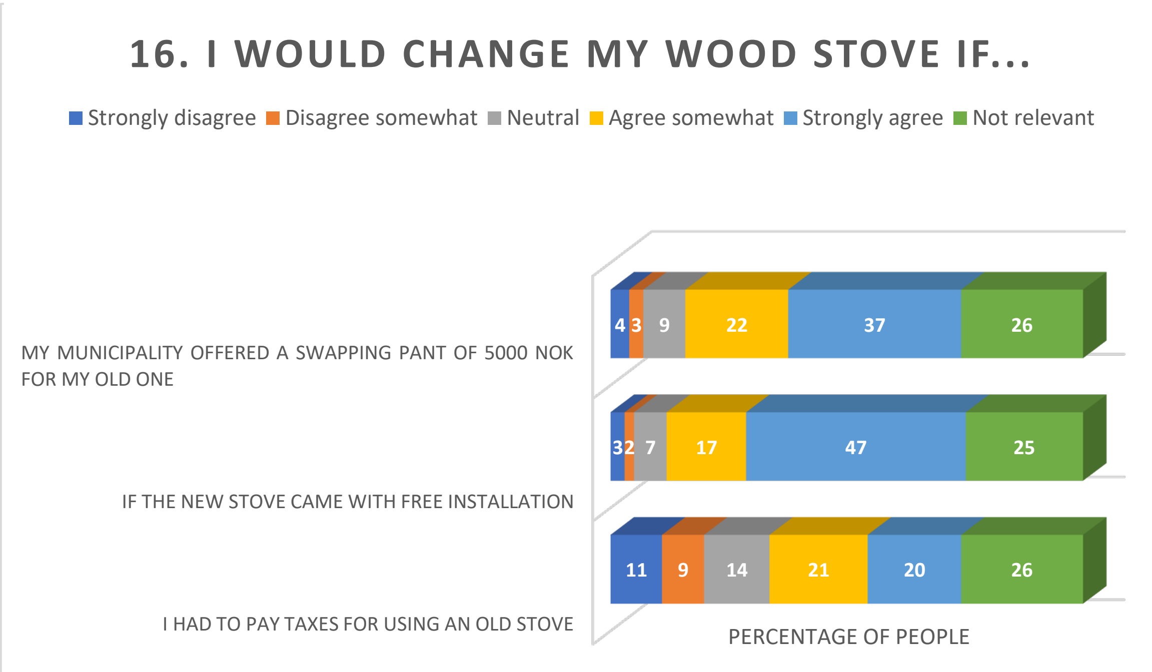
Potential factors to limit oven use were categorized as economic, behavioural, or knowledge based. The results were most widely divided on knowledge-based statements concluding either experts decided it was bad for air quality or bad for health. The results show even if the experts concluded against it for health (45%) and air quality(57%), users would tend not to alter their oven use. This demonstrates awareness is insufficient to change behaviour and adequate willingness must be firmly in place(Samson et al., 2015).

The largest responses of agreement with the limiting factors were economic based. Over half of the respondents (53%) agreed with limiting oven use in exchange for a discount on electricity payments. The next largest group (45%) in agreement were those who were loss averse and had to pay a tax to use it. Due to respondents being responsive to economic factors, we may find emission factors lower at slower rates as the assessment on Oslo subsidy program demonstrated in municipalities without subsidies(Lopez-Aparicio & Grythe, 2019). It is important for the reader to remember that despite emission factors improvement, the subsidy program did not have significant affect on wood use or actual emissions(Lopez-Aparicio & Grythe, 2019).

Respondents were not in agreement on the behavioural factors to limit oven use. Respondents were amenable to limit oven use if neighbours were bothered by the smoke, providing those bothered could overcome the threshold of addressing the issue with a neighbour. Contrary to social norm theory described by Frederiks, half of respondents strongly disagreed about altering oven use to fit in socially with neighbourhood normative behaviour(Frederiks et al., 2015).

Figure 26

Factors to switch to a new technology oven



Government programs to loan at low or no interest to incentivize purchasing zero emissions technologies (heat pumps) relieve the burden on less robust municipalities. could be less financial burdensome than small municipalities funding oven exchange programs for technologies that have uncertain emissions depending on user operating and knowledge.

