
# Industrial Decarbonization:

## Surviving and Thriving in the North American Pulp and Paper Industry

SIEMENS energy

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## Executive summary


Over the last 20 years pulp and paper usage in the US has risen from 92 million tons to 208 million tons annually, provided through hundreds of pulp mills and thousands of paper and tissue machines. At the same time, imported inexpensive paper products have led to depressed market prices, and now represent over 10% of the US market supply. Thin margins and environmental regulation have forced tens of mills to close in the last several years representing a tremendous loss to domestic manufacturing capacity. However, the North American pulp and paper industry must be prepared for a new balance shift back toward onshore production with the potential introduction of tariffs on imported paper goods, tax incentives for domestic manufacturing, and shifts in industrial policy.

**The pulp and paper industry is adapting to an unprecedented set of challenges.** The shift from printed to electronic media, growing expectations of regulators, investors, and the public to reduce greenhouse gas emissions, expensive and less reliable electricity, and increasingly stressed water supplies threaten the traditional operating strategies of resource intensive pulp and paper mills. The pulp and paper industry is the world's 4th largest industrial consumer of energy and is responsible for nearly 2% of global greenhouse gas emissions. In addition, with the modernization of the electrical grid and its power mix, stresses to the overall system's economics and reliability are expected. **To survive and thrive, industry participants need to embrace the most affordable, reliable, water-efficient, and sustainable energy systems.**

Siemens Energy is uniquely positioned to leverage its experience as a global technology leader to help pulp and paper customers overcome their most pressing energy challenges. **This whitepaper discusses the technologies, solutions and services Siemens Energy can provide while exploring electrical and thermal energy solutions to power mill systems:**

- **Steam Turbine Generators and Waste Heat Recovery**
- **Energy System Design and Integration**
- **Combined Heat and Power**
- **Power-to-Heat, Compression, and Wind Power**
- **Electrification, Automation, Digitization**
- **Grid Consulting and High Voltage Transmission**
- **Hydrogen, Power-to-X, & Carbon Capture Support**

**Pulp and paper mills must respond to the industry's unprecedented energy and regulatory challenges before they are left behind with carbon excessive operations, regulatory penalties, unreliable and expensive power, and stranded assets.** A successful energy transition requires balancing affordability, reliability, and sustainability. Siemens Energy works with its industrial customers to maximize each of these in their current and future energy systems by identifying robust energy system strategies and designs and delivering the world's most efficient energy technologies.

# Energy use in the pulp and paper industry

**More efficient and sustainable energy solutions are needed to keep mills viable, maintain production and reduce environmental impact.**

The global pulp and paper industry is worth more than 350 billion USD with continued growth driven by the transition from newsprint and printing materials to packaging board for consumer goods [1]. Worldwide, over 400 million metric tons of paper products are produced by more than 700 virgin pulp mills and nearly 6,000 paper machines, not including operations that repulp secondary (recycled) fiber [2, 3]. To achieve this level of production, pulp and paper mills require substantial amounts of energy to generate process steam and power.

**Pulp and paper mills have traditionally been adept at managing energy resources, generating up to 65% of their electrical and steam needs on-site by recovering and burning biogenic process materials** (such as black liquor, solids, and other extractives) and other wood byproducts. Additionally, these mills typically recover waste heat and steam to reduce freshwater usage and avoid unnecessary auxiliary heating [3, 4]. Supplemental energy comes from on-site power and steam generation using fossil fuels and through external purchases, accounting for about 15% and 23% of the total operating costs for virgin pulp mills and paper machines, respectively [4, 5].

Annually, the U.S. pulp and paper industry spends billions of dollars on purchased fuels and electricity [6]. Over the past 15 years, the U.S. has retired nearly 50% of its coal power generation assets, and the continued retirement of these assets will soon eliminate over 25% of the power grid's least expensive generation [7]. This, combined with the costs of replacing these assets with renewable and modern gas generation systems and upgrading trans-mission infrastructure, will lead to higher grid electricity rates. Meanwhile, the price of natural gas has stabilized at historically low levels due to advances in recovery techniques. **Pulp and paper producers must stay ahead of these changes and maintain flexibility to ensure reliability within the mill at the lowest cost**.

