Concept and strategy on up-scaling chemical process for BCG industry

Dr. Suchat Pongchaiphol

Tentative Program for TNChE Asia 2023 Conference
2# Process Scale-up Sharing

https://www.bangkokpost.com/business/2179811/reimagining-thailand-with-a-bcg-economy

Integrative Biorefinery Laboratory

BIOTEC- JGSEE

BIOTEC a member of NSTDA

JGSEE The Joint Graduate School of Energy and Environment

Technologies & Expertises

- Enzyme technology & Biocatalytic process
- Microbial cellulose processing
- Cell factory development & engineering
- 2G Bioprocess development
- Bio-CCU technology
- Biomass fractionation process
- Catalyst design & catalytic process
- Downstream processing
- Reactor & system design
- Chemical CCU technology

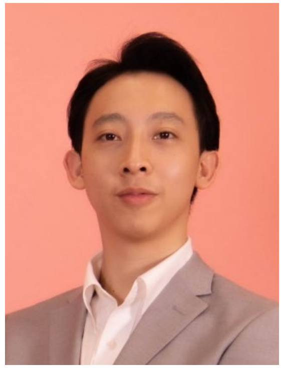
JGSEE, KMUTT

IBBG, BIOTEC

Prof. Dr. Navadol Laosiripojana

Dr.Verawat Champreda

Assist.Prof.Dr. Marisa Raita



Dr. Chayanon Chotirotsukon

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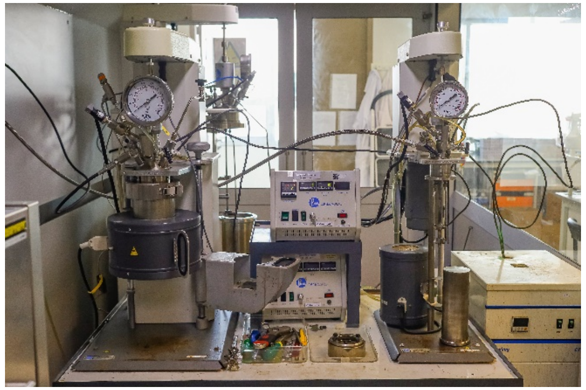
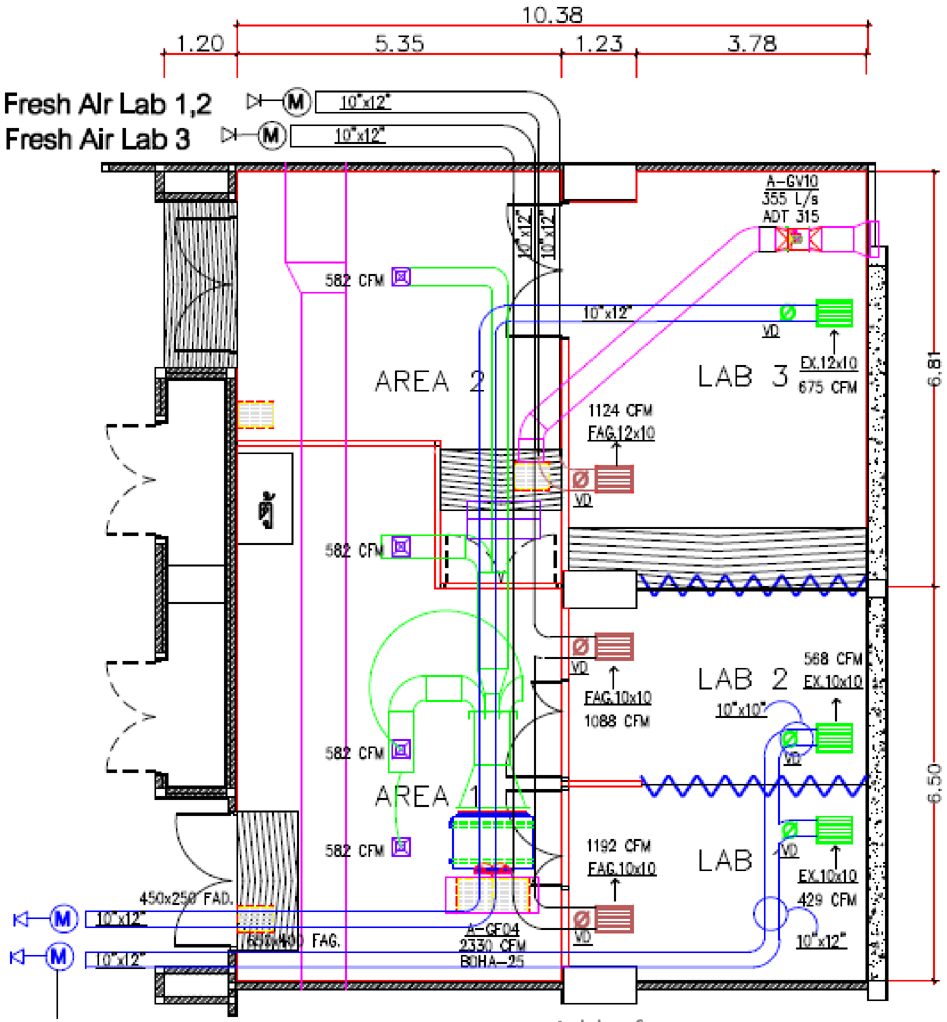
IBL Pre-pilot facilities for biomass fractionation





Mr. Suchat Pongchaiphol, Senior Research Engineer (Doctor degree, experience 10 yrs ++)

EXPERIENCE PROJECT WITH GLOBAL R&D Company (2012-Present)

