Non-Confidential Final Report to ERA

ERA Project ID: E0160385
Kraft Pulp Mill Flue Gas Energy Recovery Project

Alberta Pacific Forest Industries Contact;
Darcy Tangedal
darcy.tangedal@alpac.ca
780-525-8130

ERA Project Advisor;
Sanah Dar

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Executive Summary

The Flue Gas Energy Recovery Project was conceived in 2009 but did not provide significant enough returns to incent project approval considering the risk associated with attempting to recovery heat from an acidic condensing gas for the first time. In 2018, the ERA Industrial Efficiency Challenge provided funding to offset the risk and the project was fully approved in October 2019.

The project identified materials that would withstand the acidic environment within the heat exchanger and provided this information to the heat exchanger manufacturer. The project construction and commissioning were completed in late October of 2021 and the exchanger began operation in November 2022.

The Flue Gas Energy Recovery Project successfully produces the hot water for mill processes and heated boiler feedwater that both contribute to reduced steam usage. This excess steam is then redirected to the low-pressure condensing steam turbine (G4) producing approximately 38,000 MWh of electricity annually. This electricity offsets energy otherwise produced by natural gas within the province of Alberta which equates to roughly 14,000 tonnes CO_2e of emissions reduction. Based on the annual emissions of a typical passenger vehicle (4.6 CO_2e), this would be the equivalent of taking 3,000 cars off the road or removing 2.1% of the new vehicles purchased in Alberta in 2022.

Project Description

Introduction and background

Alberta-Pacific Forest Industries Inc. (Al-Pac) operates Canada's newest and North America's largest single-line bleached kraft pulp mill. Located near Boyle, Alberta, Al-Pac produces nearly 650,000 air dried metric tonnes of elemental-chlorine free pulp annually, has the capacity to generate 95-100 MW of 'green' electricity per day (of which, we can provide up to 30-35 MW onto Alberta's electrical grid, even after providing for all of our own electric needs) and is one of the world's only producers of high-quality renewable bio-methanol available in the world. We aggressively strive to improve our environmental and economic performance, while ensuring that Al-Pac remains a strong and active corporate citizen.

As a large final emitter, Al-Pac utilizes wood waste (i.e. sawdust, bark) in the power boiler and pulping by-products (i.e. black liquor) in the recovery boiler to generate energy and steam for use within our pulping processes, including the generation of hot process water. By installing an energy recovery system on the exhaust gas from our recovery boiler; the steam currently used to heat water can be completely displaced by the recovered waste heat energy, thereby directly reducing our greenhouse gas (GHG) emissions. This displaced steam can then be used for additional power generation, which will allow Al-Pac to continuously export green power onto Alberta's electric grid.

Although heat recovery systems are not a new concept, the highly corrosive environment of kraft pulp mill boilers has made their adoption very challenging (in fact we are not aware of any adoption globally), despite the significant energy saving opportunity. The cooling of pulp mill boiler exhaust gases to recover energy results in the condensing of acids, and these acids potentially could cause significant corrosion damage to heat exchange / recovery components. The use of advanced metallurgy on these components has never been implemented in a Canadian pulp mill. In addition to the waste heat recovery, by condensing out the acid we expect an overall reduction in the mill's Total Reduced sulfur (TRS) emissions. This reduction will be achieved through the water recovered from the exhaust gas, with that water absorbing CO_2 and SO_2, in addition to the emissions' reductions achieved through increased combustion efficiency.

Detailed technology description

Alberta-Pacific Forest Industries (Al-Pac) historically used a significant amount of low pressure (LP) steam to produce hot water for use in mill process and demineralized feed water for use in the steam plant. To reduce the amount of LP steam used, Al-Pac installed a two-stage condensing economizer/ heat exchanger system using the waste heat in the Recovery Boiler flue gases. The offsetting steam is redirected from heating water and instead is used to produce electricity that is exported to the Alberta power grid.

