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RENEW

Renewable fuels for advanced powertrains

Integrated Project

Sustainable energy systems

D3.3.1 & D3.3.2
Preliminary engineering of the balance of plant systems and changes in the mill's energy and mass balances by implementation of a BLGMF demo plant at the Mörrum pulp mill

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Contents

1 Introduction

In the present report the impact on the energy and mass balances by implementation of a Black Liquor Gasification Motor Fuel (BLGMF) unit at a pulp mill is studied. The basis for the study is the implementation of a 45 MW_{th} BLGMF demonstration plant for DME/methanol production at the Södra Cell Mörrum mill in Sweden. The present report is focused on the influence on the mill while the preliminary engineering of the BLGMF plant itself is studied within WP 3.2 (Ingman, 2006). To attain the total situation, both reports have to be studied.

The implementation of the BLGMF unit will affect many of the mills main and sub systems such as steam, liquor, water, off-gases and electricity. Furthermore, in order to maintain the mill energy balance additional biofuel has to be imported and fired in the existing power boiler. The consequential process integration systems are identified and specified in the report and conceptual and basic design work of these systems is made.

The green liquor produced in the gasifier has a lower concentration of sulphur and a higher concentration of carbonate compared to the green liquor produced in the recovery boiler. A negative consequence of this is that the additional carbonate has to be converted to hydroxide (OH) in the causticising unit. Since the causticising unit at the Mörrum mill is a bottle-neck, the impact on this is of special interest. In order to study the mass balance of the associated chemicals in the causticising unit, a process simulations model developed in the software Extend is used.

Included in the report is also an estimation of the investment costs for the implementation of the BLGMF plant (Deliverable 3.3.2).

2 Process design basis

2.1 General

At the Mörrum pulp mill 420 000 ton pulp per year is produced in two fibre lines. The throughput of the two lines differs according to:

- Line 1, 500 ton/24 h
- Line 2, 900 ton/24 h

In line 2 either softwood or hardwood pulp is produced while in line 1 only softwood pulp is produced. Depending on the combination of production in the two lines, softwood/softwood or softwood/hardwood, the heating value of the generated black liquor will vary (cf. Appendix I). As mentioned above, the basis for the study is the implementation of a 45 MW_{th} BLGMF plant at the mill. The different heating values of the black liquor thus lead to a required flow to the gasifier given as:

- 330 ton DS/24 h when softwood/softwood pulp is produced
- 370 ton DS/24 h when softwood/hardwood pulp is produced

The recovery boiler at the Mörrum mill has a black liquor capacity of 3 000 ton DS/24 h (≈380 MW_{th}).The capacity of the gasification unit thus corresponds to approximately 12 % of the recovery boiler capacity.

The existing power boiler, placed side by side with the recovery boiler, is a bubbling fluidized bed designed for the separate or combined combustion of biomass, sludge and oil. The capacity of the boiler is approximately 80 MW_{th} when firing biofuel and sludge and approximately 100 MW_{th} when firing oil.

2.2 Location of BLGMF-unit and biomass handling system

The preliminary location of the BLGMF plant is given in Figure 1. The detailed layout of the BLGMF-unit is described in WP 3.2 (Ingman, 2006). The BLGMF plant, occupying an area of approximately 100 m x 100 m, will be located close to the recovery boiler on the opposite side of the existing main road to the mill. By this the unit is easily accessible from the existing transport road system and the length of the interconnecting systems (piping, cabling etc.) will be minimised.

When black liquor is directed to the gasifier instead of the recovery boiler, the decrease of steam production in the recovery boiler has to be compensated by additional steam production in the power boiler. The increased consumption of biomass fuel to the power boiler will result in the demand of a new biomass handling and storage system with increased capacity (see section 3.3). The new biomass handling system will also be placed on the opposite side of the existing main road.

For access to the BLGMF plant, a new transportation road has to be built. For internal transports between the mill and the BLGMF plant, a tunnel under the existing main road will also be built. Access to the BLGMF is also possible for pedestrians via the new pipe rack that will be combined with a foot-bridge (see section 3.2).