- Fixed & Fluidized Bed Resin in Ion Exchange Unit
- Highly Turbulent Circulating Flow by Fixed Bed Reactor & Berty Reactor
- Catalyst Polymerization Production by 50L Reactor Size
- Hydrogen Gas Blending Unit for welding unit system
- Dust Cyclone Separator (Size separation)
- Scale-up Steam Explosion reactor from 1 liter to 10 liters
- Scale-up and design system from batch reactor to continuous reactor in the biomass supercritical water gasification continuous flow process
- Carbon Nanotube Production from Fixed Bed, Downer and Fluidized Reactor
- Waste Gas and Water Effluent Treatment by Photo catalytic Reactor
- Scale-up and design system from Batch to Continuous Reactor for Carbonization Process
- Design Rotary Fluidized bed Reactor unit for polymerization process
- Furfural synthesis vis Pervaporation process
- Aluminum recycle process potential and technology benchmark
- Pyrolysis oil process from plastic waste and technology benchmark
- Titanium dioxide production process from catalyst waste and technology benchmark”

EXPERIENCE PROJECT WITH Integrative Biorefinery Laboratory, IBL (2016-present)

- Lignin production process from residue biomass and technology benchmark
- Design Food Waste Composter unit
- 5L High pressure reactor unit for hydrothermal reaction
- 30L High pressure extractor unit and solvent recycle unit
- 50L High pressure Reactor unit and Overall downstream unit
- 10 and 40L High pressure Fermenter unit and automation controller unit
- Modified 18 L Catalyst Synthesis Reactor for polymerization process
- Design and Fabricate Fixed Bed Reactor for Steam Reforming Unit
- Cellulose Pulping Production Process (Alternative Technology)
- Furfural Production Process by Reactive Distillation (วช)
- Alternative sugar conversion by Photocatalyst Reactor
- Alternative sugar purification by Absorption, Membrane and Falling film Evaporation Unit
- Wax Extraction Process and Purification process for policosanol product
- Glycerol Hydrogenation from Batch to fixed bed reactor
- Modified Electric Controller of 1L High pressure Parr reactor unit
- Modified Membrane Reactor Unit in Humidifier and Impurity Generation Mode

BCG Economy THAILAND

เพื่อยกระดับเศรษฐกิจฐานราก

BCG is multi/inter/trans disciplinary by nature

Bio Economy
เศรษฐกิจชีวภาพ

Green Economy
เศรษฐกิจสีเขียว

Circular Economy
เศรษฐกิจหมุนเวียน

https://www.youtube.com/watch?v=hwuUK-b6TLY

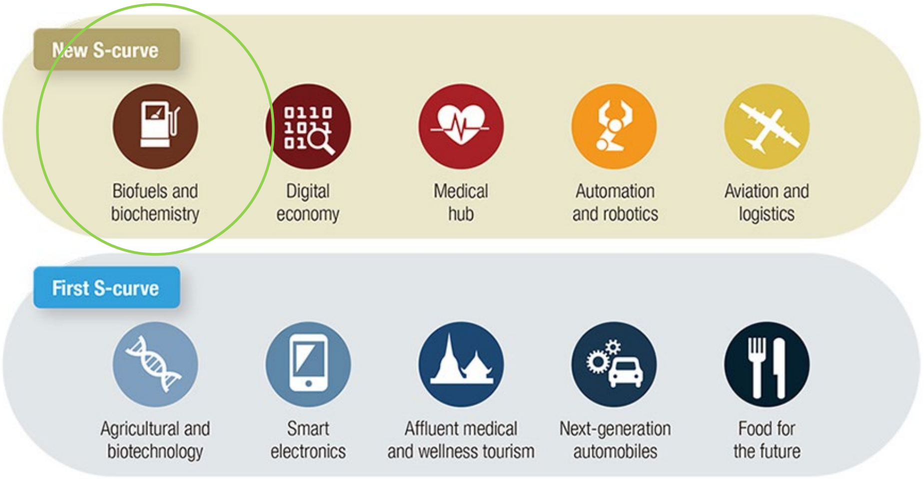
Biorefinery: New S-curve industry for Thailand

