HOW PYROLYSIS AS A NEGATIVE EMISSION TECHNOLOGY CAN GUIDE THE EXPANSION OF THE GERMAN POWER SYSTEM TOWARD CLIMATE NEUTRALITY

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Overview

Germany's Climate Protection Act of 2021 [1] determined that total emissions in Germany must be reduced to net zero by 2045. Numerous studies agree that greenhouse gas neutrality can only be achieved if unavoidable residual emissions are offset by correspondingly large carbon sinks [2–5]. The development of the necessary negative emission technologies should take place promptly due to long innovation and investment phases and the political framework conditions that still need to be established [6]. In addition to other negative emission technologies pyrolysis is particularly interesting from the perspective of energy system analysis, as it can act as a carbon sink on the one hand and supply alternative energy on the other hand [7]. In a pyrolysis process, biomass (such as wood, straw, recyclables, feedstock waste, and others) is burned under a low-oxygen condition to biochar. In there the carbon absorbed through photosynthesis can be stored for centuries. The other resulting products like heat, gas or oil can be used directly or partially converted into electricity. This negative emission technology has the potential to make an important contribution in achieving greenhouse gas neutrality. This paper investigates the expantion of this technology in Germans electricity system until 2050 and gives answers to the following questions: What role can pyrolysis play in the German energy system from 2020 to 2050? And how will the expansion and deployment of pyrolysis take place?

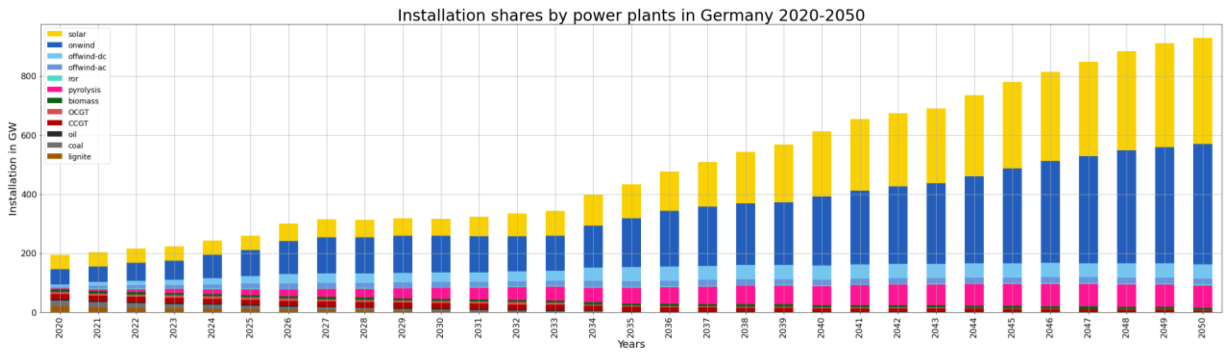
Method

For the energy system analysis, the model MyPyPSA-Germany [8] was used, which was further developed at our university from PyPSA-Eur [9] into an annual cost-optimized tool for system expansion planning. The tool already includes the annually specified CO_2 limits and the development of costs for all existing power plants. Also included in the model are, for the conventional power plants, the times when each individual one must be taken off the grid and, for the renewable energies such as wind and solar, the regionally highly resolution weather data, after which the regional output of the renawable energies is capped. Pyrolysis technology was integrated into this model as a new power plant. The annual expansion of pyrolysis depends, among other parameters, mainly on capital and marginal costs and biomass availability. In the scenario investigated to date, the values for which pyrolysis is more advantageous, the maximum available biomass and the lowest costs were used from the bandwidths of the researched values. These were chosen to first develop and test the new model and make sure that pyrolysis is used in the energy system. In the following weeks, the more pessimistic scenarios with the values at the other end of the bandwidth will also be investigated and dicussed in the conference paper. In the reference scenario, an equivalent power plant expansion up to 2050 is examined but without the pyrolysis technology.