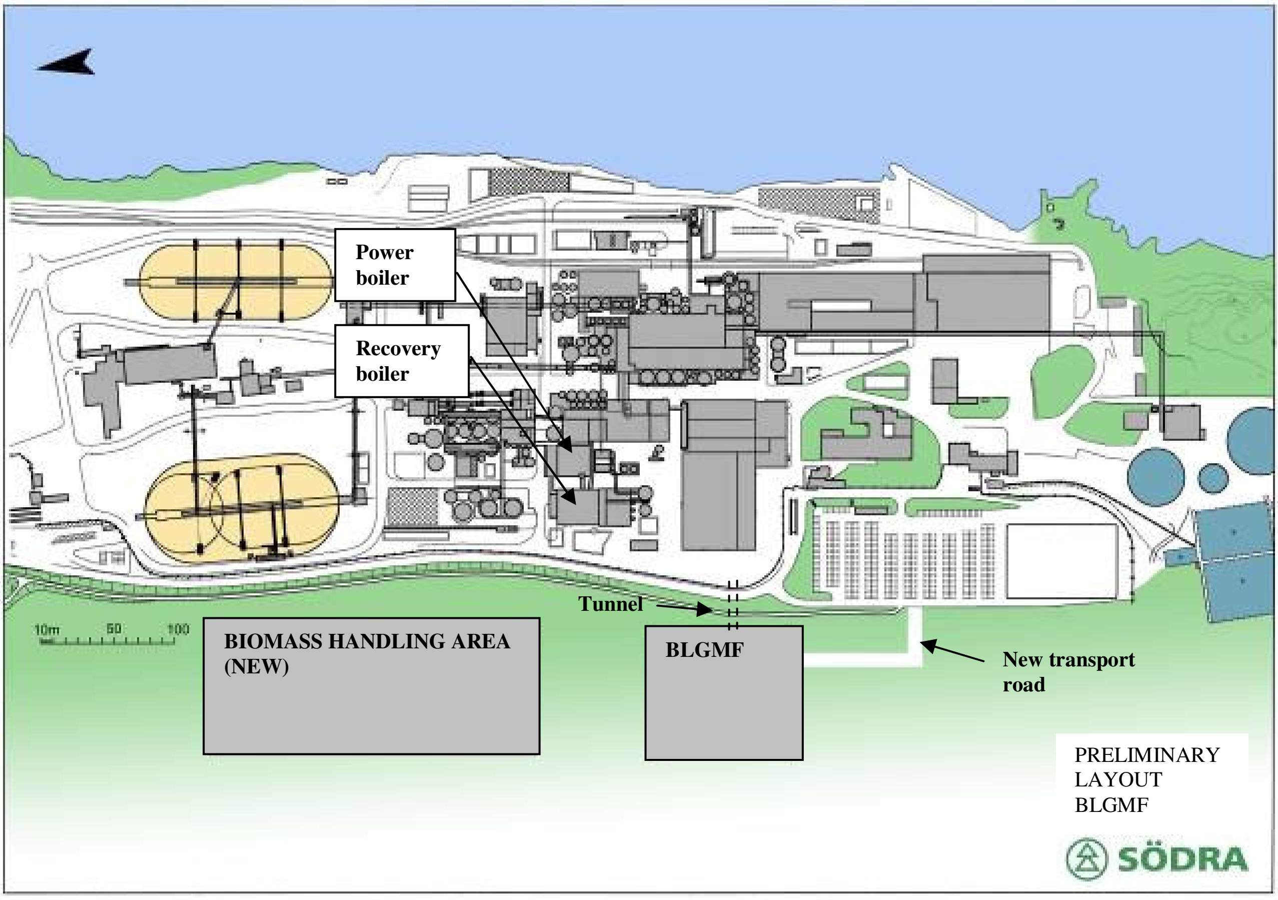

Figure 1. Preliminary location of BLGMF unit at Mörrum pulp mill.

2.3 Integration process systems

In Table 1 below all process streams crossing the battery limit is defined. The process medium code according to the mill standards is given in the table and the direction of the stream is also indicated, i.e., if the media is consumed or produced in the BLGMF plant. In general, data for the design case (balance case) is given. When deemed necessary maximum values are also given.

Medium	**Code**	**Mill ⇔ BLGMF**	**Flow nom**	**Flow max**	**Temp °C**	**Press bar(a)**
Black liquor	L61	⇒	3.8 kg/s 1)	4.3 kg/s 1)	120	3
Black liquor recirculation	L61	⇐	0.46 kg/s	2.3 kg/s 2)	120	3
Weak wash	L02	⇒	10 kg/s		90	40
Green liquor	L16	⇐	13 kg/s		90	5
White liquor	L01	⇒	2.2 kg/s		90	4
Orange liquor	L04	⇐	2.3 kg/s		90	3
District heating water	W36	⇒	4.4 kg/s		60	1.5
District heating water	W36	⇐	4.4 kg/s		120	1.5
Boiler feed water	W50	⇒	7.8 kg/s	10 kg/s	125	2
Steam HP	S03	⇒	0	0.56 kg/s 2)	450	58
Steam LP	S01	⇒	0	0.42 kg/s 2)	155	4.3
Steam LP	S01	⇐	5.5 kg/s		155	4.3
Steam condensate	C10	⇐	4 kg/s		100-120	4
Process water	W03	⇒	4.2 kg/s		10-25	6
Fire water	W23	⇒	intermittent		5/20	10
Potable water	W10	⇒	intermittent		5/20	4
Pump seal water	W04	⇒	3.3 kg/s		30	4
Instrument air	G76	⇒	0.17 m^3_n/s		30	6.3
Process water drain	D35	⇐	1.22			
Closed liquor drain	L10	⇐	intermittent			
Surface water	D05	⇐	intermittent			
Claus off-gas	V53	⇐	0.5 m^3_n/s		160	1.4
Synthesis purge gas	G29	⇐	0.17 m^3_n/s		30	1.5
NCG off-gas	G29	⇐	0.006 $m3_n$/s		95	1.5
Electric power	-	⇒	5.2 MW			

1) Flow to gasifier. Flow in connection pipe to be added with recirculation flow.
2) During start-up of BLGMF

Table 1. Process media streams.

3 Impact on mill

3.1 Process systems

In the following sections connection points for the different process streams are specified and the impact on the mill is described. Additional equipment required and other specific operation conditions are also identified. The preliminary engineering of the BLGMF plant itself is presented in WP 3.2 (Ingman, 2006).

For some of the process systems, new transportation pumps have to be installed since the capacity of existing pumps is too small. In general these pumps are placed in the existing mill area but are controlled from the BLGMF control system. The compositions for some of the process media are presented in Appendix I and data for the pumps is given in Appendix II.

3.1.1 Black liquor

The black liquor to the gasifier will be supplied from one of the two existing black liquor tanks for the recovery boiler (id # 83-3153 or -54). A new transport pump is required and the supply line has to be heat traced.

3.1.2 Black liquor recirculation

Black liquor reject is separated in a strainer in the BLGMF pump station which is returned to one of the black liquor tanks (id # 83-3153 or -54). The line is also used to re-circulate black liquor at start-up of the gasifier. The pipe has to be heat traced.

