

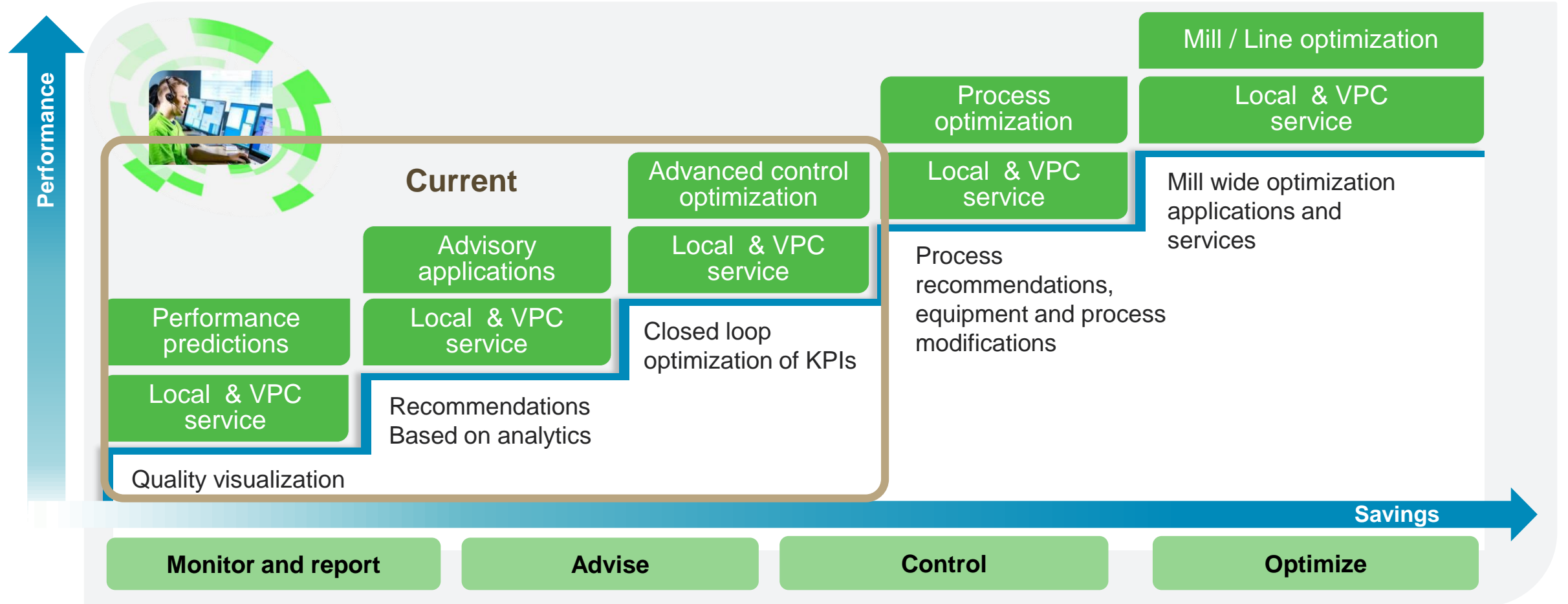


Valmet Mill of the Future

Mill Wide Optimization - Automated Decision Making

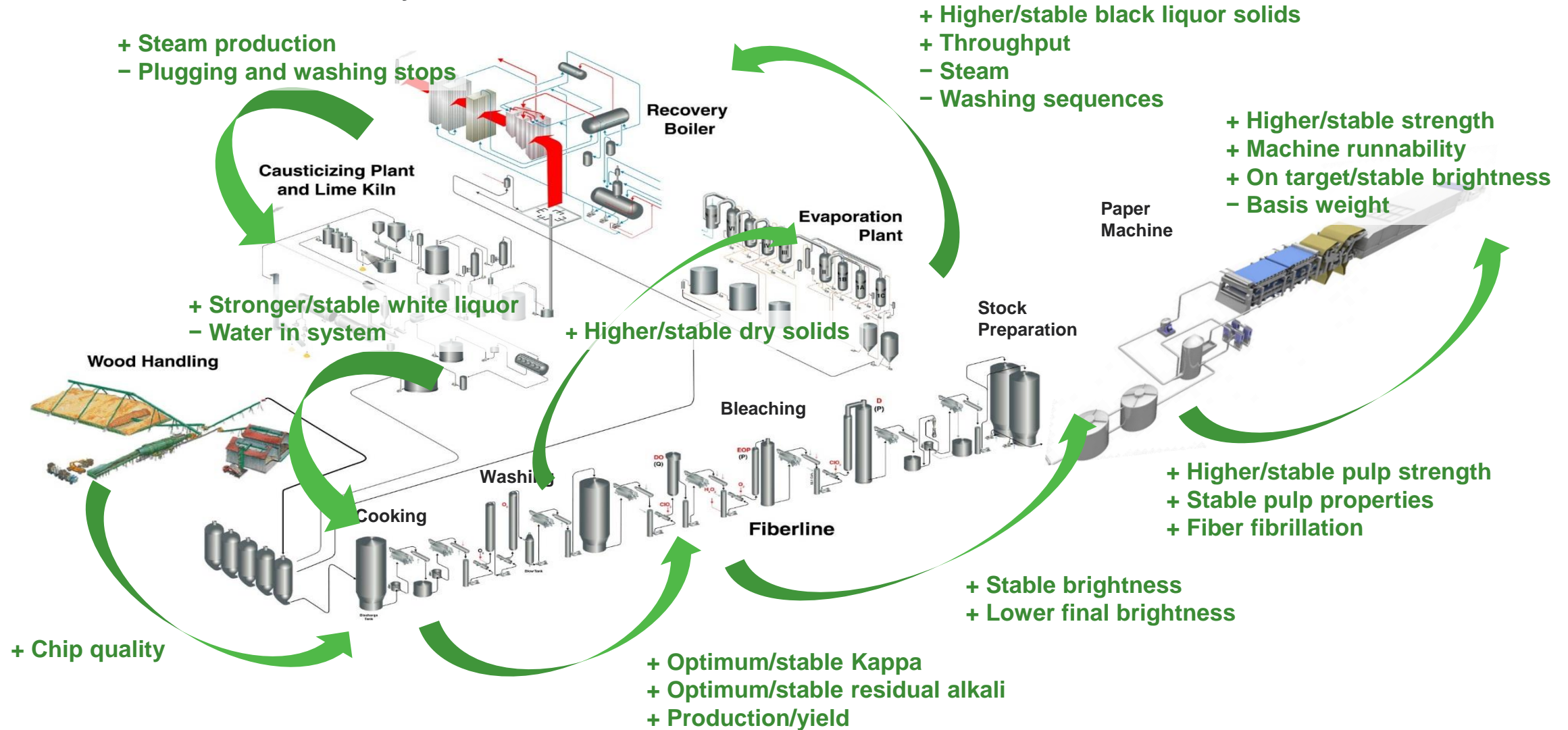
Mill-Wide Optimization

Facilitated by Industrial Internet



Optimization of integrated paper mill

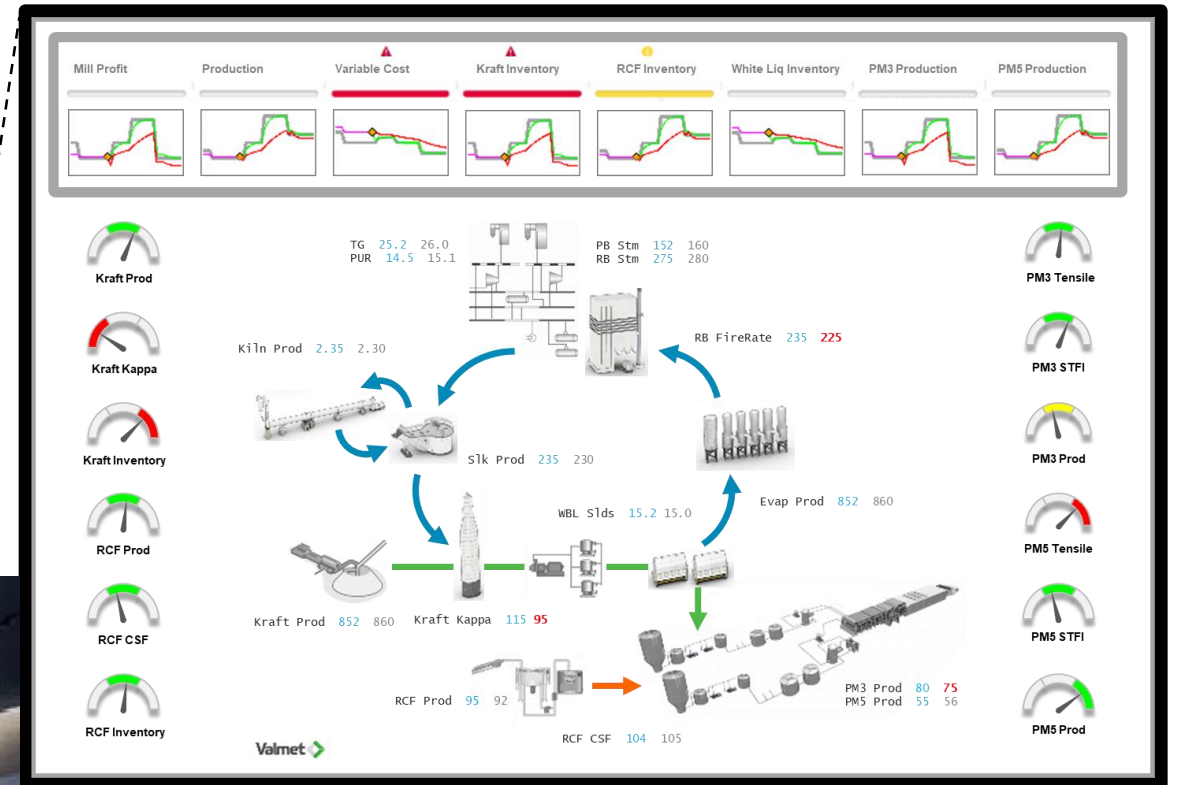
Benefits of APC and analyzers cascade forward



Control Room of the Future

Real-time centralized automated decision making

- Operating decisions are based on the total mill balance and forecast
- Process area decisions are coordinated to maximize profit subject to product quality and process stability