Waste heat is categorized as sensible and latent heat. Sensible heat is the energy that can be recovered from waste heat without creating a phase change in the exhaust – no water is condensed from the exhaust gas. Latent heat recovery involves transferring so much energy out of the exhaust that a phase change from vapour to liquid occurs in the heat transfer process. When this water vapour is condensed, the latent heat, recovered at 980 Btu per pound (544.88Kcal/kg), is captured. Given that water represents approximately 12% (by weight) of exhaust gas, significant energy savings can be achieved through the recovery and use of latent heat. The new heat recovery system recovers both the sensible and latent heat energy currently lost in the flue gas.

The new heat recovery system integrates the Recovery Boiler exhaust stream and uses a forced-draft fan to divert the exhaust from the existing stack to the heat exchangers. Plant process water and demineralized boiler feedwater, currently heated via steam energy, will instead be heated by the boiler exhaust gas. The water and flue gas, exchange heat in a counter-flow pattern, maximizing energy transfer efficiency and heating the plant process water using previously wasted energy. The water within the exchanger will be pumped through the finned tubes. The flue gases and water will never be in direct contact with one another, thereby preventing contamination of the water by the exhaust gas.

Because the temperature of the process water inside the exchanger is less than the acid gas dew point of the exhaust gas, a significant portion of the total SO_2 contained within the exhaust gas will be condensed in the exchanger. The exchanger will also cool the flue gas to temperatures well below the dew point of the water vapour, allowing for the collection and recovery of water from the exhaust. Because CO_2 and SO_2 are water soluble, a portion of the total emissions of both species will then be collected in the condensed water. This will further lower the total plant emissions, in addition to the reductions achieved through the energy efficiency gain achieved by the exchanger system.

The material selected for the exchanger fin tubes was also used for all equipment that could come in contact with the acid condensed flue gas. This included the exchanger casing outlet ducts and stack. The inlet ducts, booster fan and auxiliary equipment upstream of the new exchanger are all carbon steel.

The particulate (salt cake) within the flue gas was initially considered a plugging risk for operating the exchanger as such a future allowance was made for additional cleaning through use of sootblowers. Although we did not install sootblowers or the steam lines required to operate the sootblowers provisions were made within the design so sootblowers could be added if needed.

The nature of the condensing heat exchanger raised the potential for carry over and for droplets to fall as rain around the mill site. The booster fan was sized to accommodate increased draft requirements that would allow installation of a demister if required.

Project objectives

The project objective was to construct a new heat exchanger and stack, drawing flue gases only from the recovery boiler to provide hot water for mill processes and low-pressure boiler feed-water (LP BFW). The new exchanger will draw no more than 85% of the recovery boiler flue gases. The offsetting steam usage will be directed to G4 (condensing steam turbine) and converted to power sales.

Work scope overview

The work scope included adding a new sliding guillotine damper (isolation requirements) and duct connecting the recovery boiler ducting to the new booster fan. The booster fan forces flue gas through the new exchanger and out the new stack.

Performance/success metrics identified in the contribution agreement

After one full year of operation of the Flue Gas Energy Recovery Project, a third-party verification quantification will be performed on the annual GHG reductions. Preliminary results suggest that the stack heat recovery has successfully replaced the hot water requirements for pulp production. In addition, the system prewarms the boiler feedwater. Both these savings result in excess steam made available for power generation.

Based on the operating results from October 13, 2022, to September 11, 2023, it was calculated that the system produced, the system produced 37,842 MWh of electricity from the steam savings. The generated electricity corresponds to a reduction of approximately 14,118 tonnes in CO_2e emissions, aligning with the estimates proposed initially.

Many factors come into play with the Alberta GHG reductions with the commercialization and energy savings objectives. For example, with Al-Pac, the Flue Gas Energy Recovery Project was intended to recover the steam generally used for process and convert it into electricity. Usually, the process would require the steam to be passed through a steam heating system to generate the hot water. The stack heat system eliminates that requirement. In addition, it also preheats some of the boiler feedwater to reduce the energy to produce the steam. Other facilities may utilize the recovered heat by lowering fuel in their boilers or generating more electricity like Al-Pac.