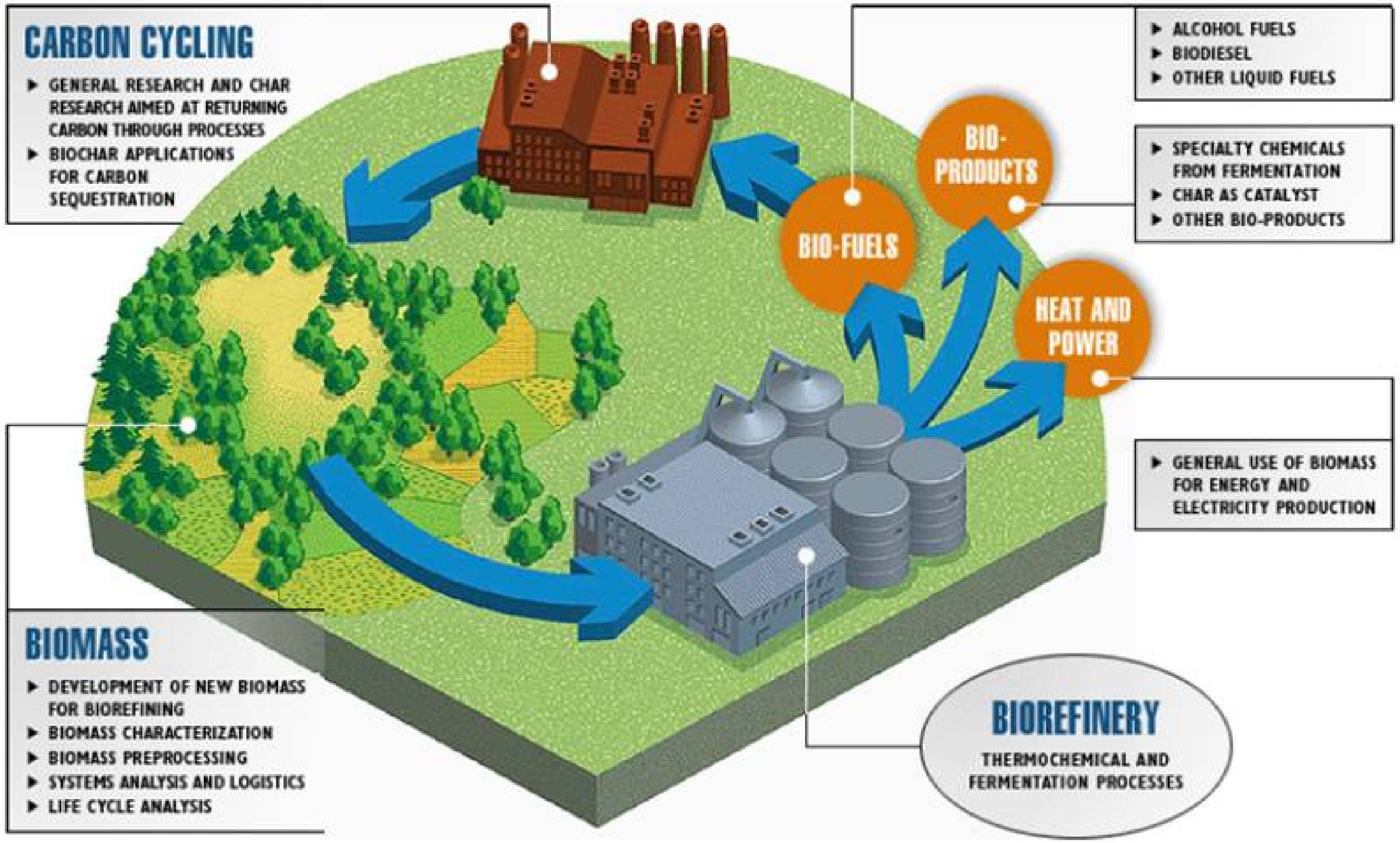
BIOrefinery is becoming a key new driver for **BCG ECONOMY** platform in Thailand.