Beyond the financial implications, the supplemental power consumption by U.S. pulp and paper mills contributed to an estimated 31.2 million metric tons of $CO_2e$ emissions in 2022 [8]. Improving the energy efficiency of both the processes within pulp and paper mills and the energy systems used to power them is crucial for reducing overall mill costs and carbon emissions. Pulp and paper mills will need to explore all available options for powering their unique energy transition. A simple diagram of an integrated mill is shown in Figure 1.

Figure 2 illustrates the U.S. Department of Energy's analysis comparing the energy consumption of industry-standard technology with both available state-of-the-art technology and the ultimate thermodynamic minimum for a few energy-intensive processes within mills [9]. **The potential for improvement by adopting the latest technologies is quantified for each process, revealing a total opportunity for 48% energy savings over the industry standard**. Historical inertia and the availability of cheap, carbon-intensive, fuel sources have hindered the adoption of these energy-efficient technologies. However, investing in energy efficiency improvements in these areas is becoming unavoidable as the expectations from regulators, investors, and the public to decarbonize operations continue to rise, and unprecedented tax credit opportunities and financial incentives become increasingly available.

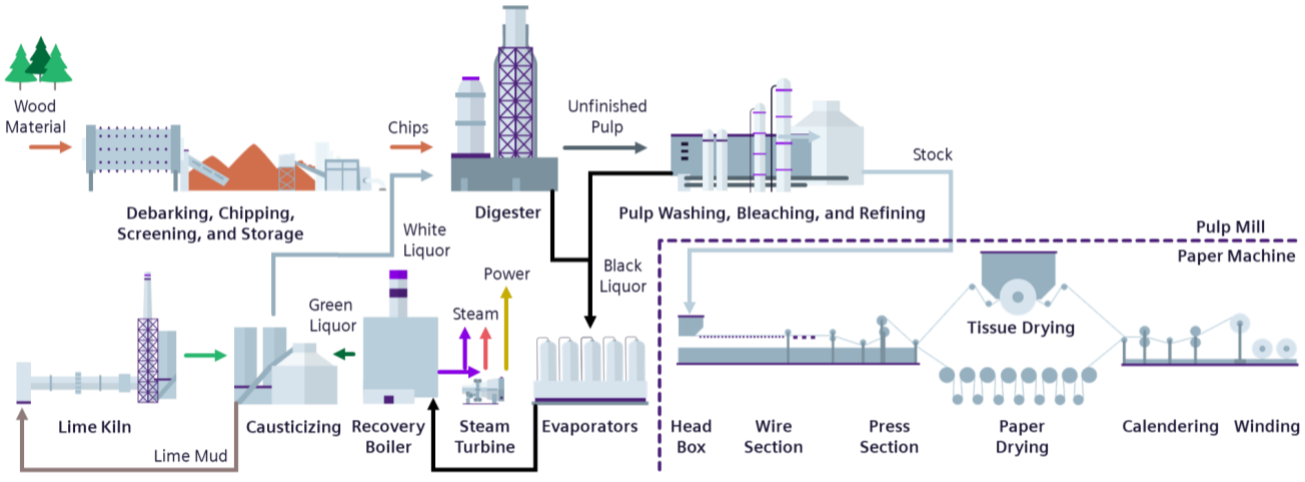


 

**Figure 1** Flow diagram of processes within an integrated pulp and paper mill.

Beyond technology upgrades, **pulp and paper mills can further decarbonize their operations and lower energy costs by reassessing their methods for obtaining power and steam**. Worldwide, government incentives like the U.S. Inflation Reduction Act and the E.U. Green Deal Industrial Plan are encouraging the electrification of heating and processes, power generation from renewable sources, combined heat and power systems, and waste heat recovery. To take full advantage of these opportunities, some of the best practices include:

- Replacing traditional boilers with combined heat and power (CHP) units
- Electrifying heat through heat pumps with waste heat recovery, induction- and turbo heaters
- Mill hybridization with renewable energy and electrical, thermal, and chemical ($H_2$) energy storage systems
- Substituting coal with biomass and natural gas as the supplemental fuel source
- Increasing heat recovery from pulp and paper-making processes, including de-inking, drying, cooking, etc.