DCS Display of the Future
- high level view of mill performance

Mill Optimization Solutions

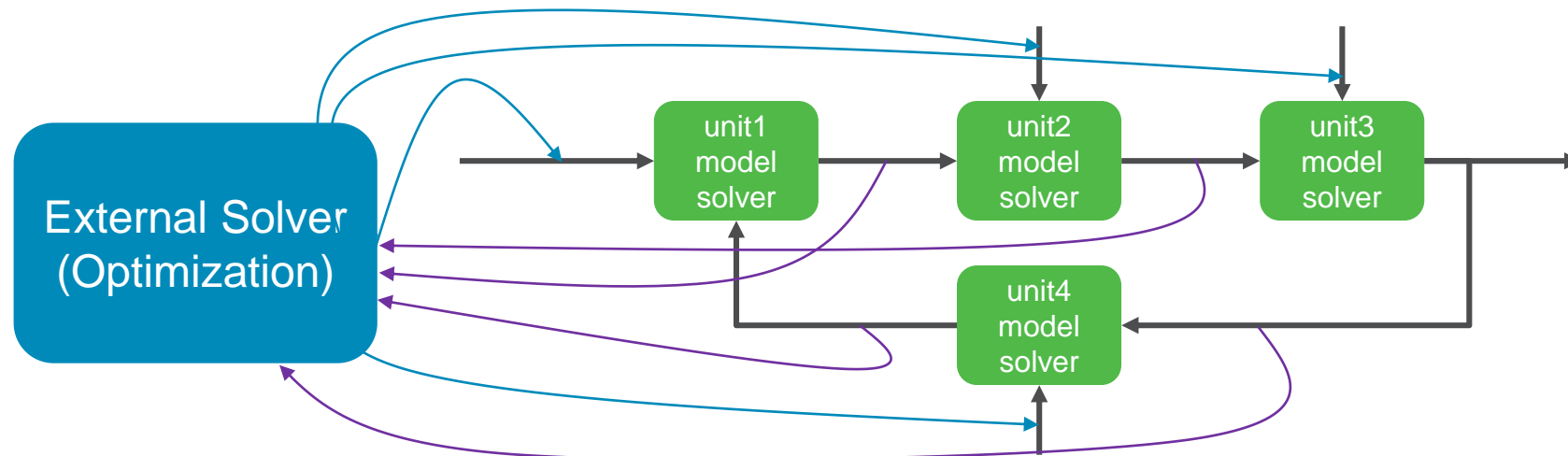
Types of Optimization Problems

- The optimization solution may include one or more optimization problem types:
 - Linear optimization with constraints – solving an optimization problem with linear relationships (or linearized relationships), and process constraints.
 - Nonlinear optimization with constraints – solving an optimization problem with non-linear relationships, and process constraints.
 - Discrete optimization - some or all of the variables are restricted to be discrete variables such as integers. These could include unit operation state (up/down) or product grades.
 - Dynamic optimization – solving time based optimization problem (how to run the plant for the next days-weeks)
- All optimization problems require a process model (Industry4 Smart Manufacturing). Process models fall into one of two categories (or hybrid):
 - Sequential modular (majority of pulp and paper process simulators)
 - Equation Oriented (simultaneous, global resolution)
- Equation oriented modeling has significant advantages over sequential modular when solving optimization problems.

Mill Optimization Solutions

Sequential Modular Models

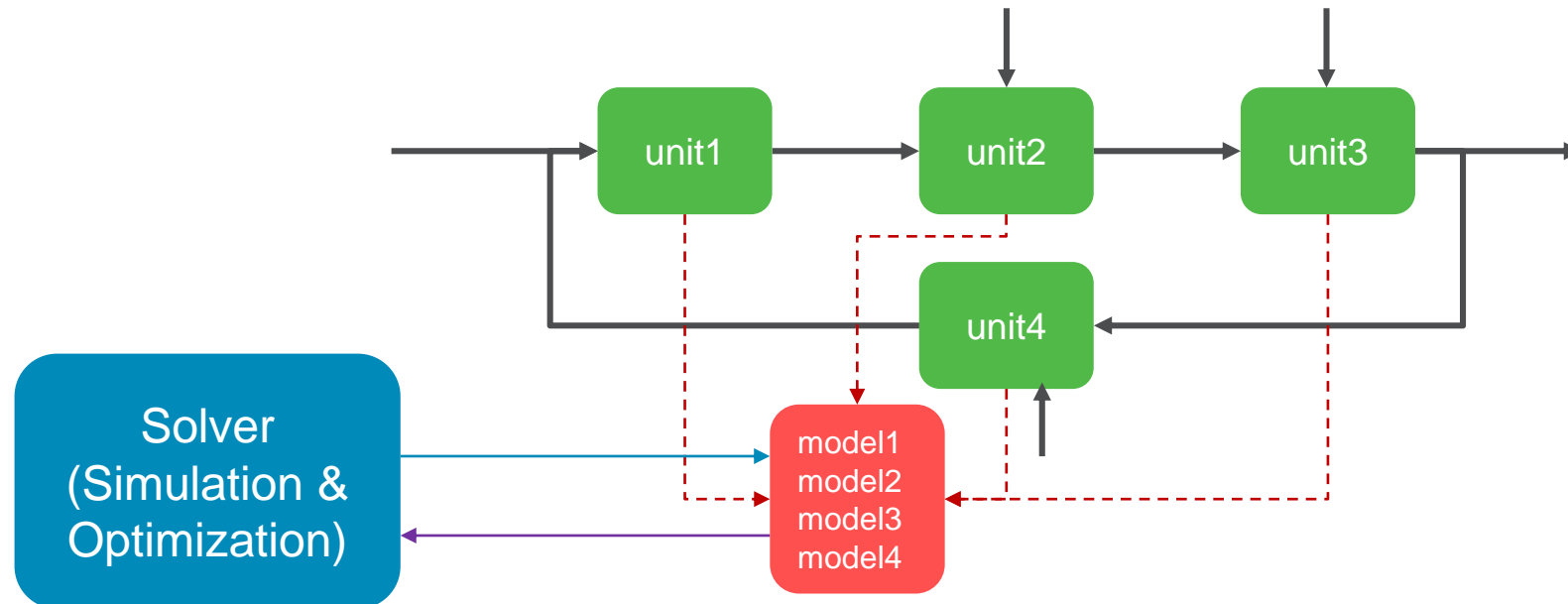
- Each unit operation is calculated and solved independently and sequentially, starting with feed streams.
- The outputs of a given unit operation are fed as inputs to the downstream unit operation.
- Unit operation model inputs/independent and outputs/dependent variables are predefined.
- External solvers (optimization calculations) do not have access to the process models which are embedded in the unit operation modules (black box models).
- Most commercial simulators are sequential modular.



Mill Optimization Solutions

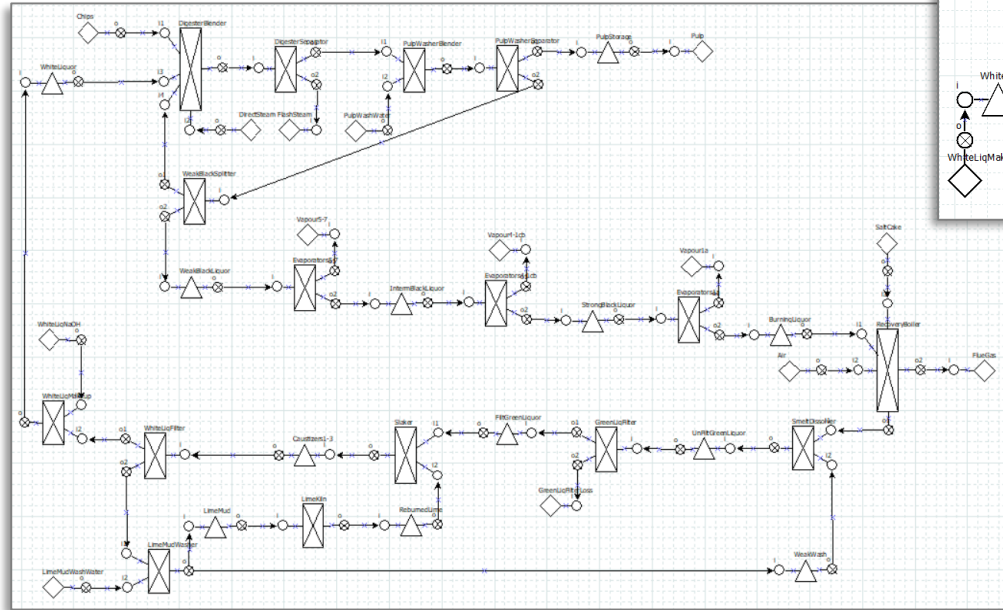
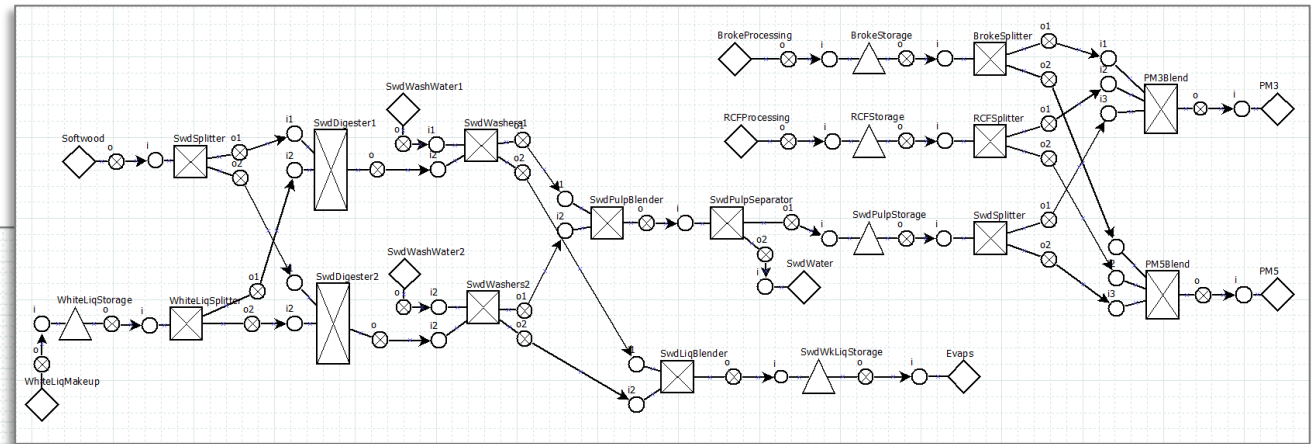
Equation Oriented (Simultaneous, Global Resolution) Models

- Only model functions (calculations) are defined for each unit operation.
- The process flowsheet is treated as a set of equations to be solved simultaneously.
- No assumption of inputs/independent and outputs/dependent for a given unit operation.
- Solver (optimization) methods are separate from the models. The solver has access to all of the models.
- Equation oriented models are primarily used for process optimization solutions.



