Long-term energy efficiency and decarbonization trajectories for the Swiss pulp and paper industry

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Overview

The contribution of the whole industrial sector is essential to realize long-term energy and climate policy goals. Swiss pulp and paper mills produce around one million tons of paper products per year and account for 9.4% of the final energy consumption and 3.8% of the CO_2 emissions in the Swiss industrial sector in 2015. The present research paper explores trajectories improving energy efficiency and reaching net-zero emissions in the Swiss pulp and paper industry by 2050.

Methods

Energy system models help to identify energy and climate policy strategies by understanding the energy technology development and its interaction in a system context. A techno-economic bottom-up cost optimization model is developed based on the Swiss TIMES Energy system Model (STEM) and applied for a scenario analysis. Establishing an advanced modeling methodology including material and product flows in addition to energy flows, allowed us to assess explicit process improvements and the impact of specific technologies. Furthermore, dividing industrial heat demand into different temperature levels enables a detailed assessment of high temperature heat pumps and waste heat recovery.

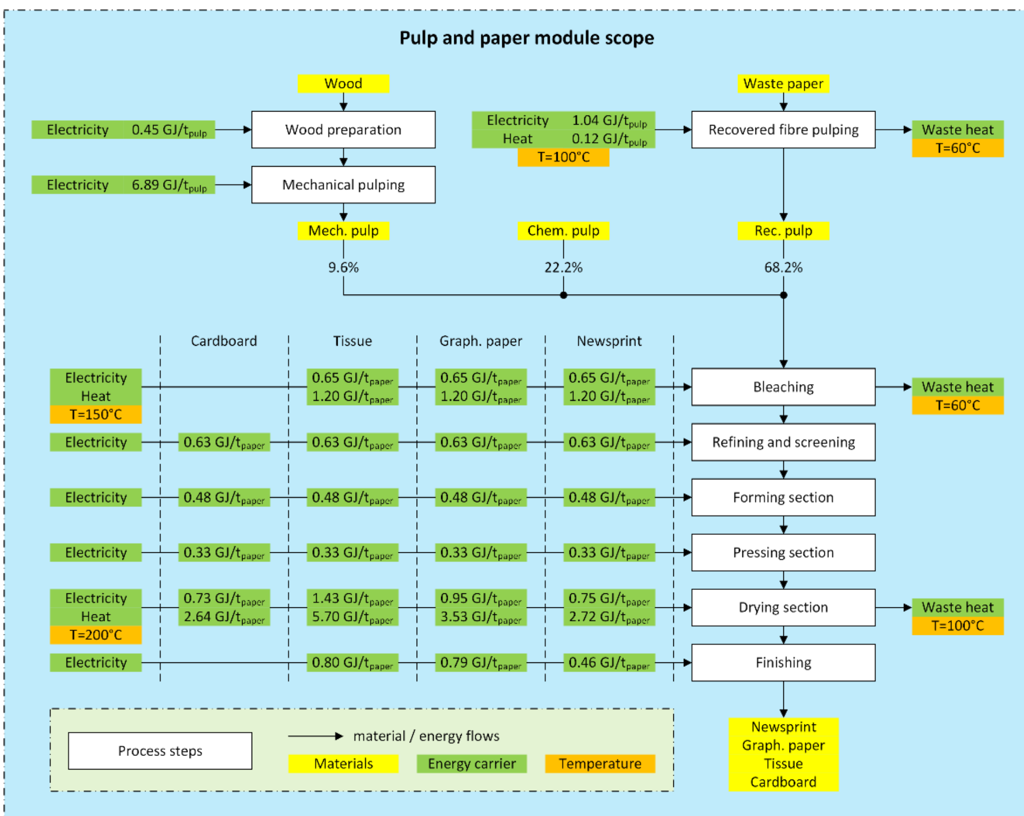

Figure 1: Schematic overview of the extended modeling approach of the pulp and paper sector with material and energy flows

Results

Analyzing the final energy consumption reveals that mainly due to the costs of efficient energy efficiency improvements, the final energy consumption decreases in all scenarios. The highest energy efficiency improvement is observed in the energy policy (E-POL) scenario (-32% or -3.8 PJ in 2050 compared to 2020) followed by the climate policy (CLI) scenario (-29% or 3.4 PJ) and the business as usual (BAU) scenario (-23% or -2.7 PJ). Electricity remains the main energy carrier across all scenarios because of the high share of electric motors. Furthermore, most heat in 2050 is supplied by the already existing district heating networks.