To simplify the commercialization potential, it will be assumed that the production rate of the pulp mill digester is directly related to the total amount of steam saved. Therefore, the recovery boiler steam production is directly related to the digester output, as the recovery boiler is fixed on the digester's production rate, savings and increased digester production rate will result in additional steam savings.

Alberta has four kraft pulp mills, West Fraser Hinton Pulp, International Paper (IP) Grande Prairie, Mercer Peace River and Alberta-Pacific. Assuming that the stack heat recovery will be used in the same configuration, each facility will reduce its low-pressure steam. As the steam savings can be used for fuel reduction, increased power generation, or increased pulp production, it isn't easy to ascertain a proper greenhouse gas reduction without conducting an engineering study of each facility. However, if the steam is used for a low-pressure condensing turbine, as it is at Al-Pac, then an estimation of emission reductions can be estimated to give a sense of scope.

The following table represents the power generation and greenhouse gas emission offset of each kraft mill in Alberta.

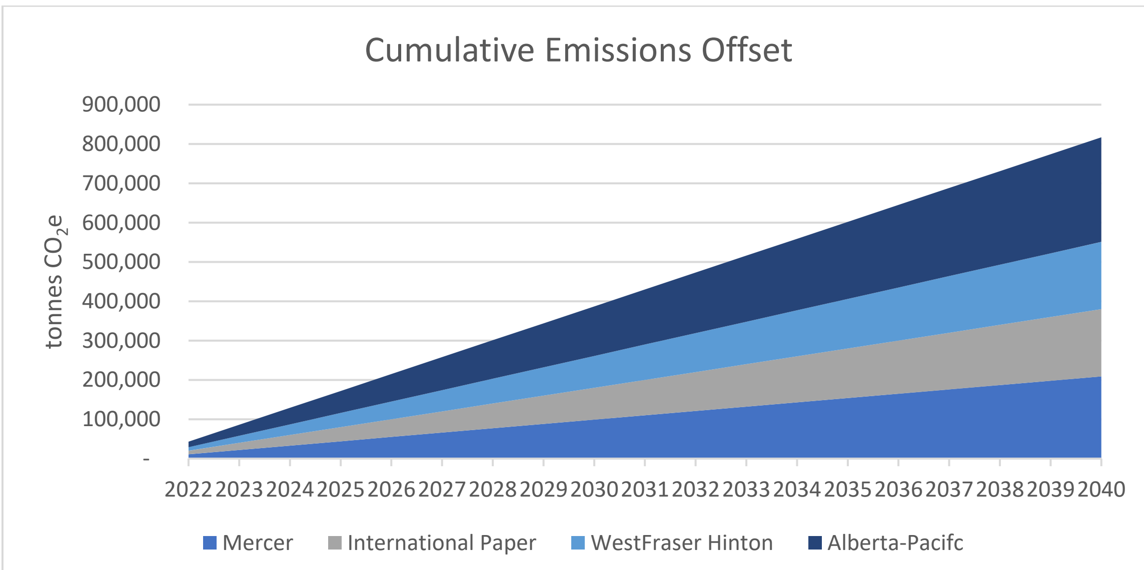

Figure 1: Emissions Offset

If each mill had a stack heat recovery unit installed and in service, starting 2022, the emission offset would equate to 43,000 tonnes of CO_2e of emissions reduction. Cumulatively, in 2025, 2030, 2035 and 2040, the emissions reduction would be 172,000, 387,000, 602,000 and 817,000 tonnes, respectively, of CO_2e recovery. The commercial roll-out of such a technology for the remaining pulp mills in Alberta would significantly positively impact reducing greenhouse gas emissions.