Mill Wide Optimization

Process Flowsheet Optimization



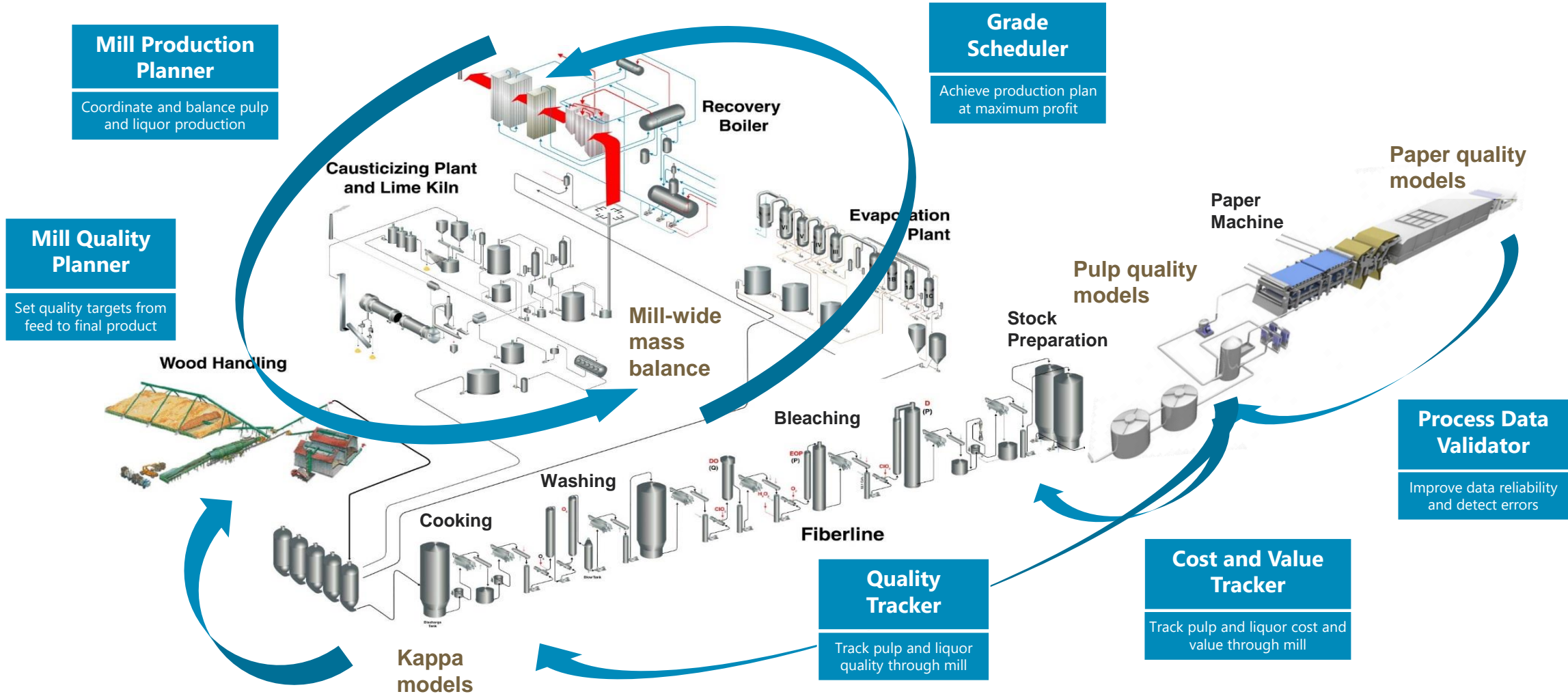
Process Flowsheet Simulation and Optimization

- Pulp and paper mill is modeled as a flowsheet
- Includes mass balances, process models, quality models, time delays, and inventory constraints
- Pulp and liquor production, components, and properties are tracked through the process
- Flowsheet is treated as a set of equations that is solved simultaneously, calculating the optimum now and in the future

Mill Wide Optimization

High level process coordination and optimization

Profit improvement potential evaluated at mill level



➤ Production maximization and/or stabilization

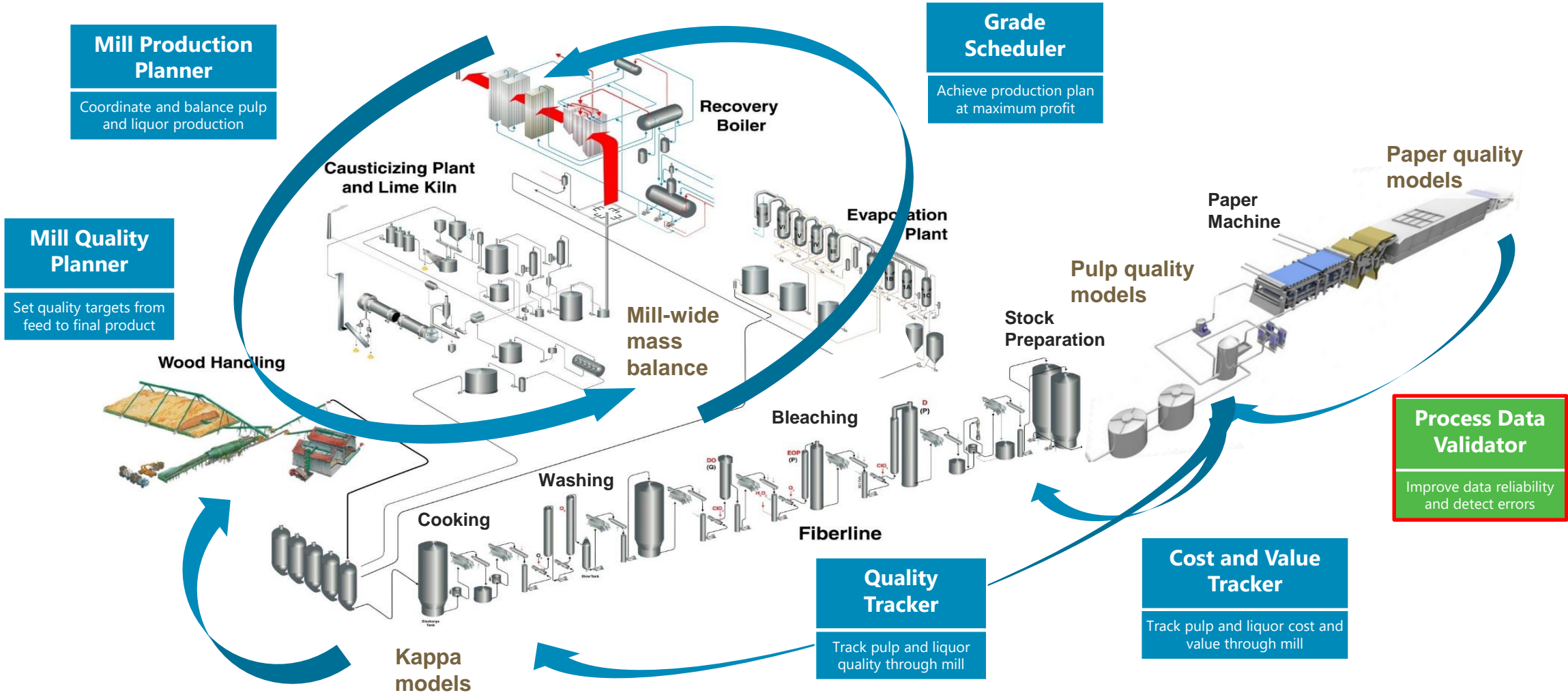
➤ On-spec final quality and production plan met at minimum costs

➤ Visibility of process stream quality, cost and worth across the mill

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Process Flowsheet Optimization

Process Data Validator

Challenge:

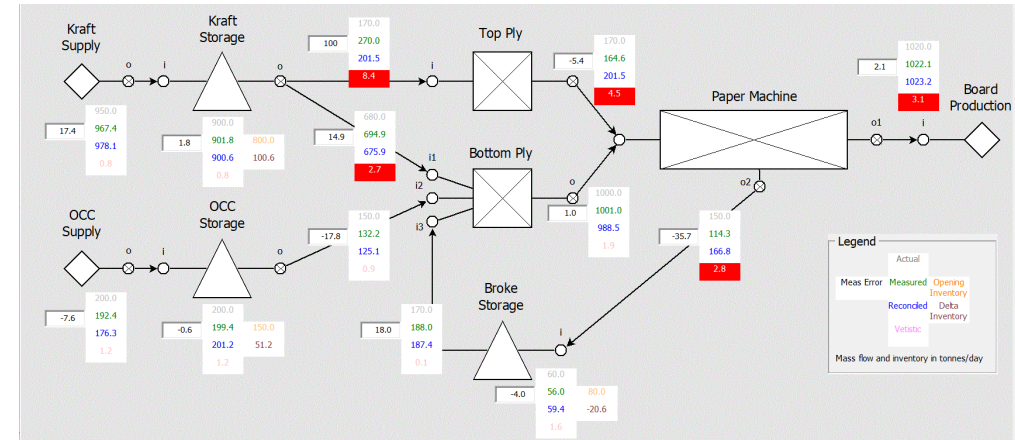
- Make informed process operating decisions based on process measurements that have inaccuracies and are inconsistent with other measurements.

