The environmental and health impact of the use of biomass fuel;

Summary of postgraduate student project at Cranfield University supported by the Gas Safety Trust and Milton Keynes Council, June 2014.

Students from environment and energy themed MSc courses at Cranfield came together to conduct a 10 week project to investigate the environmental and health impact of the increasing use of biomass fuel for the production of heat and electricity generation. Biomass use equates to fuel switching away from the current major fuels (e.g. gas, electricity) either for use in existing buildings or in those to be built in the future. Biomass burning creates a range of gasses and particulate pollutants, and has characteristics that differ from those produced by combustion of other fuels. This could have both local and national implications for air quality and health.

The 15 students were split into two groups; one focussed on domestic application and the other on non-domestic. Both groups explored the background issues and likely future scenarios. There was a particular focus on implications for Milton Keynes (MK) although some findings could be generally applicable to other regions. The project period was 10 weeks and this had to include developing a study plan, approval of risk assessments and methods, familiarity with experimental techniques, ethical approval if required, as well as conducting investigations, evaluation of results and preparation of a report together with a poster and oral presentation. It was therefore an intense and challenging exercise undertaken by students from different disciplines who may have only met within the study group for the first time.

Group 1 examined the health and environmental effects of emissions from domestic biomass burning devices. A questionnaire-based survey was conducted to understand the public perception of biomass. Trial measurements of indoor air quality were conducted in six houses. CO and PM were measured in order to assess the impact of domestic biomass burning devices. Laboratory analysis of metal content and particulate matter of bottom ash from such combustion was carried out using Inductively Coupled Plasma Mass Spectroscopy (ICP-MS) and Dynamic Light Scattering (DLS) methods.

The fossil fuel predominantly displaced by biomass would certainly be natural gas, which was been found in the survey as the main source of heating. This switch of fuels will increase CO, PM and NOX emissions. Also ash will be produced, which is not the case with natural gas combustion systems. Results of the survey showed that people are more aware of benefits of biomass use than of drawbacks. Indeed, half of the participants from MK believe that the use of biomass would have a positive impact on climate change, and less than 10% consider that the impact on air quality will be negative. 61% of the total participants said they would like to have a biomass-heating device in their home. Results showed that PM and CO2 were the most known emissions from biomass burning. The highest risk is associated with CO but it is noteworthy that between 40% and 50% of the sample does not have much knowledge on the emissions and the risks associated with them. Therefore although people are generally aware of the health risks associated with CO, a high percentage of the sample group did not know that CO is one of the pollutants emitted when biomass is burnt.

A rise in CO and PM concentrations in indoor air in houses with biomass burning appliances has been revealed by the trial measurements and the literature. Nevertheless, modern systems have much lower emissions levels. These levels are even lower when using wood based pellets rather than logs. Results showed that other factors, such as poor ventilation and outdoor air quality, can drastically affect the concentration levels. The levels of emissions observed during the trial measurements suggest low impact on health according to WHO guidelines for the protection of health. However, this does not mean there is no risk, and further research must be done. Incomplete combustion in an inefficient wood burner has proved to have more risks for human health than burners that optimise the combustion. The use of modern biomass boilers will help minimise health risks associated with emissions by achieving a maximum level of combustion which averts formation of incomplete combustion products (organic and soot particles).

The laboratory analysis showed that the bottom ash from the biomass contains low concentrations of heavy metals. During the winter, when bigger amounts of biomass are used for heating, the heavy metal concentration might exceed European standards. Improper handling and disposal of ash will pose a possible risk via ingestion and inhalation. On the other hand, biomass burning is arguably protective of health as it combats climate change. The trade-off between air quality drawbacks and climate change benefits on human health related to small-scale biomass combustion should be further investigated.

Recommendations of Group 1 arising from their study are as follows;

For future scenarios using locally supplied energy crops, it is recommended to study the human health impacts of small-scale biomass burning devices for these different types of feedstock. In order to analyse how a large increase in biomass burning devices would affect Milton Keynes air quality, further research needs to be done. More houses and longer measurement times are required to have more conclusive results. There should be an incentive to improve appliances by replacing old burners by new ones. Also smart undertaking of maintenance

and use of ventilation are advised to reduce health risks. Awareness should be raised on the risks associated with current fireplaces or old appliances, especially regarding the possible health impact of long term exposure to the emitted pollutants, notably CO and PM. A functional ash handling and disposal system should be put in place for homes in the Milton Keynes area, to address the potential risks posed by heavy metals from biomass burning.

Group 2 conducted trial measurements to determine PM emissions in both smoke control areas and no smoke control areas, in seven selected locations in Milton Keynes. Moreover, a questionnaire was conducted in order to determine the industry's perception of biomass emissions and its future in the UK. This survey included an interview with a company regarding the measures taken to control and regulate CO emissions from wood chips during storage. In addition, the project included laboratory analysis to determine physical characteristics of three types of biomass, and particle size distribution of ash.

To date there are thirteen non-domestic biomass boilers in the Milton Keynes area. Their installation and expected future increases in biomass capacity is in keeping with the Low Carbon Action Plan set up in 2012 with an overall target for Milton Keynes to reduce carbon emissions per person by 40% by 2020 from the 2005 baseline. The main potential pollutants (NOx, PM10) from biomass burning are being monitored by MK council. However, these pollutants are also caused by heavy road traffic and it is that factor that determined the current locations of the air monitoring stations. Therefore, in locations where biomass burning could cause a significant rise in the concentrations of NOx and PM10 there is no monitoring equipment (or data) available or plans for future monitoring.

