Aalto University
School of Chemical
Engineering

CHEM-E0115 Planning and Execution of a Biorefinery Investment Project (5 cr)

Lecture 4
Introduction to Process Engineering
September 28, 2023
Sakari Vuorinen

MY CAREER DEVELOPMENT

Sakari Vuorinen, Team Leader

Graduated from Aalto,
Bioproducts Technology,
Major: Biorefineries
Minor: Work psychology & Leadership

2015 2016 2017 2018 2019 2020 2021 2022 2023 2024

Product Engineer (NCG),
Valmet Technologies Oy, Tampere

Senior Process Engineer (Pulp),
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AFRY
ÅF PÖYRY

Contents

- **Introduction**
- **Process engineering in different phases of a project**
  - Development of process concepts
- **Tools in process engineering**
- **Engineering case examples**
- **HVAC process engineering**

INTRODUCTION

Investment implementation phase – Technology & Engineering

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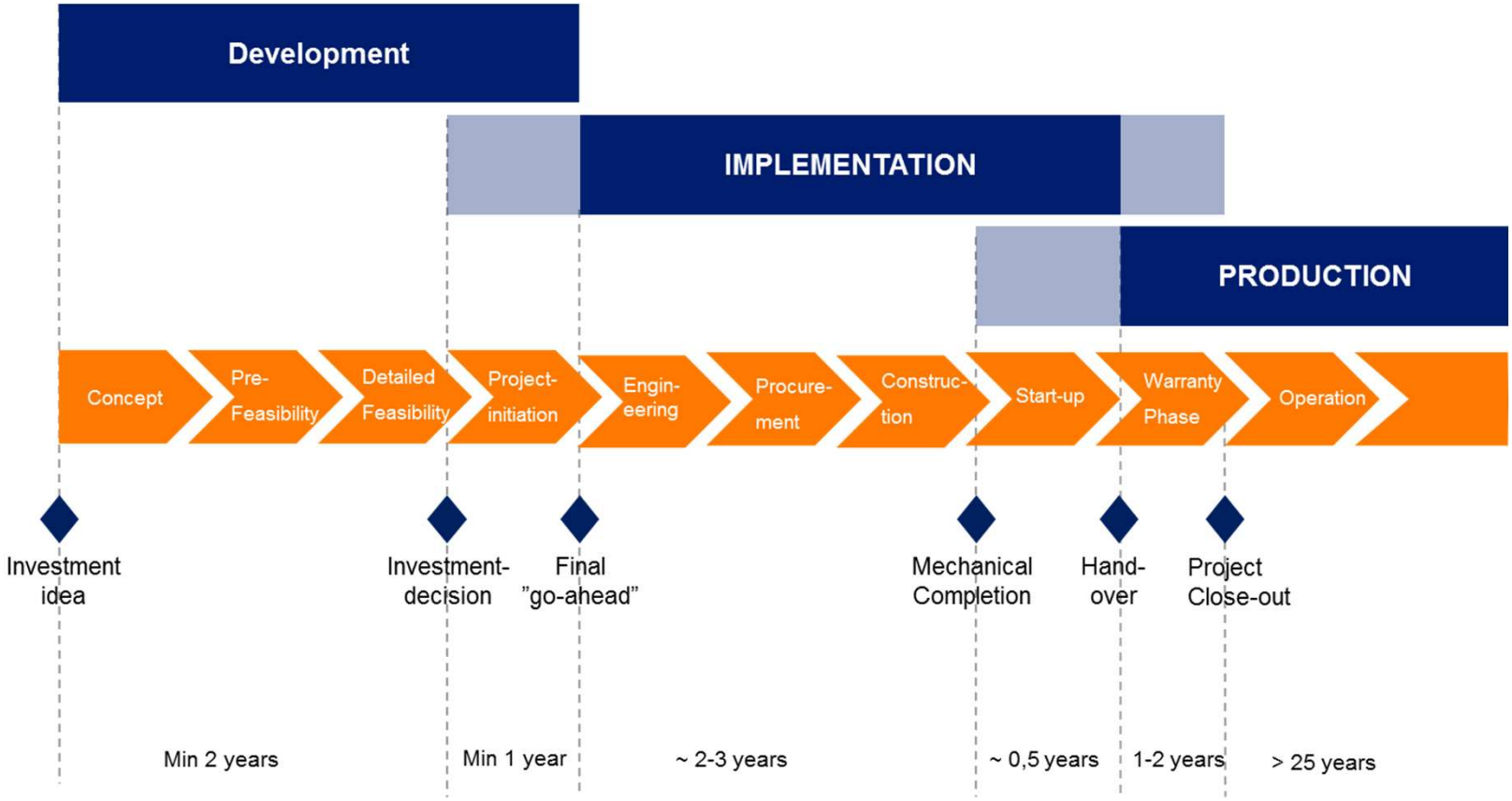
Introduction - Investment project



Introduction

Process engineering is done in all phases of a project

Process engineer's role in a project

- Responsible for process concept and design
- Coordinating engineering in other disciplines (mechanical, electrical, automation)
  - *Information to other disciplines*
  - *Responsible for designed system process-wise (piping, control valves, check valves, DCS etc.); system is possible to operate*

Process engineering in different phases of a project

Pre-feasibility study

- Assessment of the technical viability of a proposed project
- Comparison of concept alternatives

Feasibility study

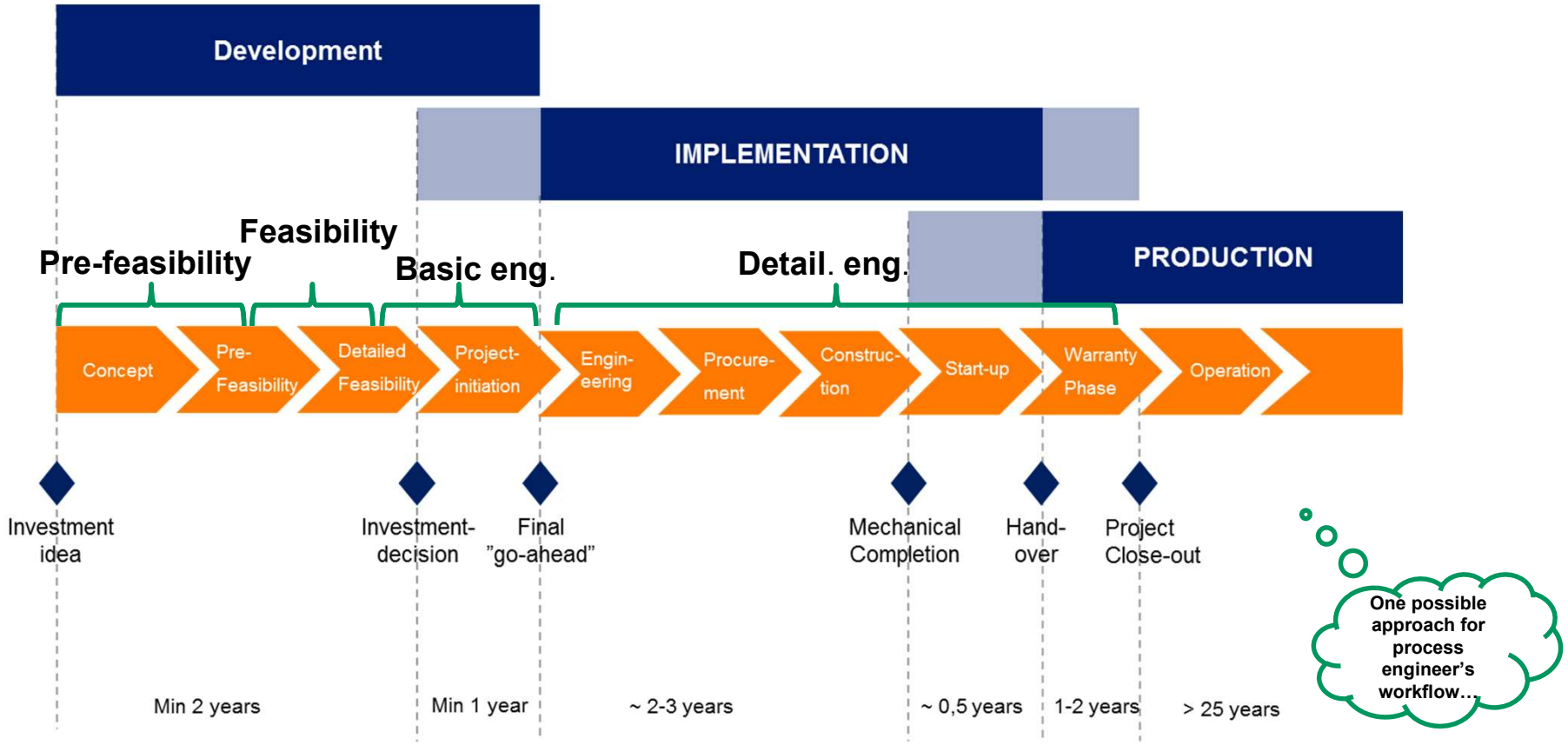
- Preliminary design of the chosen solution
- Investment cost estimate for investment decision