The ERA Industrial Efficiency Challenge application states that Al-Pac offsets natural gas emissions produced by the best in class combined cycle gas turbine. Using the TIER emissions factor of 0.37 tonnes CO_2e per MWh, Al-Pac can calculate the offsets generated from the stack heat recovery system. The following formulas represent the estimated reductions used in the determination of the reductions:

Calculated Steam Savings

$$Steam\ Savings = 4.19\ \times (a - 40) \times b \times 1.46 + 4.19\ \times (c - d) \times e \times 1.22$$

Where:

- 4.19 – Specific heat of water
- 1.49 & 1.22 – Constants, heat flow rate
- a – Hot mill water from heat recovery (°C)
- b – Mill water from heat recovery (L/s)
- c – Demineralized water from heat recovery (°C)
- d – Temperature Demineralized water from heat recovery economizer (°C)
- e – Demineralized water to heat recovery (L/s)

Calculated Power Generation from Steam Savings

$$Power\ Generation = \frac{Steam\ Savings}{(Low\ Pressure\ Steam\ to\ trubine/TG4\ Power)}$$

Grid Carbon Offset

$$Grid\ Carbon\ Offset = Power\ Generation\ \times 0.37$$

Project Outcomes and Learnings

Technology risks

Exchanger salt cake accumulation and difficulty with cleaning was identified as a significant project risk. The project made allowances to install future sootblowers if needed. The water wash system has been used to clean the exchanger every 24 hours depending on conditions and based on performance there is no need for further cleaning.

Heat exchanger performance was identified as a project risk. The contract with the heat exchanger supplier required they warrant the performance as described in the contract with liquidated damages as the selected remediation. The exchanger design met the performance requirements as determined during commissioning.

The booster fan performance was identified as a project risk. The contract with the supplier required they warrant the performance as described in the contract with liquidated damages as the selected remediation. The booster fan design met the performance requirements as determined during commissioning.

The exchanger material selection was identified as a primary risk to the project. Al-Pac chose a special grade of stainless steel even though it significantly increased project costs. Actual performance will be determined over the next 30 years.

The project identified there was some risk that moisture exiting the stack could be entrained in the flue gas and result in local precipitation. The engineers suggested that the booster fan be designed such that it could accommodate increased draft requirements in the event a demister system would need to be installed.

The project budget and schedule exceedances were identified as a risk to the project execution. The project focused on increased engineering detail requirements (even though this increased engineering costs) that would provide highly detailed construction packages. These high-quality construction packages were used to extract firm pricing from construction vendors. Although, firm pricing is fairly common, typically the construction packages are not fully complete with some details left to the constructor's discretion. This invariably leads to bid "padding" to ensure risks are covered with dollars. By providing very detailed construction packages it reduces risk to the constructor and thereby reduces firm prices. The project was completed on time and on budget.

Other than the choice of materials which has been previously described there has not been any other technology advancement.

Greenhouse Gas Benefits

The stack heat recovery unit installation (Flue Gas Energy Recovery Project) is specifically designed to capture the waste heat coming from the flue gas of the recovery boiler. The heat is then transferred to the water systems used for process heating and the boiler feedwater. The boiler steaming rates do not change, but the heat recovered frees up the steam to generate electricity in the low-pressure condensing turbine.

The Flue Gas Energy Recovery Project's main goal was to put additional electricity onto the Alberta power grid, thereby offsetting best-in-class power generation. Under the current Technology Innovation and Emissions Reduction (TIER) Regulation, the amount of carbon produced from these power plants is assumed to be 0.37 CO_2e /MWh. Therefore, it is considered that for every MW of power created from the steam saved, it offsets the emissions generated from these gas-based generators.

Al-Pac's heat recovery unit (Flue Gas Energy Recovery Project) has been in service since the beginning of November 2021. It shows great promise with the recovery of the waste heat from the recovery boiler. Based on third party verification, the system produced enough excess steam to generate approximately 38,000 MWh of electricity (annualized based on two months of operation). The electricity produced can offset about 14,000 tonnes CO_2e of emissions, generally made from gas-based power generation. Based on the annual emissions of a typical passenger vehicle (4.6 CO_2e), this would be the equivalent of taking 4,300 cars off the road or removing 2.1% of the new vehicles purchased in Alberta in 2022.

