

Understanding the Energy and Emission Implications of New Technologies in a Kraft Mill: Insights from a CADSIM Plus Simulation Model

Adam Rogerson, Luciana Savulescu, Etienne Bernier and Serge Bedard
CanmetENERGY In Varennes



Outline



Industrial Context & Kraft Mill of the Future Avenues



Base Case Description and CADSIM Plus Kraft Mill Simulation Model



Simulated Technology



Simulation Results and Lessons Learned



Closing Thoughts



Industrial Context - Canadian Kraft Mills

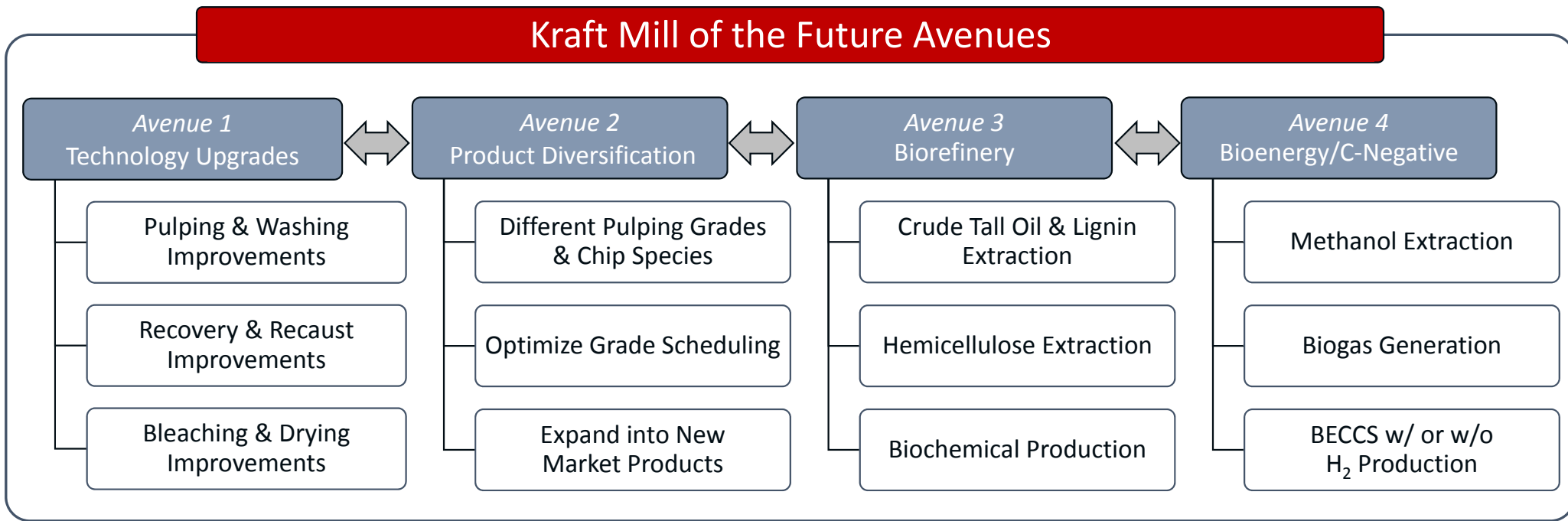


- Most Canadian Kraft mills are relatively old with moderate production rates
- Many bottlenecks and combinations of bottlenecks
 - Recovery boiler, pulp/paper machines, dryers, digesters, liquor storage
- Must maximize existing assets and consider implementation of biorefineries

Understanding system interactions and their direct and indirect implications on resource utilization and emissions is critical for strategic decision-making.



Kraft Mill of the Future Avenues



Develop mill-wide modelling and simulation of process changes and new technologies integration to assess process interactions and collect emissions data.



Research Questions and Challenges

Research Questions:

- What are the system-level implications of new technologies, new products, and carbon capture for Kraft mills?
 - How does the consumption of black liquor, hog fuel, and fossil fuels change?
 - How does the production of HP steam and electricity shift?
 - How does the demand for LP and MP steam in the mill respond?
 - How are biogenic and fossil emissions impacted?
 - How does water demand and related temperatures fluctuate?
 - How does bleaching and makeup chemical demand adjust?
 - What energy efficiency improvements are required to implement processes?
 - How is the mill's OPEX, revenue, and profit altered?

Challenges:

- Highly integrated system (cross-departmental impacts)
- Chemical recovery performance and constraints
- Process stage limits (bottlenecks)



Base Case Description: 900BDMT/d SW Kraft market pulp mill

BASECASE SIMULATION RESULTS OF SOFTWOOD KRAFT MILL

LP Steam = 55psig/165°C
MP Steam = 155psig/202°C
HP Steam = 850psig/427°C
Fresh Water = 2°C
Warm Water = 42°C
Hot Water = 70°C

EVAPORATORS
Steam Economy = 4.88
LP Steam = 88t/hr
MP Steam = 4t/hr

RECAUSTICIZING
LP Steam = 5t/hr
Fresh Water = 1440LPM
Warm Water = 2800LPM
Hot Water = 2920LPM

KILN (KN)
NG = 38t/d
Reburnt Lime = 308tDS/d

UTILITY
LP Steam = 17t/hr
Fresh Water = 8770LPM
Warm Water = 2100LPM

DIGESTER

Chips = 2138BDMT/d
Pulp = 988BDMT/d (Outlet)
LP Steam = 47t/hr
MP Steam = 25t/hr

BROWNSTOCK WASHING

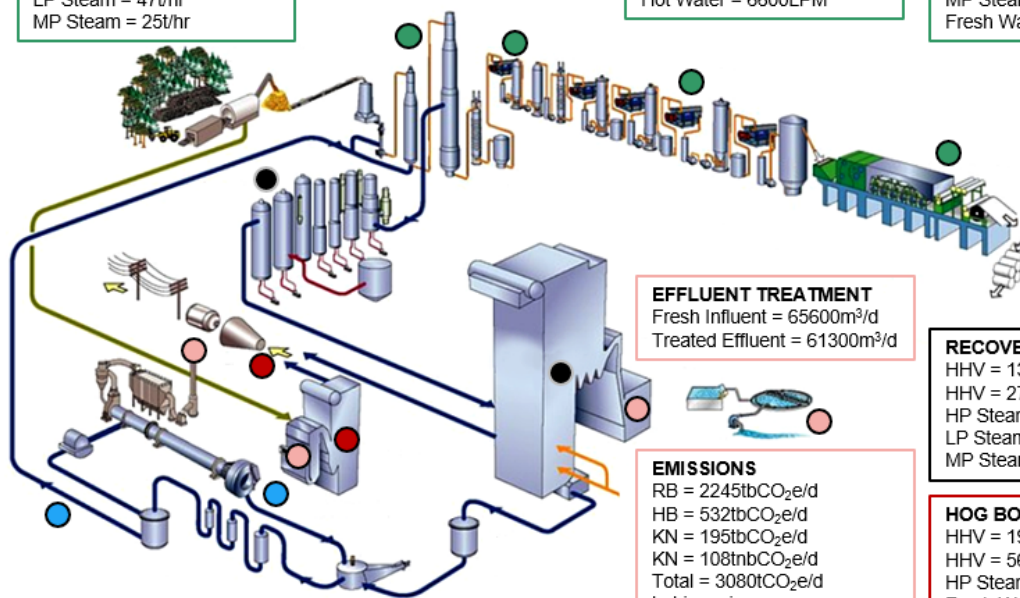
Hot Water = 6000LPM

BLEACHING

LP Steam = 37t/hr
Fresh Water = 7900LPM
Hot Water = 6600LPM

MARKET PULP MAKING

Pulp = 900BDMT/d (Outlet)
LP Steam = 18t/hr
MP Steam = 61t/hr
Fresh Water = 6200LPM