Diverse agricultural products/ by-products

Existing industry platform

New S-curve Thailand 4.0





https://www.intechopen.com/chapters/48650

Transformation of current industries to biorefineries

New business

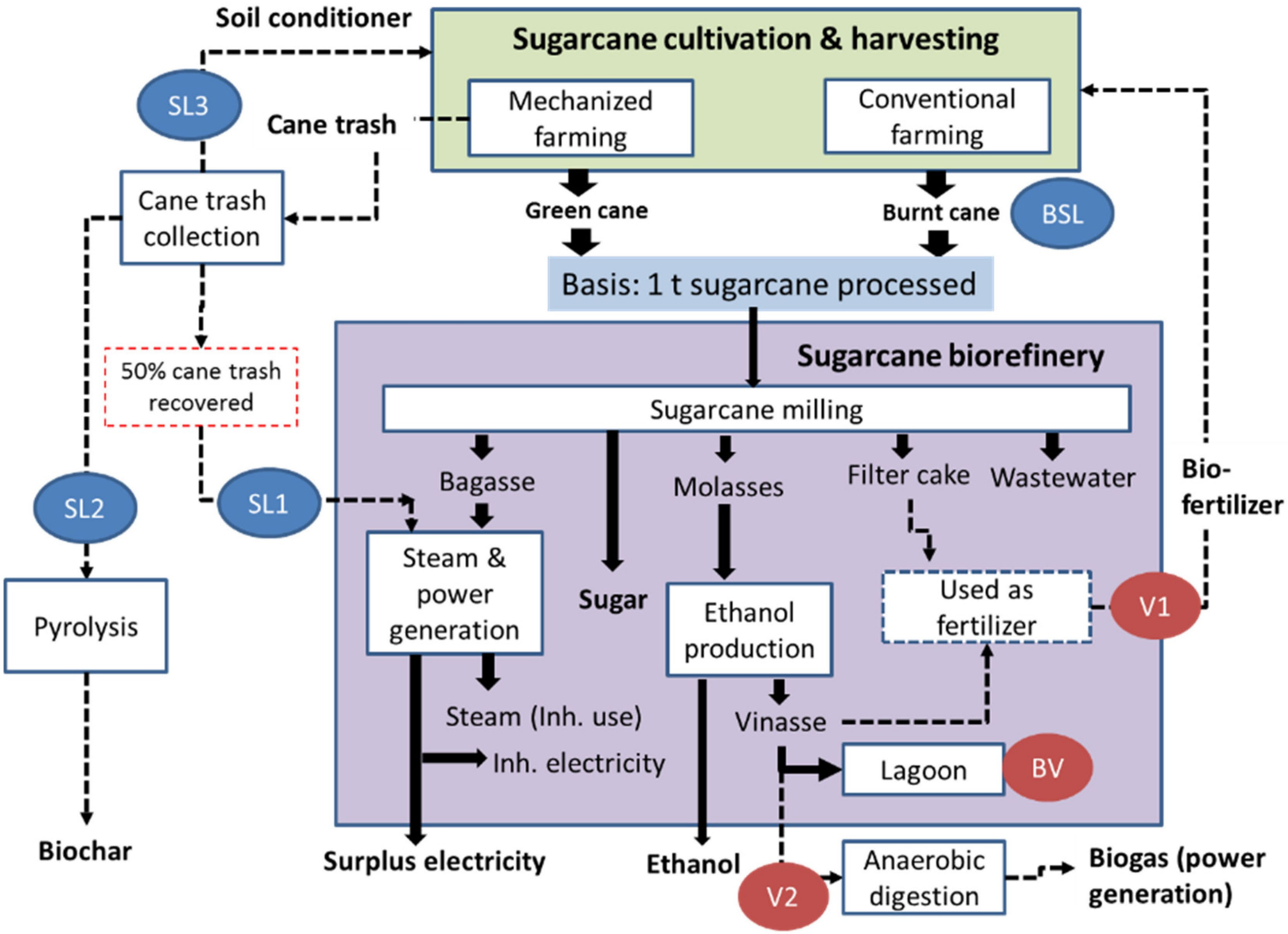
Zero waste

Multi-product

Sustainability

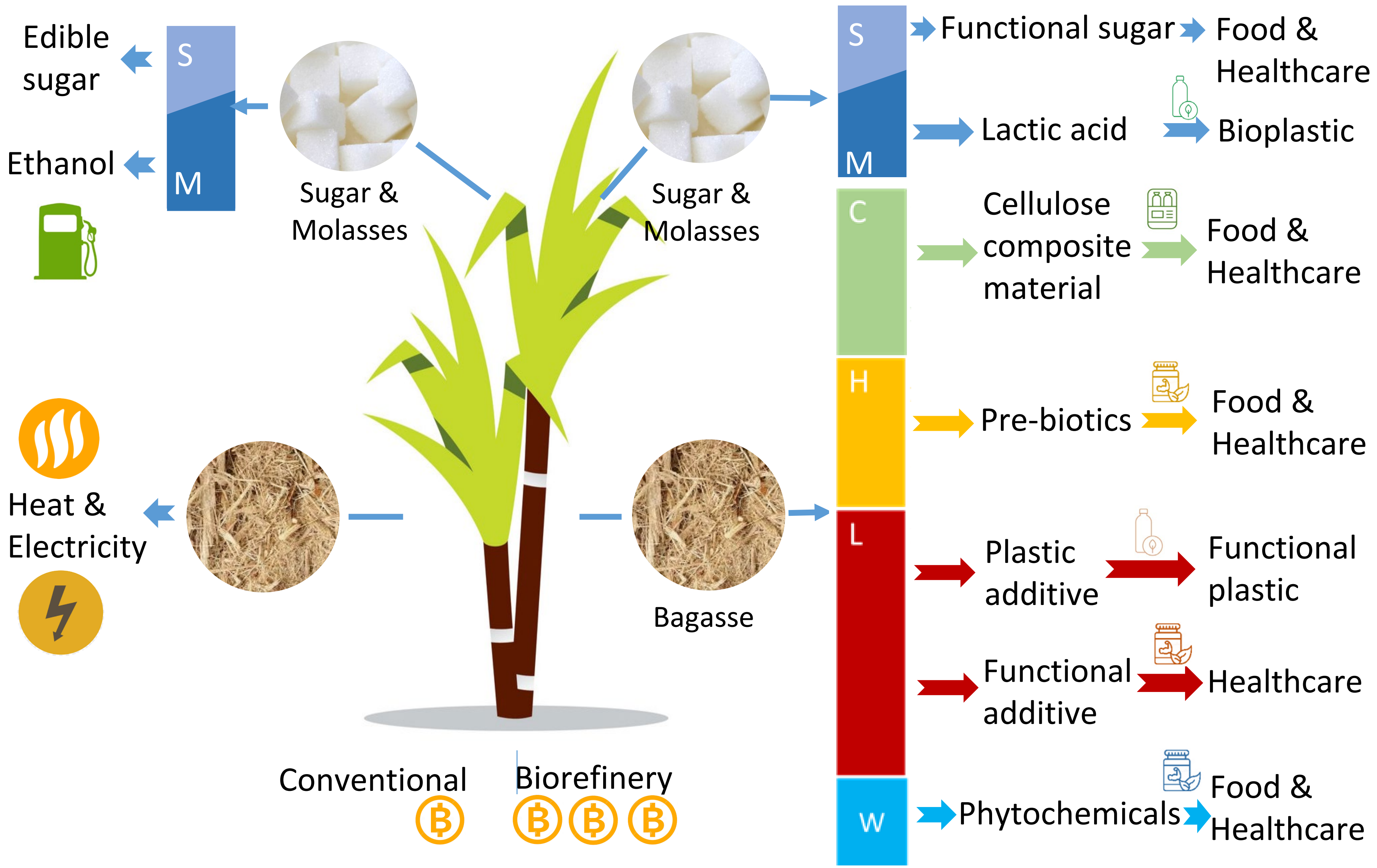
Competitiveness

Sugarcane processing

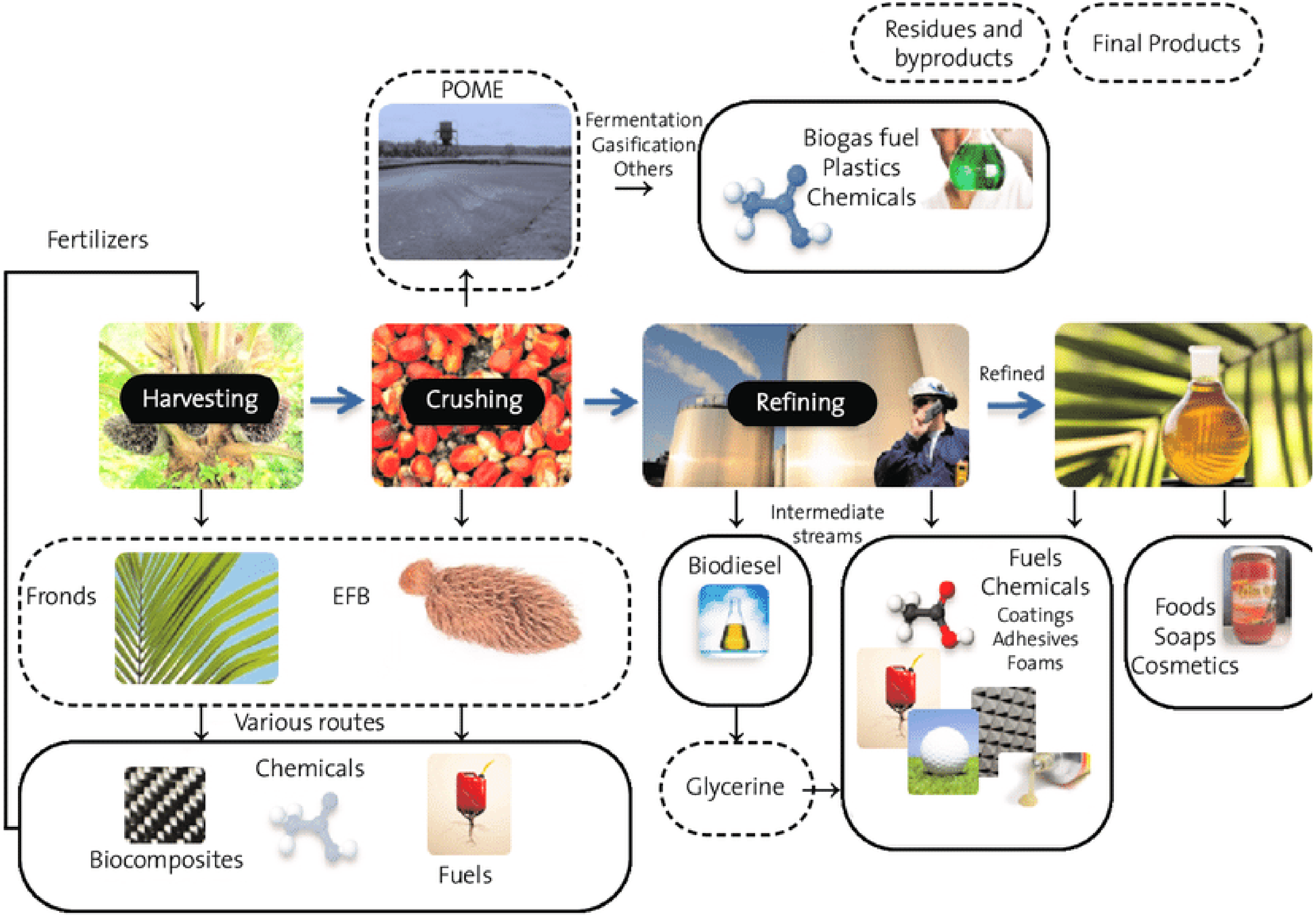


https://www.mdpi.com/1996-1073/15/24/9515

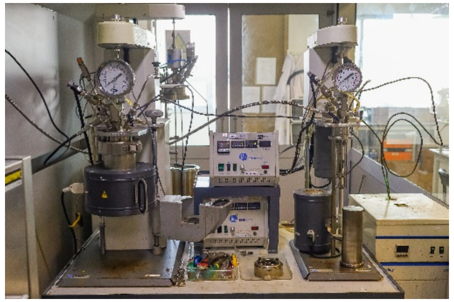
Sugarcane biorefinery model

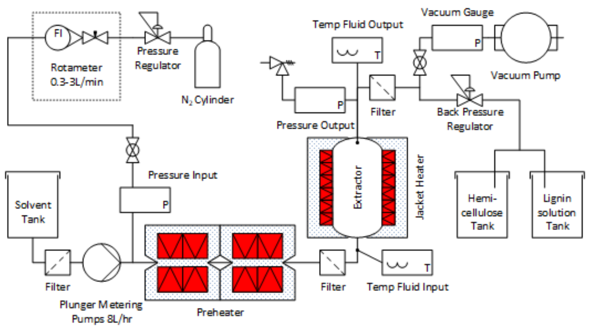


Palm oil biorefinery



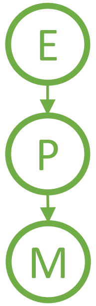
Example Research Scale up: Biorefinery of sugarcane to bio-based products





Conventional | Biorefinery

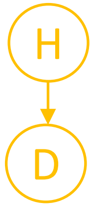
Eco-pulp food container [RGF2020]/ TRL6



Eco-pulp process (TRL6)
1,000 product prototypes
- Physical performance test ✓
- Heavy metal test ✓
- Microbial test ✓
- Biodegradation test ✓

Trade secret application
Up-scaling plan on progress

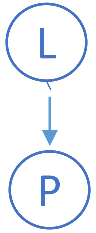
Xylooligosaccharide (XOS)/ TRL6*



Downstream process prototype
Detoxification unit (resin)
Purification unit (membrane)
Concentration unit (falling film)

→ Target XOS > 90%
Product testing

Organosolv Lignin fine chemicals/ TRL6*



Lignin powder
Oven drying process
Powder Packaging unit
Yield >60%
Purity>95%
Mw 1800-3000
GPC/FTIR/NMR

Example Research Scale up: Pre-pilot organosolv lignin prototype and application

Organosolv process

- Ethanol
- +/- catalyst
- Solvent recycling
- Batch/FT

ORG lignin [TRL5/6]