Traditional approaches have led to pulp and paper mill assets being acquired and commissioned for specific, singular purposes. For instance, auxiliary boilers have been built to provide auxiliary steam, while diesel generators have been used to sup-ply electricity. Historically, improvements to the overall mill system have focused on enhancing the efficiency of each individual asset. **While upgrading assets is a key method for improving process energy efficiency, significant improvements in mill-wide efficiency and carbon intensity can only be achieved by considering energy system designs that integrate power, steam, heating, and/or cooling**. This involves responsibly managing the energy content available across the mill's processes and steam flows. Siemens Energy assists pulp and paper customers in enhancing the affordability, reliability, water efficiency, and sustainability of their energy systems throughout the various stages of their decarbonization and energy efficiency improvement programs, offering a range of products, solutions, and services.

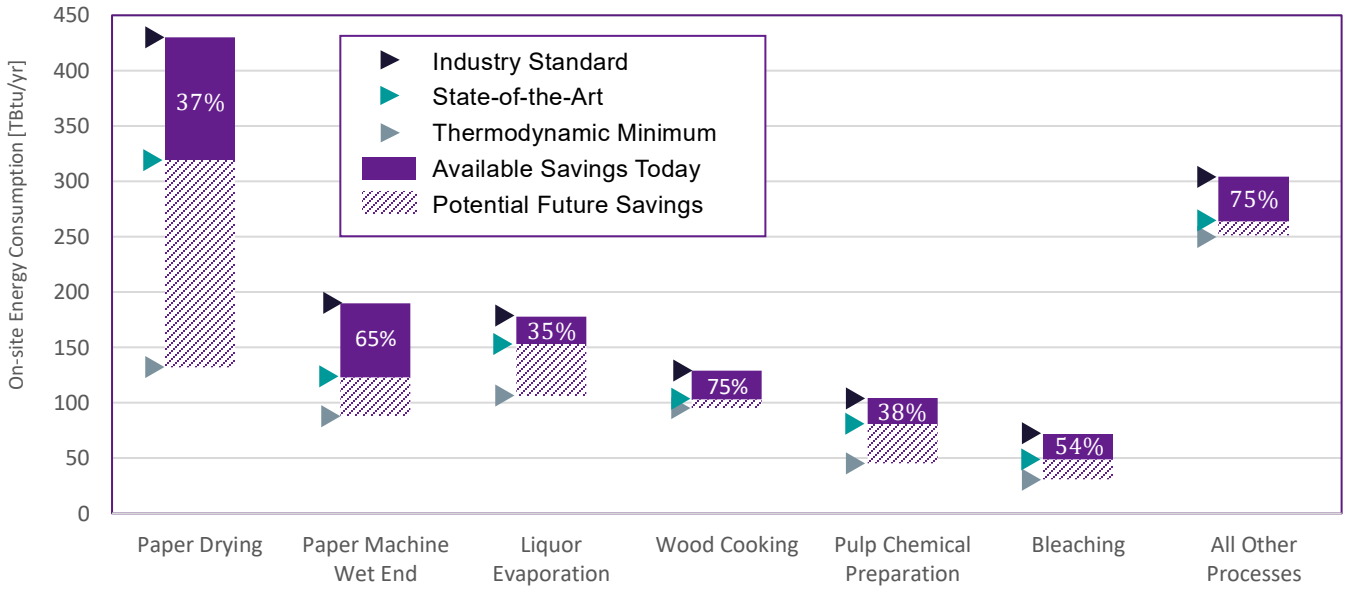


**Figure 2** Current opportunity energy savings bandwidths for processes in pulp and paper manufacturing. Figure adapted from Figure 5-1 of Bandwidth Study on Energy Use and Potential Energy Saving Opportunities in U.S. Pulp and Paper Manufacturing [9]

# Siemens Energy's Transformative Energy Solutions

**Providing a holistic approach to address the pulp and paper industry's energy challenges**

## Steam Turbines and Waste Heat Recovery (WHR)

*Capitalizing on unused energy*

Siemens Energy works with pulp and paper customers to recover valuable excess heat across the mill's processes for beneficial reuse elsewhere in the mill. Excess high-pressure steam or upgraded low-grade steam may be used to produce additional mill power using one of Siemens Energy's leading industrial steam turbine systems. **Our steam turbine solutions set the standard for reliability, efficiency, uptime, and operational flexibility, while minimizing operation and maintenance costs, and specific steam consumption.** Heat transfer systems may be deployed to redirect low-grade waste heat toward pre-heating other mill energy streams to improve mill-wide efficiency or toward nearby industrial operators and nearby residential areas as district heat.