EFFLUENT TREATMENT
Fresh Influent = 65600m³/d
Treated Effluent = 61300m³/d

EMISSIONS
RB = 2245tbCO₂e/d
HB = 532tbCO₂e/d
KN = 195tbCO₂e/d
KN = 108tnbCO₂e/d
Total = 3080tCO₂e/d
b: biogenic
nb: non-biogenic

RECOVERY BOILER (RB)
HHV = 13.96GJ/tDS
HHV = 27500GJ/d
HP Steam Made = 277t/hr
LP Steam = 5t/hr
MP Steam = 15t/hr

HOG BOILER (HB)
HHV = 19.86GJ/tDS
HHV = 5660GJ/d
HP Steam Made = 56t/hr
Fresh Water = 420LPM
Hot Water = 120LPM

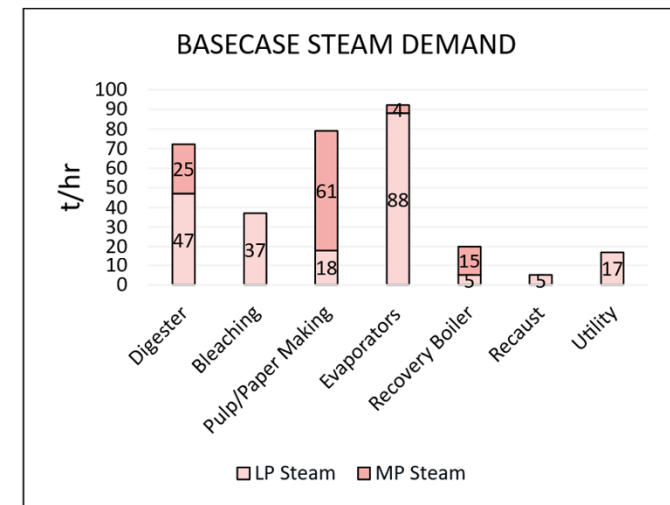
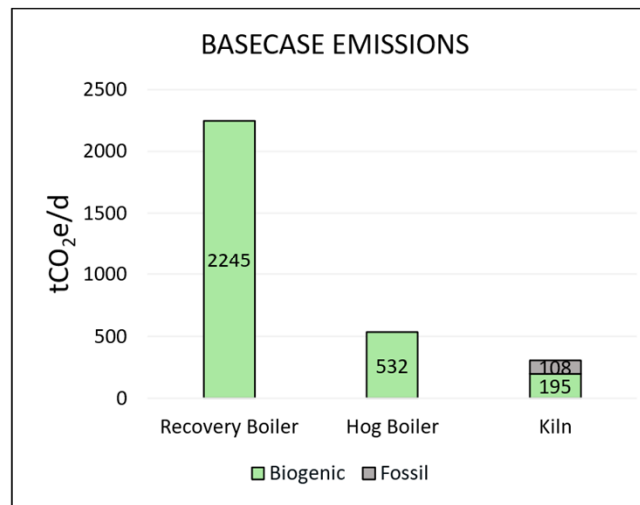
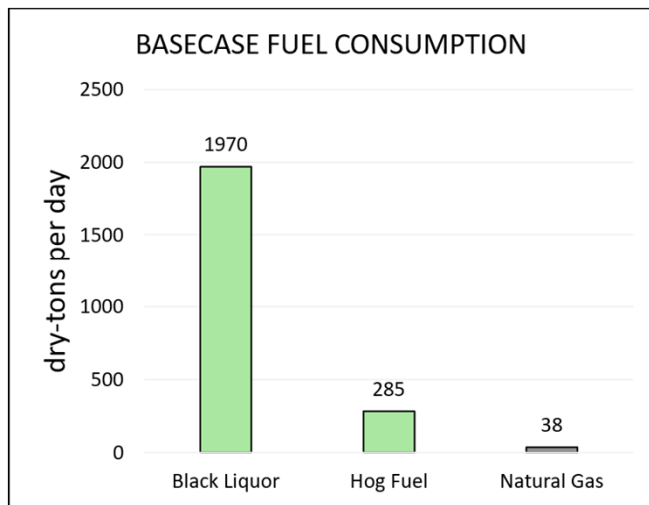
Technology

- Vacuum drum brownstock washer
- No oxygen delignification
- Six-effect evaporation plant with steam stripper
- Typical fibreline de-watering technology

