Decarbonization of a tissue paper plant: Replacing fossil LPG with renewable biosyngas

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INTRODUCTION:

Process heat used in the manufacturing industry represents around 20% of the world's energy consumption (International Energy Agency, 2022). As the global push for reducing greenhouse gas emissions intensifies, manufacturing industries are facing pressure to adopt sustainable energy solutions. This challenge is particularly pronounced in energy-intensive sectors such as tissue paper production, where decarbonization must be balanced with operational efficiency and cost-effectiveness.

The European Union's commitment to achieving net-zero emissions by 2050 has spurred interest in renewable gases as part of its broader strategy for decarbonizing the energy sector. Among the various renewable energy technologies, biomass gasification has emerged as a promising solution, offering a versatile approach to converting solid organic waste materials into clean energy.

This article explores how biomass gasification can contribute to the decarbonization of a tissue paper plant, with a particular focus on a case study from Sofidel's tissue mill in Kisa, Sweden, which implemented this technology to replace fossil LPG with renewable biosyngas.

Article highlights:

- ***Use of biosyngas from biomass gasification to decarbonize a tissue paper plant.***
- ***Reduction of 8,500 ton/y of CO_2 emissions in comparison to fossil LPG.***
- ***The potential of biomass gasification to achieve carbon-negative emissions through biochar sequestration***
- ***Renewable biosyngas produced on-site, reducing transportation and upgrading costs.***

Biosyngas is a renewable gas produced by thermal gasification of low-quality biomass residues. In relation to other biogases, the energy carriers in biosyngas are mainly Carbon monoxide (CO), Hydrogen (H2) and Methane gas (CH4).

Figure 1. Meva Energy´s renewable gas plant replacing fossil gas consumption at Sofidel Sweden's tissue mill in Kisa, Sweden.

The energy challenge in tissue paper production

Producing tissue paper is an energy-intensive process, particularly during the drying phase, which requires significant heat to remove moisture from the paper. In today's tissue machines, a large share of the energy is consumed in drying hoods where hot air generated is in direct contact with the tissue, which places high demands on the quality of the heat. It is crucial that the hot air does not introduce any odours or black particles that could affect the final product. Currently, to maintain low cost, process stability, and high-quality heat, the best practice is to combust fossil fuels, such as natural gas or LPG, in the tissue drying hoods. However, this approach conflicts with the tissue industry and EUs sustainability goals.

One promising alternative is biomass gasification. By generating biosyngas on-site, from locally sourced organic low-value waste materials, biomass gasification has the potential to offer a renewable and cost-efficient substitute for fossil fuels in energy-intensive processes like tissue drying.

Understanding Biomass gasification

Biomass gasification is a highly energy-efficient process, already applied in the manufacturing industry today by converting locally generated low-value biogenic residual and waste streams into renewable biosyngas, consisting primarily of hydrogen (H_2), carbon monoxide (CO), and methane (CH_4). This makes it highly suitable for industrial applications that require substantial thermal energy.

Unlike fossil fuels, the CO_2 released from biomass gasification originates from biogenic sources and is part of the natural carbon cycle, reabsorbed by plants during photosynthesis as new biomass grows. When biomass is sustainably sourced, this results in net-zero carbon emissions, positioning biomass gasification as a climate-effective energy solution.

During the gasification process a highly stable organic carbon fraction remains, called biochar. Biochar serves as a permanent carbon sink when incorporated into soil or used in other carbon-sequestration applications. As a result, biochar is recognized as one of the most effective existing technologies for carbon dioxide removal (CDR). Both the European Commission and the Intergovernmental Panel on Climate Change (IPCC) acknowledge its potential, and biochar currently accounts for over 90% of carbon credits sold on the voluntary market. Beyond its carbon-sequestration properties, biochar can enhance soil fertility and improve water retention, making it valuable for sustainable agriculture.

Figure 2: Biochar - a valuable by-product from biomass gasification.

Case Study: Implementation of a biomass gasification plant at a Tissue Mill in Sweden

An example of this technology can be found in Sweden, at Sofidel's tissue mill in Kisa, which has successfully integrated a new type of thermo-chemical biomass gasification technology to replace industrial consumption of fossil gas. The tissue mill, a major producer of tissue paper for various commercial and consumer applications, has long been dependent of LPG consumption in its drying hoods. While LPG is an efficient fuel for such purposes, it is a fossil-derived energy source that contributes to carbon emissions and energy price volatility.