Solution:

- Process Data Validator

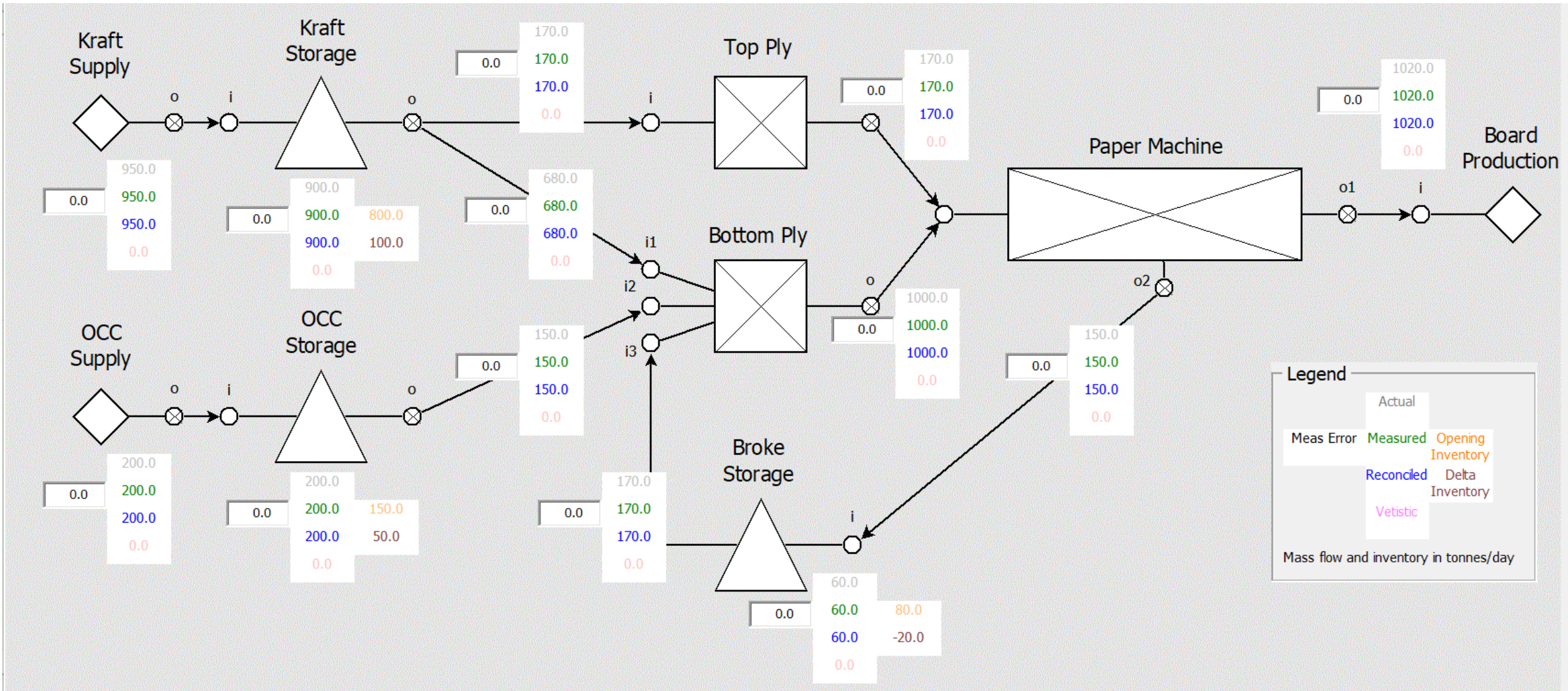
Results:

- Statistically adjusted process measurements based on reconciliation calculations that utilize measurement redundancy and conservation of mass and energy.



Process Data Validator

Perfectly Balanced – All measurements in agreement (never happens!!)



Process Data Validator

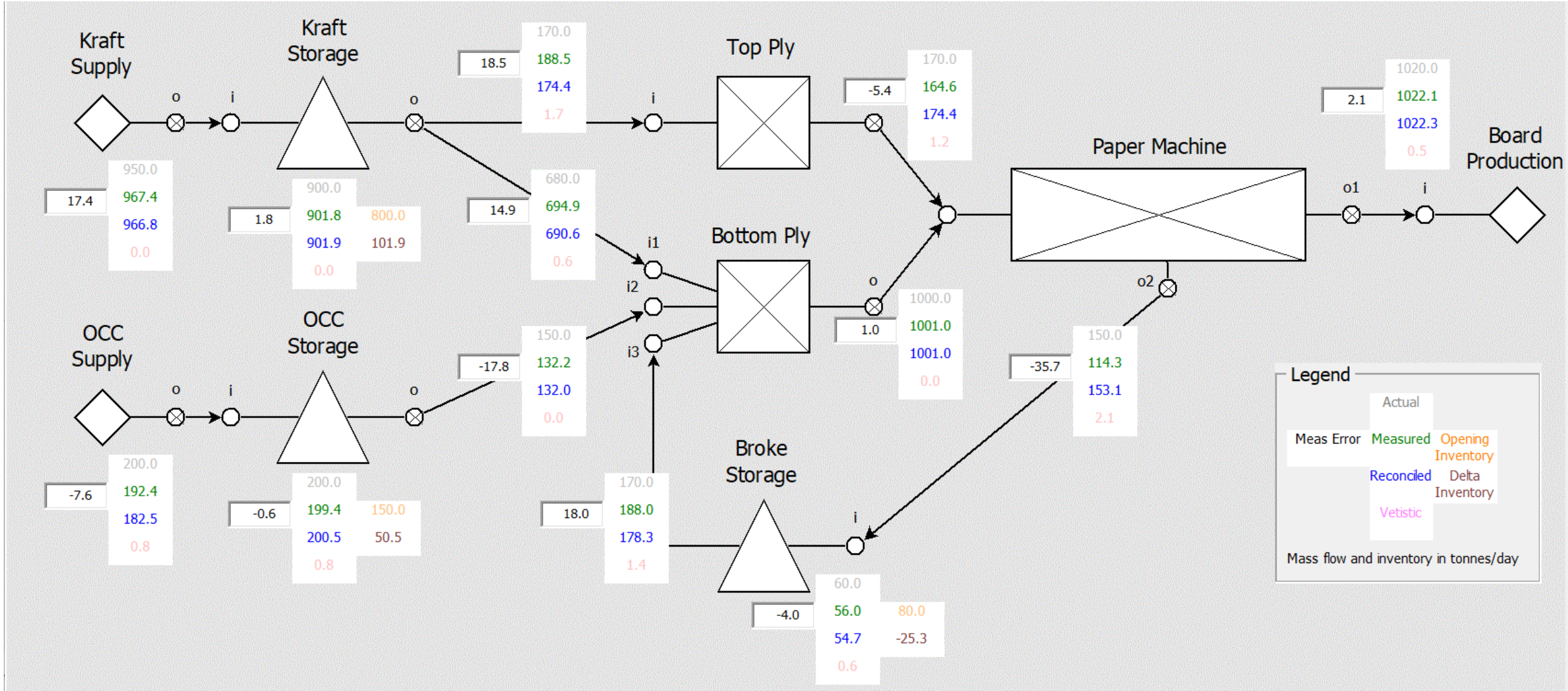
Measurement uncertainty

	Measurement Uncertainty (Standard Deviation*)
KRAFT SUPPLY	15.0
OCC SUPPLY	15.0
TOP PLY KRAFT	10.0
BOTTOM PLY KRAFT	10.0
BOTTOM PLY OCC	10.0
BOTTOM PLY BROKE	10.0
TOP PLY TO PM	10.0
BOTTOM PLY TO PM	10.0
BOARD PRODUCTION	2.0
BROKE PRODUCTION	20.0
KRAFT STORAGE	5.0
OCC STORAGE	5.0
BROKE STORAGE	5.0