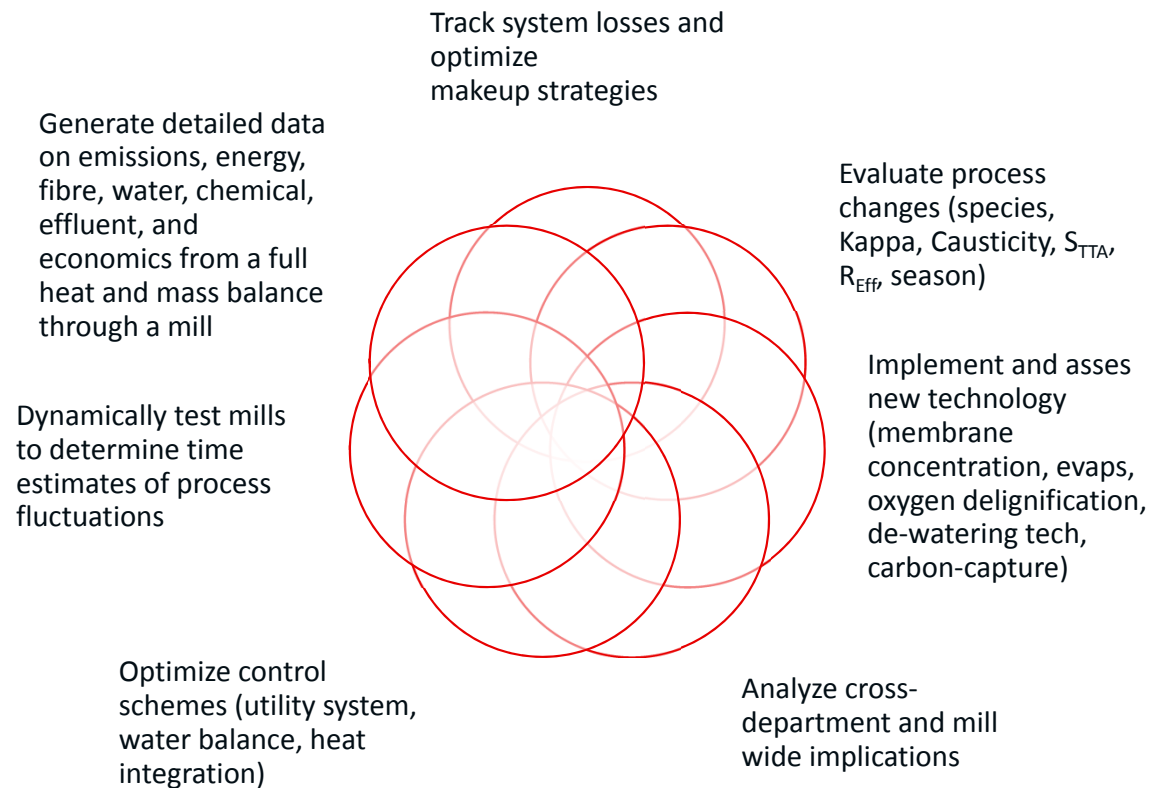


Base Case Description: 900BDMT/d SW Kraft market pulp mill

- In order to ensure that the impacts of each technology could be isolated and analyzed, the following precautions were taken:
 - Chip feed, Kappa target, causticity, sulphidity, dilution factors were held constant
 - No additional heat recovery measures were implemented
 - Natural gas flow to the hog boiler was held constant at 1t/d and hog fuel was adjusted as required



Benefits of Process Simulation



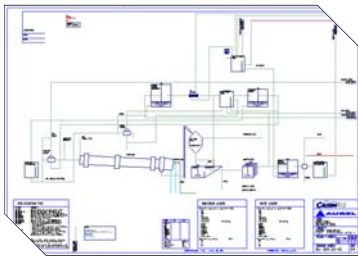
Process Simulators

- CADSIM Plus
- Aspen Plus
- WinGEMS
- MATLAB Simulink

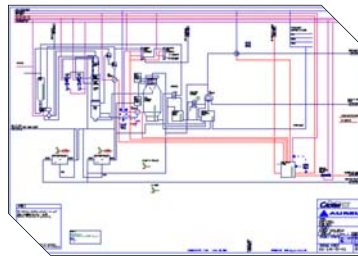


Base Case Description: 900BDMT/d SW Kraft market pulp mill

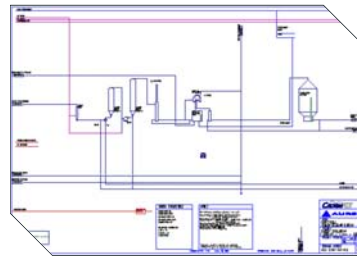
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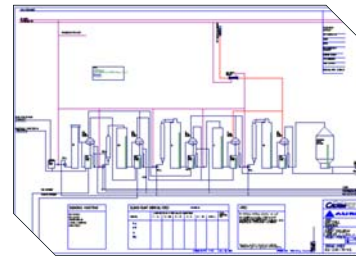
DIGESTER



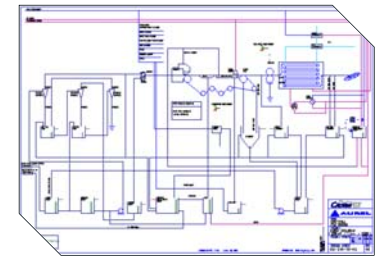
O2 DELIG.