As stated in the ERA Industrial Efficiency Challenge, the project was not designed to change the overall emissions' profile of the facility; but rather does indirectly reduce overall provincial emissions by offsetting power created from fossil fuel. In addition, Al-Pac's primary fuel source is biogenetic. Therefore, there is an increased benefit of having the stack heat recovery as additional power generation is already produced from a carbon-neutral fuel source.

The application of heat recovery technology is new for kraft pulp mills. Al-Pac's stack heat recovery system (Flue Gas Energy Recovery Project) shows that it is possible to extract the heat from the flue gas from a recovery boiler. In the past, facilities and designers avoided such systems due to corrosive operating conditions and implementation challenges. The Al-Pac system is an important step forward in improving the efficiency of these types of boilers. The extra heat can also be used to reduce boiler demands on process heating; this capacity can be used for power generation or reduction of fuel requirements. Both of these are important to help facilitate Alberta's reducing carbon emissions. Furthermore, this technology isn't just applicable to recovery boilers. This project demonstration that the metallurgy has advanced enough to handle harsh environments and, therefore, could help reduce emissions across different sectors. These improvements expand the number of potential applications and sites for these heat recovery systems.

Economic and Environmental Impacts

The Flue Gas Energy Recovery Project has resulted in reduced greenhouse gas production in Alberta. As verified from a third-party auditing firm, the total emissions avoided from the stack hear recovery system was 14,118 for the period October 13, 2022, to September 11, 2023. As described earlier in the report, this equates to removing 3,000 cars from the road or removing 2.1% of the new vehicles purchased in Alberta in 2022.

The economic benefits support a continued sustainable operation of Al-Pac’s pulp mill near Boyle Alberta. The pulp mill provides direct employment for roughly 400 direct employees and 1000 contractors each day, and broader indirect and induced employment. The energy generated by the mill is sold to the Alberta power pool at market rates and reduces the greenhouse gas emissions from electricity generation within Alberta.

Overall Conclusions

The Flue Gas Energy Recovery Project has resulted in improved environmental outcomes for Al-Pac and Alberta. Aside from the improved environmental outcomes, the project provides increased revenue for Al-Pac with minimal increased operational cost which helps to sustain and support 400 direct jobs and another 1000 indirect jobs.

Communications plan:

Throughout the project, Al-Pac has actively communicated progress internally to staff and to our parent company. With more operational experience, we will be able to communicate actual performance statistics, such as GHG reductions and additional power revenue. Al-Pac will communicate the successful commissioning and operation of this project on our social media feeds, including acknowledgement for the funding support received from Emissions Reduction Alberta.

EMISSIONS REDUCTION ALBERTA	Project Emissions Reductions	ID: E0160385
Recipient Organization	Alberta-Pacific Forest Industries Inc.	
Title	Kraft Pulp Mill Flue Gas Energy Recovery Project	

GHG Emission Reductions (ERs): 2011–2050

2011	0
2012	0
2013	0
2014	0
2015	0
2016	0
2017	0
2018	0
2019	0
2020	0
2021	0
2022	1,769
2023	7,303
2024	7,368
2025	6,704
2026	6,799
2027	6,937
2028	7,051
2029	7,135
2030	7,078
2031	7,147
2032	7,273
2033	7,341
2034	7,406
2035	7,490
2036	7,566
2037	7,631
2038	7,852
2039	8,074
2040	8,123
2041	8,226
2042	8,352
2043	8,478
2044	8,711
2045	8,650
2046	8,791
2047	8,894
2048	8,684
2049	8,455
2050	8,238

Please Refer to ERA's Website For the Quantification Methodologies
https://www.eralberta.ca/calculating-ghg-emissions-reduction/