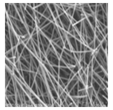
Yield >60%
Purity>95%
Mw 1800-3000
GPC/FTIR/NMR

Standard test & Certification

- RoHs certified
- Heavy metal free (ACM THA 05, 2006)
- Pathogenic microbial free (ISO 21149:2006)
- Migration test
- Evaluation of the acute cutaneous tolerance (Patch test)

Application

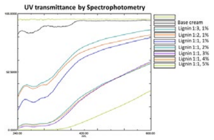
Carbon fiber



NANOTEC a member of NSTDA
MTEC a member of NSTDA

Functional plastics

Cosmetic/ healthcare



Medical material

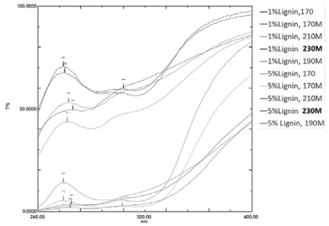
IMIT

100 pieces for 2022 New year event

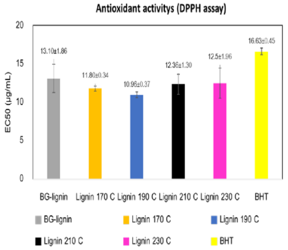
Thermal/ Physical Modification

Activity test: Functional Bioadditive

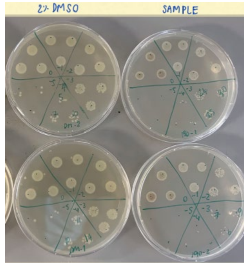
UV-block



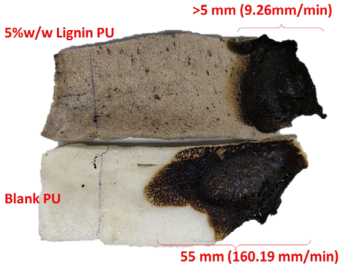
Anti-oxidant



Anti-microbial

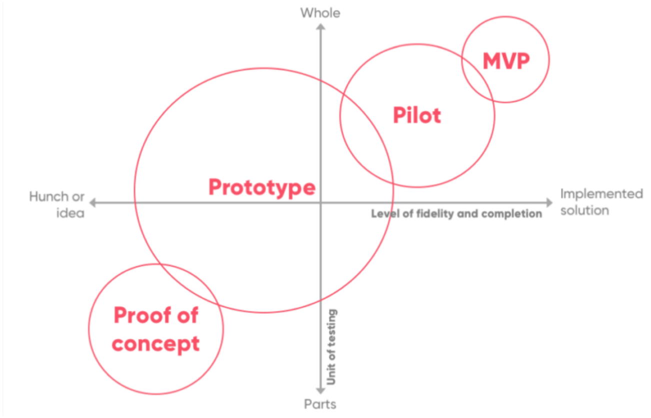


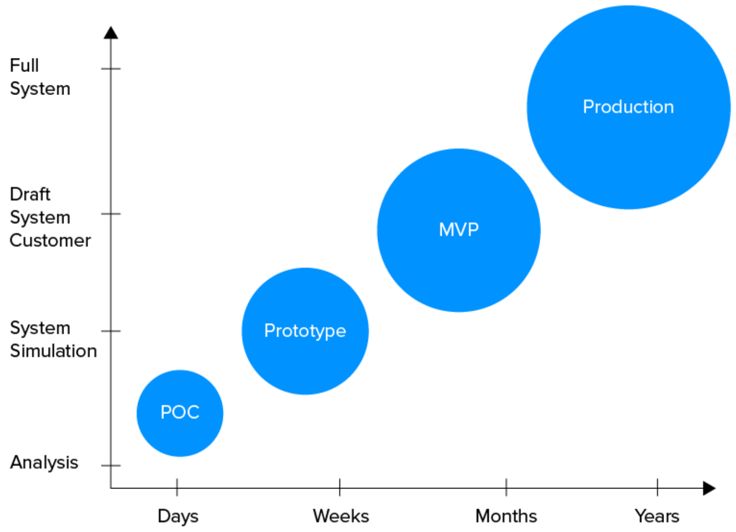
Flame retardant



Concept and strategy on up-scaling chemical process for BCG industry

Difference Proof of Concept, Prototype, minimum viable product (MVP)