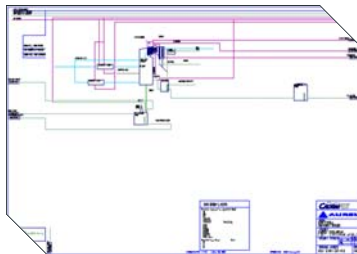
BLEACHING



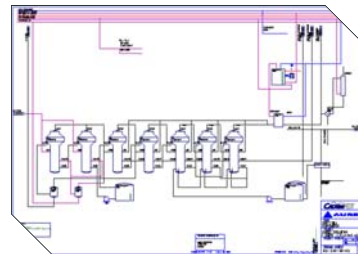
PULP MAKING



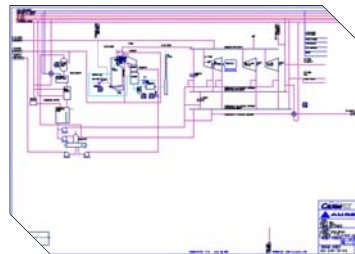
RECOVERY



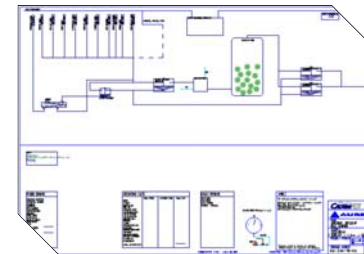
EVAPORATION



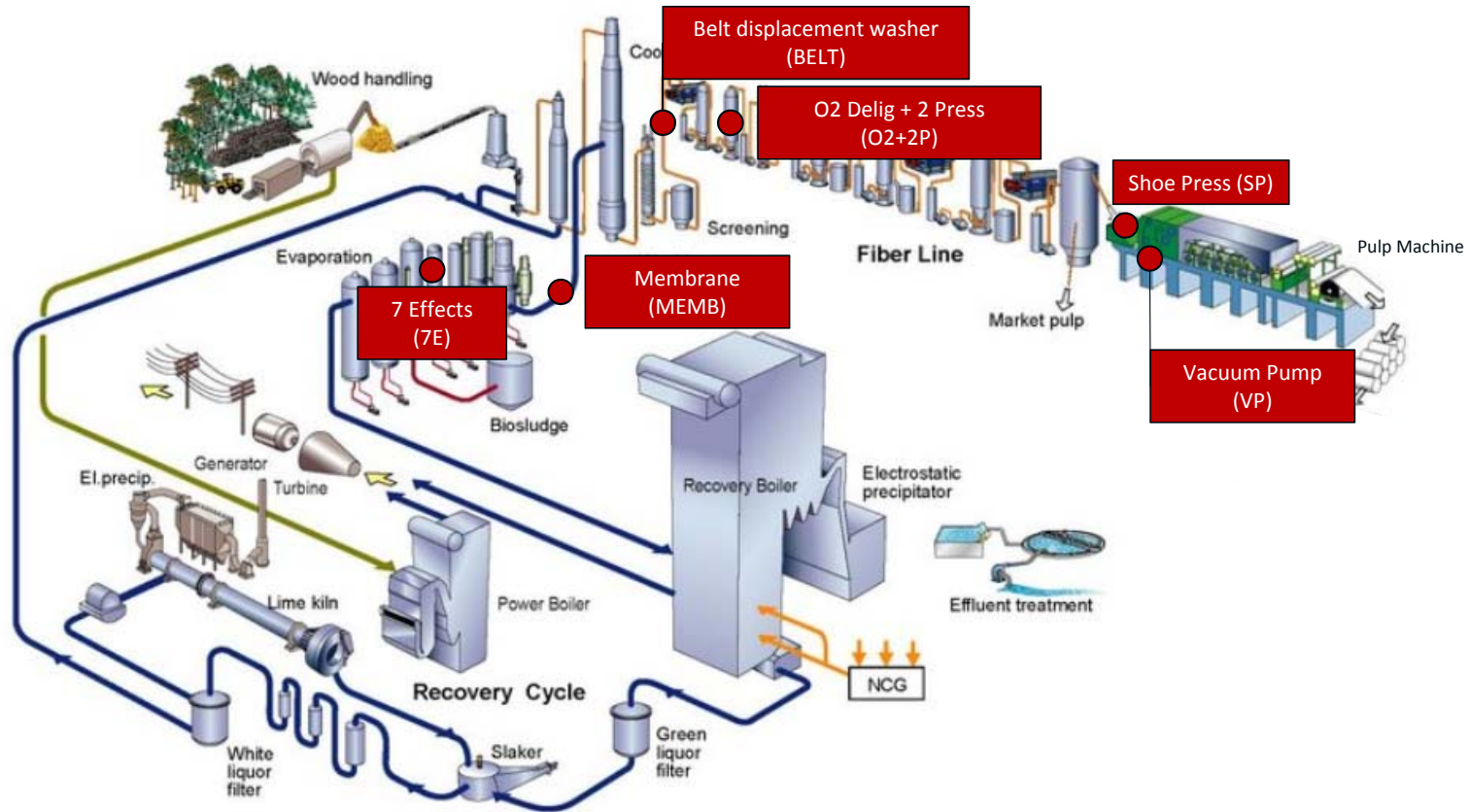
UTILITY



TREATMENT

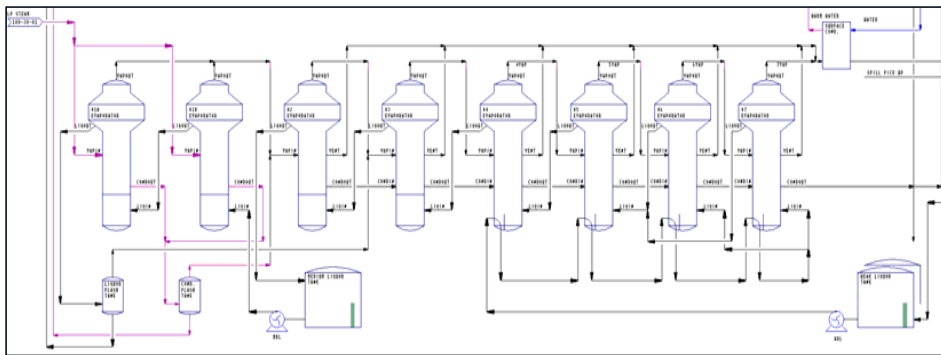


Avenue 1 - Technology Upgrades



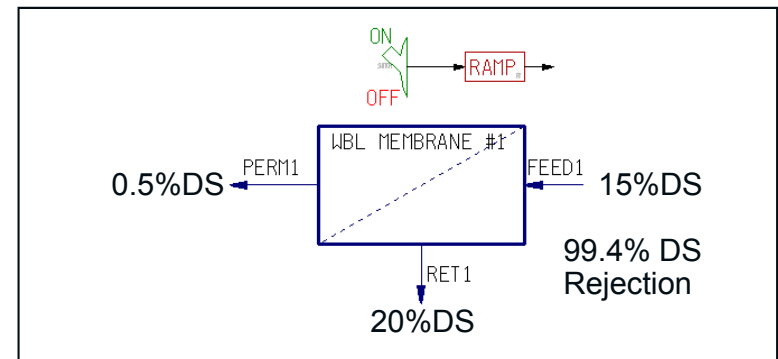
Avenue 1 - Technology Upgrades

7E



- Increases steam economy with additional vapour pass
- More gradual pressure/temperature profile for the same endpoints

MEMB

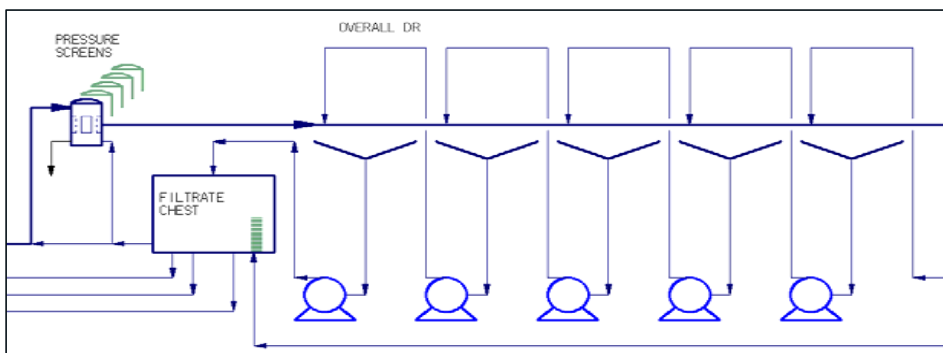


- Concentrates weak black liquor with reverse osmosis (filtration+pressure)



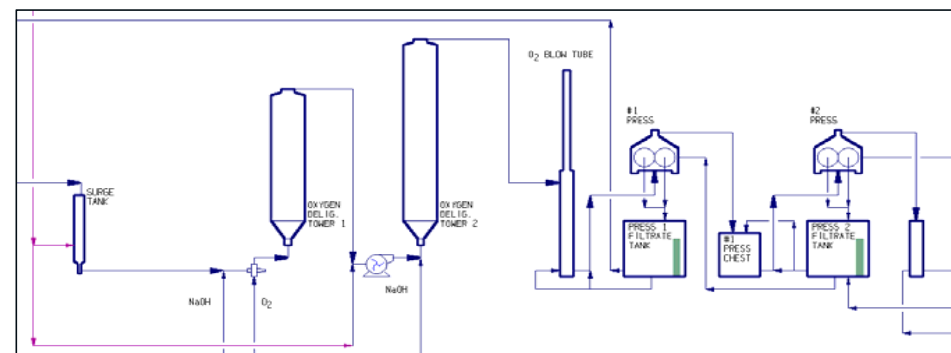
Avenue 1 - Technology Upgrades

BELT



- Replaces conventional vacuum drum brown stock washer
- Shower temperature goes from 70 to 80°C
- Dilution factor goes from 2.5 to 1.0
- Displacement ratio goes from 0.7 to 0.98