* Values must be greater than 0

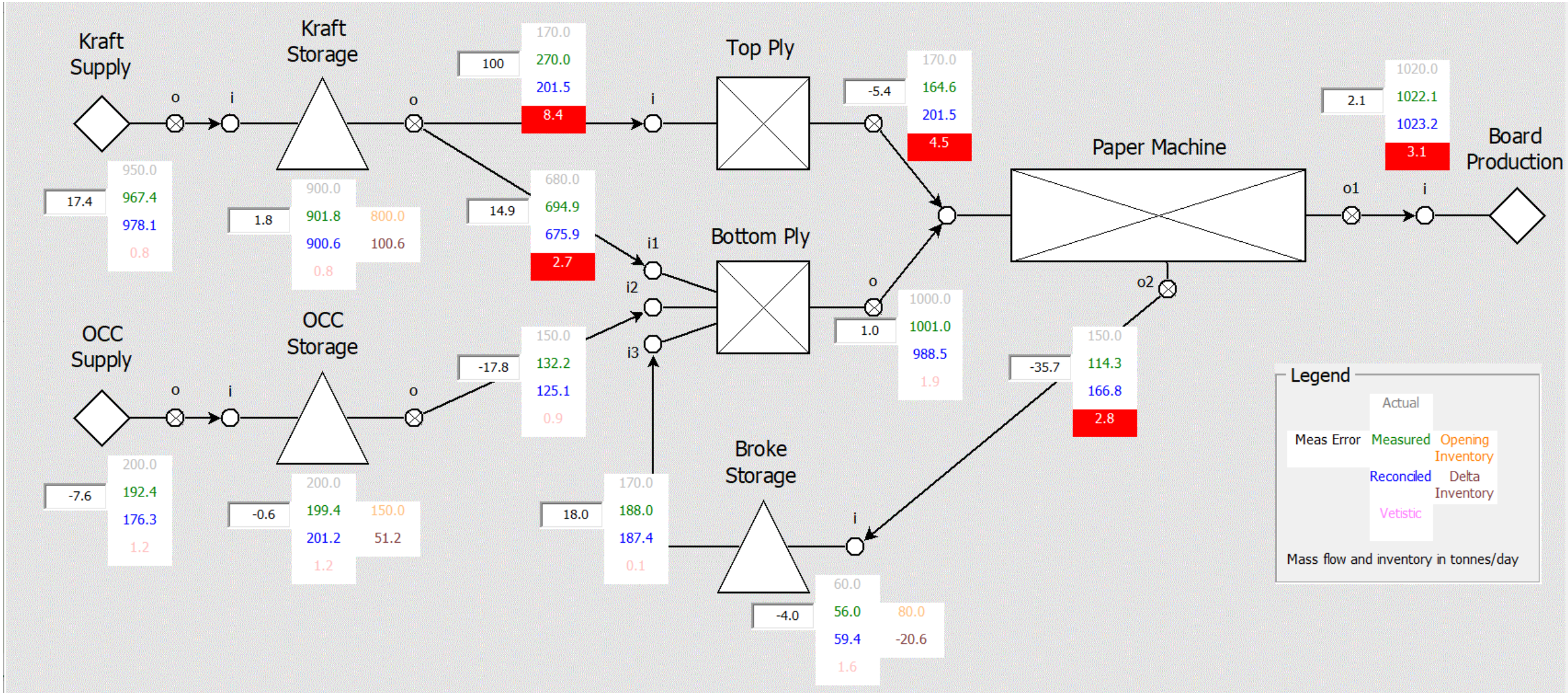
Process Data Validator

Measurements within uncertainty limits



Process Data Validator

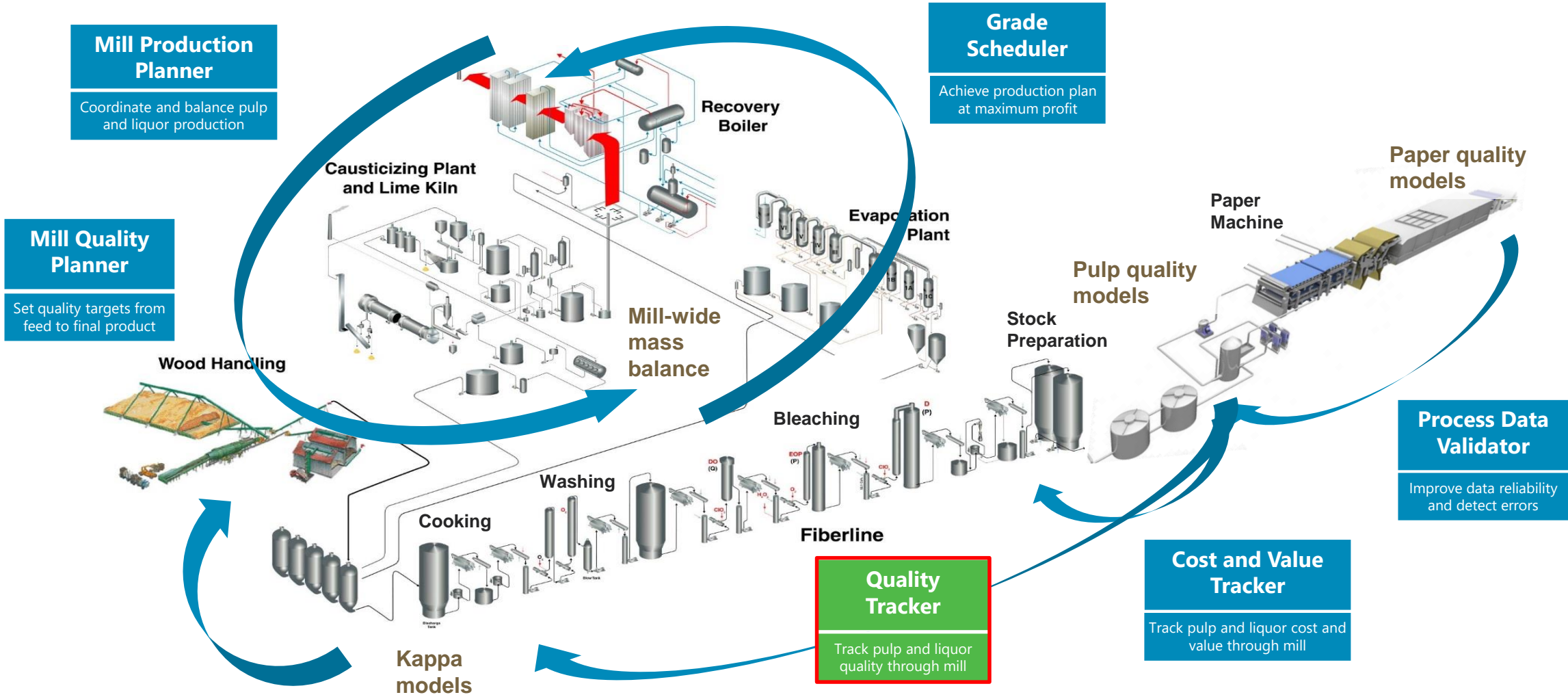
Measurement with gross error



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Process Flowsheet Optimization

Quality Tracker

Challenge:

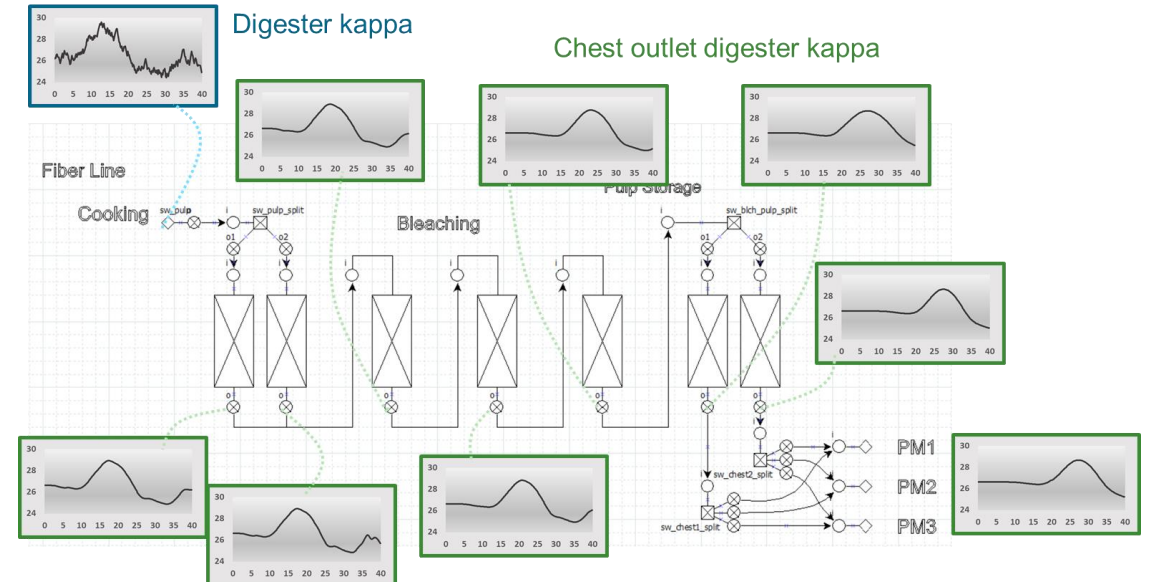
- Make informed process operating decisions based on upstream pulp and liquor quality, accounting for time lags through piping, chests and tanks.

Solution:

- Quality Tracker

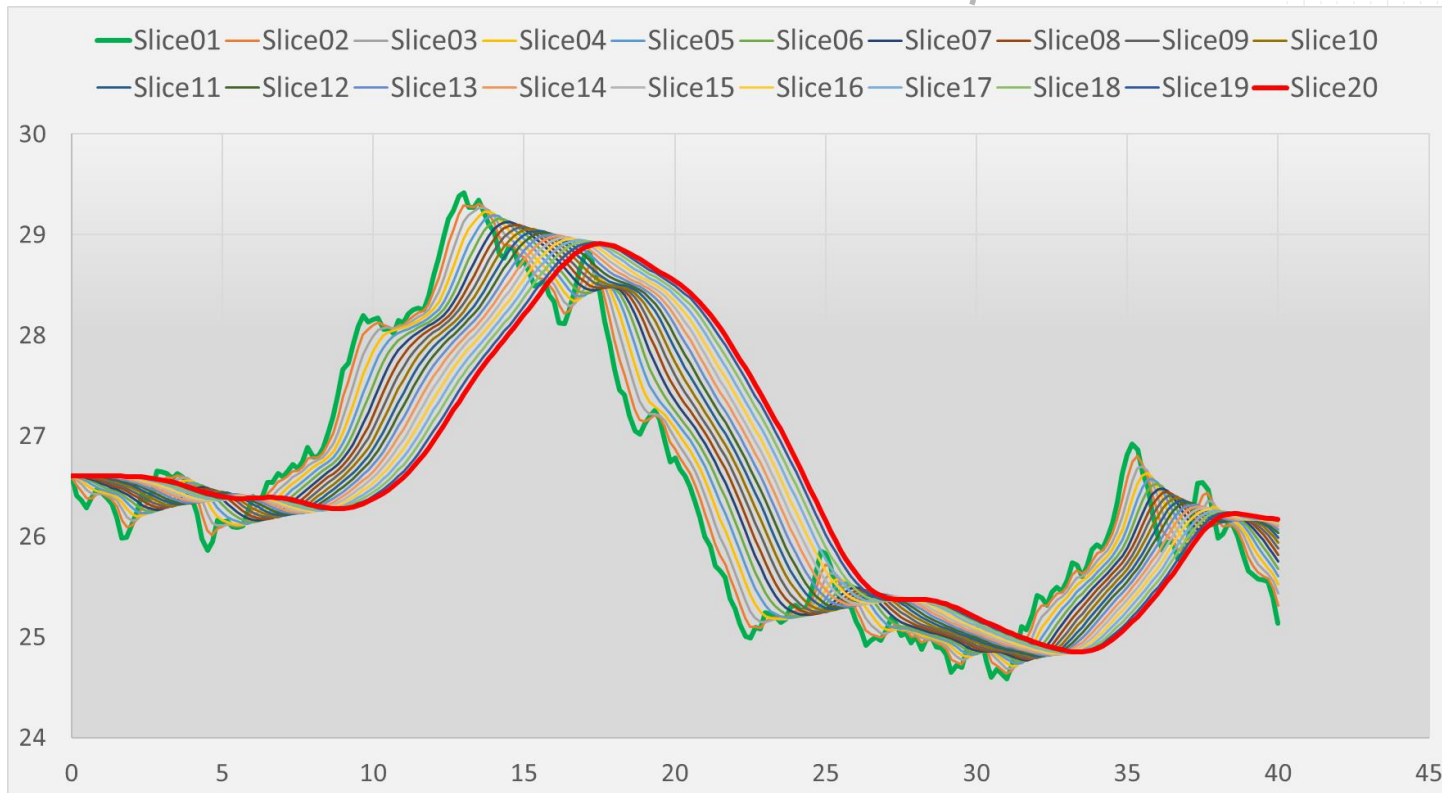
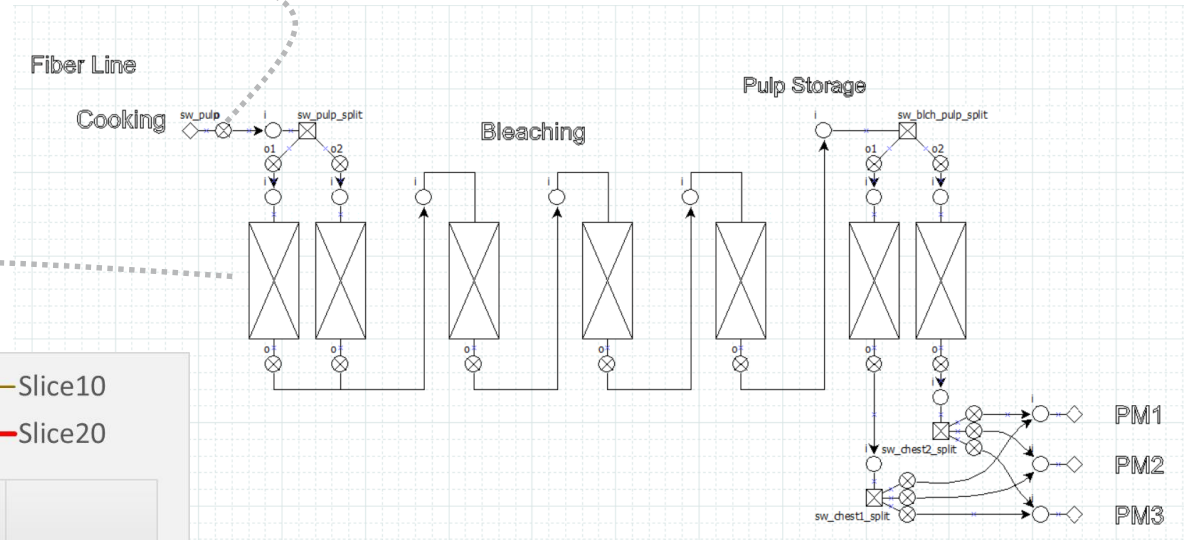
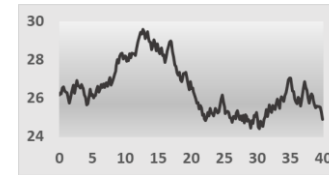
Results:

- Quality is tracked through the process providing visibility of current and future process stream composition and quality across the mill, at every point in the process.