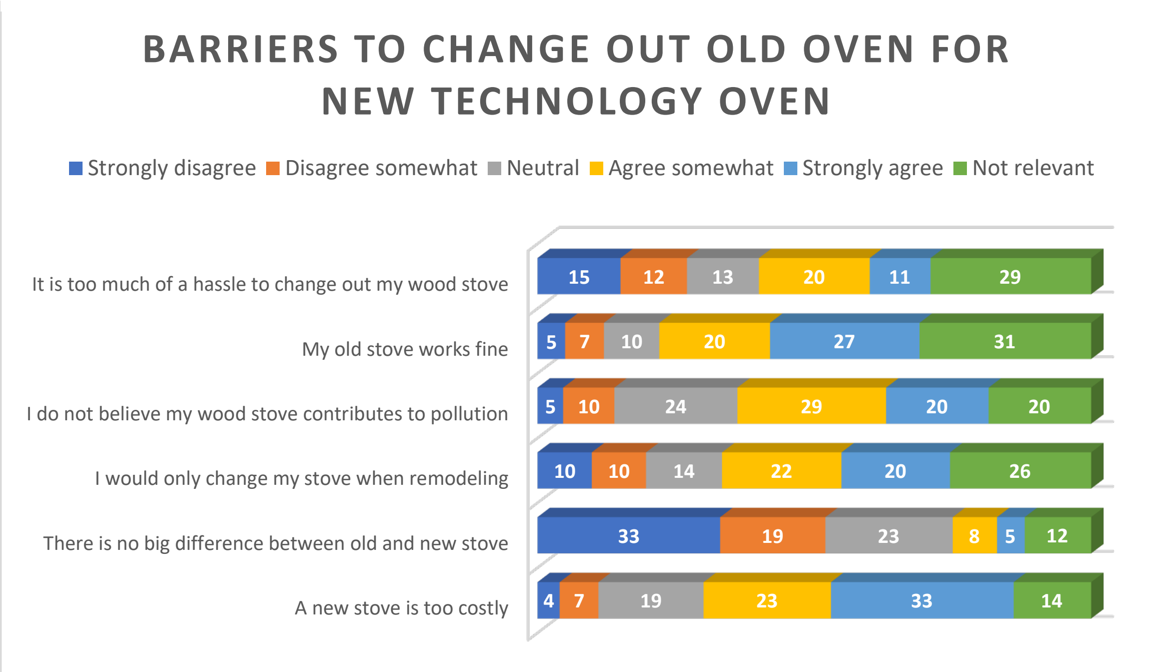
NILU found the emission factors lowered more quickly in OSLO compared to cities without oven change out subsidies but emissions were not significantly different and Oslo's wood use actually reduced the least(Lopez-Aparicio & Grythe, 2019). As Lopez and Grythe point out, a reason behind the low wood reduction could be people switched out old oven that were used seldom in turn for new ovens that were more frequently used(Lopez-Aparicio & Grythe, 2019). This can be an example of the sunk cost fallacy behavioural effect(Arkes & Blumer, 1985).

If an individual has an old technology oven and experts and agencies increasingly report the increased health and climatic risk of using wood ovens, he or she may choose to simply no longer use it. However, if a person recently went to the bother and cost to change out a wood oven (incentive or not) they may choose to burn more often than before simply to recuperate costs (sunk costs), even given that experts disseminate the same risk information (Arkes & Blumer, 1985). Possibly the incentives to switch out oven technology could be reinforcing people's propensity to burn more when they may not have done much burning prior to going to the expense to switch ovens.

The Oslo subsidy assessment revealed less impact than intended. If other municipalities choose to remove financial subsidies for new technology stoves, stove users may not feel motivated to change technology types. Most questionnaire respondents had ambiguous attitudes about changing technology types simply based on awareness from experts (intrinsic motivational factors)(Gomez Vilchez & Thiel, 2019; Schultz et al., 2007). Alternatively, the sunk cost fallacy is removed from the situation as people may not be burning more frequently than they might otherwise to recover extra incurred costs in terms of time, effort or kroners (Frederiks et al., 2015)

