# Local Environmental Impact of Wood Combustion in Agro-Tourism Structures

Lucian Ionel Cioca
Ramona Giurea
Ioan Achim Moise
Department of Industrial Engineering and Management
University Lucian Blaga
Sibiu, Romania
lucian.cioca@ulbsibiu.ro, ramona.giurea@ulbsibiu.ro,
achimmoise@yahoo.com

Ilaria Precazzini
Marco Ragazzi
Elena Cristina Rada
Department of Civil Environmental and Mechanical Engineering
University of Trento
Trento, Italy
ilaria.precazzini@gmail.com, marco.ragazzi@unitn.it,
elena.rada@unitn.it

***Abstract*—Domestic biomass fuel combustion can become significantly polluting if the process does not develop properly; problems related to exhaust gases' emissions can actually occur in spite of the renewable nature of the fuel. The present article analyses the key questions that influence the quality of the biomass combustion process. Concerning this, high quality and controlled biomass and a technological appliance that assure a good combustion process development together with a proper utilization and maintenance of the whole system assume a significant role. A correct attention to the entire process reduces therefore the emissions' dangerousness and improves the energy efficiency in exploiting the fuel's heat value.**

***Keywords*: *Agro-tourism, biomass, combustion, emissions, energy.***

## I. INTRODUCTION

Tourism has become one of the most important global industries nowadays with a major economic activity and with not negligible impacts on the environment in the European Union [1]-[6]. During the years, new forms of tourism are becoming popular and agro-tourism is one of these. Romania and Italy are two countries with an important tourist heritage. These two destinations are showing a considerable growth in tourist arrivals. The number of international tourist arrivals grew also in both countries in 2016 [7]. According to the European Parliament, the tourism sector is the third largest socio-economic activity in the EU and one of the major challenges facing the tourism industry is sustainability [8]. The heating sector plays a significant role in the tourism ambit as well as in the residential one. In the heating sector, residential consumption is presently a strong driver with half of total final energy consumption of bioheat (50.1%) as reported in Figure 1. The residential sector in terms of heating consists of individual heating appliances such as stoves and boilers and these kind of devices can be stoked using wood logs, woodchips or pellets, depending on the technology of the system. This sector could decrease the volume of biomass consumption in the near future due to energy efficiency measures [9].

In 2009, through the Renewable Energy Directive (2009/28/EC), EU established to fulfil at least 20% of the total European energy consumptions with renewable energies by 2020 [10].

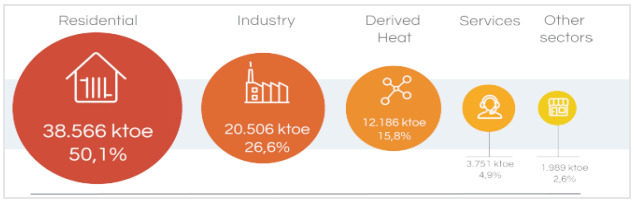


Figure 1. EU-28: total energy consumption of biomass for heating [9].

Italy and Romania adopted a number of measures in order to achieve the renewable energy targets provided in their National Renewable Energy Action Plans; in rural context, in particular, the energetic use of biomass assumes a significant role in order to achieve the European 2020 renewable energy target [11]. As consequence, some authors analysed the availability of biomass for energetic purposes in the two countries [12]-[13]. Wood combustion for domestic heating is a widespread practice performed especially in rural and mountain areas with great availability of high woody plants. This type of biomass is used to feed various kind of appliances: simple and ancient stoves as well as modern and advanced technologies such as boilers [14]-[18].

The use of biomass is supported since it is a renewable source and the $CO_2$ produced during the oxidation process is neutral; this kind of combustion can generate significant polluting emissions since the combustion process that involves solid fuels is difficult to achieve in an optimal way

978-1-5386-3943-6/17/$31.00 ©2017 IEEE

from the point of view of the pollutants' production [19]-[22].