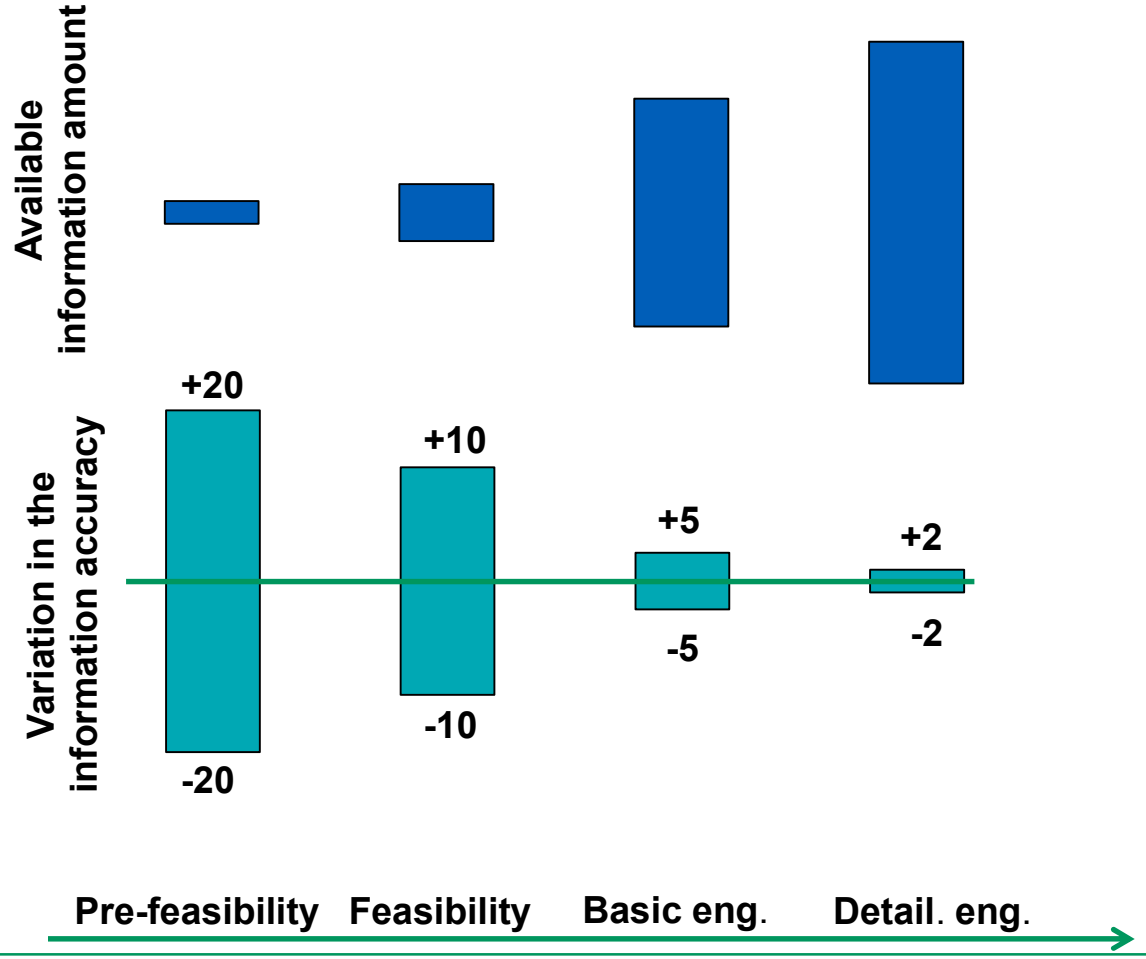
Basic engineering

- Preparatory engineering for selection of equipment suppliers and permit applications
- Investment cost estimate and budget for final ”go-ahead”

Detailed engineering

- Project implementation with selected processes


Development
IMPLEMENTATION
PRODUCTION
Pre-feasibility
Feasibility
Basic eng.
Detail. eng.
Concept
Pre-Feasibility
Detailed Feasibility
Project-initiation
Engin-eering
Procure-ment
Construc-tion
Start-up
Warranty Phase
Operation
Investment idea
Investment-decision
Final "go-ahead"
Mechanical Completion
Hand-over
Project Close-out
Min 2 years
Min 1 year
~ 2-3 years
~ 0,5 years
1-2 years
> 25 years
One possible approach for process engineer's workflow…


Available information amount
Variation in the information accuracy
+20
+10
+5
+2
-20
-10
-5
-2
Pre-feasibility
Feasibility
Basic eng.
Detail. eng.

PRE-FEASIBILITY STUDY & FEASIBILITY STUDY

PROCESS ENGINEERING

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Pre-Feasibility study

- Definition of design criteria
- Calculation of preliminary main dimensioning
- Preparation of preliminary process description
- Preparation of preliminary equipment lists for investment cost estimates

Feasibility study

- Process concept selection
- Review of design criteria for process design
- Update of preliminary main dimensioning (balances)
- Calculation of preliminary energy balances
- Revision of process description
- Preparation of simplified line diagrams
- Update of equipment lists for revised investment cost estimate
- Special studies
- Preliminary discussions with equipment suppliers

Feasibility study

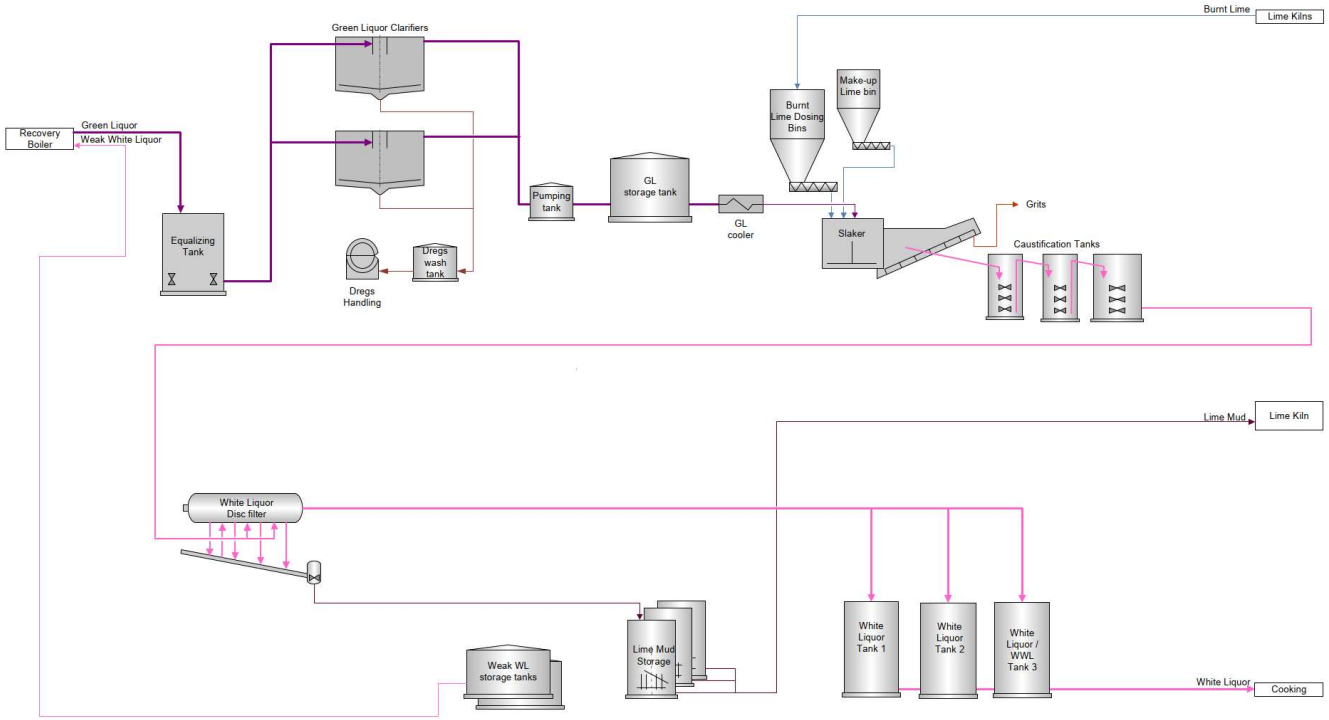
Design criteria for pulp mill

- Product (bleached/unbleached, ECF/TCF, etc.)
- Raw-material base
- Cooking method
- Production, ADt/a
- Design factor
- Annual operating days
- Department capacities (from main dimensioning calculations)