Measurement results showed no significant differences regarding PM10 emissions between the smoke and no smoke area. There was a strong positive correlation between the PM10 emissions and PM2.5 emissions whereas there were no significant relationships between PM2.5 emissions and the PM0.02-1 emissions. No general trend was found between the PM0.02-1 emissions in the smoke control areas compared to the no smoke control areas.

The survey's responses highlighted the absence of a clear common perception between companies within the biomass industry. This is indicated by the high disparity in the responses received. Regarding the laboratory results, physical properties of the biomass were consistent with the literature. In addition, results from the heavy metal content analysis revealed that none of the samples (White cedar, Poplar and wood pellets) exceeded the European Union safety thresholds for biomass ash.

Regarding the trial measurements, results could be enhanced by increasing the measuring period to 24 hours per location and possibly over a period of a year to determine whether the seasons affect the measurements. Moreover, in order to receive more relevant responses from the biomass companies the survey needs to be handed directly to the professionals and an adequate period of time needs to be allocated for completing the survey. Regarding the control of the CO emissions in fuel stores, commercial implementation of CO alarms should be required. It is advised that ash is collected separately in order to minimise hazards to health and the environment and to recycle it into agricultural additives. Some additional laboratory tests and monitoring schemes could be useful to reinforce the findings.

In summary Group 2 concluded that biomass combustion has a potential to become one of the leading renewable energy sources in the UK. However, it may have a negative impact on human health and environment, despite the fact that it produces less emissions than some other fossil fuels (coal, oil). Improvement in the treatment, process and evaluation of biomass should be done to reduce these impacts. However, the trial measurements did not show a significant air quality impact for the moment in MK, although studies in the literature of cities with higher wood burning have highlighted the potential. The biomass industrial companies' opinion is that when biomass burning is well used there is no risk for the population health. Therefore, further expert opinions are needed to improve the knowledge of the impact of biomass use on health and environment.

Recommendations of Group 2 arising from their study addressed improvements and extensions to their own study to achieve more definitive data as well as issues of policy concerning biomass use.

To improve the quality of the data on ambient air quality in MK, measurements at the seven locations should be conducted over longer periods of time such as 24 hours per location. Also, the duration of the study should be increased to at least a year. The weather is an important factor that affects the PM emissions and all the data obtained from the trials was from the same season. Therefore, to collect comprehensive data and draw conclusions about the relationship between weather conditions and PM concentrations in the air it would be advisable to conduct measurements during different seasons and atmospheric conditions.

Another issue is related to the amount of traffic pollution in the area. Particulate matter emitted from car exhausts is one of the confounding factors in predicting the levels of emissions from biomass. A partial solution to this problem could be to measure the PM concentration at industry sites (those using biomass compared to those that are using conventional fuels), where the flow of traffic would be at a minimum.

Furthermore, other pollutants such as VOC could be measured with a Photo Ionisation Detector (PID) in the same locations that the PM emissions where monitored with possible more detailed speciation of individual compounds by GC/MS (gas chromatography/mass spectrometry) methods. This could be used to determine if there is a difference in VOC emissions between the smoke control areas compared to the no smoke control areas. This further work would determine if the VOC emissions follow a similar trend to the PM emissions.

One way to reduce hazards to human health relating to CO emissions from wood pellet storage is the use of CO monitoring systems such as alarms. These devices have been implemented by a company interviewed during the study, and help the personnel to detect any potential problems through continuous monitoring. This is an example of good practice with regard to dealing with occupational hazards and should be widely promoted.

Regarding the methods used to conduct the survey of businesses, several recommendations could be implemented in order to achieve more accurate results. First of all, the survey could be handed directly to the participant rather than via email to ensure quick and accurate responses. Moreover, it is important to give appropriate time between sending the surveys to the participants and receiving the responses. Giving a long time period for example a month, followed by a weekly reminder could yield better results. Creating a technical person contact list to ensure the survey is completed by a professional in the biomass field rather than administration staff will also ensure that the responses give an accurate view of the industry's perspective on biomass.

Future research regarding the industry's perspective towards biomass could focus more on the factors and criteria behind the development of energy crops in the UK. Future questions could investigate more about the farmer's position about switching from typical agriculture to energy crops and the perception industrial companies have of the future of energy crops agriculture in the UK.

Biomass energy is very cost-effective if the wood used as a fuel has good quality – i.e. low moisture content and ash content. The quality may be very hard to assess for a person who is not a specialist. Therefore, Milton Keynes Council might want to look into local chips and pellets providers and advise the residents of the borough where to source high-quality biomass. The Council may also be interested in informing the local biomass providers about proper storage conditions, which would make their fuel more marketable.

One of the most overlooked aspects of popularising biomass as an energy source is the waste disposal. Chip and pellet incineration produces ash which varies from 0.5g to 7.7g per 100g of burnt fuel. Since individual disposing may pose a risk to certain susceptible groups, an ash collection service could be established in addition to the weekly waste collection. Handling the ashes by trained staff would minimise health hazards and risk of environmental contamination. Moreover, collecting the ashes separately from other types of domestic waste would help to recycle them as agricultural additives. Further analysis on heavy metal content in wood pellets and chips (especially arsenic, mercury and nickel content) should be conducted. An ultrafine in-vitro toxicity test (using A549 cell line) in compliance with a methodology identified would be useful to improve the knowledge of effects of biomass emissions on human health.

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