In response to these issues, Sofidel partnered with the Swedish company Meva Energy, a leading provider of gasification technology for renewable energy production. The collaboration also involved ANDRITZ EnviroBurner multifuel solutions, which played a role in upgrading the mill's burner systems to ensure compatibility with biosyngas. ANDRITZ expertise in air and energy systems for tissue production allowed the modification of the mill's combustion chambers and burners, ensuring they could efficiently process the biosyngas, which has different properties compared to LPG. Furthermore, the Department of Energy at the University of Pisa (UniPi) and ANDRITZ Novimpianti provided combustion research expertise to verify the compliance with the existing drying system. Together, they developed an integrated solution tailored to the mill's specific needs. In 2023, this initiative resulted in a significant breakthrough: the production of the world's first batch of tissue paper using biosyngas. The gasification plant, designed and operated by Meva Energy, has a capacity of 4.5 MW, enough to supply the thermal energy required for the mill's drying section.

Figure 3: Meva Energy's gasification plant is located right next to Sofidels tissue mill in Kisa, Sweden.

Figure 4: Meva Energy's thermochemical conversion technology converts biogenic residue, including sawdust, to renewable gas. The gas can then be used to fuel power generation or to replace fossil gas consumption in industrial heat systems.

Site: Sofidel Kisa, Sweden
Application: Renewable gas for tissue drying hoods
Gas production: 4,5 MW
Biochar output: 400 ton/year
Feedstock: Locally generated wood pellets made from sawdust
CO_2 reduction potential: 10.600 tonnes CO_2/year (including biochar sequestration)
Commissioned: 2023

The use of fossil-free biosyngas from biomass gasification to feed the burners of the hoods in the drying section of the tissue plant allows CO_2 emissions to be reduced by 8,500 tons per year as compared to the carbon footprint from fossil LPG.

Environmental benefits of biomass gasification in Sofidel's tissue paper production

The adoption of biomass gasification in tissue paper production provides substantial environmental benefits, particularly in the context of carbon footprint reduction. A Life Cycle Assessment (LCA) of the biomass gasification process reveals that replacing fossil LPG with biosyngas have the potential to reduce fossil CO_2 emissions by up to 80-90%, depending on factors such as feedstock type, gasification efficiency, and system integration. (1)

In the specific case of Sofidel's Kisa mill, the implementation of biosyngas has the potential to reduce fossil CO_2 emissions by up to 8,500 tonnes per year compared with the consumption of fossil LPG. This reduction represents a significant contribution to the mill's sustainability goals and aligns with EUs targets for carbon neutrality.

The Kisa plant utilizes biomass residues, such as sawdust and wood fibers, sourced from a nearby sawmill as fuel. This localized approach not only eliminates the need for fossil fuel imports but also reduces transportation emissions and the energy losses typically associated with fuel distribution and upgrading processes.