Process Flowsheet Optimization

Quality Tracker – Digester Kappa

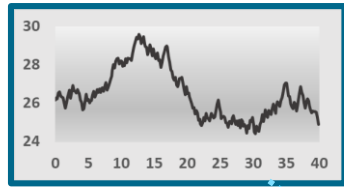


To track pulp quality through the storage chests, each chest is divided up into multiple horizontal slices. Pulp quality is tracked through each slice. The residence time of each slice is a function of the chest level.

In the graph to the left, the slice 20 is at the bottom of the chest.

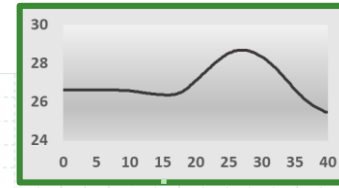
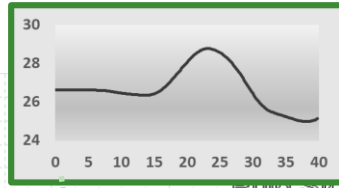
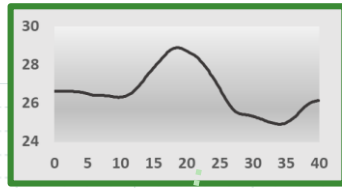
Process Flowsheet Optimization

Quality Tracker – Digester Kappa

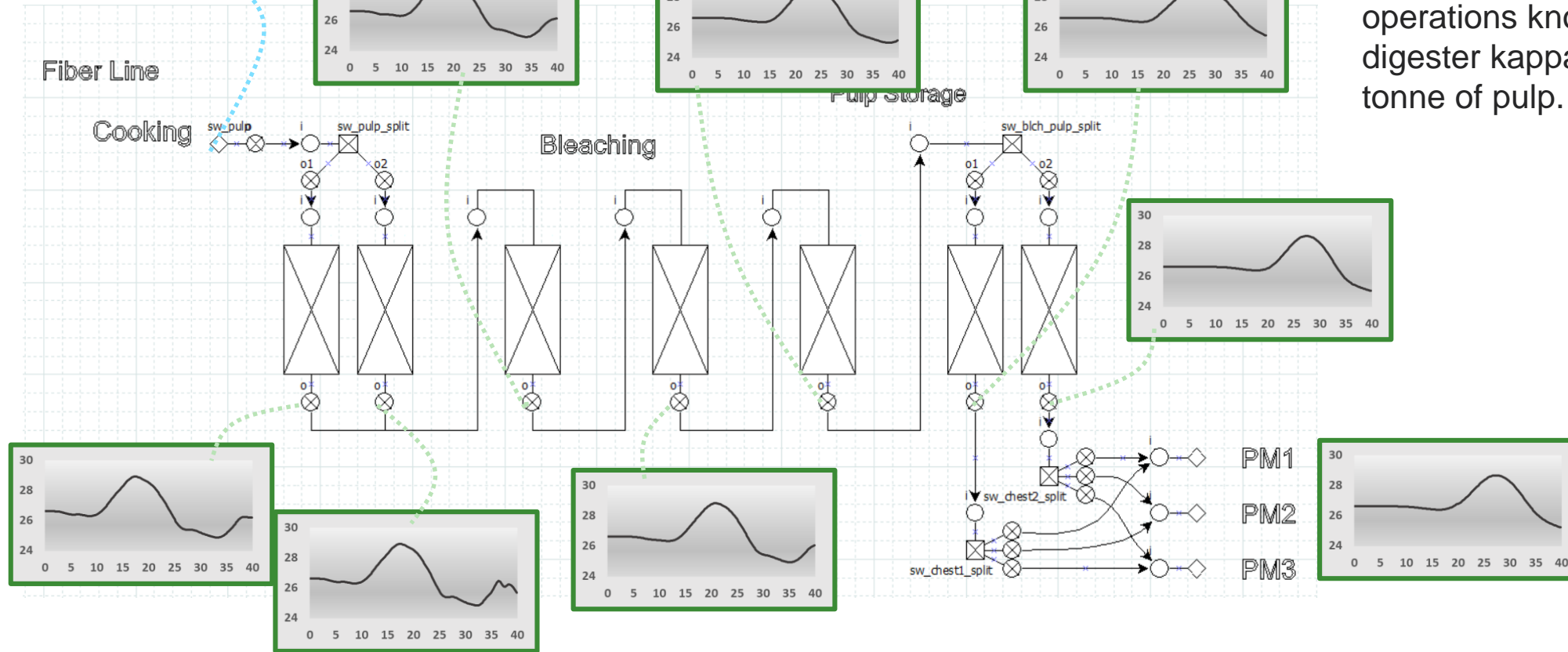


Digester kappa

Chest outlet digester kappa



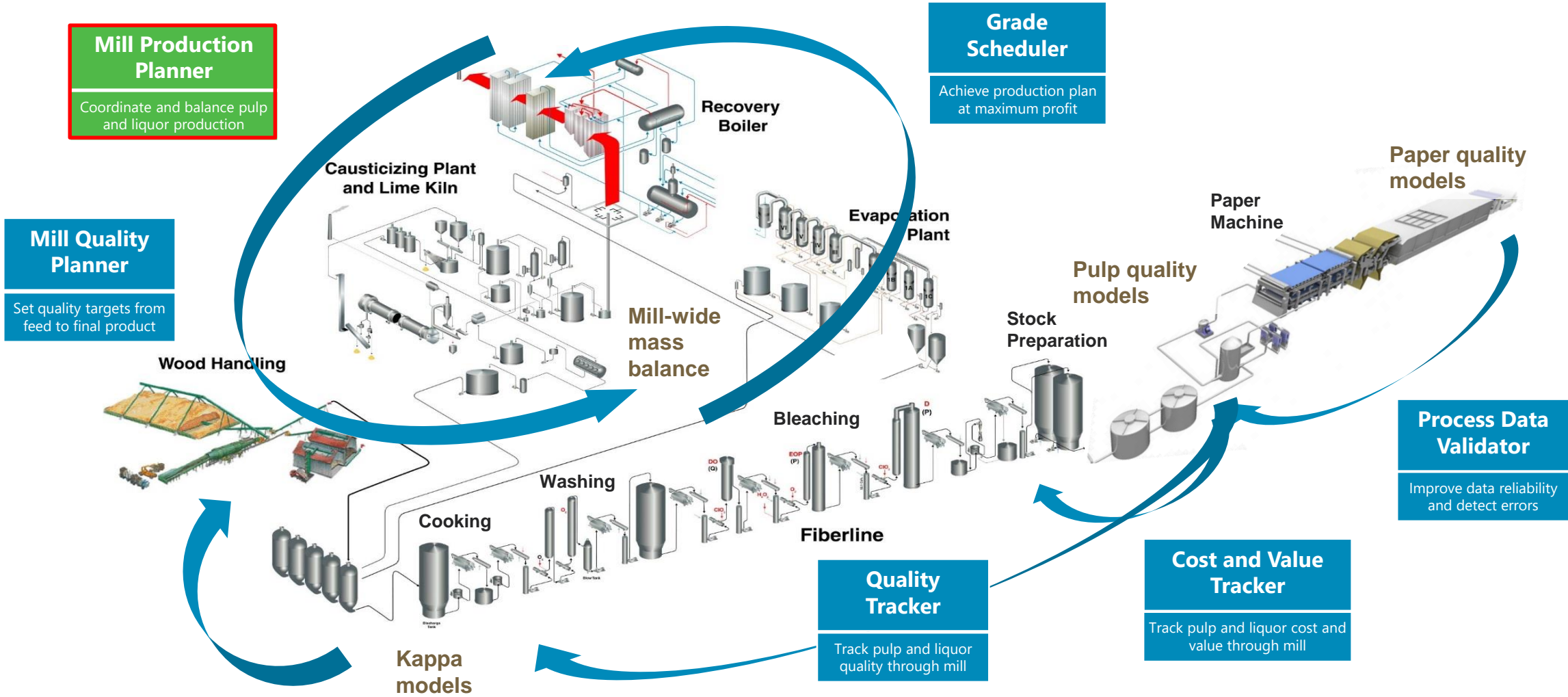
The trends to the right show how the digester kappa can be tracked through the process so operations knows what the digester kappa was for a given tonne of pulp.