		Softwood
Annual production	ADt/a	350 000
Operation days	d/a	350
Average production, bleached pulp	ADt/d	1 000
Capacity efficiency Woodhandling Drying	% % %	90 80 85
Design capacity, bleached pulp	ADt/d	**1 111**
Raw material		Pine + spruce

Feasibility study

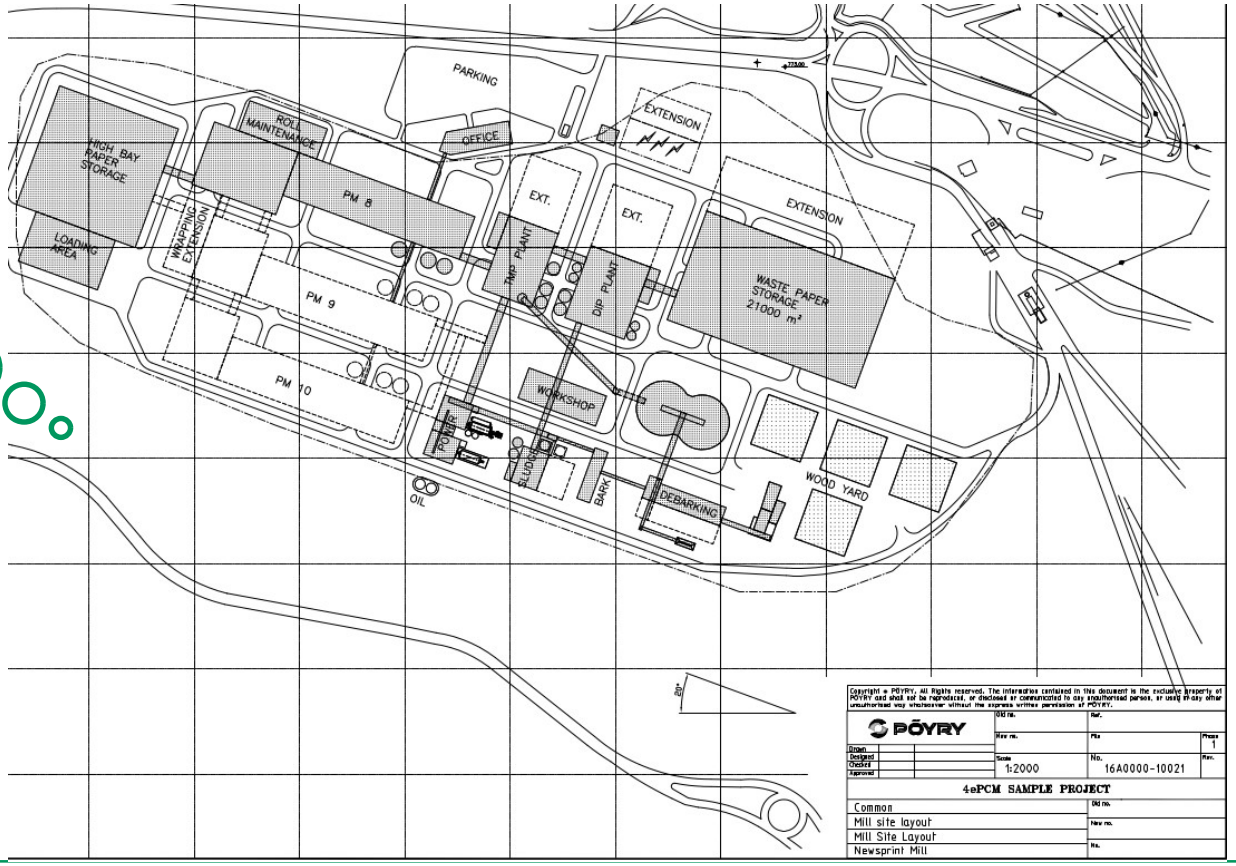
Line diagram example
Example tool: Visio



PÖYRY	PÖYRY LINE DIAGRAM EXAMPLE
EXAMPLE	Re-causticizing

Feasibility study

Mill site layout example
Example tool: CAD
Plant engineering



BASIC ENGINEERING

PROCESS ENGINEERING

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Basic Engineering

General process engineering

- Preparation of technical specification documents for main equipment enquiries
- Preparation of technical tender comparisons
- Participation in technical negotiations, minutes of meetings

Process design

- Review of design criteria for process design
- Update of main dimensioning
- Update of energy balances
- Calculation of water and secondary heat balances
- Standards for the process design
- Definition of process flow substances
- Special studies

Basic Engineering

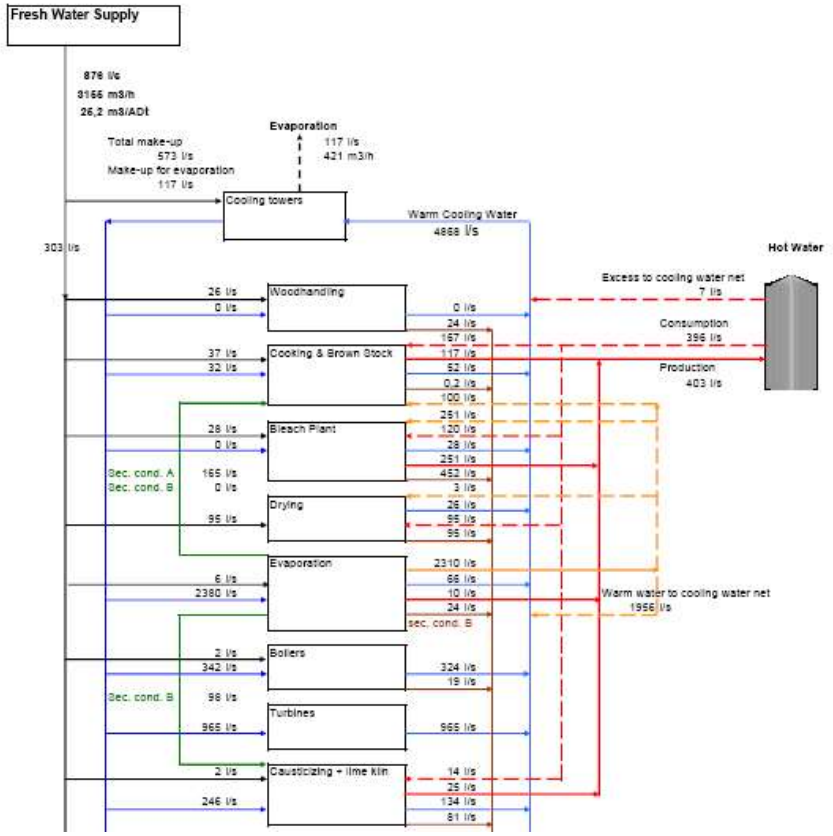
Departmental design criteria

- Departmental dimensioning of different mill departments

		Selected
Wood handling		
Debarking and Chipping	m^3sub/h	**600**
Chip screening	m^3loose/h	**2 000**
Fibreline		
Cooking	ADt/a	**3 000**
Deknotting/Screening	ADt/a	**2 900**
Oxygen delignification	ADt/a	**2 800**
Bleaching	ADt/a	**2 700**
Drying	ADt/a	**2 800**
Recovery plant		
Evaporation	t H_2O/h	**1 000**
Recovery boiler	tDS/d	**4 000**
Causticizing	m^3WL/d	**10 000**
Lime kiln	t CaO/d	**700**