## II. STATE OF THE ART

The quality of the biomass that will be used for energetic purposes is crucial; concerning this, moisture content and the type of species are particularly important. Moreover, the use of varnished or lacquered wood or waste in the domestic appliances has to be abandoned. It is recommended the use of seasoned biomass whereas green wood has to be avoided because the presence of high moisture content can significantly affect the combustion quality in terms of dust, polluting emissions and energy efficiency level as part of the generated heat is used to vaporize the water contained in the biomass.

Making a comparison with green wood, biomass with moisture content of around 20% (obtained with appropriate seasoning processes) can double its calorific value. This moisture level can be obtained with adequate conservation of biomass, stocking it in well ventilated and protected (from the rain) areas, for a period of time of not less than two years [23]. Different types of wood, broad-leaved or coniferous species can be used for the combustion process, even if the various species have different calorific values. The choice often depends on the type of wood that is mainly present in the surrounding woods.

Hardwood such as beech or oak is particularly suitable for domestic combustion since it can guarantee for example a more enduring combustion process, better energy yields and less dirty residues thanks to the low presence of resins. If biomass is not autonomously supplied from woods and it has to be purchased, there are certifications that guarantee the consumers the fuel quality in terms of origin, production processes, transport and storage of the product; these quality certifications are a useful guarantee for wood logs and above all for pellet and wood chips. In case of processed biomass, it is actually particularly important that it is produced using controlled raw materials, it is treated with physical processes and it does not contain any additional chemical substance.

The use of biomass for energetic purposes is currently diffused mainly in households for heating scopes and a significant biomass amount feeds also small-scale heating plants and district heating systems. The quantity of biomass used for domestic heating is expected to slightly increase from 28.2 Mtoe in 2005 to 35.6 Mtoe in 2020; it will represent the 39.4% of the biomass used for heating in 2020, compared with the 25.5% share of biomass used in domestic purposes in 2005 [24].

Solid biomass combustion develops through a sequence of phases. Even if biomass is a solid fuel, combustion is a process that always occurs in gaseous phase; for this reason it is important to create suitable conditions in order to make it possible that biomass could release vapors so as to produce and maintain combustion.

Firstly, it is necessary to supply heat to the biomass; heat actually warms up the fuel and vaporizes the residual moisture content. Although seasoned wood is usually used, the moisture content is rarely less than 20%.

The drying phase ends when the biomass is heated to the water boiling point and then the temperature rises again.

Solid fuel absorbs thermal energy and, thanks to pyrolysis effect, releases volatile substances that mix with the available oxygen and burn with flames production at a certain temperature; during this process, thermal energy is released. The heat supplied to the biomass has to be sufficient to produce volatile substances that permit the combustion's beginning and the development of additional combustible gaseous substances in order to sustain the process and maintain the flame.

Combustion goes on in form of charcoal; during this phase, carbon that remains after the gasification and oxidation phase of the emitted volatile substances is oxidized and, in this way, the coal gradually becomes ash.

As far as the proper working of the biomass heating system concerns, the combustion process just described above requires specific attentions in order to ensure that the various phases could be carried out in the best way and with reduced polluting emissions. A good combustion process requires high temperature in the firebox and a correct amount of air to ensure turbulence and contact of combustible gases with air combustion. This gaseous mixture needs also to be able to remain in the firebox enough time to allow the reaction development.

It is recommended to follow the technical instructions of the appliance manufacturer; these concern the type and the maximum quantity of fuel to be used and good behaviours to be put into practice. Fuel quality and quantity together with the system ignition and maintenance mode are essential for a correct combustion; this is particularly relevant in presence of manual loading devices. These types of systems actually, without technological control devices, often produce significant polluting emissions; in this case, correct and careful procedures are essential to limit the pollutants production.

Although most users are traditionally used to turn the fire on from the bottom of the firebox, studies have proved that the arrangement of large wood pieces at the base and the smaller ones on the top together with the positioning of the *ignition module* (i.e. small pieces of wood) can generate a better ignition and a slower and controlled combustion. In this way, there are improvements to the process with significant consequences in terms of particulate emissions, with reductions of 50-80% compared to the common ignition from the bottom of the firebox. The ignition from above allows creating a convective flow that dries the underlying pieces of wood and lets the biomass on the top to receive the necessary oxygen, oxidizing the volatile compounds and reducing the emissions from the combustion chamber [25]-[26].