Mill Wide Optimization

High level process coordination and optimization

Profit improvement potential evaluated at mill level



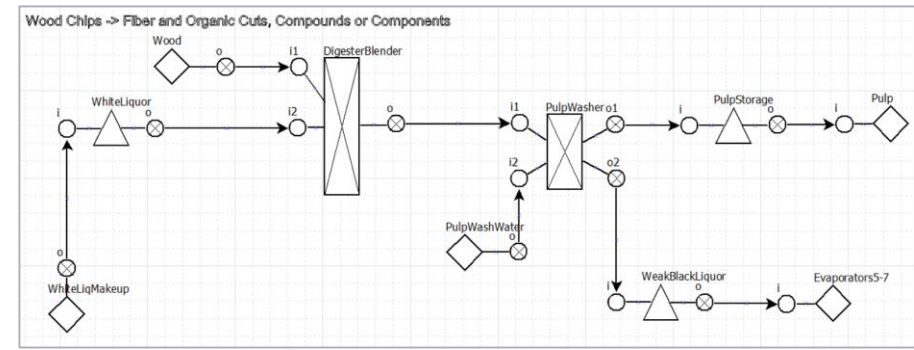
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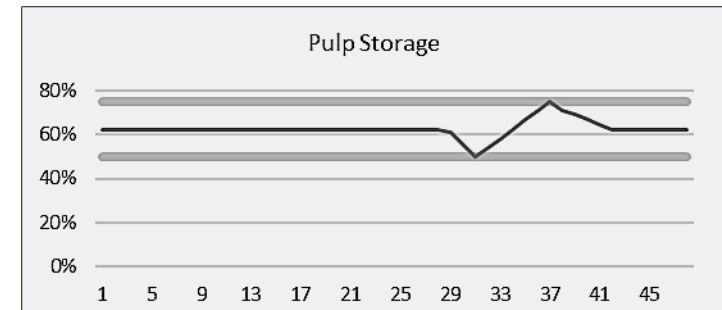
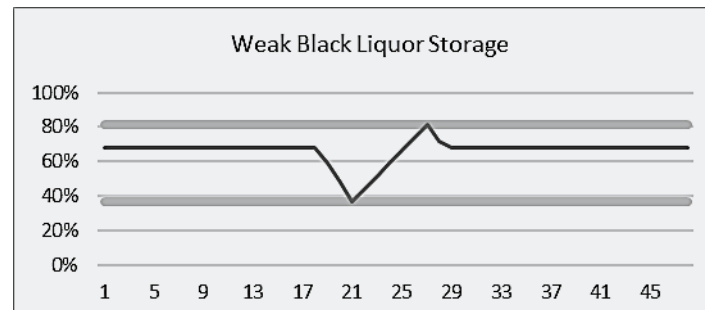
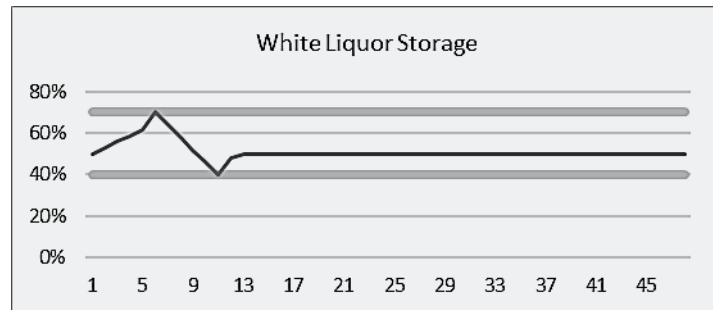
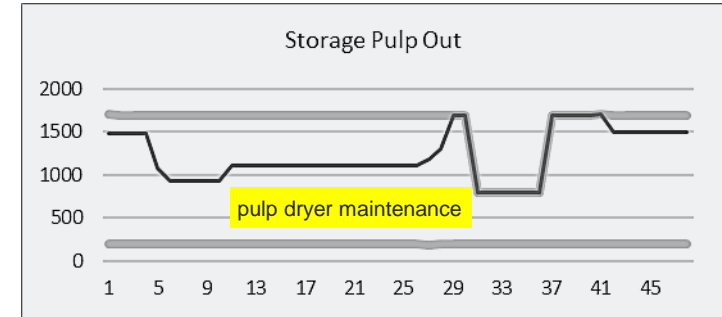
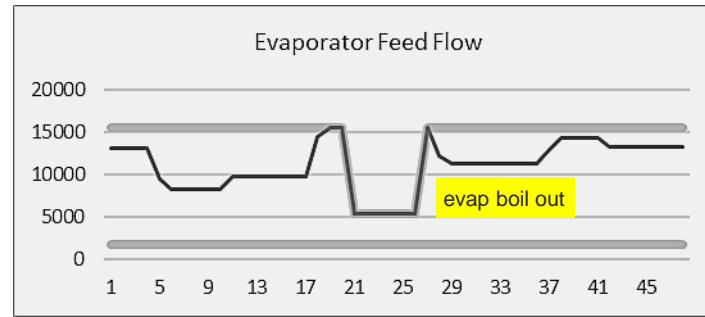
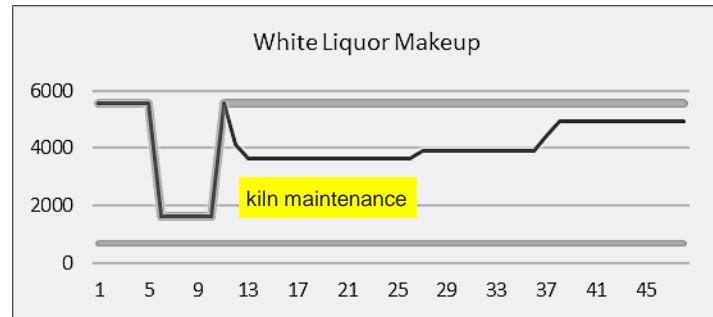
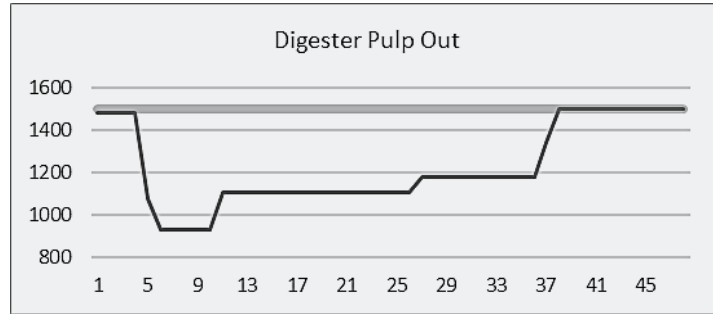
Production Planner

Base Case – Conservative Inventory Limits



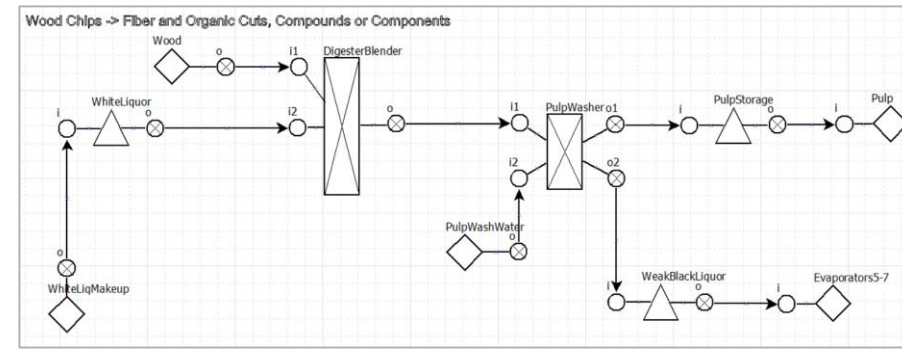
Total Prod (tonnes)
2461

Graphs show production plan for next 2 days
User enters current and future process limits based on maintenance plan
Production maximized subject to process limits



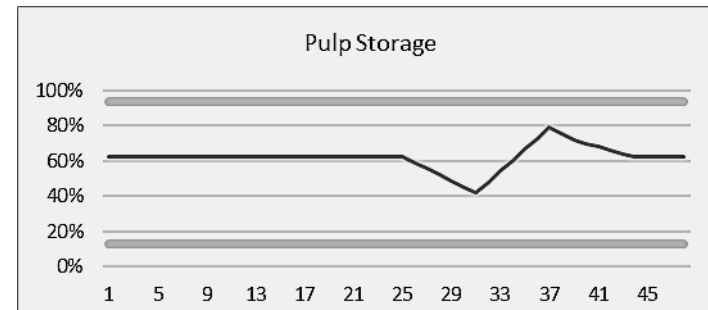
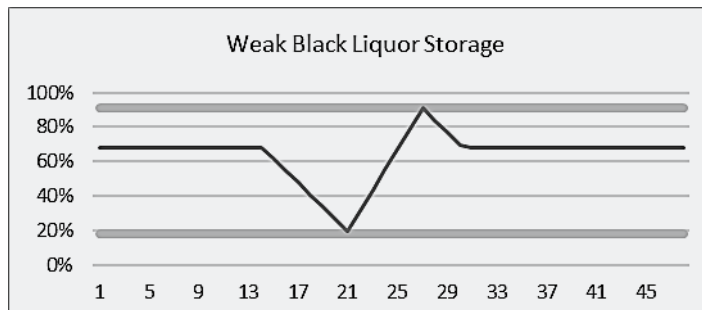
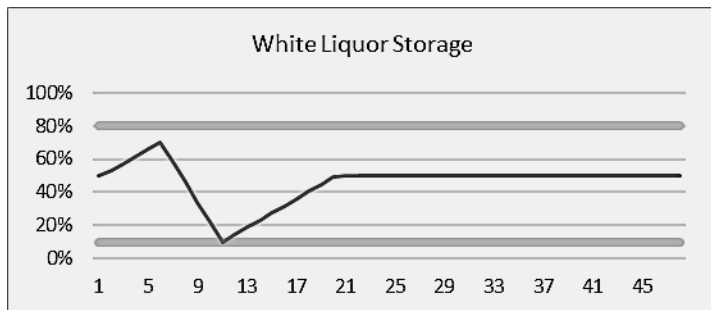
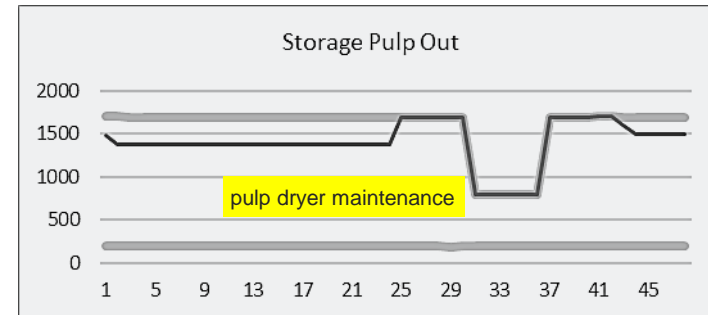
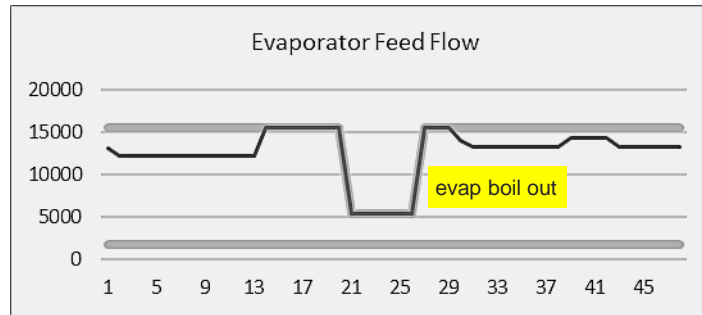
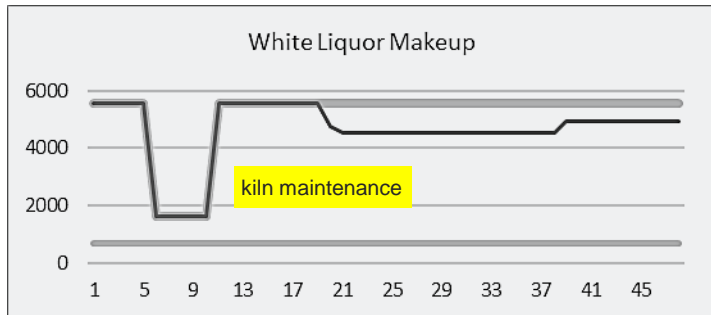
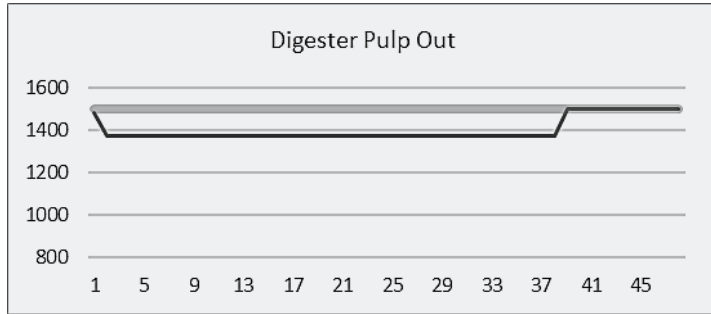
Production Planner