O2 2P

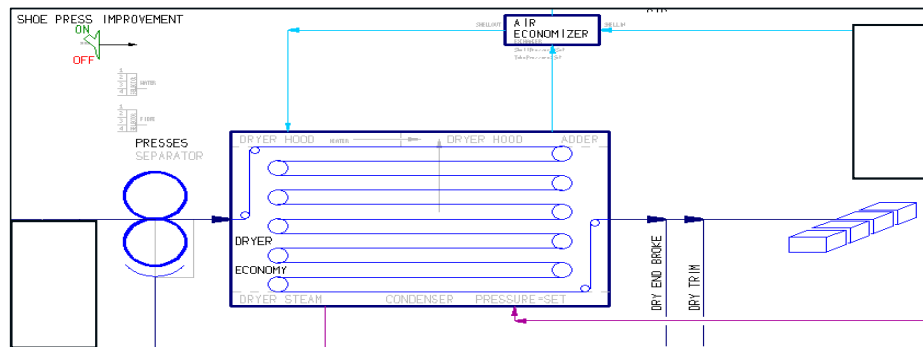


- Selectively oxidize lignin with NaOH and O₂ under pressure
- Allows for a less severe cook in the digester, thereby, increasing pulp production
- Results in lower kappa pulp to bleaching, reducing chemical demand and produced effluent; Kappa is an input not an output



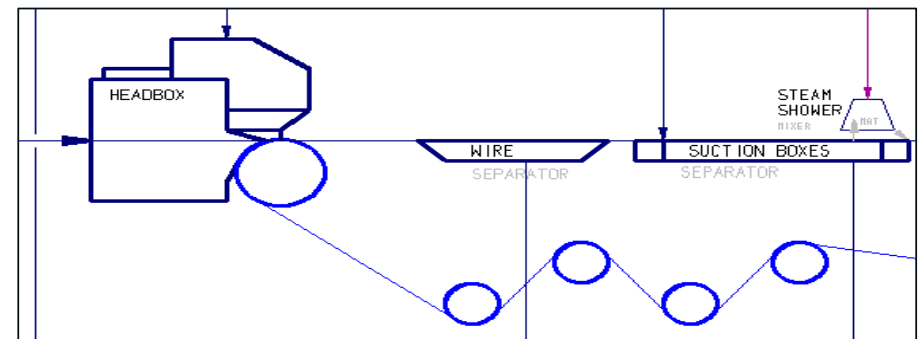
Avenue 1 - Technology Upgrades

SP



- Consistency goes from 42 to 45% entering dryer

VP



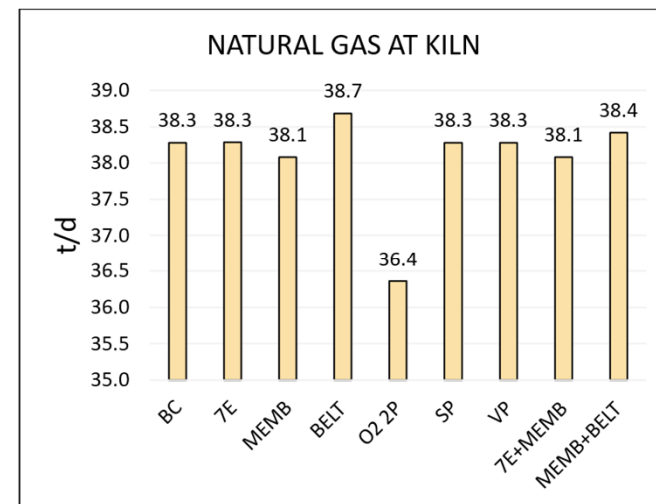
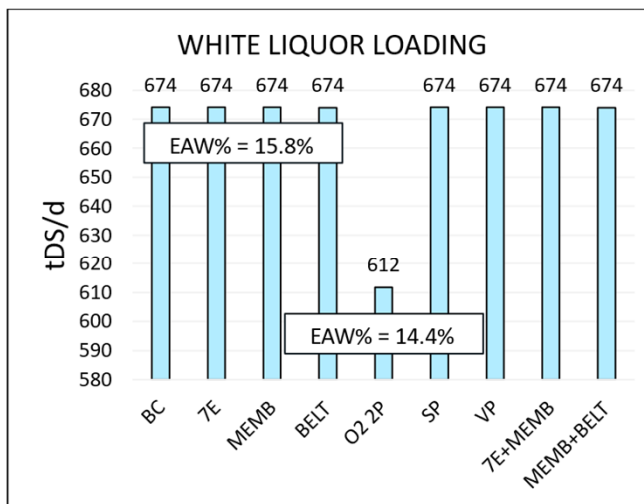
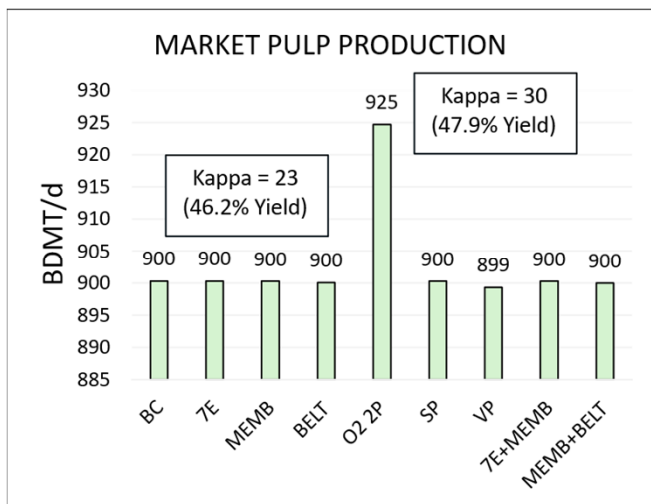
- Consistency goes from 42 to 44% entering dryer
- SP+VP achieves 47% consistency into dryer



Simulation Results: Impact of Oxygen Delignification

• Main Findings:

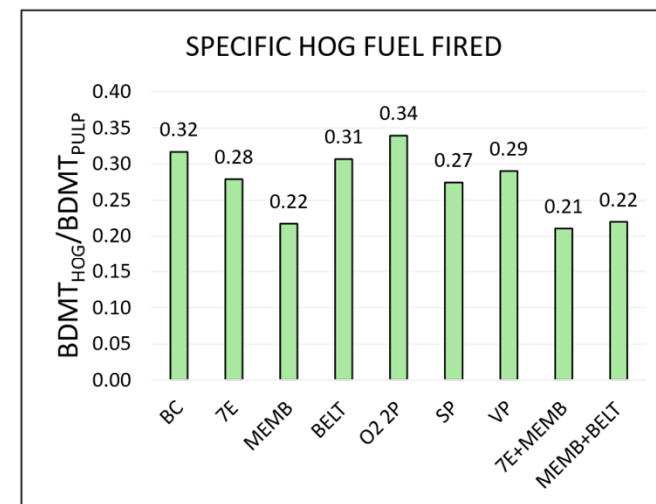
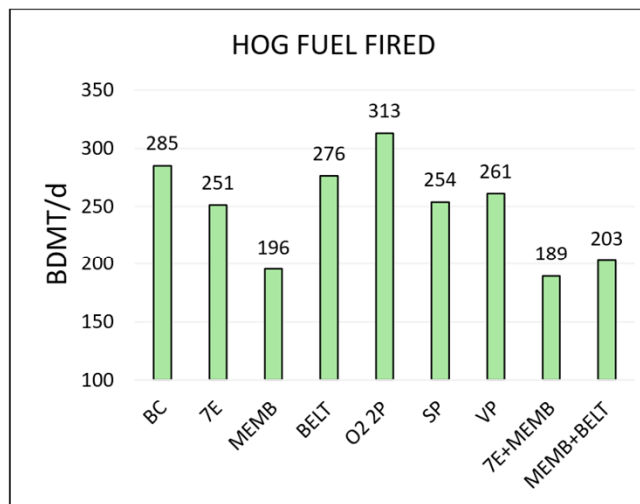
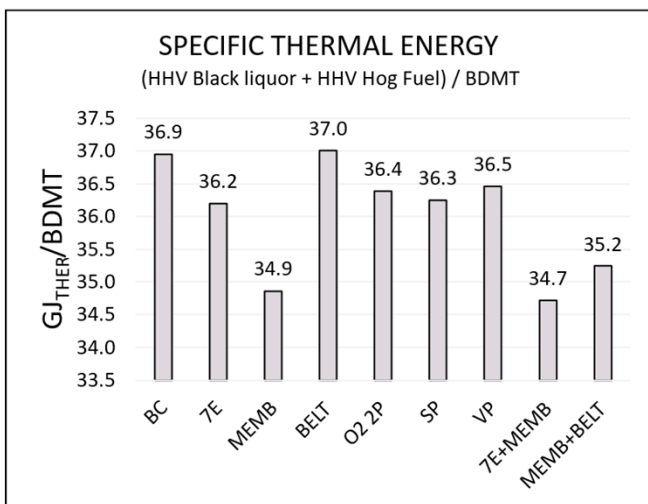
- O2 2P resulted in a less severe digester cook, which increased pulp yield by 1.7% and decreased EAW% by 1.4%; Also produces a 17 Kappa pulp to bleaching as opposed to basecase Kappa of 22
- Natural gas consumption in the kiln decreased by 2t/d as less lime was required to causticize less white liquor



Simulation Results: Energy / Biomass Consumption Implications

• Main Findings:

- MEMB produced a $34.9 \text{ GJ}_{\text{THER}}/\text{BDMT}$ and decreased hog fuel consumption by 89BDMT/d (-31% from BC) mostly due to 18t/hr reduction of LP steam to evaporators
- O2 2P increased hog fuel consumption by 28BDMT/d mostly due to MP steam demand to oxygen delignification towers and increased pulp sent to dryer; Specific hog fuel fired does not change much



Simulation Results: LP Steam Implications

• Main Findings:

- 7E achieved a 5.6 steam economy with the additional vapour pass
- 7E+MEMB reduced total LP demand by 29t/hr
- BELT increased total LP demand by 7t/hr to heat shower to 80°C

LP Demand =

Evaporators +

Steam Stripper +

Deaerator +

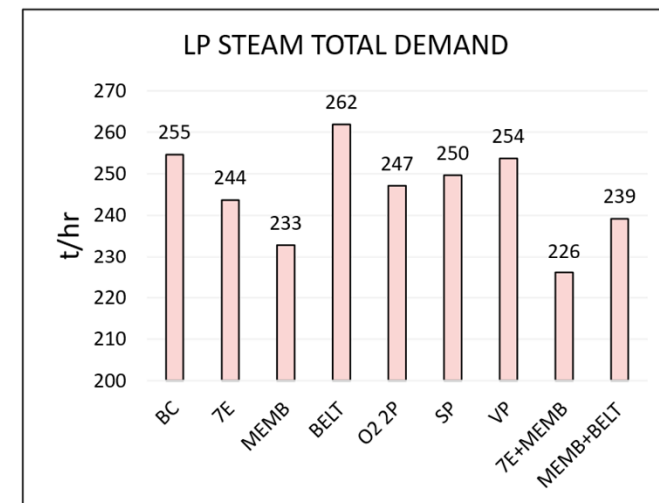
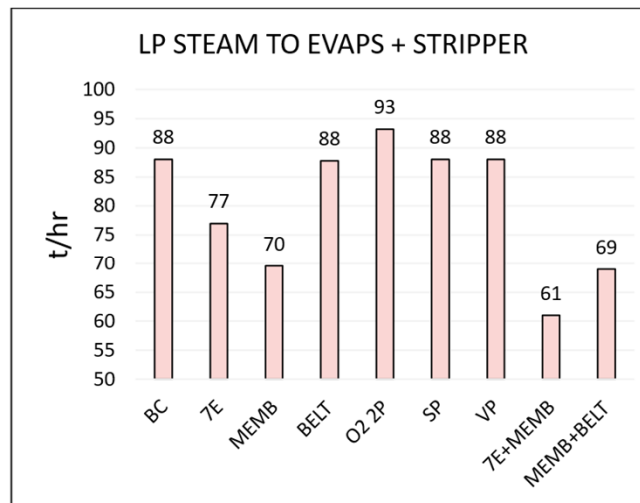
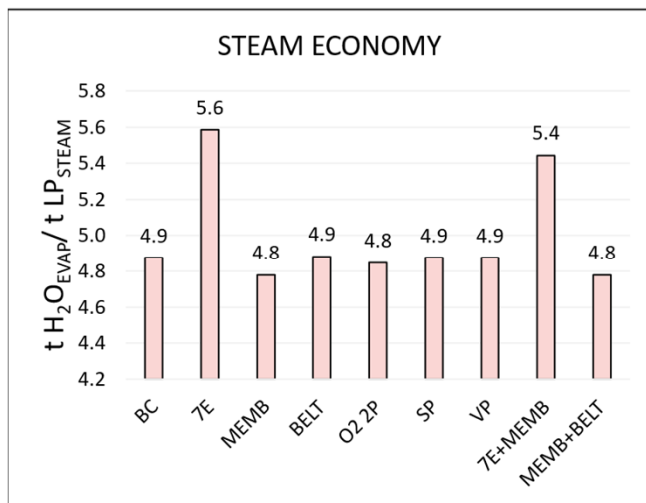
Chip Steaming / De-icing +