Figure 27

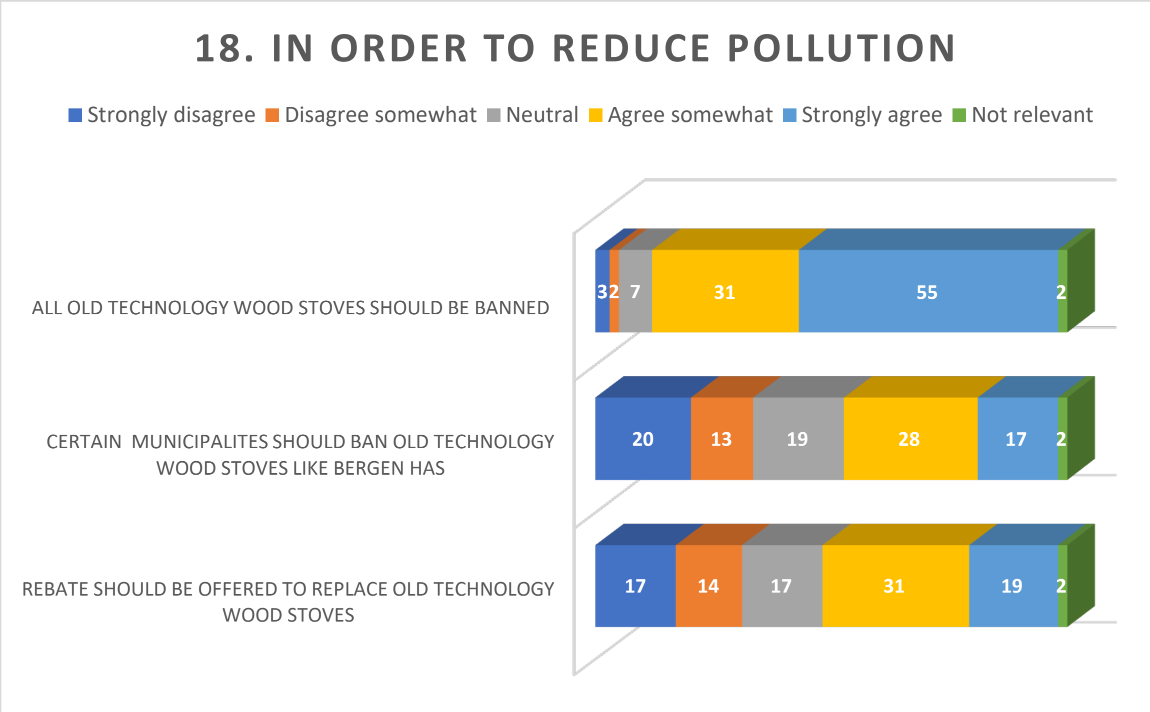
Barriers to Change Oven Technology



There were significant differences between acknowledging a general contribution of old technology stove to air pollution and personal acknowledgment of contributing to the emissions by burning in an old technology stove.(OTS) Only 13% of respondents agreed positively there was no big difference between OTS and NTS regarding emissions. On the other hand, 49% of respondents agreed that their OTS did not contribute to emission. See Figure 38.

Figure 28

Pollution Reduction



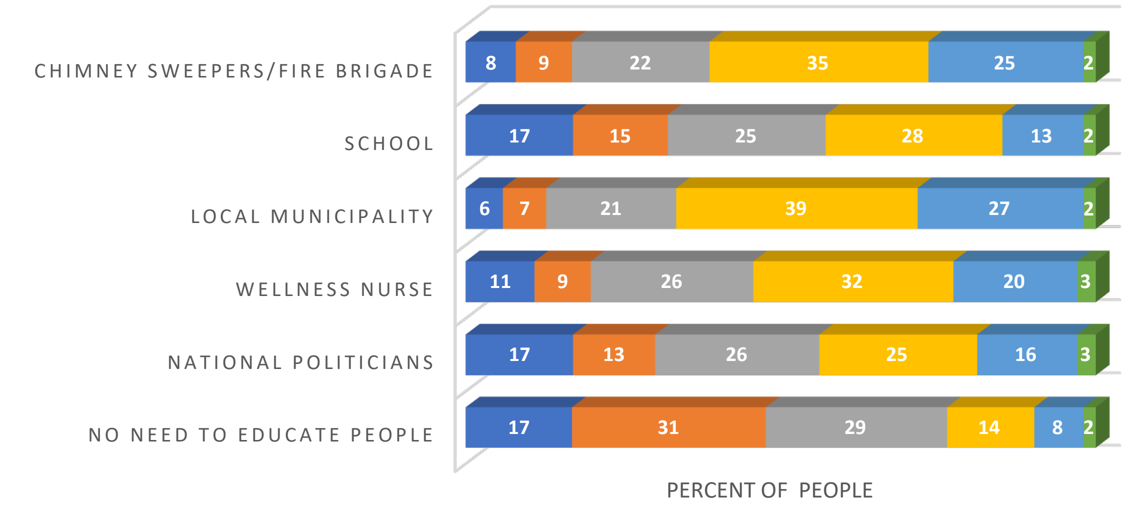
Note. *Respondents were asked how they felt about the above statements in order to*