Siemens Energy's **industrial heat pumps efficiently upgrade low-grade waste heat up to a more useful temperature for steam or process heat generation.** Heat pumps can offer the added benefit of de-humidifying and cooling exhaust flows from other areas in the mill. The recovered condensate may be reused to reduce the mill's total water consumption, and the cooler, dryer exhaust may improve other environmental emissions properties. Siemens Energy's **mechanical vapor recompression (MVR) solutions help mills to upgrade low-grade waste heat to produce higher-grade heat or steam for processes and power extraction.** Excess HP/IP steam or upgraded low-grade steam may be used to produce additional mill power using one of Siemens Energy's leading **industrial steam turbine** systems. Finally, Organic Rankine Cycle (ORC), and supercritical $CO_2$ cycle systems are being developed by Siemens Energy to help customers directly generate power from low-temperature waste heat.

***Example:*** *Upgrades to a collection of integrated mills' steam turbine generator systems doubled the time between major overhauls and produced up to 7% more power within the same footprint with payback periods of 3 to 7 years.*

## Energy System Design

*Developing optimized energy solutions*

Siemens Energy has introduced Energy System Design (ESD) to help pulp and paper mills make the right decisions for energy system expansions, upgrades, and new system designs, in light of the need for decarbonized and low-cost energy, the current regulatory and incentive landscape, and the broad range of technologies available. **ESD is a model-based engineering optimization study that selects and sizes energy conversion and storage assets to supply thermal and electrical power to an individual mill or paper machine.**

***Example:*** *An ESD study found an energy system concept with 16% lower $CO_2$ intensity at 12% less cost for a large paper mill.*

## Combined Heat and Power (CHP)

*Reducing costs and carbon intensity*

Pulp and paper mills require large amounts of both electrical energy and steam. **Siemens Energy produces best-in-class gas turbines (GT), coupled with heat recovery steam generators (HRSGs) and steam turbines to provide electricity, thermal energy, and process steam.** Natural gas auxiliary burners may be used to provide supplemental process steam within the HRSG, or electric heat can supplement energy to meet the design needs. In addition, Siemens Energy produces industrial steam turbines that can improve process steam control and significantly increase mill efficiency by drawing additional electricity from the 80+ bar high-pressure (HP) steam generated by the HRSG. These systems can be sized to produce intermediate-pressure (IP) steam for pulping and other heating operations or low-pressure (LP) steam for recovery evaporators, paper drying, and other mill processes.

***Example:*** *Two SGT-300 GTs are supplying power and steam to a large paper mill, saving 20% cost at 60% lower $CO_2$ intensity.*

## Power-to-Heat and Compression

*Innovating for efficiency*

Decarbonizing mill operations requires electrically driven options for producing process heat which outperform traditional fossil fuel combustion-based systems. These technologies are shown in Figure 3. Siemens Energy produces **industrial heat pumps which upgrade low-grade waste heat up to a more useful temperature** for use in other processes. Heat pumps operate at significantly lower energy intensities compared to competing technologies but are limited to lower maximum delivered heat temperatures. Another solution**, induction heaters, efficiently and quickly produce heat by the process of electromagnetic induction.** Induction heaters may be used in the production of steam up to 1000°C, which can

then be used across a mill's processes. Siemens Energy also offers the **turboheater, an electrically driven turbomachine which can heat air and steam to very high temperatures** (370 – 1000 °C) which may be useful for lime kiln operations, or other HP steam mill applications.