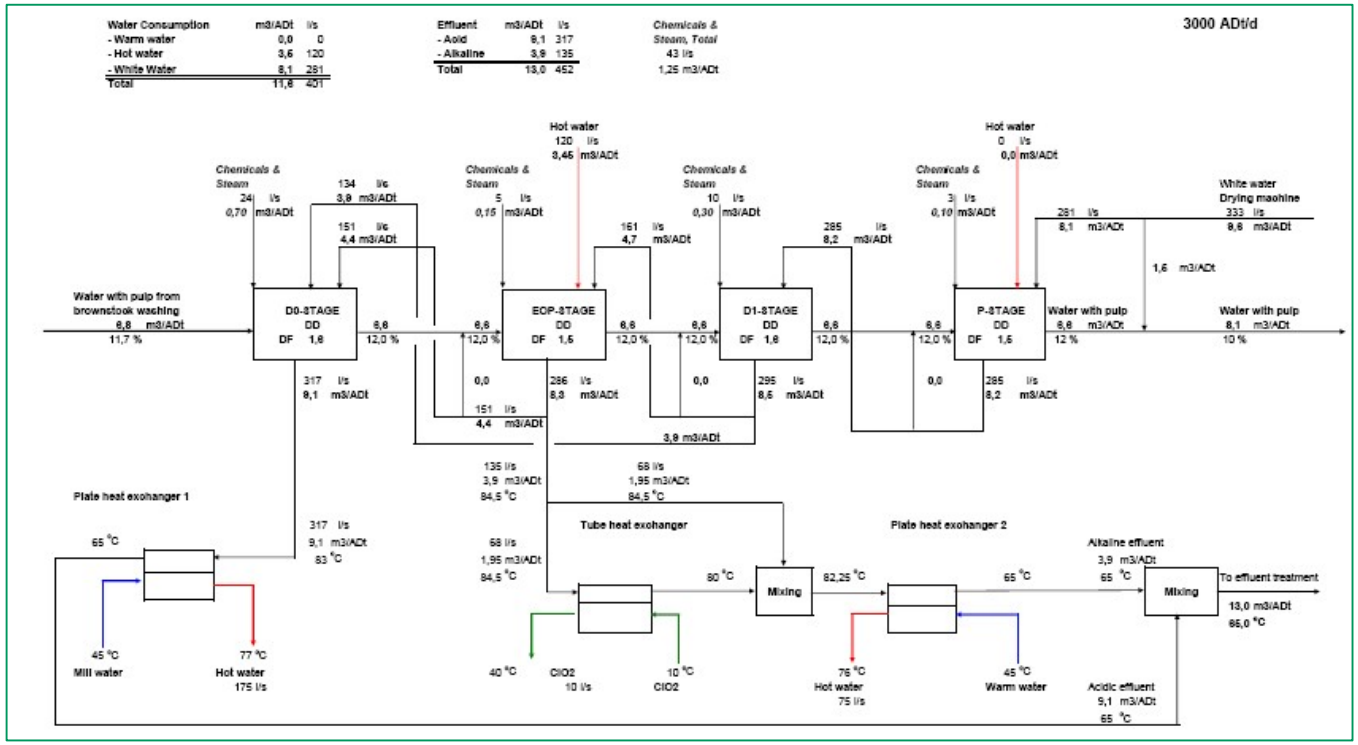
Basic Engineering

Water balance example
- Mill water
- Cooling water
- Hot water
- Warm water
- Effluent
- Etc.



Basic Engineering

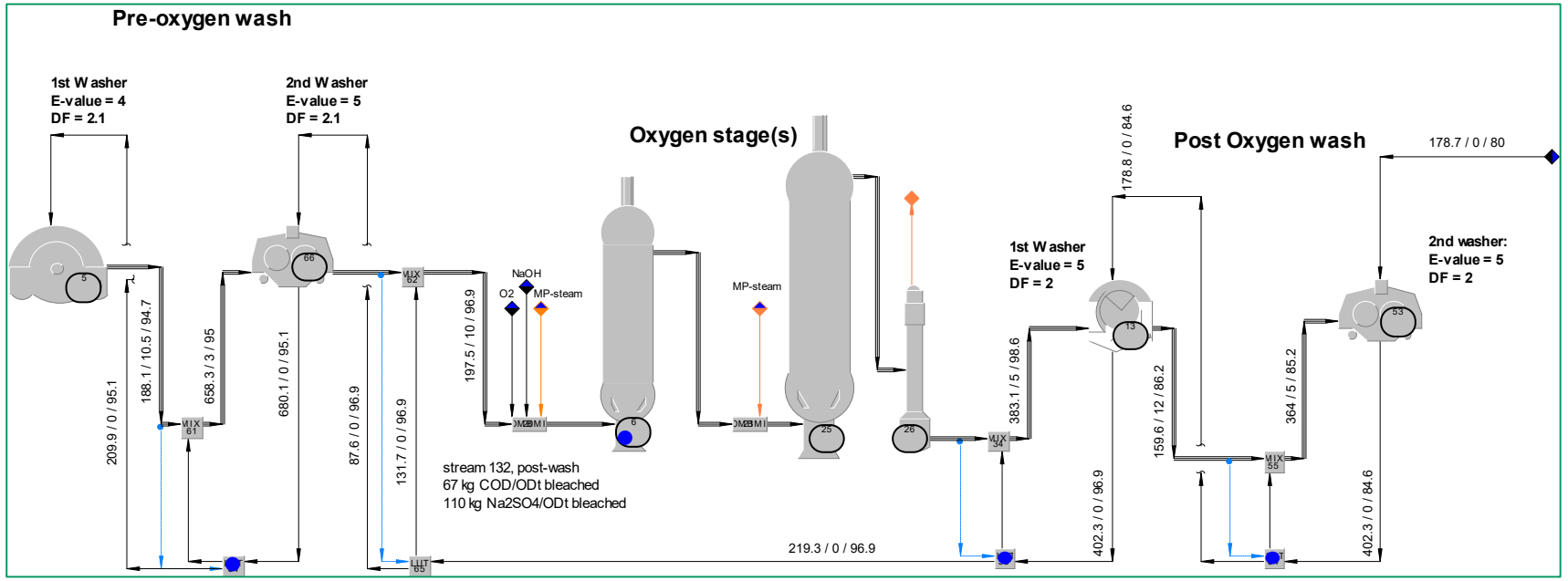
Bleach plant water balance example: Example tool excel



Basic Engineering

Process simulation: Example Tool WinGems

Principally a more sophisticated way to do calculations



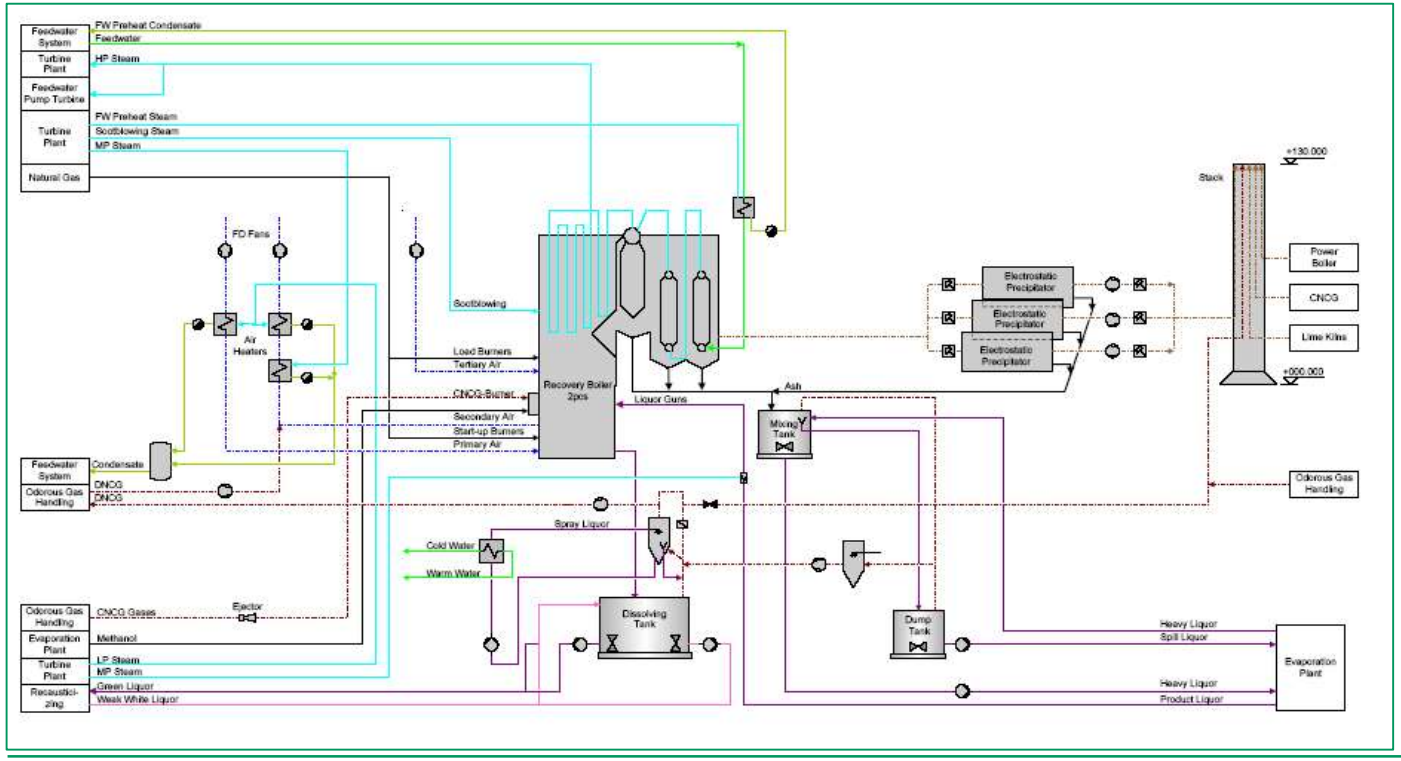
Basic Engineering

Process design continues…

- Preparation of line diagrams
- Preparation of connections between departments diagram
- Update of equipment lists for investment cost estimate
- Technical documents for contracts
- Preparation of process description and control philosophy for detailed engineering