During the volatile compounds' oxidation phase, it is important that the maximum amount of air combustion could always be guaranteed; it is also a good practice not to overburden the combustion chamber and avoid a continuous and too frequent introduction of biomass. For the biomass refills, it is preferable to put the new pieces of wood on the embers, avoiding excessive filling of the firebox and favouring air recirculation among the new pieces. In order to obviate the problems related to improper and not careful system management, innovative technological solutions have been developed. Modern stoves are equipped with a fuel storage compartment that is separated from the combustion

chamber; in this way, it is possible to perform a double combustion exploiting also a forced secondary air intake in order to improve the process.

Since the oxidation phase is particularly relevant for the combustion process, the correct air control is crucial. Concerning this, modern technologies are often provided with a *lambda sensor* (oxygen sensor) and exploit therefore a feedback mechanism for the optimum air intake control. Technological advances of biomass-powered appliances has been made possible with technical devices that allow optimizing the various phases of the process and reaching a significant progress in terms of energy performance. Given that the biomass furnace yield in the various domestic stoves is significantly influenced by leakages in terms of heat and unburnt discharged through the exhaust fumes, future developments are therefore related to the progressive reduction of the exhaust off-gases' temperature together with a general improvement of the combustion reaction so as to reduce the unburnt releases.

In order to ensure a good process development as well as safety conditions, it is basic to carry out proper maintenance practices such as cleaning the combustion chamber, removing the residual ashes in the firebox, checking the exhaust gases' draught and cleaning properly the chimney taking advantage of highly qualified technicians.

Emissions generated by biomass combustion processes and their resulting negative effects should be properly taken into consideration although the use of wood biomass is often connected to the fuel's economic advantage and in spite of the use of biomass has been recently favoured by the European Union, since this kind of fuel is a renewable source. The use of biomass for energy purposes involves notable effects on air quality in indoor and outdoor environments, with direct consequences for the health of the exposed population.

The situation becomes more difficult during the winter seasons as the emissions' increase, due to the use of heating systems. Biomass combustions frequently occurs in presence of thermal inversion layer with inevitable increases in pollutants' concentrations. Fine dust concentrations represent a significant question in term of environmental air protection, as domestic combustion of biomass is one of the main producers of this type of dust; this is especially true in contexts where wood is frequently used for energy purposes [17]. Since particulate matter represents a significant problem for biomass combustion, it is therefore important to reduce as much as possible these emissions in order to ensure better environmental air quality in indoor spaces as well as to reduce impacts on the external atmosphere. The technological development of the devices has led to changes aimed at reducing dust production improving the combustion firebox and the oxidation phase.

Primary actions can be followed by secondary measurements that directly work on exhaust off-gases, using devices such as filters (filters characterized by different mesh dimensions depending on the size of the particles that have to be held back), which allow reducing the emitted dust.

With regard to the particulate matter toxicity, Swiss researches and Austro-Finnish studies pointed out the polluting emissions produced by different technologies and confirmed that the health hazard of these particles is related to their composition, which is consequently the result of the combustion process that generated them [27]. Modern boilers with automatic biomass feeding or technologically advanced wood burning stoves that allow the *two-stage combustion process*' development permit high-quality burnings with reduced unburnt' productions and the emitted particulate matter is mainly characterized by inorganic substances. Traditional and non-technological wood burning stoves or malfunctioning devices produce on the contrary particulate matters with a toxicity level similar to that of Euro III Diesel engines and up to ten times higher. The toxicity of the particulate matter generated by a malfunctioning stove is especially about 100 times higher than which produced by a modern boiler [27].

Particulate produced by old appliances, in which bad quality combustions occur frequently, is mainly composed of soot and organic carbon compounds; these kind of substances are instead almost absent in the particulate matter produced by modern biomass boilers.

Given that pollutants are mainly produced in presence of bad combustion processes, technological progress has moved in order to introduce changes to the appliances, once identified the problems, with the purpose to create gradually better conditions for the reactions; this results in the production of less toxic particulate.