3.1.3 Weak wash

Weak wash, used for the green liquor production, will be supplied from the existing storage tank (id # 83-0204). A new transport pump is required.

3.1.4 Green liquor

Green liquor produced in the gasifier is returned to existing buffer tank (id # 83-0216). The temperature of the green liquor from the gasifier can occasionally be higher than green liquor produced in the recovery boiler but this should not be a problem since the flow from the gasifier is low compared to the flow from the recovery boiler. The green liquor is also cooled in a heat exchanger before the lime slaker.

3.1.5 White liquor

White liquor is used for the production of orange liquor, polysulphide liquor. The white liquor will be supplied from existing white liquor tanks (id # 83-0202). As the existing transportation pump is not in continuous operation, a new pump is required.

3.1.6 Orange liquor

By using orange liquor during the pre-treatment phase in the cooking process, an increased pulp yield can be obtained (Olm et al., 2005). At the Mörrum mill the largest benefits will be achieved if the orange liquor is used in fibre line #1, i.e. in the line where only softwood pulp is produced.

Orange liquor is produced in the sulphur recovery unit in the BLGMF unit. The liquor will be pumped to a new tank at the mill. A new transportation pump is also required. The tank, with a volume of approximately 300 m^3, will be placed close to existing tanks in the digester area. Orange liquor should not be stored at temperatures above approximately 80 °C.

3.1.7 District heating water

For the cooling of the counter current condenser (CCC), water from the district heating return system will be used. The pipe is passing close to the BLGMF plant and it is therefore favourable to connect to this system. Since only a part of the return flow is used, a new pump is required.

The temperature of the return water, i.e. the flow to the CCC, varies between approximately 45 and 60 °C. By regulating the flow to the CCC, the temperature of the heated water can be varied between 85 and 120 °C depending on the demand from the mill system. The heated water will be returned to the system at a connection point close to the district heating water accumulator (id # 83-3164).

3.1.8 Boiler feed water

Boiler feed water is used for steam production in the BLGMF plant and will be supplied from the feed water tank (id # 83-0178). Since the pressure requirements for the BLGMF unit is different from the mill and redundancy is required to secure process cooling, two new pumps will be installed.

3.1.9 High pressure steam

High pressure steam is supplied from the mill during start-up of the BLGMF. Since the import is only intermittent and the consumption is negligible, less than 1% of normal production from recovery and power boiler, it will not affect the balance of the mill. Connection will be made to a suitable place in the high pressure steam header close to the recovery or power boiler.

3.1.10 Low pressure steam

Low pressure steam is both consumed and produced in the BLGMF plant. At start-up LP steam is used for preheating of the black liquor to the gasifier. When the BLGMF is in operation saturated steam at 4.9 bar(a) is produced. A pressure control valve located in the BLGMF area is used to reduce the pressure to the mill level, 4.3 bar(a). By this the steam will also be superheated to avoid condensation in pipes during transport to the mill. The delivered steam will be monitored for contaminants before supply to the mill LP steam header.

3.1.11 Steam condensate

All steam condensate streams from the BLGMF are collected and returned to the mill in one condensate return pipe. At the mill three condensate tanks with different temperature levels exist, 100, 115 and 120 °C. The 100 °C tank has most available capacity and the steam condensate will thus be connected to this (id # 83-2176). Condensate will be monitored with conductivity metres before transfer to the mill.

3.1.12 Process water

Mechanically treated water (VKM) will be used as general distributed process water. It is, for example, used as make-up in quench and cooling tower as well as in the synthesis unit.

3.1.13 Fire water

Fire water to the BLGMF plant is supplied from the existing mill system. The capacity of the mill network is assumed to be sufficient to cover the demands of the BLGMF plant.

3.1.14 Potable water

Potable water to the BLGMF plant is supplied from the existing mill system. The capacity of the mill network is assumed to be sufficient to cover the demands of the BLGMF plant.

3.1.15 Pump seal water

Chemically treated water (VKK) will be used as pump seal water. Pressures exceeding existing mill standard will be required in BLGMF plant and a booster pump is therefore installed.

3.1.16 Instrument air

The current instrument air system is limited in capacity and a new compressor has to be installed. The most appropriate placement of the compressor and related equipment is not fully investigated but should not cause any major problems.

3.1.17 LPG

LPG is used continuously only for the flare for the off-gases while intermittent use is made for start-up and hot stand-by of the gasifier and the Claus process. Since existing capacity at the Mörrum mill is limited a new LPG tank and evaporator is required. The placement of the unit is not fully investigated but the most appropriate location is probably at the BLGMF plant.

3.1.18 Process water drain

This system contains contaminated effluents such as condensate from shift cooling and water from the methanol distillation column. The water will be passed to the mill biological effluent treatment plant. The flow from the BLGMF is very low compared to normal flow from mill (less than 0.5 %) and it will not contain any harmful components for the biological treatment (Ingman, 2006). The performance of the biological treatment plant will most probably not be affected.

3.1.19 Closed liquor drain

This system contains off-spec black liquor, green liquor, white liquor etc. At normal operation there is no off-spec liquors formed and the flow is only intermittent during start-up of gasifier. The effluents will be collected and transported to the waste liquor tank in the causticising unit (id # 83-0236).

3.1.20 Surface water

The surface water from the BLGMF will be passed to the sedimentation plant. The quality will be monitored and if necessary the surface water will be directed to the same waste liquor tank as described above (id # 83-0236).