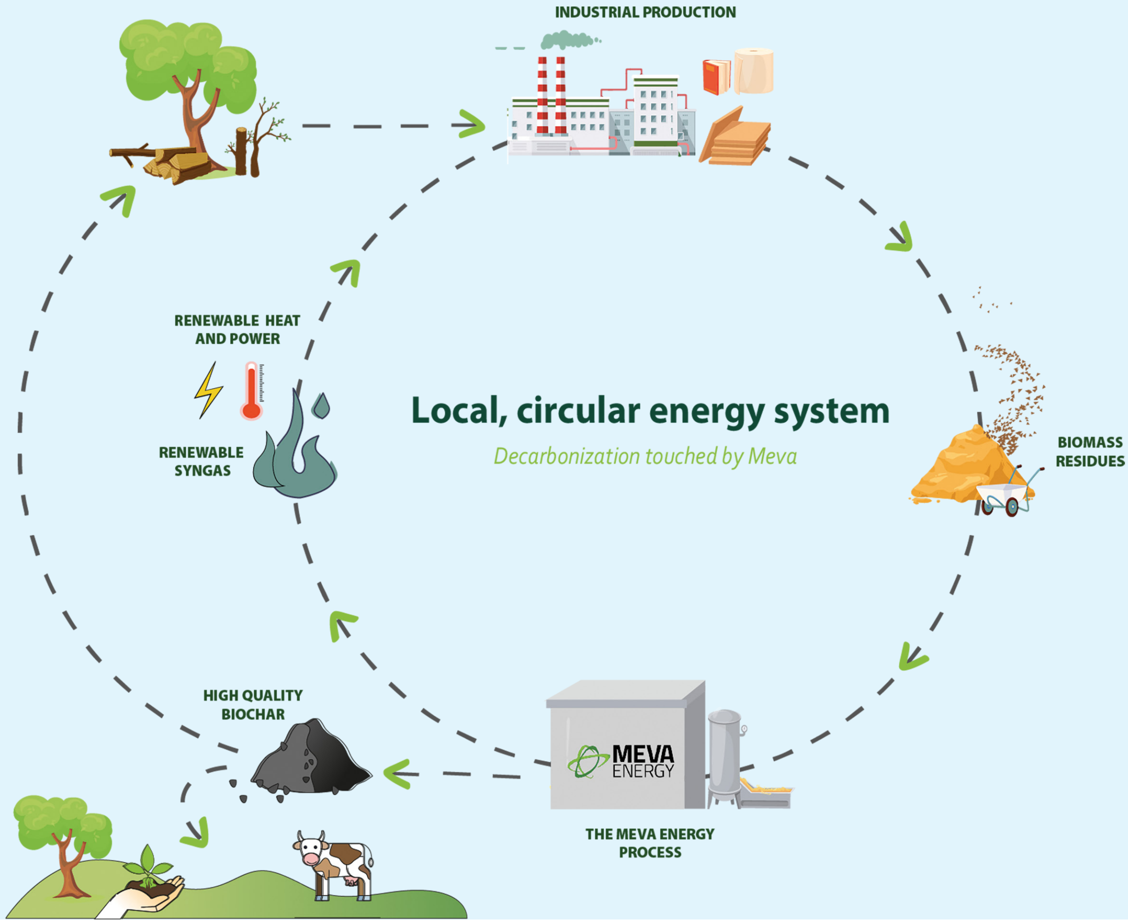

Figure 5: Local and circular energy system. The energy model at the Kisa mill, developed by Meva Energy showcases use of locally sourced biomass waste to produce high-quality renewable gas and biochar at the production site, contributing to both environmental and economic sustainability.

Renewable gas production directly at the mill enables carbon negative tissue production and independence from fluctuating global fossil gas prices.

Renewable gas production directly at the mill

The philosophy of the Kisa mill is to produce gas on-site, using with locally generated biogenic waste streams as fuel. By eliminating the need for extensive upgrading of the gas to meet standardized quality parameters, as well as avoiding long-distance transportation of fuels, the system minimizes unnecessary energy losses and reduces overall costs.

In addition to generating renewable biosyngas, the gasification process produces biochar as a byproduct, which contributes to the circular energy system. The biochar not only provides a means of carbon sequestration, helping to offset emissions, but also creates opportunities for agricultural applications by enhancing soil quality. These combined factors enable a local, circular energy system and independence from fluctuating global gas prices.

Furthermore, the gasification system in Kisa reduces the mill's dependence on external energy suppliers, enabling the facility to be more energy self-sufficient. This, in turn, offers Sofidel greater operational stability and cost predictability in the long term.

A potential negative emissions technology

To fully understand the environmental impact of biomass gasification, Meva Energy has together with two master students at Chalmers University of Technology conducted a comprehensive Life Cycle Assessment (LCA) of its biomass gasification plant in Kisa. The results are nothing short of promising.

The LCA revealed that the combination of replacing fossil gas with biogenic renewable gas and harnessing the carbon sequestration potential of biochar creates a unique opportunity to go beyond zero emissions and achieve negative emissions. The LCA study, conducted in 2024 in collaboration with Chalmers University of Technology is based on the ISO 14040/14044 standards and verifies that when the biochar sequestration effects are included, the gasification process gives rise to a negative emissions value, -6 g CO_2-eq/kWh. This value includes the impact of the entire system (from cradle to grave) and includes the climate impact from building, construction and end of life management. Despite this expansion, the result is still a negative emission value. When only considering the impact allocated to the biosyngas and exclude the biochar effects, the process shows a climate impact of 22 g CO2-eq/kWh, following the energy allocation according to the Renewable energy directive.

Compared to the fossil alternative, LPG, Meva Energy's biomass gasification plant has a significantly lower climate impact, see figure 6 where different sources of LPG have been used for the comparison.

When the biochar sequestration effects are included, the gasification process gives rise to a negative emissions value, -6 g CO_2-eq/kWh. This means more carbon dioxide is removed from the atmosphere than is emitted. When only considering the impact allocated to the biosyngas, the process shows a climate impact of 22 g CO_2-eq/kWh,

The inclusion of biochar as a carbon sink allows the system to remove more CO_2 from the atmosphere than it emits, enabling the gasification plant in Kisa to contribute to a carbon-negative operation.