## III. DISCUSSION

The presented state of the art of the sector of wood combustion can be taken into consideration for a critical analysis in the agro-tourism's ambit. The traditional wood combustion in agro-tourisms brings actually not negligible pollution problems at local level. In case of domestic combustion, the major problems originate from pollutants and dust that compromise the indoor air quality; this is especially true in presence of manually fueled devices.

In order to limit these problems, it is crucial to give proper importance to the whole system (the combustion device and the chimney flue) to perform high-quality combustion processes and good energy performances. A high-quality combustion reaction can actually reduce the production of hazardous particulate matters as well as polluting substances in general since a controlled combustion optimizes all the reaction phases. Improvements in the domestic biomass fuel combustion contribute to increase the agro-tourisms' environmental sustainability since even if wooden biomass is a renewable source and for this reason is positively seen, it is important to reduce as much as possible the pollutants produced by the combustion in order to generate a clean heat and enhance the energy performance.

An important example of application of these concepts can be seen in Italy, where in the last years the heating plants based on biomass, new or renewed, are co-financed by significant discounts in the taxes to be payed: 50-65% of the cost of the heating plant is given back as taxes reduction within 10 years [28].

## IV. CONCLUSIONS

Considering the relevant impact due to the biomass combustion on air quality, it is important to adopt best

technologies favoring the progressive replacement of old domestic appliances with modern and technologically assisted solutions, provided with efficient systems that allow the combustion control limiting as much as possible the pollutants' production and improving the energy efficiency.

It is important to choose properly the appliances used for biomass combustion. Concerning this, there exist certifications that can be adopted by biomass stoves or boilers manufacturers; these certificates help consumers in identifying and adopting products that could guarantee a *clean heat* production with reduced dust emissions and better energy performances.

Users very often underestimate or ignore the high emissions that daily biomass combustion practices can cause; these actions are often driven by habitual and unconscious procedures.

Although atmospheric pollution and the resulting consequences on human health are topics that are frequently discussed by the media, users do not often pay proper attention to emissions related to domestic combustion especially in terms of indoor air quality.

It is important to diffuse themes that concern type and quality of the fuels, correct practices of control and maintenance of the system and the chimney flue in order to increase citizens' sensitivity and consciousness towards the proper management of the appliances and their progressive substitution.

## REFERENCES


[1] European Commission, *Tourism, 2017.* Available: https://ec.europa.eu/growth/sectors/tourism_en.

[2] R. Giurea, M. Ioan, M. Ragazzi, L. I. Cioca, "Focusing agro-tourism structures for environmental optimization", *Quality - Access to Success*, vol. 18, pp. 115-120, 2017.

[3] E. C. Rada, C. Zatelli, P. Mattolin, municipals solid waste collection and tourism, *WIT Transaction on Ecology and the Enviornment,*vol. 180, pp. 187-197, 2014.

[4] M. Ragazzi, I. Precazzini, R. Giurea, E. C. Rada, M. I. Achim, "Criteria for water management optimization in agrotourisms", in *Proc. TE-RE-RD'17-6th International Conference on Thermal Equipment, Renewable Energy and Rural Development,* pp.253-258, 2017.

[5] R. Giurea, M. Ragazzi M., M. V. Zebres, M. I. Achim, "Is agrotourism eco-frendly?", in *Proc. MATEC Web of Conferences*, vol. 121, 2017.

[6] R. Giurea, I. Precazzini, M. Ragazzi, M. I. Achim, "Criteria for environmental optimization of electrical and thermal energy in agro-tourism", in *Proc. Energy and Sustainability 2017- 7th International conference on Energy and Sustainability*, in press.

[7] UNWTO World Tourism Organization, Tourism Trends - European Union Short-Term Tourism Trends, vol. 1, 2017.

[8] European Parliament, Tourism and the European Union - Recent trends and policy developments, 2015. Available: http://www.europarl.europa.eu/RegData/etudes/IDAN/2015/568343/EPRS_IDA(2015)568343_EN.pdf.