3.1.21 Claus off-gas

The Claus-off gas is initially regarded as a strong gas (LVHC) since the concentration is above the explosion limit. The current strong gas system at the mill is limited in capacity. In order to be able to handle the Claus off-gas as a weak gas (HVLC) it will be mixed internally with nitrogen derived from the air separation unit (ASU) before it is supplied to the mill.

The weak gas from the BLGMF will be mixed with the existing weak gas. In the existing system, the weak gas is supplied via the secondary air system into the recovery boiler. The flow from the BLGMF is comparably low (current weak gas flow is approximately 7 m^3_n/s) and will probably not affect the combustion in the recovery boiler to any great extent.

3.1.22 Synthesis purge gas

The synthesis purge gas is a pure and sulphur-free gas with a relatively high heat value. The gas will be supplied to the power boiler, where it will decrease the incremental biomass requirement. However, a new burner with related equipment and burner management system is required.

3.1.23 NCG off-gas

The off-gas from the green liquor flash tank is mixed with the synthesis purge gas before it is delivered to the mill. The amount is very small and will probably not affect the performance of the gas burner mentioned above.

3.1.24 Electric power

Electric power will be supplied to the BLGMF at two voltage levels:
- 6.3 kV to be transformed to suitable voltage levels for pumps, fans etc.
- 400/230 V for lighting.

Power to the mill is delivered on a 50 kV grid. The contract with the supplier guarantees a supply of 10 MW and, additionally, 16 MW if capacity is available.

During 2005 a new steam turbine was installed at the Mörrum mill. By this, three steam turbines are producing electrical power sufficient to cover the demand at the mill. Export of power is also possible, especially during the winter season. As shown in Table 1 the electrical power demand of the BLGMF plant is approximately 5 MW_{el} and occasionally it could be possible to cover the demand by the production at the mill. However, in order to deliver the electric power directly from the mill to the BLGMF, Södra need to have the majority ownership of the plant. If not, the power has to be exported to the external grid and then imported to the BLGMF plant. This issue need to be further evaluated.

3.2 Piping

The process media streams described in section 3.1 will be connected via a built-in pipe rack (see Figure 2). Most of the process media is available close to the recovery or power boiler. The liquid effluents such as the process water drain and the surface water will be directed directly to the effluent treatment plant. The preliminary dimensions for the interconnecting pipes are given in Appendix III.

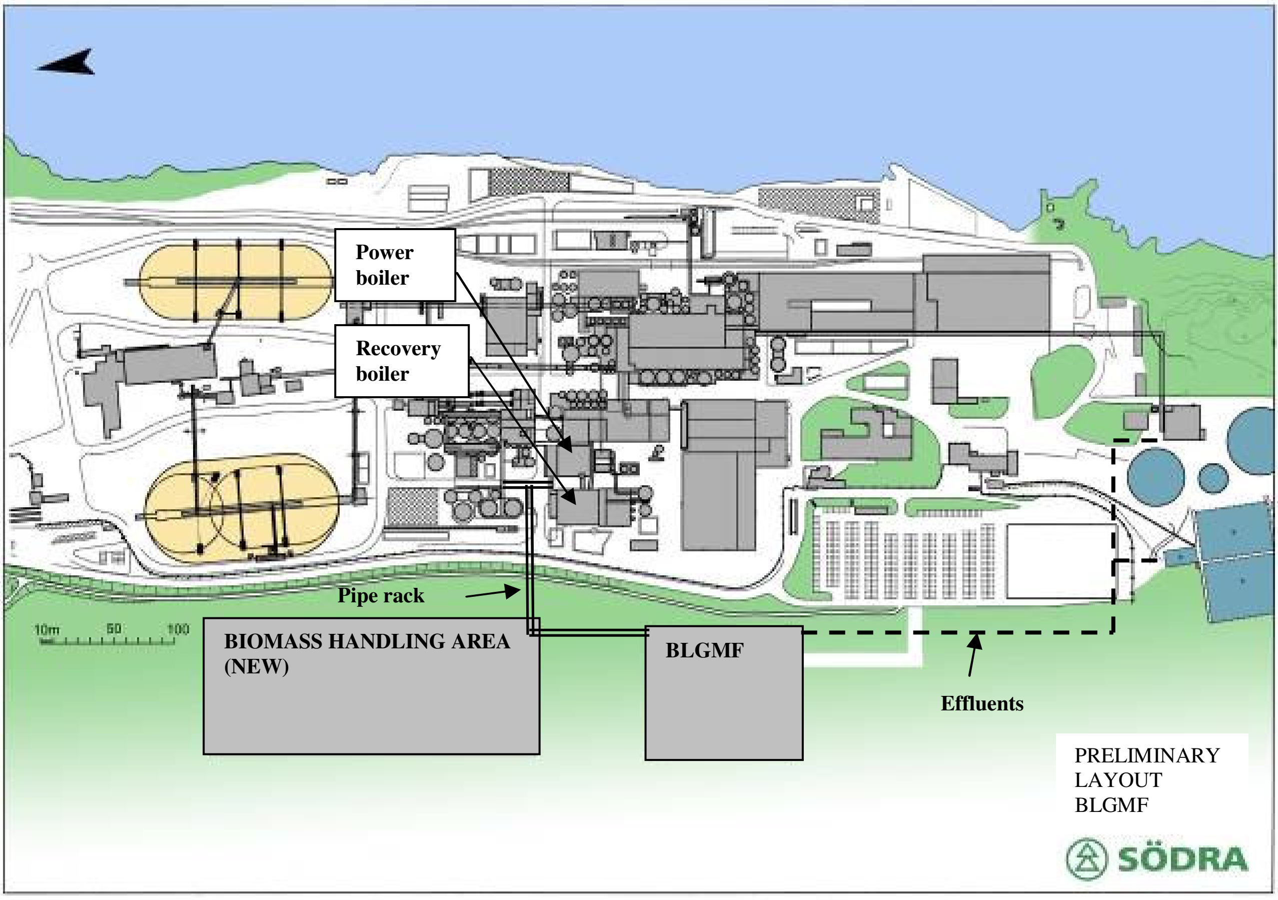

Figure 2. Interconnecting piping between the Mörrum mill and BLGMF.