Basic Engineering

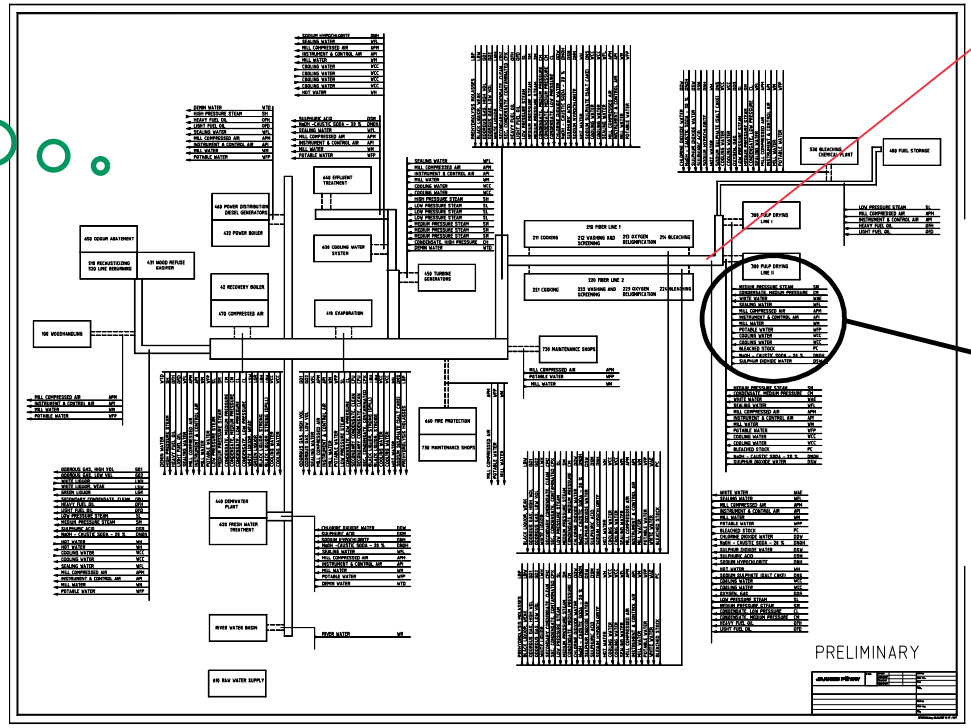
Line diagram



More details appear in line diagrams
Example Tool: Visio

Basic Engineering

An example how connections between departments can be illustrated



Pipe bridge

MEDIUM PRESSURE STEAM	SM
CONDENSATE, MEDIUM PRESSURE	CM
WHITE WATER	WAE
SEALING WATER	WFL
MILL COMPRESSED AIR	APM
INSTRUMENT & CONTROL AIR	API
MILL WATER	WM
POTABLE WATER	WFP
COOLING WATER	WCC
COOLING WATER	WCC
BLEACHED STOCK	PC
NaOH - CAUSTIC SODA - 20 %	DNOH
SULPHUR DIOXIDE WATER	DSW

DETAILED ENGINEERING

PROCESS ENGINEERING

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Detailed Engineering

General process engineering

- Preparation of technical enquiry specifications
  - *for tanks, vessels and agitators*
  - *for pumps and vacuum pumps*
  - *for auxiliary equipment*
- Equipment and machinery specifications for purchase
  - *Checking of contract documentation*

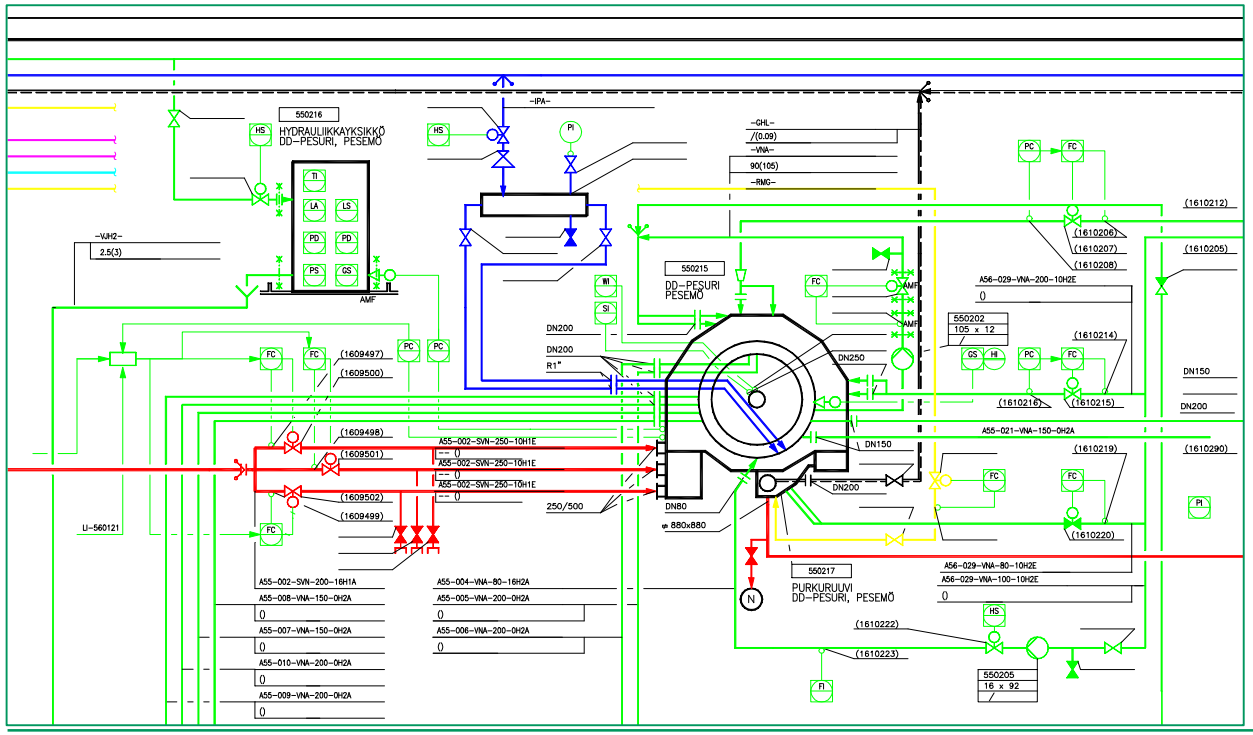
Detailed Engineering

Process design

- Preparation of dimensioned flow sheets
- Establishment of process and equipment data base
- Compilation of final process and equipment data
- Compilation of lists
  - *Equipment and motor*
  - *Pump*
  - *Tank, vessel and agitator*
- Preparation of flow diagrams for process utilities
- Process engineering of interconnections between mill departments
- Checking pump calculations
- Preparation of PI-diagrams