The majority of respondents (86%) were positive to the statement that all old technology ovens/stoves should be banned in order to reduce pollution. This demonstrates a general understanding of the technological difference between the two types of burning technology and acknowledges old oven technology as a heavier contributor to pollution. The following query stated only certain municipalities should ban old technology stoves and resulted in a larger diversity of opinions. 33% of respondents disagreed that only certain municipalities should ban old ovens and 19% were neutral, which can be further interpreted as acknowledgement for the case of a need to ban all old stoves.

However, it disputes respondent described barriers to switching oven type from Figure 38. The principal of inertia is demonstrated from reasons given by respondents which potentially can impede individuals from switching oven technology from old to new. See Figure 38 which describes these barriers. 31% said it was too much of a hassle. 47% said their old stove worked fine and 49% did not believe their old stove contributed to pollution.

Figure 29

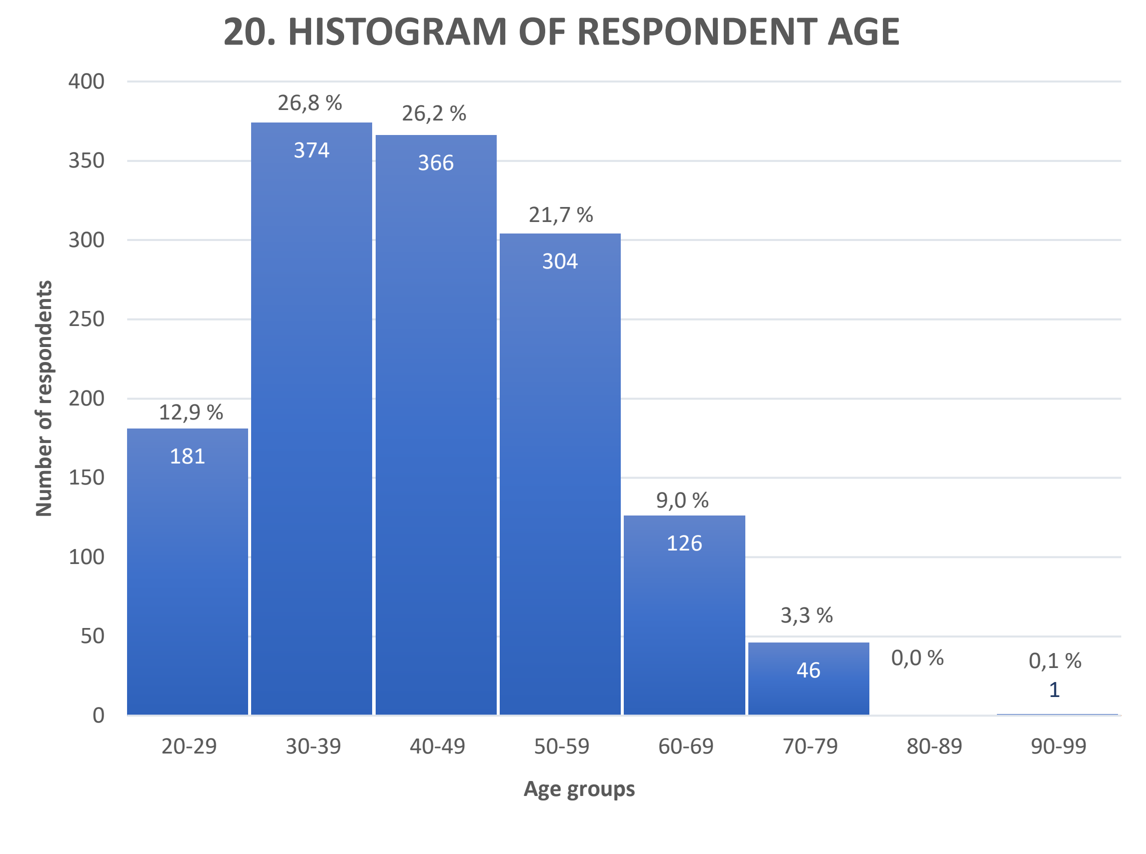
Emission Education Should Come From



Most respondents felt it was the job of the local municipality to education about smoke pollution. Local municipality emissions values may differ significantly based on technologies

Figure 30

Respondent age group



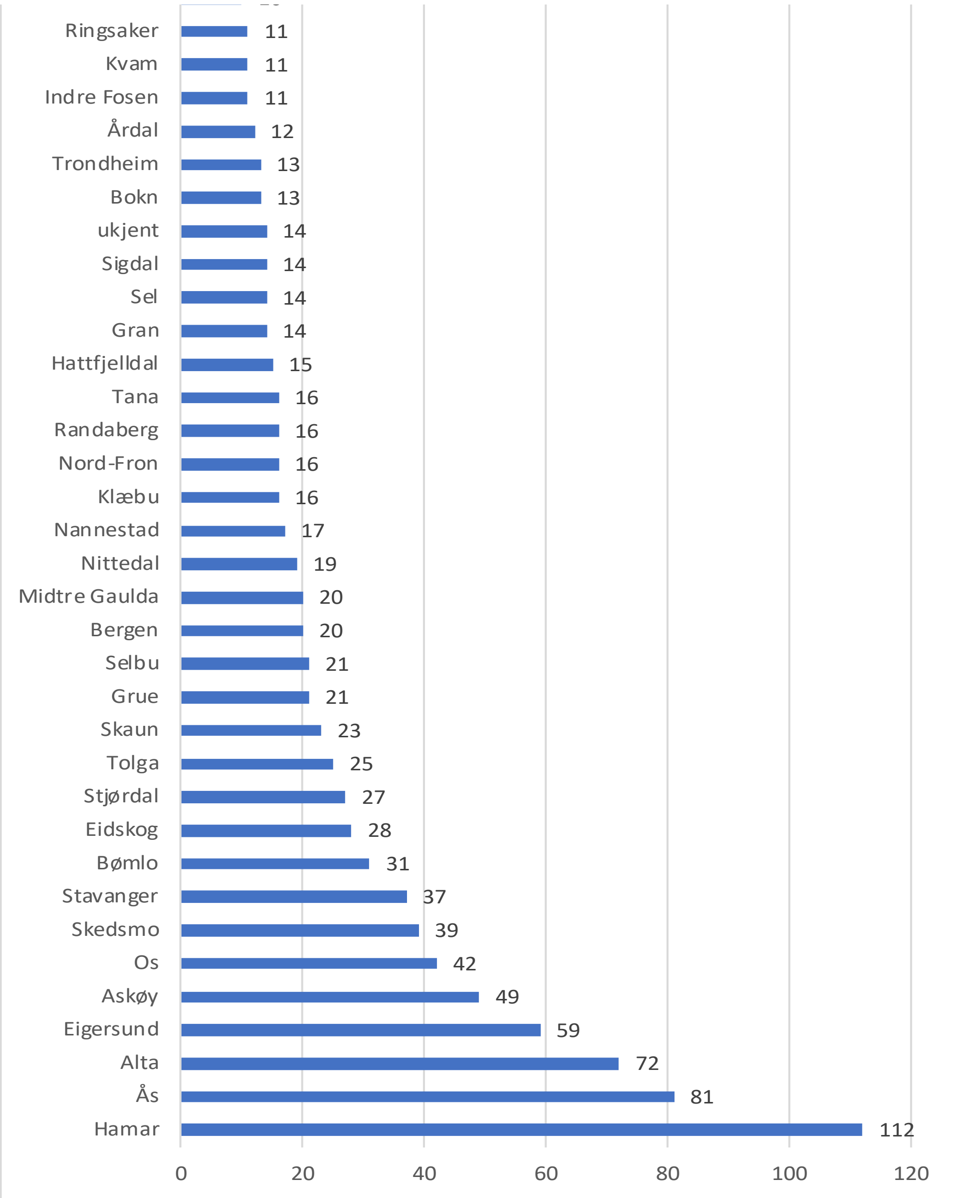
use, density of living, climate and even small towns can suffer poor air quality(Krecl et al., 2008).