***Example:*** *A heat pump solution can supply paper mill steam at 45% lower energy and 75% lower $CO_2$ intensity than a traditional boiler.*

Siemens Energy also offers a comprehensive portfolio of **turbo and reciprocating compression solutions for the pulp and paper industry**. Compressors are used to upgrade steam from heat pumps or low-grade process streams to be beneficially used or re-used across the mill, or as critical equipment for carbon capture, sequestration, and storage, and the pressurization of hydrogen and other gases.

| Required Heat Temperature (°C) | 50 - 80 | 80 - 150 | 150 - 270 | 270 - 370 | 370 - 1000 |
|---|---|---|---|---|---|
| Pulp and Paper Mill Use Cases | | Evaporators, Paper Drying, Heating | | Cooking, Heating | Lime kiln, Power gen. |
| CHP | Yes | Yes | Yes | Yes | No |
| Heat Pump | Yes | Yes | Yes, w/ steam comp. | No | No |
| Mechanical Vapor Recompression | No | Yes | Yes | No | No |
| Induction Heater | No | No | Yes | Yes | Yes |
| Turboheater | No | No | No | Yes | Yes |

**Figure 3** Power to Heat technology comparison.

## Electrification, Automation, Digitalization

*Future-proofing the industry*

Decarbonizing operations and reducing operating costs begins with improving the energy-efficiency of the mills components, processes, and overall system. Siemens Energy's **Electrification, Automation, and Digitalization (EAD) team** works with pulp and paper customers to:

- Monitor and optimize process, equipment, and energy asset performance, reliability, uptime, and control using Digital Fiber Suite
- Replace conventional mechanical drives with highly efficient electric drive systems containing electric motors and variable frequency drives (VFDs).This includes mill critical sectional drive systems, winding systems, and more
- Maximize mill return-on-investment through energy management systems (EMS) which improve demand-side flexibility, asset power generation, and steam management in-line with hourly price signals
- Maintain maximum boiler efficiency using soot-blowing optimization solutions
- Optimize the quality and production intensity of their products using AI-based smart controls built for the pulp and paper industry
- Develop concepts into reality through engineering studies and decarbonization consulting

***Example:*** *A successful drive electrification project helped an integrated pulp and paper mill to need 7% less energy mill wide.*

## Grid Consulting and High Voltage Transmission

*Ensuring reliability*

Siemens Energy offers innovative solutions that enhance grid interconnection reliability, resilience, and flexibility. Siemens Energy's complete **air-insulated and gas-insulated substations, and large power transformers** help pulp and paper customers purchase and sell electricity from and to the electrical grid at the highest efficiency, reliability, and safety performance available. Siemens **Energy's grid consulting experts can also help pulp and paper customers to maintain the highest standards of stability in their exported power** voltage and frequency and ensure that load flows are managed.

## Wind Power Generation

*Harnessing renewable energy*

Siemens Energy provides best-in-class **wind turbine generation systems** for converting wind power into carbon-free electricity for driving processes or export to the grid. Individual turbine systems can provide between 2.9 and 7.0 MW of electricity for driving processes or use within Power-to-Heat systems for producing process steam.

## Hydrogen, Power-to-X, and Energy Storage

*Pioneering low-carbon fuels*

Pulp and paper mills produce a wide range of residuals, from wastewater solids to wood wastes, rejects, and extractives such as tall oil, turpentine, and methanol, and even emissions of biogenic carbon dioxide. Siemens Energy helps pulp and paper customers to **reclaim benefit from these waste streams through off-gas recovery, and non-fossil biochemical production including BioMEG, BioMPG, RFF, and industrial sugars.** In addition, Siemens Energy can help customers capture biogenic carbon and use this in the synthesis of e-fuels.

Conventional on-site power and steam generators rely on fossil fuels to produce heat. Low carbon fuels offer an alternative to fossil fuels by delivering the same thermal energy as conventional fuels when burned, but with significantly lower net

car-bon emissions. These fuels are either carbon free, as in the case of hydrogen and ammonia, or are hydrocarbons synthesized from captured carbon dioxide, as in the case of e-methane, e-methanol, and other e-fuels. Siemens Energy's **industrial gas turbine systems may be operated using a range of convention-al and low-carbon fuel, and even co-fired to incorporate mixes of each.** The same GT systems may therefore be used to produce power and steam with readily available conventional fuel today and low-carbon fuels as these become financially and logistically more available in the future.

Hydrogen may be used as a carbon free fuel to produce on-site heat for steam and power generation or as a critical feedstock in the production of e-fuels. E-fuels, including the synthetic natural gas e-methane, and e-methanol, are low carbon fuels synthesized using green hydrogen and captured carbon dioxide. These may be produced and sold using the abundant carbon dioxide and water resources within a pulp and paper mill. Siemens Energy **offers expertise in advanced chemical processes and produces a world class hydrogen production technology, the PEM electrolyzer Elyzer P-300**, to help pulp and paper customers maximize the opportunity to expand into the hydrogen and e-fuels production markets.