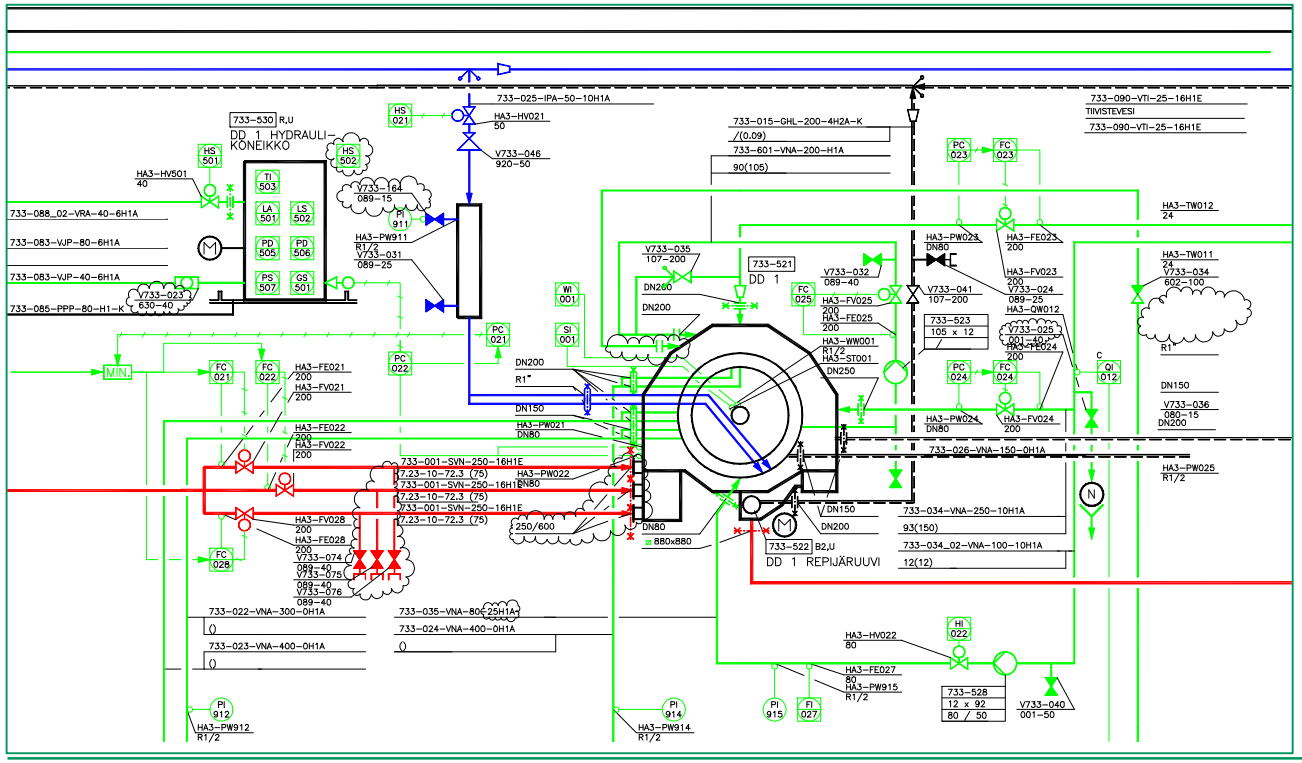
Detailed Engineering

Flowsheet: example tool CAD



Detailed Engineering

PI-diagram: example tool CAD



Detailed Engineering

Operating Instructions

- Process start-up
- Operation procedures
- Shut-down procedures

Training

- Preparation of training material
- Training

Other possible

- Participation on making a simulator
- FAT/SAT testing ≈ testing the functionality of control systems and instruments

Detailed Engineering

Engineering for commissioning and start-up

- Definition of water run test loops
- Preparation of coloured PI-diagrams presenting each group
- Compilation of check-out lists
- Technical definitions for the execution of commissioning, test runs and start-up
- Participation in commissioning, test runs and start-up
- Compilation of commissioning and test run results
- Assessment of performance against guarantees

Detailed Engineering

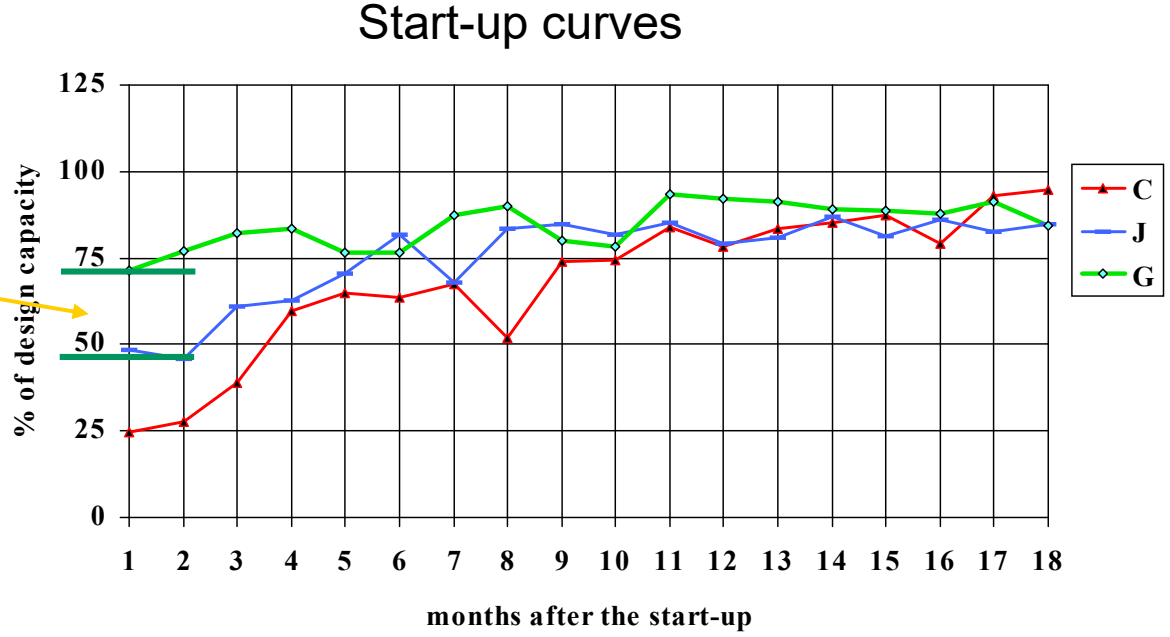
Commissioning check-out after start-up is expensive

Production 2000 ADt/d

Difference 15 000 ADt/month

BHKP price 485 EUR/ADt

Profit 7,275 MEUR/month



Detailed Engineering

As-built documentation

- Equipment, pump, tank etc. lists
- PI-diagrams
- Operating manuals

Development of process concepts

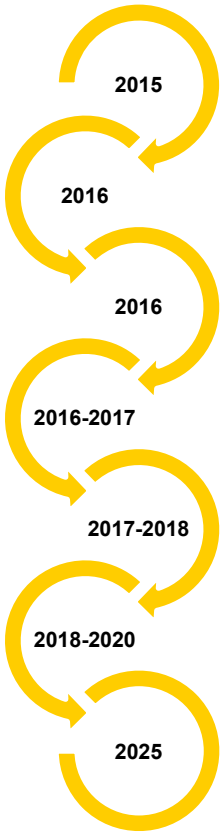
What was presented in the previous slides define project work in one way. There are other definitions too for example:

- AACE Practice
- FEL classification (Front-end loading)
- FEED (Front-end engineering design)

Often technologies consist of conventional sections as well as solutions for which there is yet no experimental proof of functionality

- Risks are required to be evaluated
- A concept of Technology Readiness Availability (TRA) is often utilized.

Development of novel process concepts



- **Feasibility study of a full-scale plant**
  - CAPEX estimate
  - Technology Readiness Level assessment
- **Pilot plant Feasibility study**
  - Choosing the demo scale
- **Start of Basic engineering of Pilot plant**
  - Contacting equipment vendors
- **Basic engineering of a De-risking plant**
  - New concept for energy recovery
  - Several other enhancements in technology
- **Follow-up engineering for De-risking plant**
  - Co-operation continued with suppliers
  - Plant scope reduction
- **Building of De-risking plant**
  - Test platform for new concepts: equipment fouling, energy recovery, oil purification, catalyst recovery etc.
- **Full scale plant**

- Technology development roadmap
- R&D plan introduced: Phase separation, water and organics recovery, catalyst purification, energy recovery

- Major involvement of technology suppliers

Illustrative example of main milestones

EXAMPLE TOOLS

PROCESS ENGINEERING

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Example tools in process engineering

CAD
- AutoCAD
- Plug-ins

AFRY databases
- ProElina (engineering database for equipment, valve, pump, tank, pipe, etc..)
- Share@AFRY (document database)