3.3 Integration aspects

3.3.1 Energy balance

3.3.1.1 Steam

When black liquor is directed to the gasifier instead of the recovery boiler approximately 12 kg/s less high pressure steam is produced. In order to maintain the mill energy balance the steam loss in the recovery boiler must be compensated by additional steam production in the power boiler. Approximately 5 kg/s steam is received from the BLGMF plant as low pressure steam (see section 2.3). Thus, approximately 7 kg/s steam must be produced in the power boiler corresponding to approximately 23 MW of supplied fuel. Approximately 3 MW of the demand is covered by the supply of synthesis purge gas from the BLGMF and an additional supply of approximately 20 MW of biofuel is required to the power boiler.

The total production of biomass at the mill, mainly in the form of falling bark, is approximately 350 GWh per year. All of this is in principle consumed at the mill today and the additional 20 MW of biofuel to the power boiler thus has to be imported. Based on a heating value of 0.8 MWh/m^3_s, 25 m^3/h or approximately 200 000 m^3_s/year (160 GWh/year) of biofuel has to be imported.

The increased demand of steam production in the power boiler can probably partly be met by energy savings at the mill. The largest potential for energy savings exists in the district heating system where secondary heat can be used instead of steam (Andersson, 2006). There is also a potential for energy savings in the bleaching and digester plants. The investments costs in proportion to the energy saving potential in the bleaching and digester plants are not as high as in the district heating system.

Another aspect that could affect the demand of imported biofuel to some degree is also that the excess of produced steam is occasionally fairly high at the Mörrum mill, especially during the summer season. By implementing a more precise control of the total situation of the biomass, steam and electricity production, a more cost and energy effective operation can probably be achieved.

3.3.1.2 Electric power

As described above, the loss of produced high pressure steam is approximately 5 kg/s corresponding to an electrical power generation of 3 - 4 MW_{el} (approximately 25 GWh/year) depending on turbine and extracted steam.

As mentioned above (section 3.1.24), the Mörrum mill is a net producer of electrical power. Three steam turbines at the mill are producing approximately 350 GWh_{el} per year. Approximately 325 GWh_{el} is consumed at the mill which means that approximately 25 GWh_{el} per year is exported, i.e. close to the consumption of the BLGMF plant.

As the newly installed turbine, G3, has been in operation less than a year, and mainly during the winter season, the net production is only estimated. The production of electrical power is also dependent on the pricing and strategy for the total energy situation. As the operation experience with the new turbine is limited, the strategy for the future is not totally determined. The power generation will also be affected if the energy savings mentioned above is made. A decreased steam demand and production will lead to a decrease of generated electrical power.

3.3.1.3 Warm water

The energy content in the warm water flows to and from the BLGMF plant is small compared to existing energy flow and will not affect the balance of the plant to any great extent.

3.3.2 Causticising plant

As mentioned above the green liquor produced in the gasifier has a lower concentration of sulphur and a higher concentration of carbonate (Na_2CO_3) compared to the green liquor produced in the in the recovery boiler (Berglin, 2006). As a consequence of this, additional carbonate has to be converted to hydroxide (NaOH) in the causticising unit, more burned lime mud (CaO) must be added in the lime slaker and more lime mud must be re-burnt in the lime kiln.

As the causticising plant at the Mörrum mill is a bottle-neck, the impact on this is of special interest. In order to study the mass balance of the associated chemicals in the causticising plant, a process simulations model developed in the software Extend was used. A part of the model is shown in Figure 3.