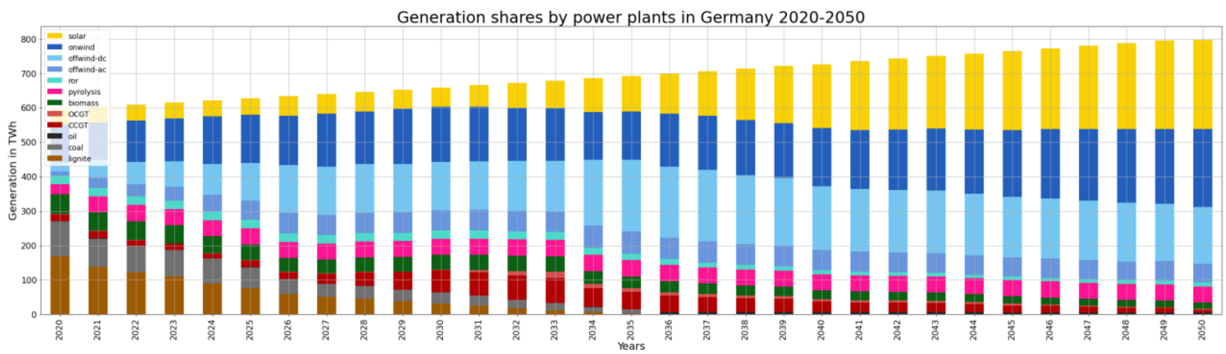
Results

Figure 1 (a) shows the installed capacity per power plants in the overall energy system in Germany for the years 2020 to 2050 and (b) the respective amounts of generated electrical power. In this scenario, all the biomass available for pyrolysis in Germany is already used after two years and the electricity generated from it reaches its limit already then. In 2050, this quantity accounts for 6 % of the generated electrical power in Germany. The situation is different for installed capacity. It increases linearly by 3.3 GW until 2036, since the annual rate of expansion is limited to this value. After 2036, the capacity does not increase as much and after 2045 it even remains constant. Pyrolysis serves different purposes for the power system. First, compared to the reference scenario, in which only renewables can be used in a fully carbonized energy system and electricity demand cannot be met without the utilisation of load shading and storage technologies, pyrolysis ensures that electricity can be generated even at times when the sun is not shining and the wind is not blowing and the energy system can therefore completely do without these flexibility measures. Second, as a negative emission technology, pyrolysis allows thermal power plants, such as gas-fired power plants, to remain online and emit CO_2, which is compensated by the biochar produced, so that the system has zero emissions overall. In the analyzed scenario, the deployment of pyrolysis stored 7 million tons of CO_2 equivalents in biochar and the same amount was emitted by the gas-fired power plants. Gas-fired power plants provide the necessary flexibility in the power supply as well, as they can be used as reserve power plants to cover residual loads.

These are the preliminary results. Investigations of further scenarios with a sensitivity analysis of costs and biomass availability will complete the analysis in the upcoming month and will be presented and evaluated in the conference paper.



(a)



(b)

Figure 1: (a) Installation of electricity capacitities by power plants for the years 2020 to 2050 and (b) generation shares of electricity by power plants for the years 2020 to 2050

Conclusions

Pyrolysis can play an important role in the future energy system, which must be greenhouse gas neutral by 2045. The use of pyrolysis could be manifold. On the one hand, power generation can be planned compared to many renewable energies, so pyrolysis is a good complement to sun- and wind-dependent power plants. It has been found that in an energy system with pyrolysis, fewer storage technologies such as hydrogen or batteries need to be used. On the other hand, pyrolysis through the production of biochar is a CCS technology that allows gas-fired power plants to remain on the grid longer and still achieve net zero emissions. However, pyrolysis can provide more than just electricity and biochar. The exothermic process generates heat and end products such as oil and gas can be reused for various applications. Therefore, the following work will investigate the influence of pyrolysis as a sector coupling measure in the German energy system and how pyrolysis can further contribute to achieve climate neutrality.

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