R8 Generator +

HXs (Wash, BFW, HW Tanks, Stock, Air) +

PM Steam Shower +

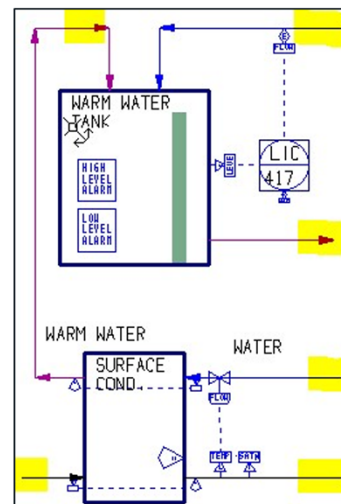
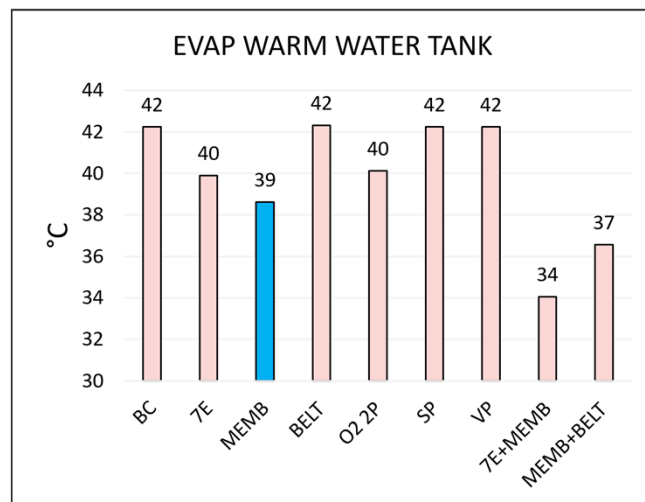
Miscellaneous



Simulation Results: Evaporator Warm Water Tank

• Main Findings:

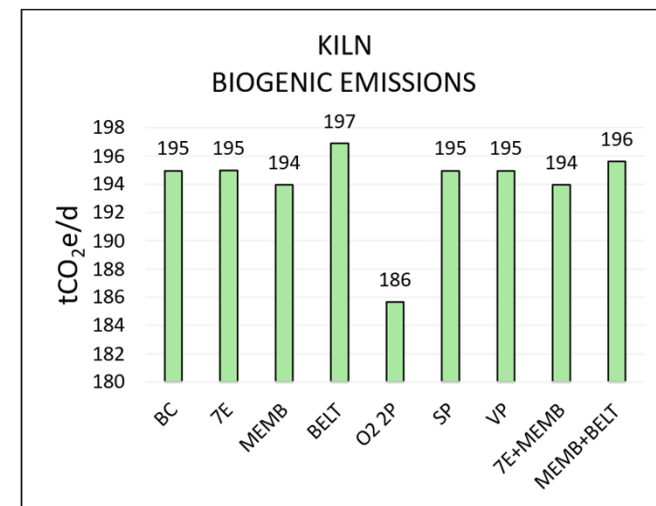
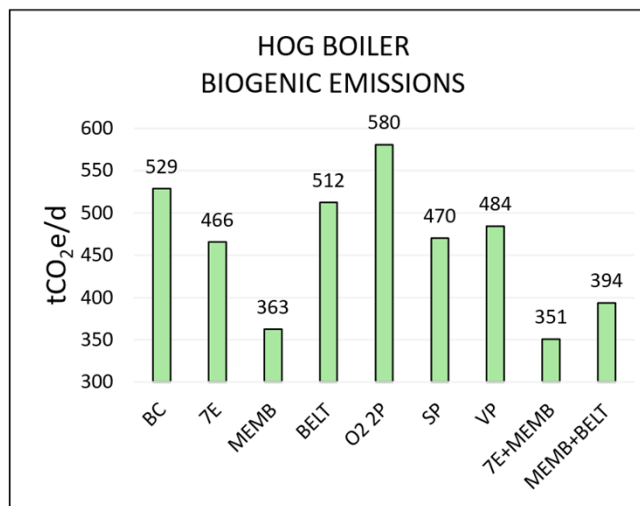
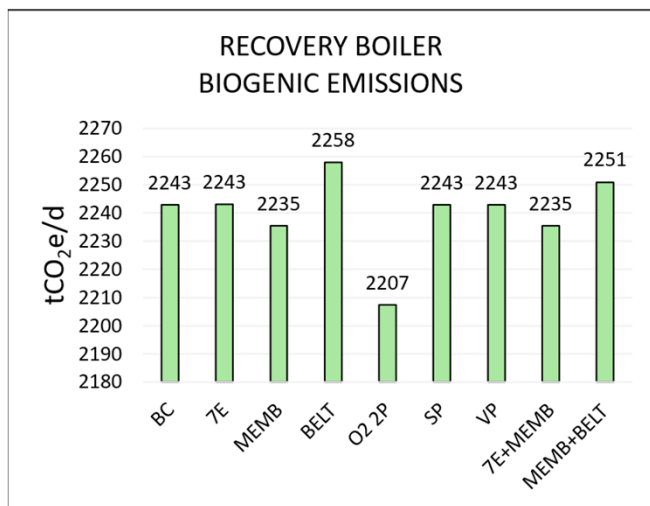
- MEMB resulted in a 3°C colder tank; As the weak black liquor was concentrated to 20%DS, less water needed to be evaporated in the evaporators. This resulted in less vapour flow to the surface condenser meaning less warm water was produced from the condensation of the vapour. This decreased warm water production means more fresh water was required for level control resulting in a colder tank.



Simulation Results: Biogenic Emission Implications

• Main Findings:

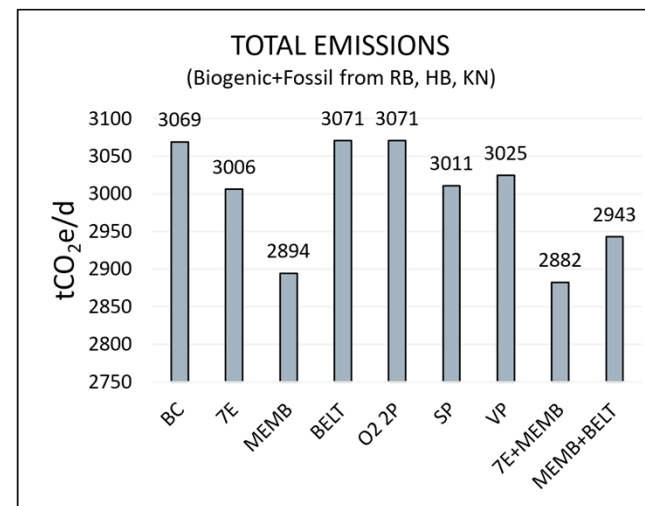
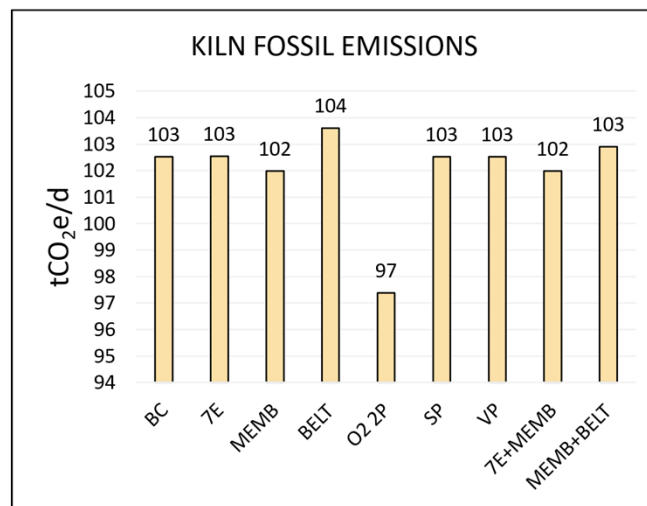
- MEMB created a 166tCO₂e/d biogenic emission reduction from the hog boiler (-46% from BC) mostly due to 18t/hr reduction of LP steam to evaporators
- O2 2P reduced recovery boiler and kiln biogenic emissions by 36tCO₂e/d and 9tCO₂e/d, respectively from changes in pulp yield and EAW%; Hog boiler biogenic emissions increased by 51tCO₂e/d