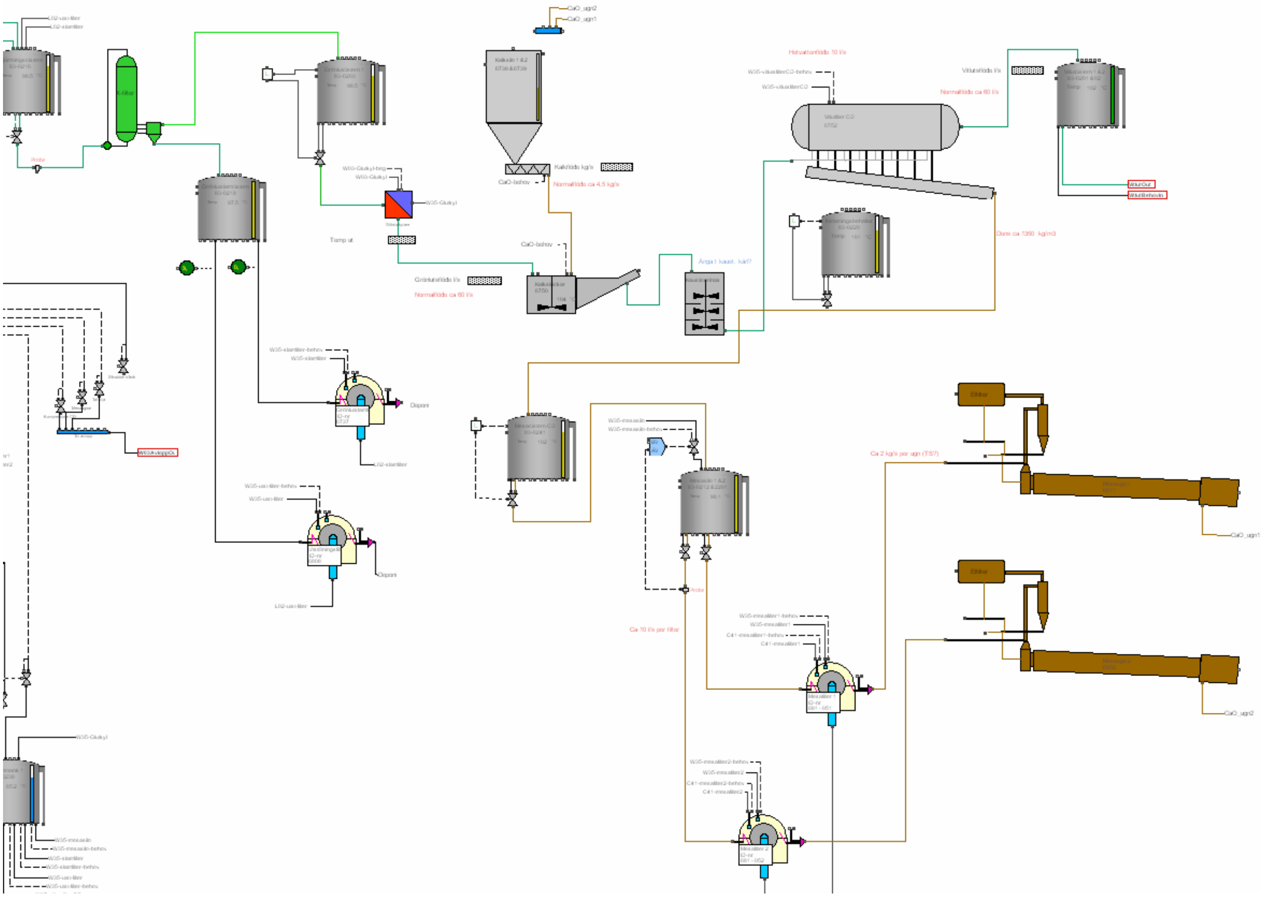

Figure 3. Extend process model of causticising plant.

The process model was first trimmed against the existing situation at the mill. Thereafter, the composition of the green liquor was adjusted in accordance with data obtained from the simulation of the gasifier performed within Renew WP 3.1 (Berglin, 2006). When studying the different cases, the same conditions have been used in the lime slaker and causticising vessels, e.g. causticising reaction rate, excess of $Ca(OH)_2$ etc. The results of the simulations are summarised in Appendix IV.

The results from the simulation show that approximately 5 % more burned lime mud must be added in the lime slaker. This in turn will lead to a corresponding increase of the load in the lime kiln were the lime mud is re-burnt. A higher lime mud load in the lime kiln will also result in a higher fuel consumption which in turn will generate a larger amount of flue gas.

Apart from the effects on the lime slaker and the lime kilns, the simulations did not imply any major impacts on the other equipment in the causticising plant.

The causticising plant at the Mörrum mill is equipped with two lime kilns. Both of them are running at maximum load and they are probably the most critical bottle neck in the causticising plant today.

Based on information available at present, it is difficult to conclude if the capacity can or cannot be increased in the lime kilns. Further investigations, not covered in the present report, must be performed.

In order to compensate for or to reduce the increased load on the causticising process some measures to be further investigated are suggested:

- Increase the sulphidity in the recovery boiler. Preliminary calculations (Berglin, 2005) show that the reduced sulhidity in the green liquor from the gasifier can be compensated for by increasing the sulphidity in the recovery boiler to approximately 42 %. However, the sulphidity in the recovery boiler at Mörrum is approximately 36 % at present and such a large increase is probably not realistic. Preliminary estimations (Arnesson, 2005) suggest an increase of the sulphidity to 38 %, i.e., 2 percent units above current sulphidity.
- Introduction of supplemental oxygen into the kiln burner. By this the capacity of the lime kilns can be increased and, additionally, fuel consumption and sulphur emissions can be reduced.
- External drying of lime mud. Makes it possible to increase capacity in lime kilns since only heating, calcination and sintering occurs in the kiln.

3.3.3 Biomass handling system

As described in section 3.3.1, the consumption of biomass fuel to the power boiler will increase as a consequence of the implementation of the BLGMF plant. The existing biomass handling system is limited in capacity and a new handling and storage system is required.

As shown in section 4, the investment cost for the biofuel handling and storage system represents the largest separate item in the present study. Planning of an updating of the bark handling system is already in progress in a separate project at the Mörrum mill. The main scope of that project is, however, not to increase the capacity but rather to improve and make the bark handling system more effective. Co-ordination with the present project would of course be beneficial but an economical evaluation is at present not possible.

3.3.4 Environmental issues

Apart from the impact on the energy and mass balance at the mill some other integration aspects that have to be considered exist. One of the most important issues is the environmental permits license that has to be revised and renegotiated at the implementation of a BLGMF plant. The mill has restrictions and demands regarding for example emissions and handling of chemicals. One of the most difficult environmental demands at the Mörrum mill today is the noise level. The maximum allowed noise level at the mill is:

- 55 dB(A) during weekdays 07-18
- 45 dB(A) during the night 22-07
- 50 dB(A) during other times

The noise levels are measured at specific measuring points around the mill.