[9] AENIOM - The European Biomass Association, Statistical Report 2016 – Europen Bioenergy Outlook – Key Findings, Bioheat Overview, 2016. Available: http://www.aebiom.org/wp-content/uploads/2016/12/AEBIOM-KEY-FINDINGS-REPORT-2016.pdf.

[10] Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009. Available: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=EN

[11] European Commission, Energy – Renewable energy - National Action Plan, 2010. Available: http://ec.europa.eu/energy/en/topics/renewable-energy/national-action-plans.

[12] E. Girelli, M. Ragazzi, E. Malloci, E.C. Rada, L. Paternoster, "Agricultural biomass availability for energy conversion in Italy", *UPB Scientific Bulletin,* Series C, vol. 74(1), pp. 11-18, 2012.

[13] S. Camelia, D. Ioan, V. Ioan, "Potential resources and opportunities for alternative energy production in central Romania", in *Proc. International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management*, vol. 1(4), pp. 401-408, 2015.

[14] M. Holubcik, J. Jandacka, P. Durcansky, "Energy properties of wood pellets made from the unusual woody plants", *AIP Conference Proceedings*, 1768,020013, 2016.

[15] R. L. Carvalho, O. M. Jensen, L. A. C. Tarelho, "Mapping the performance of wood-burning stoves by installations worldwide", *Energy and Buildings*, vol. 127, pp. 658-679, 2016.

[16] J. Swithenbank, Q. Chen, X. Zhang, V. Sharifi, M. Pourkashanian, "Wood would burn", *Biomass and Bioenergy,* vol. 35(3), pp. 999-1007, 2011.

*[17]* K. Sornek, M. Filipowicz, K. Rzepka, "Study of clean combustion of wood in a stove-fireplace with accumulation", *Journal of the Energy Institute,* vol. 90(4), pp. 613-623, 2017.

[18] O. Sippula, H. Lamberg, J. Leskinen, J. Tissari, J. Jokiniemi, "Emissions and ash behavior in a 500 kW pellet boiler operated with various blends of woody biomass and peat", *Fuel*, vol. 202, pp. 144-153.

[19] W. Du, G. Shen, Y. Chen, X. Zhu, S. Zhuo, Q. Zhong, M. Qi, C. Xue, G. Liu, E. Zeng, Xing, B., Tao, S. "Comparison of air pollutant emissions and household air quality in rural homes using improved wood and coal stoves", *Atmospheric Environment*, vol.166, pp. 215-223, 2017.

[20] R. Avagyan, R. Nyström, R. Lindgren, C. Boman,R. Westerholm, "Particulate hydroxy-PAH emissions from a residential wood log stove using different fuels and burning conditions", *Atmospheric Environment*, vol. 140, pp. 1-9, 2016.

[21] J. Müllerová, J. Puskajler, "Review of health and safety risks of wood chips use", *Advanced Materials Research*, vol. 1001, pp. 426-431, 2014.

[22] E. C. Rada, M. Ragazzi, E. Malloci, E. "Role of levoglucosan as a tracer of wood combustion in an alpine region", *Environmental Technology*, vol.33(9), pp. 989-994, 2012.

[23] Tonidandel G., Qualità e tipo di essenza importanti ai fini dell'impianto, Ecoscienza Numero 1, 2015.

[24] European Commission, Commission staff working document-State of play on the sustainability of solid and gaseous biomass used for electricity, heating and cooling in the EU, 2014. Available: http://register.consilium.europa.eu/doc/srv?l=EN&f=ST%2012334%202014%20INIT.

[25] C. Schmidl, Strategie per ridurre le emissioni delle stufe a legna fino all'80%, *Agriforenergy,* nr.2, Jul. 2014.

[26] F. Stel, Le condizioni per una buona combustione domestica, *Ecoscienza,* nr. 1, 2015.

[27] F. Francescato, Moderne caldaie a biomasse e polveri sottili, *Agriforenergy*, 2015.

[28] PAT, 2015: http://osservatorio.energia.provincia.tn.it/apeoe/node/1080 (accessed in September 2017)