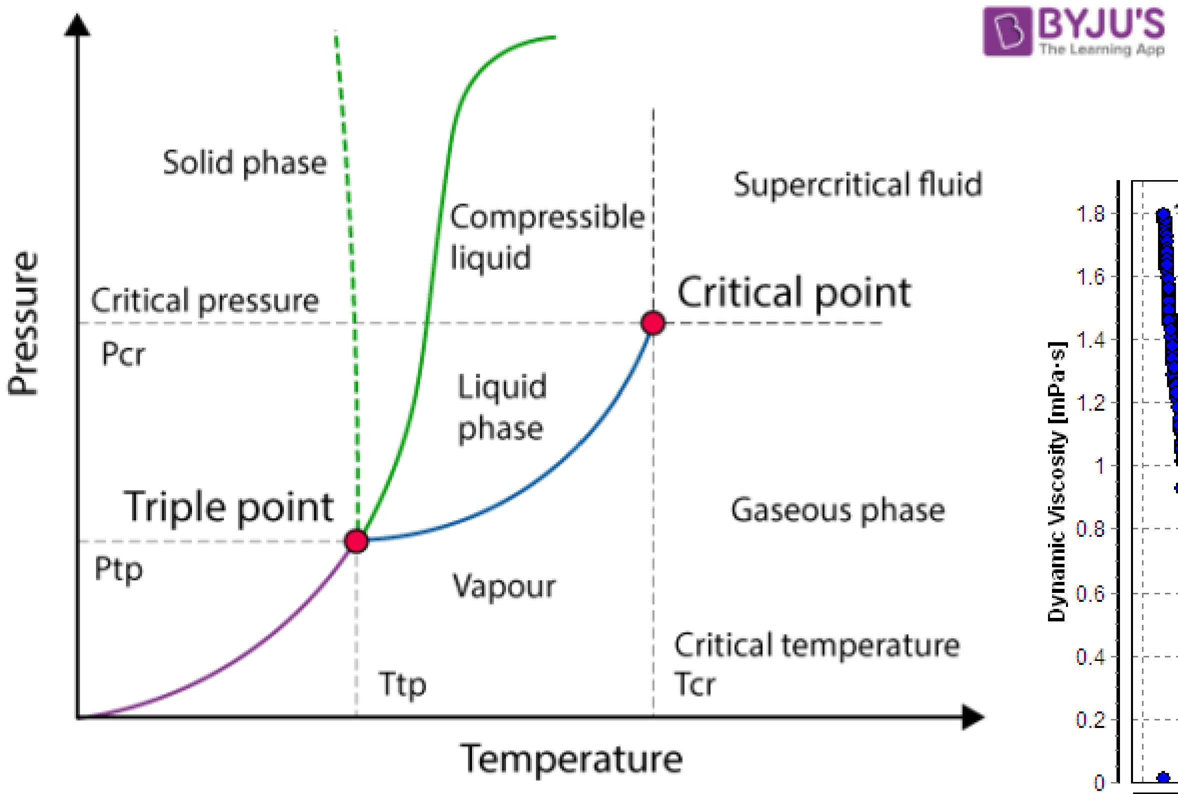


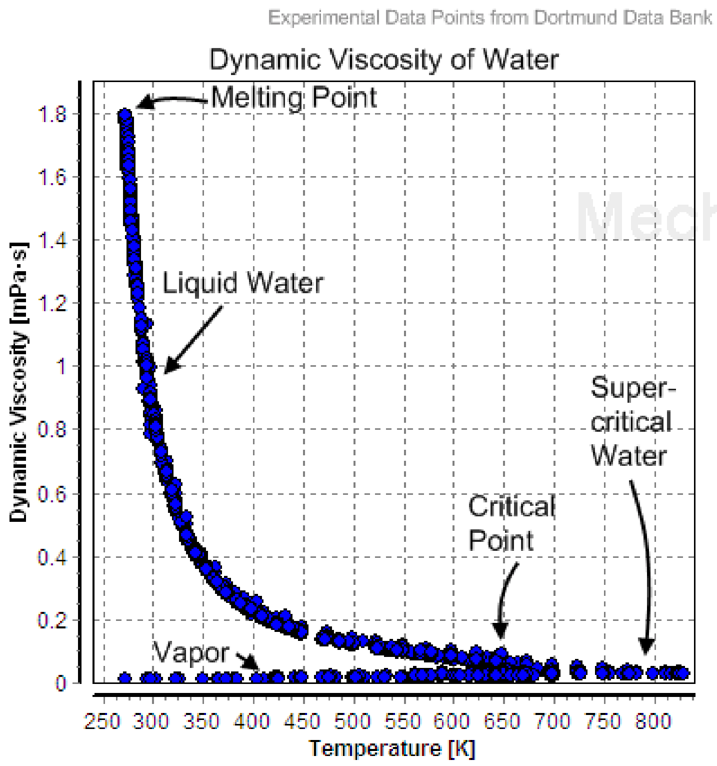
	PoC	Prototype	MVP
Goal	Prove technical feasibility	Demonstrate business concept	Validate an idea & find a product-market fit based on real end-user feedback
Development time	Days/weeks	Weeks	Months
Audience	Researchers, Developers	Stakeholders, Investors, Focus groups	Early adopters, Investors
Use case	Test technical aspects	Fill gaps in a flow, pitch the product idea	Look for a market fit by assessing user feedback, Get funding
Risk evaluation	Reduces risk of technical problems	Reduces risk of user dissatisfaction	Reduces risk of building a product with no market
Investment	Small budget	Medium budget	Well-defined budget
Revenue	Not for sale	Not for sale, Generates further investment	Sells to early adopters, Generates investment
Futher use	Technical prototype or MVP development	MVP development	Full-fiedged product development

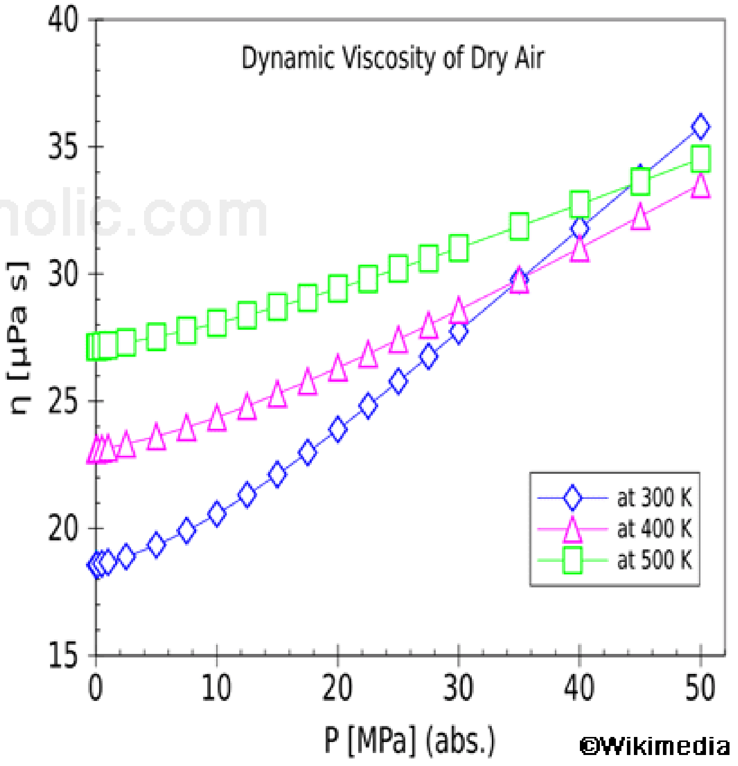
Concept and strategy on up-scaling chemical process for BCG industry