The noise level demand will probably have a significant impact on the design requirements of the BLGMF plant, i.e., layout and selection of equipment.

4 Investment cost estimate

	kEUR
Mechanical	
Biofuel handling and storage system	7 000
Piping mill ⇔ BLGMF (incl. valves)	2 000
Pipe rack (supports, insulation etc.)	1 000
Gas burner synthesis purge gas (incl. opening, piping, valves, BMS)	230
Pumps	110
Orange liquor tank	100
Ducts for Claus off-gases recovery boiler	10
Total mechanical	10 450
Structural	
Tunnel for personnel transports	400
Transport road to BLGMF	300
Fundaments for pipe rack	100
Fundament orange liquor tank	50
Pump house feed water pumps	50
Pipes to effluent treatment plant	30
Fundaments for pumps	10
Total structural	940
Instrument	
Flow meters	70
Control valves	50
Control system orange liquor system	30
Total instrument	150
Electrical	
Installation of new pumps etc.	100
Connection of 6 kV system	60
Connection of 400/230 V system	40
Temporary installations and operation costs during erection	50
Connection to existing control system	20
Connection to existing fire alarm system	20
Connection to IT and telephone system	20
Total electrical	310
Engineering, project management, administration etc. (10%)	1185
Total investment cost	13 035

Note: Possible investment costs for causticising plant (see section 3.3.2) are not included. Contingency accounted for in WP 3.2 (Ingman, 2006).

5 Conclusions

In the present report the impact on the energy and mass balances by implementation of a 45 MW_{th} Black Liquor Gasification Motor Fuel (BLGMF) plant at the Södra Cell Mörrum mill is investigated. Apart from the influence on the balance of the mill, the implementation will affect many of the mills main and sub systems such as steam, liquor, water, off-gases and electricity. Some of the most important items that have been identified are:

- In order to maintain the mill energy balance when black liquor is directed to the gasifier instead of the recovery boiler, the decrease of steam production in the recovery boiler has to be compensated by additional steam production in the power boiler. Since all the produced biofuel at the mill, mainly in the form of bark, is consumed at present conditions, approximately 160 GWh per year of biofuel must be imported. The increased demand of steam production in the power boiler can probably partly be met by energy savings at the mill. The largest potential for energy savings exists in the district heating system.
- The electric power generation will decrease with approximately 25 GWh per year due to the loss of produced high pressure steam.
- Even if the existing power boiler capacity is sufficient to handle the additionally required biofuel the capacity of the existing biomass handling system is limited. A new storage and handling system is thus required. The investment cost of the new system represents the largest separate investment item in the present study.
- The lower concentration of sulphur and higher concentration of carbonate in the green liquor produced in the gasifier compared to the green liquor produced in the in the recovery boiler will require an increased production of hydroxide in the causticising unit. A mass balance simulation in an Extend process model shows that approximately 5 % more burned lime mud have to be added in the lime slaker leading to a corresponding increase of the load in the lime kilns. Since the lime kilns are the most critical bottle neck in the causticising plant today further investigations, not covered in the present report, must be performed in the future. In order to compensate for or to reduce the increased load on the causticising process some measures to be further investigated could be; higher sulphidity in the recovery boiler, introduction of supplemental oxygen into the kiln burner or external drying of the lime mud.
- The implementation of a BLGMF plant makes it possible to generate polysulphide liquor (orange liquor). By using orange liquor during the pre-treatment phase in the cooking process, an increased pulp yield can be obtained (Olm et al., 2005).

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Appendix I

Composition of process media.

Black liquor from mill

		Softwood/softwood pulp	**Softwood/hardwood pulp**
S	% wt	4.92	5.22
Cl	% wt	0.34	0.35
Na	% wt	19.94	20.03
K	% wt	2.19	2.27
C	% wt	34.40	32.10
H	% wt	3.50	3.50
N	% wt	0.07	0.10
O	% wt	34.64	36.43
Dry substance	% wt	71.2	70.9
Ash	% wt	37.3	39.0
HHV	MJ/kg DS	14.01	12.97
NHV[1)]	MJ/kg DS	11.68	10.54

1) Net heating value = lower heating value with compensation for sulphur reduction.

Weak wash from mil

NaOH	5	g/l as NaOH
Na2CO3	1	g/l as NaOH
Na2S	1	g/l as NaOH
TTA	7	g/l as NaOH
Specific Gravity	1008	kg/m^3 @ 20 °C

Green liquor from BLGMF

NaOH	8	g/l as NaOH
Na2CO3	138	g/l as NaOH
Na2S	14	g/l as NaOH
TTA	160	g/l as NaOH
Specific Gravity	1204	kg/m^3 @ 20 °C

White liquor from mill

NaOH	85	g/l as NaOH
Na2CO3	20	g/l as NaOH
Na2S	50	g/l as NaOH
TTA	155	g/l as NaOH
Specific Gravity	1150	kg/m^3 @ 20 °C

Orange liquor from BLGMF

NaOH	88	g/l as NaOH
Na2S3S	45	g/l as NaOH
Na2CO3	19	g/l as NaOH
Na2SO4	5	g/l as NaOH
TTA	157	g/l as NaOH
Specific Gravity	1150	kg/m^3 @ 20 °C

Claus off-gas from BLGMF (delivered as weak gas)

H2	1.6	% mole
N2	26.7	% mole
CO	5.9	% mole
H2S	0.6	% mole
CO2	41.7	% mole
COS	0.25	% mole
H2O	23.3	% mole
SO2	0.26	% mole
LHV	1.4	MJ/m^3_n

Synthesis purge gas from BLGMF

H2	55	% vol
N2	9	% vol
CO	2	% vol
CO2	5	% vol
CH4	26	% vol
MeOH	1	% vol
By-products	1-2	% vol
LHV:	15.5	MJ/m^3_n

NCG off-gas from BLGMF

H2O	61.5	% mole
CO	15.4	% mole
H2	23.1	% mole
LHV:	4.4	MJ/m^3_n

Appendix II

Preliminary data (design values) for new pumps.