Few respondents (12.4%) were over the age of 60. This is a weakness in the study, since the older population is often disproportionately affected by lung and heart disease compared to the younger demographic. Representing this group more equally might reflect a larger portion of respondents reporting health vulnerabilities. It could also show whether the older generation was more inclined to lay and ignite the fire a certain way based on methods passed down through family tradition, instead of seeking information from the internet.

Households with children under 18*, n=729. This assumes that each respondent comes from an individual household and are not doubled up by spouses. This is a weakness in the format of the questioning.

Figure 31

Municipalites with at least 10 respondents



Hamar was one of the X municipalities who participated by putting a link to the questionnaire on their web site. Do they suffer from bad air pollution? What were there responses to the bothered by air pollution question?

8.7. Weaknesses of study

Weaknesses:

Although the method of reaching respondents was taken from previous study, NILU, (López-Aparicio et al., 2017) crowd sourced, the respondents to the study may not be representative of the population, since only certain municipalities agreed to participate. It could mean that the topic was already on the radar of those municipalities with poor air quality or oven exchange programs. Also we found, the people that chose to be respondents were primarily in their 40s (27%) and 50s(26%) and 60s (22%). This could mean primarily only this age group visits municipal web sites or this age group is more attentive to the oven situation due to purchasing new wood ovens as part of house remodelling.

A weakness is not asking oven users whether they operate their oven with pollution emissions in mind. Sintef research in 2018 points out, provide the fuel wood is dry, that the most important parameter for emissions is the load of the oven(Skreiberg O. & Seljeskog M., 2018). Questioning the respondents about their loading habits should have been queried in order to ascertain their knowledge and contribution to emissions.

9. Conclusion

Respondents revealed as expected that wood burning is a lifestyle habit learned through family and tradition. The majority of respondents ignite the fire in the traditional method which enhance emission levels. Respondents have a low awareness of oven emission having health implications. It could be people are unaware of oven emissions because the majority of respondents stated they were not bothered by stove pollution. Experts say user operation of stoves is critical to keeping emissions low even in new ovens, but respondents were only correct and confident about the moisture of the wood. Loss aversion whether conscious by the user or not plays a role in choosing to heat with wood.

Overall people view on the source of poor air quality was reflected by what the authorities describe, traffic is the largest risk for poor air quality. It is surprising that respondents recognize stove burning being significant for outdoor and indoor quality but do not see it as a factor for personal health. Agencies and vendors over sell the modern stove technology as clean technology, misleading users to think its environment and health friendly. Policy development should focus on improving awareness but in a heuristic which residents can identify with. For example, the images of 6 trucks left running outside house for the evening. If people had a better awareness of the amount of emissions coming from new advanced stoves they might choose to heat alternatively. A surprising finding revealed that even if experts said PM2.5 wood pollution was harmful; most respondents would not limit burning. Awareness in this case is not enough to change behaviour. Only 1% of the respondents had heart vulnerability but they are the group that said they accommodate their wood oven habits the most. The group of respondents who seem most risk averse are those with heart conditions.

Respondents revealed they burn mainly for economic reasons and some municipalities speed the process of changing stoves type but at the cost of little emission improvement. Additionally, users would limit stove use if their electricity was discounted. Research showed poor air quality in homes with children often correlated with low income. Since Norwegians demonstrated economic motivation to use stoves, this area should be further researched in particular for children's health to ensure their welfare is not stratified by income levels.

Another area for future research should investigate how to accurately present risk to the public as literature revealed, modelling behaviour and repeat prop reminders are more successful than simple education.

There is a significant disconnect between the problem of stove pollution and people's recognitions of their own contribution to it. Respondents largely supported banning all old stove technology, but also believed their stove did not contribute to the problem of emissions.

Additionally, as a final note, if municipalities continue to subsidize exchanging old oven technology for new technology, effort should be put into examining *unintended* results. Due to behavioural economics and sunk cost, people may be motivated to actually burn more often then required, because they think it is 'clean' and harmless.

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