Conclusion

In conclusion, biomass gasification presents a promising solution for decarbonization of a tissue paper mill, with substantial economic potential. The inclusion of biochar as a byproduct further amplifies the environmental impact of the system, providing a viable method for carbon sequestration and supporting sustainable agricultural practices.

The case study highlights the potential for biomass gasification to serve as a key technology in the decarbonization of industrial sectors. It demonstrates that, through innovative energy solutions, industries can achieve not only emissions reductions but also contribute to the broader goal of achieving the European Union's commitment to achieving net-zero emissions by 2050.

How do you see your energy supply in the future?

"Through our biomass gasification technology, we can transform locally sourced biogenic residues into two valuable products: biogas and biochar," explained Sara Palander, Sustainability Manager at Meva Energy.
"Biosyngas serves as a renewable energy source for industrial processes, replacing fossil fuels, while biochar, recognized by the EU as a carbon dioxide removal (CDR) technology, enhances soil health and reduces atmospheric carbon. Combining these benefits is the reason we achieve such good metrics in the LCA study."

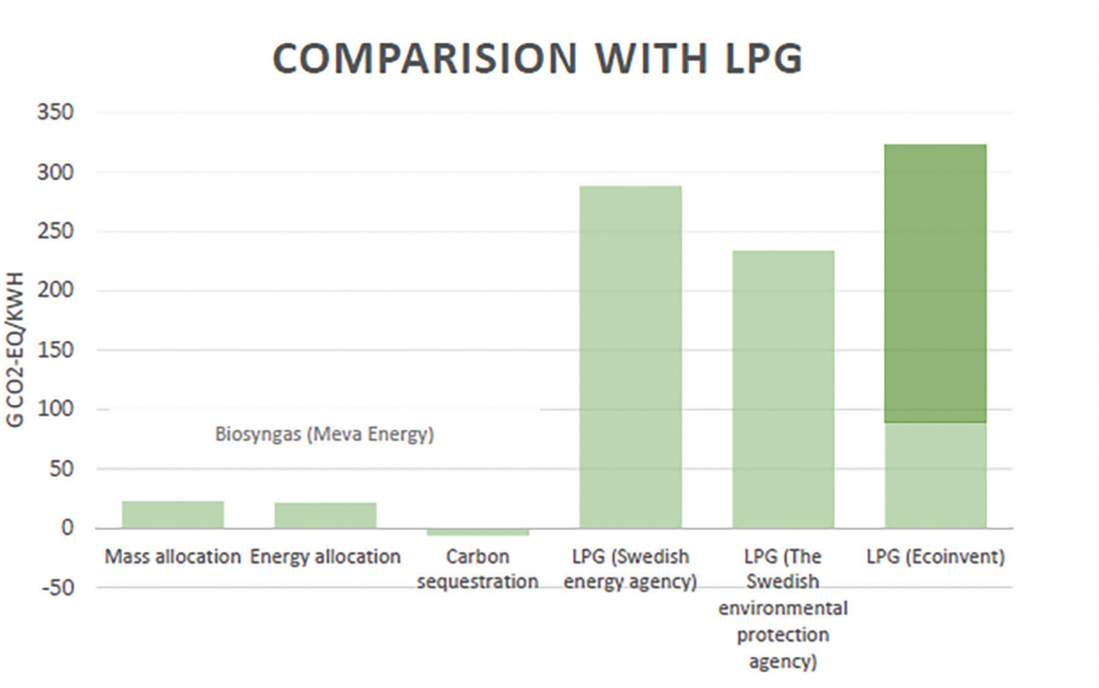

Figure 6: The three allocation scenarios of Meva Energy's biosyngas compared to fossil LPG (Hedbom, H and Lundh, P (2024).

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- The University of Pisa and ANDRITZ Novimpianti, which conducted combustion research to verify the compatibility of biosyngas with the tissue drying process and optimize its performance

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2. Hedbom, H., & Lundh, P. (2024). Life cycle assessment of biosyngas from a multifunctional biomass gasification plant in Sweden (Master's thesis, Chalmers University of Technology). Chalmers Open Digital Repository. https://odr.chalmers.se/server/api/core/bitstreams/78ba8906-19ec-479c-ace4-0deaa73ef940/content