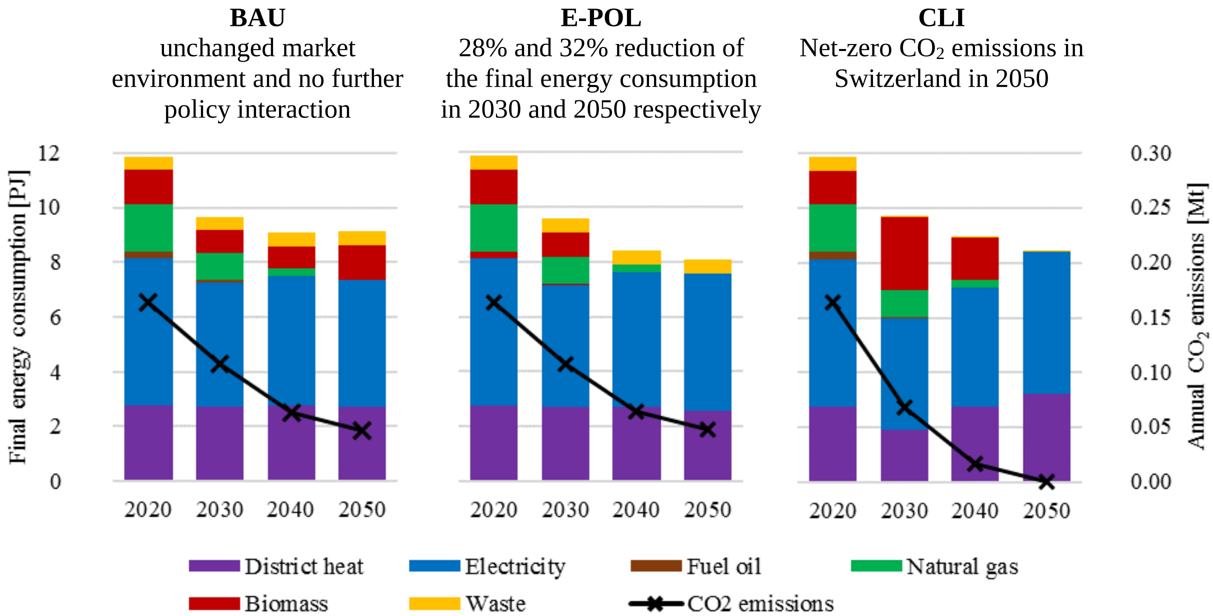

Figure 2: Results of the scenario analysis (final energy consumption and annual CO_2 emissions)

In the BAU scenario, the pulp and paper sector relies the on natural gas until 2040 to a relatively high degree by using the existing technologies. Nevertheless, when the existing technologies have reached the end of their lifetime, they are replaced by biomass technologies while the consumption of waste remains constant over the whole period. Because of their lower energy efficiency, boiler technologies are decommissioned gradually and replaced by high temperature heat pumps in the E-POL scenario. Besides the district heat consumption and the waste consumption in CHP's, the whole sector is electrified by 2050 in this scenario. Biomass plays a major role in the CLI scenario by replacing waste at first and natural gas subsequently in the fuel mix due to their relatively high CO_2 emissions. However, because of the high competition for biomass ressources with other sectors, the heat supply is ultimately electrified as well in this scenario.

Following the past trend, the annual CO_2 emissions reduce further in all scenarios mainly due to fuel switching, energy efficiency improvements and electrification of the heat supply. In the CLI scenarios, net-zero emissions within the pulp and paper sector will be achieved until 2050. However, there is a significant difference between the scenarios regarding the pathway to mitigate emissions and the cumulative CO_2 emissions. With the climate policy pathway, almost 1.2 Mt of CO_2 emissions (or 43%) are mitigated from 2020 until 2050 compared to the E-POL and the BAU scenario. Nevertheless, the energy related costs of the CLI and the E-POL scenario are 49% and 10% higher than the costs of the BAU scenario.

Conclusions

This study explores different trajectories of the pulp and paper industry to reach climate and energy policy goals by conducting a scenario analysis with a techno-economic bottom-up cost optimization model. Due to the advanced modeling methodology that includes material and production flows in addition to energy flows and its technology richness, the model is able to identify transformation technologies for the pulp and paper sector. Our analysis has shown that the Swiss pulp and paper industry reduces its energy consumption by 23% and decreases its CO_2 emissions by 71% from 2020 until 2050 without major policy intervention. Energy efficient production processes (especially in the drying section), pinch analysis, efficient motors and high temperature heat pumps represent the most important technologies, which contribute to the reduction of the energy consumption and the CO_2 emissions from fuel combustion simultaneously. In order to fulfill the energy policy goals of the Swiss energy strategy 2050 (SES), a further reduction of the final energy consumption by 32% from 2020 until 2050 is possible through further electrification of the sector. Focusing merely on emission reduction, the sector can be decarbonized in a cost-efficient way through the use of biomass CHP's in the short-term which necessitates an increased availability of biomass and causes much higher energy related cost. In addition to this, this trajectory requires the development of high temperature heat pumps for temperatures up to 200°C and a low electricity price in the long-term.