Office365
- Excel
- Visio

Simulation
- Wingems
- Balas
- Aspen

ENGINEERING CASE EXAMPLES – OPERATING MILL

PROCESS ENGINEERING

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Engineering Case Examples

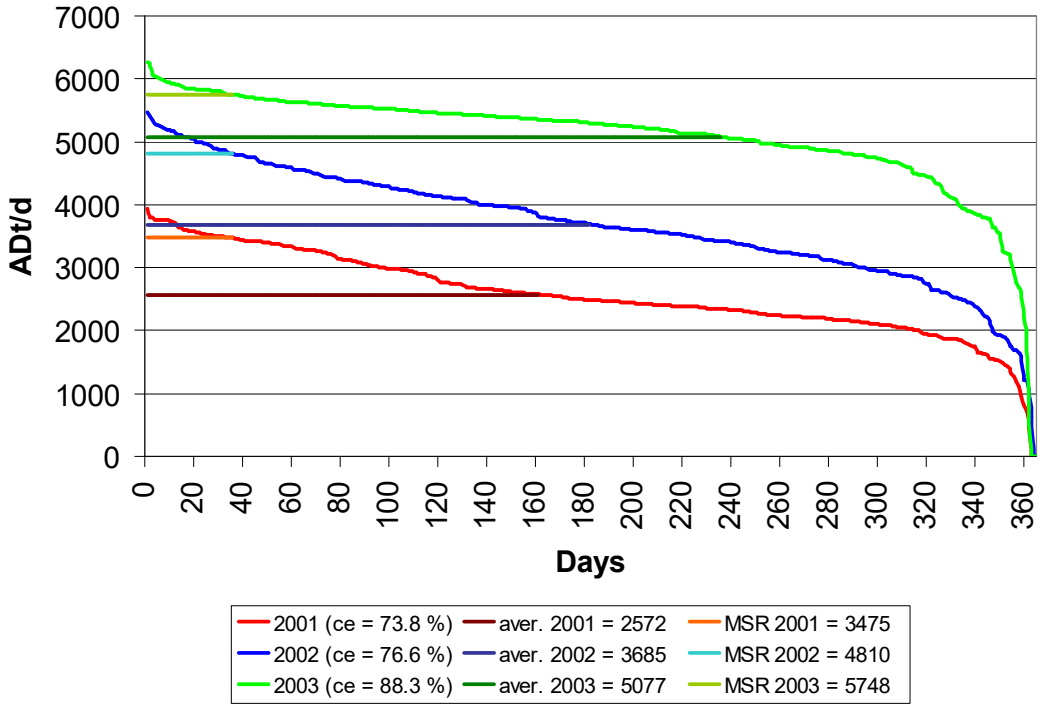
Analysis of an operating system

- Operations improvement, operating performance criteria
  - *Time efficiency (availability)*
  - *Production stability*
  - *Ratio of actual production to practical maximum capacity*
  - *Energy balance*
  - *Wood consumption*
  - *Water consumption*
  - *Personnel productivity*
  - *General overheads*
  - *End product performance*

Engineering Case Examples

Analysis of an operating system

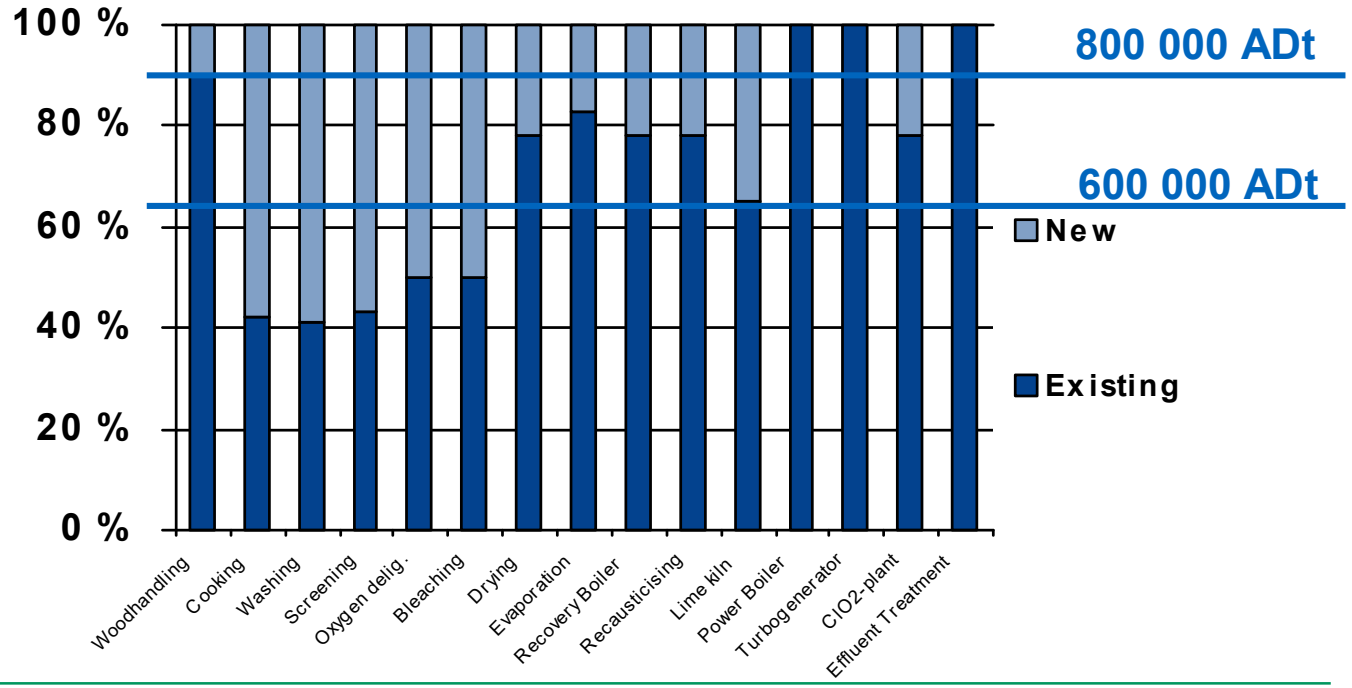
- Operations improvement, duration curves