Case #1 – Wider Inventory Limits



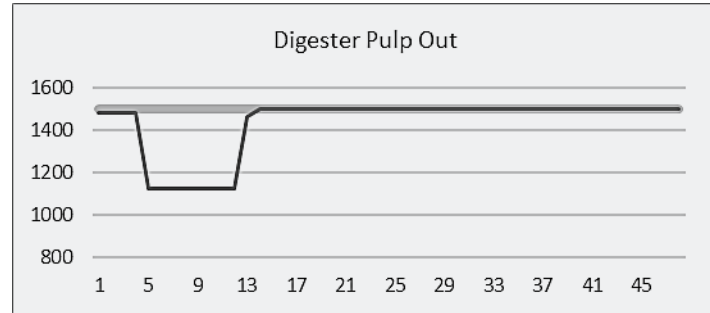
Total Prod (tonnes) **2808** **347 more tonnes**

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Production maximized subject to process limits



Production Planner

Case #2 – Coordinated Maintenance



Total Prod (tonnes)

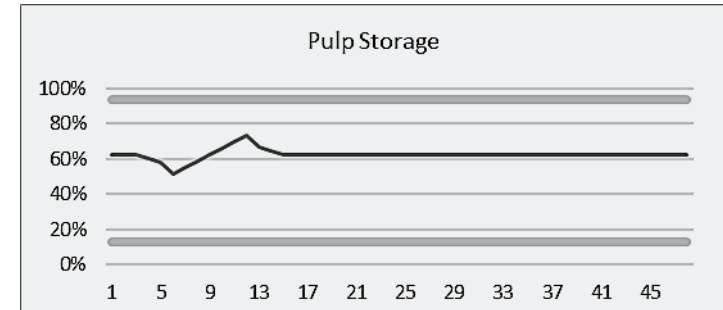
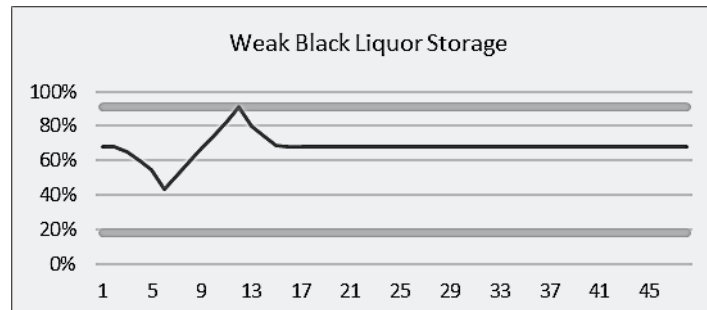
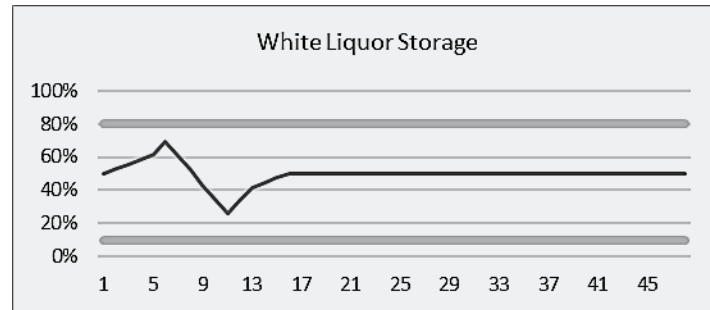
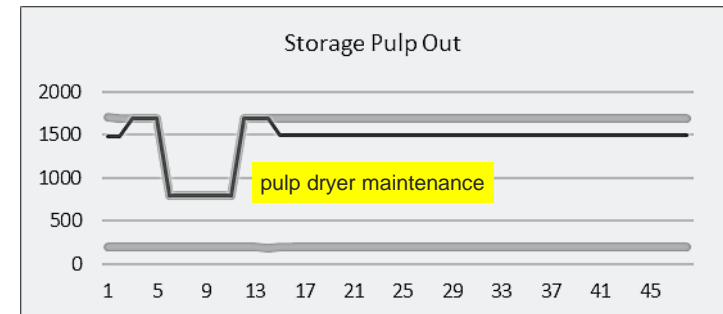
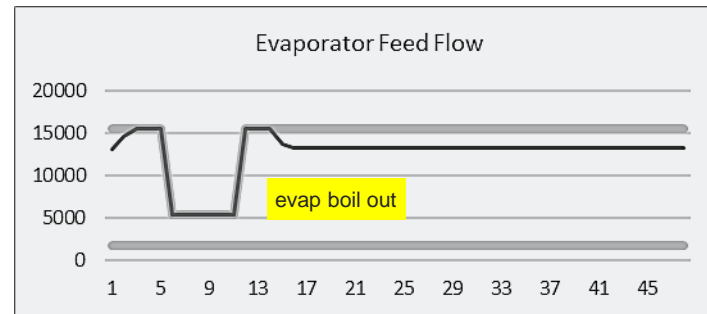
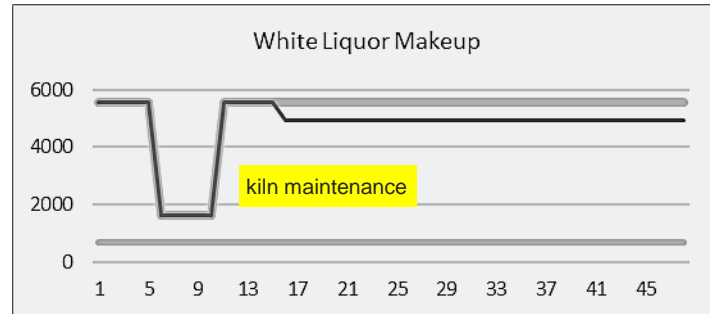
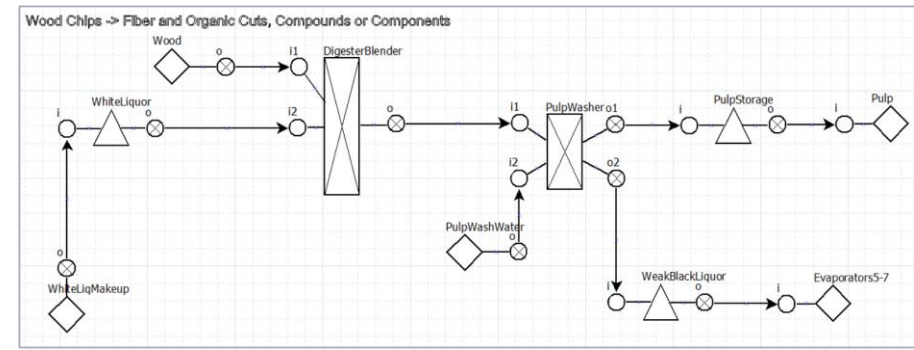
2871

410 more tonnes

Graphs show production plan for next 2 days

User enters current and future process limits based on maintenance plan

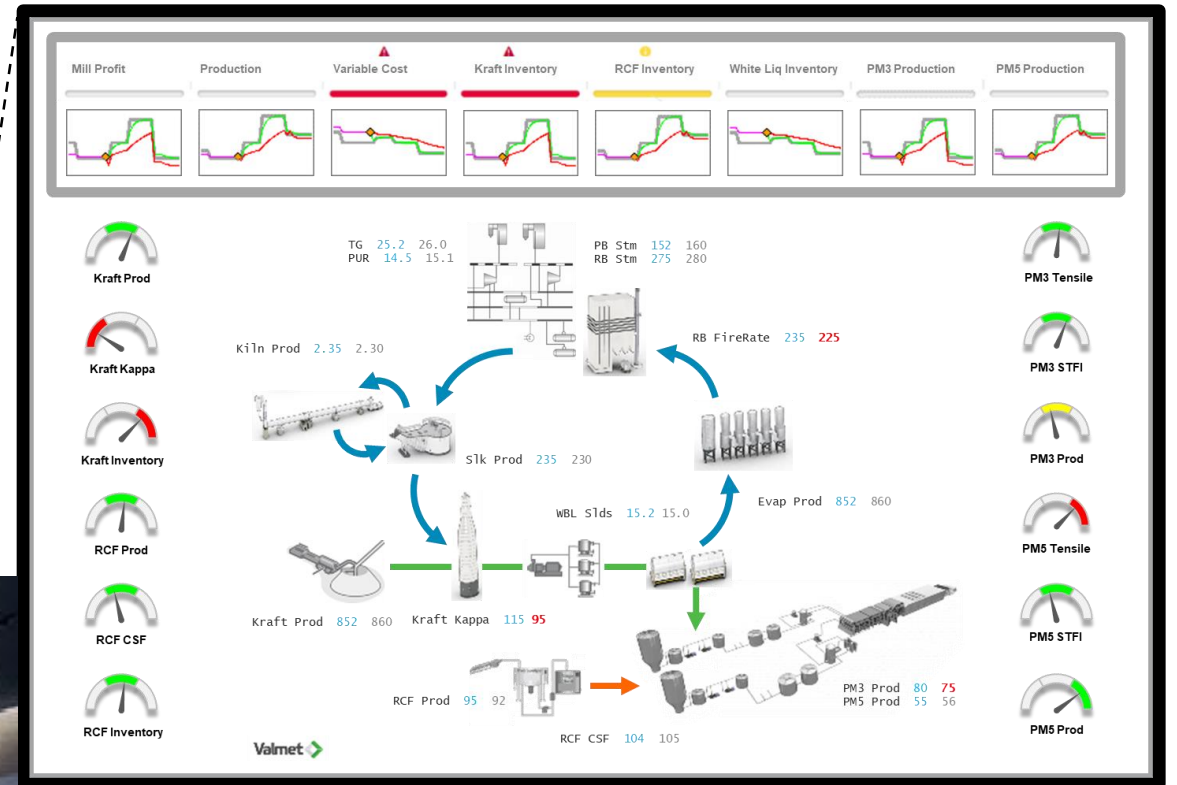
Production maximized subject to process limits



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DCS Display of the Future
- high level view of mill performance