Simulation Results: Fossil / Total Emission Implications

• Main Findings:

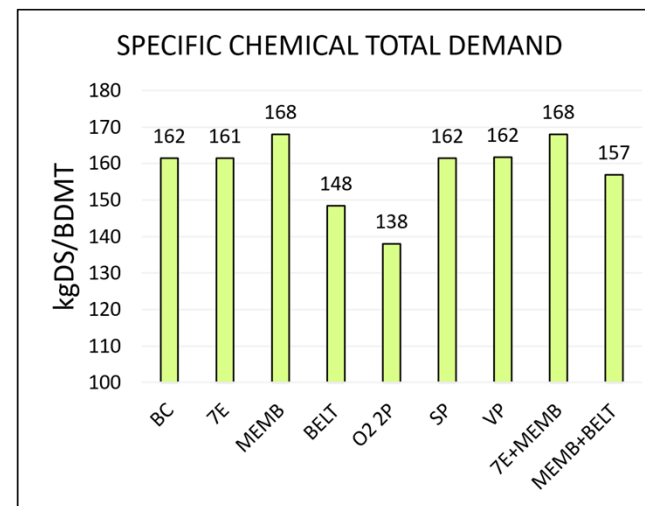
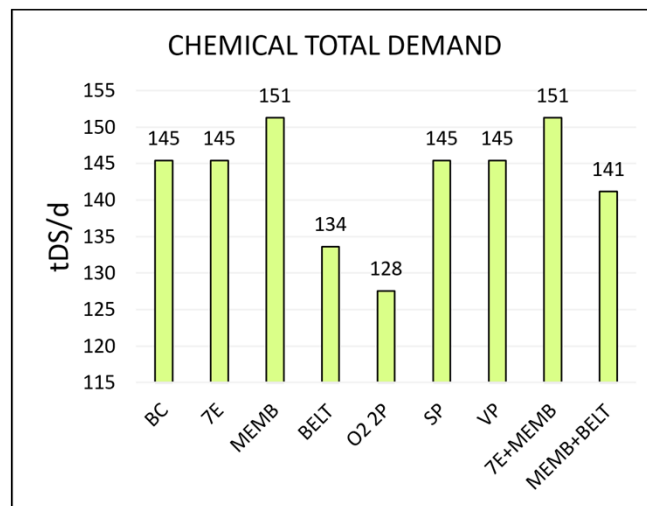
- BELT increased kiln fossil emissions by 1tCO₂e/d due to increased inorganic recovery
- O2 2P reduced kiln fossil emissions by 6tCO₂e/d with lower EAW%
- MEMB reduced total emissions by 175tCO₂e/d mostly due to LP steam savings



Simulation Results: Bleaching Chemical Implications

• Main Findings:

- Chemicals = $\text{NaOH} + \text{NaClO}_3 + \text{H}_2\text{SO}_4 + \text{CH}_3\text{OH} + \text{H}_2\text{O}_2$
- BELT reduced total chemical demand by 11tDS/d by producing cleaner pulp entering bleaching
- O2 2P decreased total chemical demand by 17tDS/d from a lower Kappa of 17 entering bleaching



Simulation Results Summary

Simulated Technology	Thermal GJ/d	Hog Fuel BDMT/d	HP Steam t/hr	Total Emission tCO ₂ e/d
BC	33221	285	334	3070
7E	32591	251	326	3007
MEMB	31418	195	315	2890
BELT	33302	276	334	3069
O2 2P	33657	313	343	3070
SP	32680	247	326	3007
VP	32824	261	330	3022
7E+MEMB	31238	189	311	2881
MEMB+BELT	31716	203	318	2943

Individual Technology:

- 1.2 – 5.4% energy savings
- 8.6 – 31.6% biomass savings
- 1.6 – 5.9% emission reduction



Lessons Learned

- **BELT:**
 - Consumes more thermal energy and generate emissions due to LP steam to wash heater
 - Enhanced washing increases RB HP steam production, reduced hog fuel consumption, and lower makeup and bleaching chemical demand
- **MEMB, BELT, O2 2P Combinations:**
 - MEMB reduces LP to evaporators and hot permeate provides heat to the BELT and O2 2P washes
 - MEMB+BELT: washing efficiency decrease from permeate balanced by steam savings at wash heater
- **7E, MEMB, 7E+MEMB:**
 - LP steam savings are significant; Can lead to a reduction in warm water production from surface condenser, potentially causing a warm water deficit depending on how the permeate is re-used
 - Lower temperatures in warm water tanks can create higher LP steam demand to other departments



Closing Thoughts

- Sophisticated tools and information are needed to evaluate different avenues to justify what investments, policies, and programs are needed for the future
- Combining technologies can amplify benefit, pose challenges, or achieve balanced solutions that compromise certain aspects for overall mill savings
- The integration of technology may require a reconfiguration of the heat and water networks to optimize their usage, avoiding unnecessary heating and subsequent cooling of water for different units
- Mill specifics, equipment capacity, and limitations dictate the true potential of each technology
- In general, the impacts of energy saving measures on electricity generation need to be considered
- Carbon neutrality and negativity will consist of a combination of energy efficiency measures, new technologies, and/or carbon capture and storage
- Major investments in existing assets should be duly assessed against the benefits of future process advancements and emerging technologies



Thank You

Adam Rogerson

Industrial Systems Optimization

CanmetENERGY

Natural Resources Canada

adam.rogerson@nrcan-rncan.gc.ca

Luciana Savulescu

Industrial Systems Optimization

CanmetENERGY

Natural Resources Canada

luciana.savulescu@nrcan-rncan.gc.ca

Questions / Comments



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