Engineering Case Examples

Analysis of an operating system

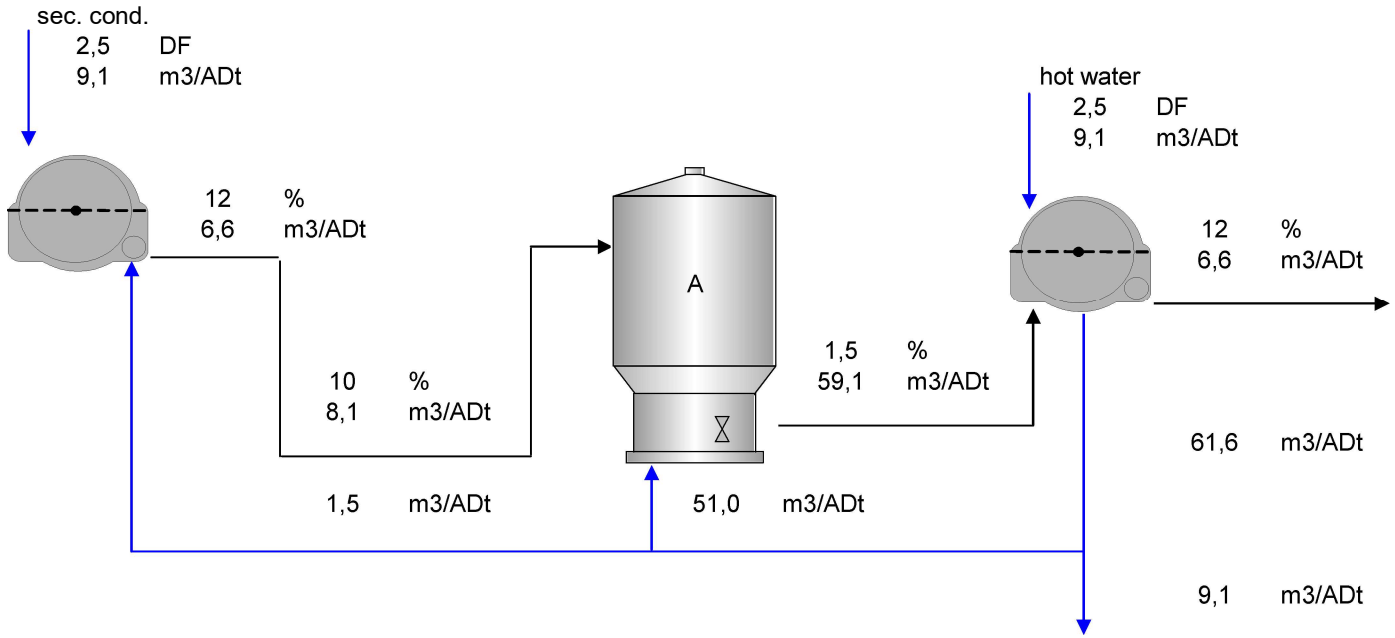
- Bottleneck analysis



Engineering Case Examples

Analysis of an operating system

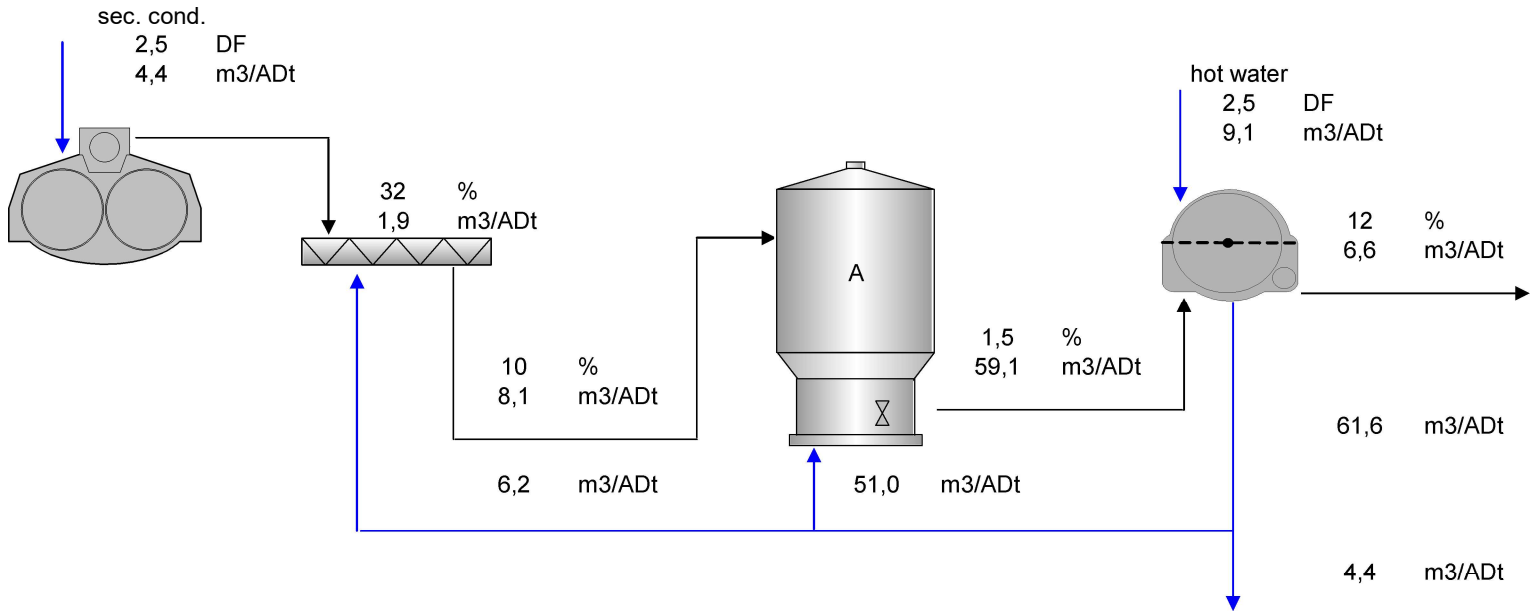
- Operations improvement, effluent volume reduction



Engineering Case Examples

Analysis of an operating system

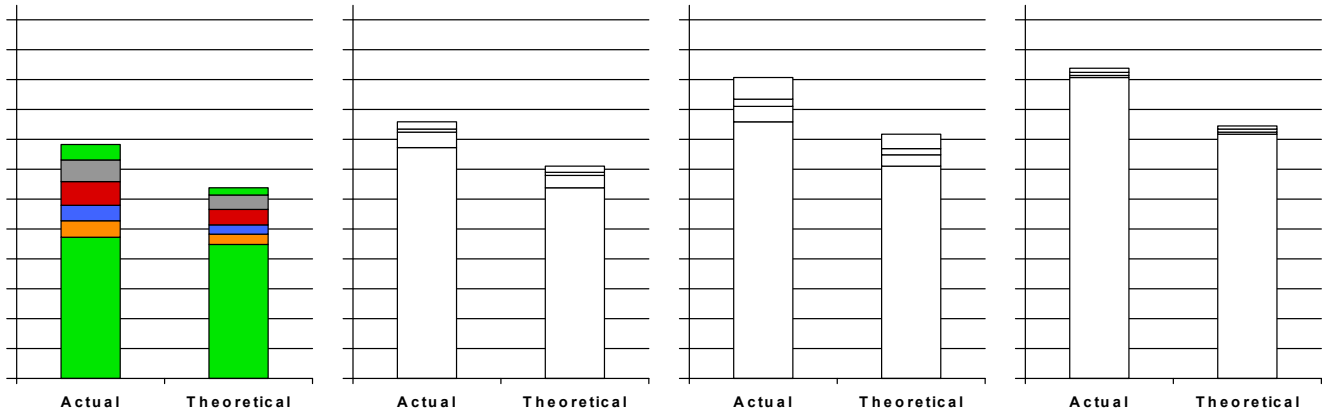
- Operations improvement, effluent volume reduction



Engineering Case Examples

Analysis of an operating system

- Operations improvement
  - *Identify the cost structure, actual vs. theoretical*
  - *Identify the costs that can be reduced*



Digester Plant **Washing & Screening** **Bleach Plant** **Pulp Dryer**

HVAC

PROCESS ENGINEERING

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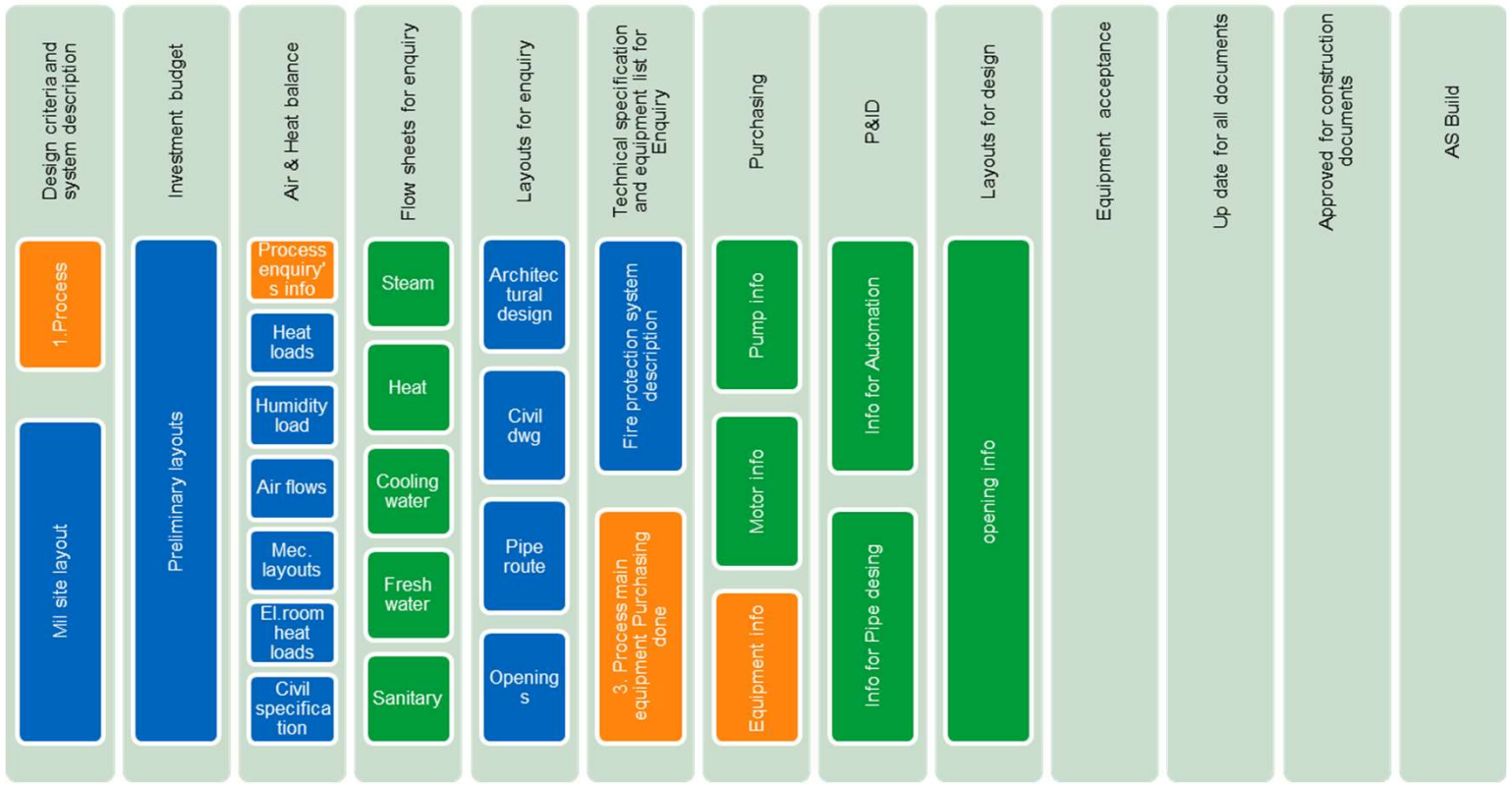
HVAC

- Heating, ventilation, and air conditioning (HVAC) is the technology of indoor and vehicular environmental comfort. Its goal is to provide thermal comfort and acceptable indoor air quality

- HVAC = **H**ealth (Humans, Air quality and Equipment, lifetime)
- HVAC = **S**afety (People, Visibility, Slips, Failures, Explosions, Air quality)
- HVAC = **E**nvironment (Noise, Energy Consumption, Emission Reduction)
- HVAC = **Q**uality (Product quality, Lifetime of building)

- The cooling power requirement is about 2-8 MW (1000 Town house)
- Heating power requirement about 15-46 MW (1000 Town house)
- 500-1000 m3/s supply air to the hall ventilation (2500 Town house)
- 100-170 m3/s air in special rooms (150 Town house) (Electrical-, cable-, automation and control rooms, office and social facilities)
- Cost 3-18 M€

HVAC design flow



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Now is a brilliant time for more questions…

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