Pulp and paper mills require rapidly dispatchable and reliable power to meet the dynamic process electricity and steam loads required to keep production on-line. Energy storage systems can help customers to increase the availability of power from renewable generation and help them to avoid peak demand electricity tariffs by strategically discharging stored power (peak shaving). Siemens Energy offers a range of **battery energy storage systems (BESS) for storing and supplying electrical energy.** Siemens Energy can also help customers evaluate or design alternative systems including thermal (pumped heat energy storage, electric thermal energy storage, and other latent and sensible energy approaches), mechanical, and chemical energy storage.

***Example:*** *Siemens Energy is helping an industrial facility synthesize captured biogenic carbon with green hydrogen to produce saleable marine fuel grade methanol.*

### Carbon Capture Support

*Mitigating environmental impact*

Pulp and paper mills produce a significant amount of power, steam, and heat by burning biogenic fuels such as concentrated black liquor in the recovery boiler and lime kiln and wood chips, rejects, extractives, saw dust, bark, and other "hog fuels" in a hog boiler. The carbon dioxide produced in these combustion reactions may be captured using solvent-based carbon capture systems. Siemens Energy can help pulp and paper customers to **engineer the right system for capturing, storing, and utilizing this biogenic carbon dioxide**. Siemens Energy's compression and heat pump systems may be included to significantly improve the efficiency of complete carbon capture packages. Biogenic carbon dioxide is derived from material which absorbs atmospheric carbon dioxide while living. Therefore, capturing this carbon dioxide yields a net-reduction to the total free carbon dioxide in the carbon cycle. For this reason, captured biogenic carbon is an exceptional candidate for use as a premium feedstock to low-carbon fuels or as a basis for the production of renewable energy certificates (RECs). Mills can use Siemens Energy's **CertaLink Energy Certification solution to track the environmental impact** of sustainable production processes along the entire product cycle.

***Example:*** *Siemens Energy provided integrally geared compressor systems as critical to the capture, storage, and transport of over a million metric tons of $CO_2$ annually for an industrial customer.*

# Summary

**Upcoming challenges require pulp and paper mills to re-examine their energy strategies**

The pulp and paper industry faces a host of unprecedented challenges, ranging from the transition from print to electronic media to expensive and less reliable energy and heightened expectations for sustainability from stakeholders. These challenges, coupled with the industry's significant energy consumption and greenhouse gas emissions, underscore the urgent need for affordable, reliable, and sustainable energy solutions. **Failure to act now threatens to leave pulp and paper mills with carbon excessive operations, regulatory penalties, and stranded assets in the next five to ten years**. Siemens Energy stands ready to join pulp and paper customers in navigating these challenges by offering a range of innovative and proven technologies and solutions. A successful energy transition requires balancing affordability, reliability, and sustainability. Siemens Energy works with its industrial customers to maximize each of these in their current and future energy systems by identifying robust energy system strategies and designs and delivering the world's most efficient energy technologies.

## Source-list


1. Fortune Business Insights : *Pulp and Paper Market Size, Share & COVID-19 Impact Analysis, By Category (Wrapping & Packaging, Printing & Writing, Sanitary, New Print, and Others) and Regional Forecast, 2022-2029 (2022)*
2. Food and Agriculture Organization of the United Nations: *Forest Products Yearbook (2019)*
3. Fisher International: *FisherSolve (2023)*
4. TAPPI Press: *Handbook for Pulp and Paper Technologists, 4th Edition (2016)*
5. Fisher International: *A Retrospective on 90 Years and the Future of the Paper Industry (2019)*
6. Lawrence Berkeley National Laboratory: *Energy Efficiency Opportunities in the US Pulp and Paper Industry (2009)*
7. EIA. 2023. U.S. Energy information administration (EIA), form EIA-860 detailed data (2023)
8. U.S. Environmental Protection Agency: *Greenhouse Gas Report Program Pulp and Paper (2023)*
9. U.S. Department of Energy Report: *Bandwidth Study on Energy Use and Potential Energy Saving Opportunities in US Pulp and Paper Manufacturing (2015)*



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