Medium	**Code**	**Temp °C**	**Press. inlet bar(g)**	**Flow l/s**	**Δp mWc**	**Power kW**	**Location**
Black liquor	L61	120	0,5	6,5	30	5,5	Mill
Weak wash	L02	100	0,5	10	400	75	Mill
White liquor	L01	100	0,5	2,2	40	4	Mill
Orange liquor	L04	100	0,3	2,5	30	4	Mill
District heating water	W36	120	6	15	30	11	BLGMF
Boiler feed water	W50	130	1	10	400	75	BLGMF

Note: Boiler feed water requires 2 pumps.

Appendix III

Preliminary pipe dimensions.

Medium	Medium code	DN	Length m
Black liquor	L61	80	280
Black liquor recirculation	L61	50	280
Weak wash	L02	100	290
Green liquor	L16	100	290
White liquor	L01	50	285
Orange liquor	L04	50	510
District heating water	W36	80	265
Boiler feed water	W50	80	375
Steam HP	S03	40	305
Steam LP	S01	400	305
Steam condensate	C10	80	375
Process water	W03	80	350
Fire water	W23	150	230
Potable water	W10	50	35
Pump seal water	W04	50	320
Process water drain	D35	40	490
Closed liquor drain	L10	80	370
Surface water	D05	150	400
Claus off-gas	V53	150	290
Synthesis purge gas	G29	40	310

Appendix IV

Simulation of causticising plant.

Normal operation (only rec boiler)

	Green liquor			White liq to tank	
	Rec boiler	BLGMF	Mixture	Measured	Calculated
Volume flow, l/s	60,0	0,0	60,0	60,0	
Density, kg/m3	1140,0	1204,0	1140,0	1130,0	
Massflow, kg/s	68,4	0,0	68,4	67,8	65,5
NaOH, g/l	4,0	0,0	4,0		
NaOH, g/kg	3,5	0,0	3,5	75,1	73,9
NaOH, g/s	240,0	0,0	240,0		
Na2CO3, g/l	105,0	0,0	105,0		
Na2CO3, g/kg	92,1	0,0	92,1	16,8	16,2
Na2CO3, g/s	6300,0	0,0	6300,0		
Na2S, g/l	50,0	0,0	50,0		
Na2S, g/kg	43,9	0,0	43,9	44,2	42,4
Na2S, g/s	3000,0	0,0	3000,0		
TTA, g/l	159,0	0,0	159,0		
TTA, g/kg	139,5	0,0	139,5	136,1	132,5
Sulphidity, %	0,93		0,93	0,37	0,36

Lime slaker

Causticising rate, %	82,0
Reburned lime mud, kg/s	4,50
Effective CaO, %	70,0
Added CaO, kg/s	3,15

White liquor filter

Outflow lime mud, kg/s	16,0
Dry solid, %	60,0

	Lime slaker		Causticising vessel	
	GL in	Out	In	Out
OH, kg/s	0,75	0,75	0,75	2,25
Na, kg/s	1,88	1,88	1,88	1,88
S, kg/s	1,22	1,22	1,22	1,22
CaCO3, kg/s	0,00	0,00	0,00	4,41
Na2CO3, kg/s	6,22	6,22	6,22	1,54
Ca(OH)2, kg/s	0,00	4,16	4,16	0,90

<u>Rec boiler + BLGMF</u>

	Green liquor			White liq to tank	
	Rec boiler	BLGMF	Mixture	Measured	Calculated
Volume flow, l/s	48,5	10,8	59,3	60,0	
Density, kg/m3	1140,0	1204,0	1151,7	1130,0	
Massflow, kg/s	55,3	13,0	68,3	67,8	65,7
NaOH, g/l	4,0	8,0	4,7		
NaOH, g/kg	3,5	6,6	4,1	75,1	74,1
NaOH, g/s	194,0	86,4	280,4		
Na2CO3, g/l	105,0	138,0	111,0		
Na2CO3, g/kg	92,1	114,6	96,4	16,8	16,3
Na2CO3, g/s	5092,5	1490,4	6582,9		
Na2S, g/l	50,0	14,0	43,4		
Na2S, g/kg	43,9	11,6	37,7	44,2	36,3
Na2S, g/s	2425,0	151,2	2576,2		
TTA, g/l	159,0	160,0	159,2		
TTA, g/kg	139,5	132,9	138,2	136,1	126,7
Sulphidity, %	0,93	0,64	0,90	0,37	0,33

Lime slaker

Causticising rate, %	82,0
Reburned lime mud, kg/s	4,71
Effective CaO, %	70,0
Added CaO, kg/s	3,30

White liquor filter

Outflow lime mud, kg/s	16,0
Dry solid, %	60,0

	Lime slaker		Causticising vessel	
	GL in	Out	In	Out
OH, kg/s	0,67	0,67	0,67	2,26
Na, kg/s	1,66	1,66	1,66	1,66
S, kg/s	1,04	1,04	1,04	1,04
CaCO3, kg/s	0,00	0,00	0,00	4,68
Na2CO3, kg/s	6,51	6,51	6,51	1,55
Ca(OH)2, kg/s	0	4,36	4,36	0,90