Research project objectives / Research hypothesis

In the project, it is proposed to improve the waste incineration process by using high purity oxygen as the oxidant. As a result, the process temperature will be increased, and thus the consumption of auxiliary fossil fuel can be eliminated. In addition, higher oxygen content and high temperature can intensify the oxidation of complex hydrocarbons, e.g. dioxins and furans, and by removing nitrogen from the oxidant, the flue gas stream will be significantly reduced, so its cleaning will be easier and more economical. However, taking into account the latest regulations introduced by the European Union regarding the decarbonisation of the economy until 2050, the most important advantage of the proposed technology is that the produced exhaust gas consists mainly of carbon dioxide and water vapour, thus after the water condensation, the obtained gas is practically ready for sequestration and storage. In addition, considering that more than half of the carbon contained in municipal waste is of biological origin, the use of CCS technology in a waste incineration plant will cause throughout the cycle, CO_2 emissions will be negative (bio-energy carbon capture and storage).

The innovation of the described technology contrasts with limited knowledge. The literature review shows that the phenomena occurring in the fuel bed under the $O_2/CO_2/H_2O$ atmosphere are particularly unknown. Therefore, the main goal of the project is to obtain basic knowledge on waste conversion under oxy-combustion conditions and to verify the following hypotheses: a) co-combustion of biomass with plastics in the presence of H_2O and CO_2 may improve the conversion of heavy hydrocarbons through increased cracking, and thus promote CO, H_2 and CO_2 production; b) the presence of water vapor activates the char, thus increasing the role of the char in the transformation of heavy hydrocarbons released during pyrolysis; c) by using diluted O_2 by CO_2 and H_2O it is possible to lower the bed temperature (below the melting point of the ash) while reaching a high temperature above the bed where less dilute oxygen is introduced; d) Since municipal solid waste contains biogenic carbon, carbon dioxide emissions are negative throughout the cycle.

Research project methodology

To verify the first and second hypotheses, it is planned to conduct an experimental campaign on a unique laboratory stand, which consists of a quartz tubular reactor enclosed in an electric furnace and connected with gas cylinders (N_2, O_2, CO_2, H_2O), which allows for obtaining different atmospheres. Then, apply a range of analytical techniques such as thermogravimetry (TGA), gas chromatography (GC), Fourier Transform Infrared Spectroscopy (FTIR) and char porosity analysis. Moreover, different types of waste as individual materials and their blends will be used to determine the effect of interactions between the various fractions of waste on the process. Additionally, it is planned to develop a mathematical model of oxy-incineration of waste, which will describe such phenomena as fuel drying, devolatilisation and char burn-out. It is planned that pyrolysis and char burn-out will be accounted for by the kinetic constants of global reactions. As part of the project, it is also planned to carry out experimental tests of the oxy-waste combustion process at an installation located at one of the largest research institutes in Norway. In particular, the influence of the atmosphere on the process and final products will be investigated, and the obtained data will be used to validate the mathematical model. These activities are aimed at verifying the third research hypothesis. In the last stage of the work, it is planned to use the Life-Cycle-Assessment analysis to determine the impact of the technology on the environment in the full life cycle of the oxy-incinerator and to verify the fourth research hypothesis.

Expected impact of the research project on the development of science, civilization and society

The main effect of the project is obtaining of basic knowledge in the field of oxy-combustion of municipal solid waste in a grate furnace. Secondly, thanks to the use of modern instrumental methods, knowledge about the conversion of single waste and their mixtures under the influence of different atmospheres will be enhanced. Particular attention will also be paid to the problem of ash melting, which may occur during the process.

The obtained results will be compiled and presented at international conferences dedicated to carbon capture and storage technology, municipal solid waste management and combustion. In addition, research results will be published in peer-reviewed journals. In the longer term, the project's results will contribute to the development of oxy-MSW combustion technology that responds to the current need for sustainable development.