Proof of Concept Parameter to Scaling Up

Temperature vs Pressure







Concept and strategy on up-scaling chemical process for BCG industry

Proof of Concept Equipment to Scaling Up

Vacuum Filter vs Pressure Filter

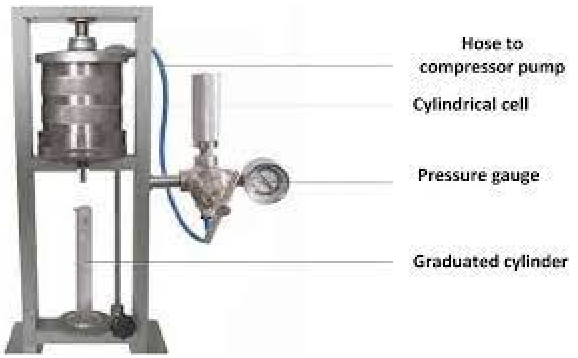


Table 1 Pressure and Vacuum Filters

Pressure Filters	Vacuum Filters
• Operates at higher flowrates, resulting in smaller, more compact filter units.	• Lower capital fabrication cost.
• Longer filter runs, reducing the use of pre-coat material and backwash water because of less frequent cleaning cycles.	• Lower maintenance costs.
• Less likelihood that gas bubbles will disrupt the media.	• Tanks are open at the top, making access and observation easy.

Source: Mel J. Mirliss, Vipin Bhardwaj, and the National Drinking Water Clearinghouse

Concept and strategy on up-scaling chemical process for BCG industry

Step in the scale up process

Product Economics based on market size and selling price compare with Production Cost

Laboratory Study and Scaleup Planning Time at the Same time. For Fine key of rate controlling step in the production process

Educate Other Parameter in Larger Size by use possible equipment in commercial scale

Design and Test in Pilot Scale for uncertainly process, environment , waste management and other effect from production

Evaluate Pilot Plant Result (Product & Process) Including Process Economic. Make Decision on whether or not to proceed with full scale commercial Plant

Concept and strategy on up-scaling chemical process for BCG industry

Product Development Process In 6 Steps

Strategic Alignment | Funding Release | MVP Release | V 1.0 Release

1. Ideation

Explore idea generation

Fill out narrative, exploring ideas

Create presentation for steering committee

Exit Criteria:
Venture Board approval to proceed to Discovery Phase

AGILE

2. Product Definition

Product discovery starts

Define core functionality

Understand market size and revenue

Exit Criteria:
Created business case

AGILE

3. Prototyping

Create prototype

Create MVP

Market research

Update business plan

Exit Criteria:
Confirmation of Business case and Go to Market plan

AGILE

4. Detailed Design

Refinement of prototype

Detailed product design

Confirmation of Business plan and GTM plan

Exit Criteria:
Design complete

AGILE

5. Validation/ Testing

Ensuring the prototype works as planned

Validating the product in the eyes of the customers

Testing the viability of the financials

Exit Criteria:
Product Quality Demonstrated
Initial Customer Acceptance

AGILE

6. Commercialization

Feature Complete

Begin GTM Execution

Customer Success Involvement

Product Launched

Exit Criteria:
Generating revenue

AGILE

Milestone Estimates | *Revenue Estimates* | *Business Plan Estimates*

DISCOVERY | ***PRODUCT DEVELOPMENT*** | ***LAUNCH***

Concept and strategy on up-scaling chemical process for BCG industry

Industrial Instrument

1. Temperature
2. Pressure
3. Flow
4. Level
5. Torque & Motor
6. Etc.

Industrial Equipment

1. Reactor
2. Mixer
3. Separation
4. Dryer

Lab Equipment

1. Oven
2. Parr Reactor
3. Glassware

Lab Instrument

Depend on Equipment

What is the Relation?

Concept and strategy on up-scaling chemical process for BCG industry

Reaction temperature and Heat of reaction

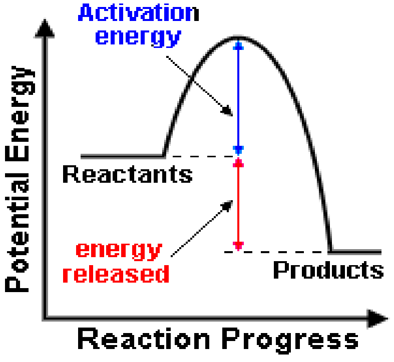
$aA + bB \longrightarrow$ products

rate $\alpha [A]^m[B]^n$

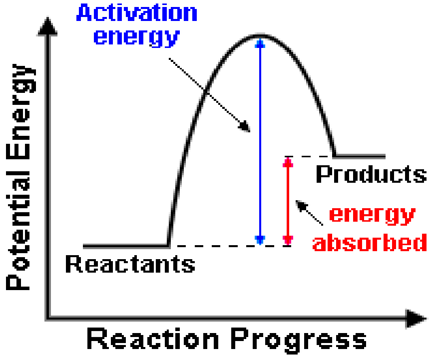
rate $= k[A]^m[B]^n$

k is the rate constant

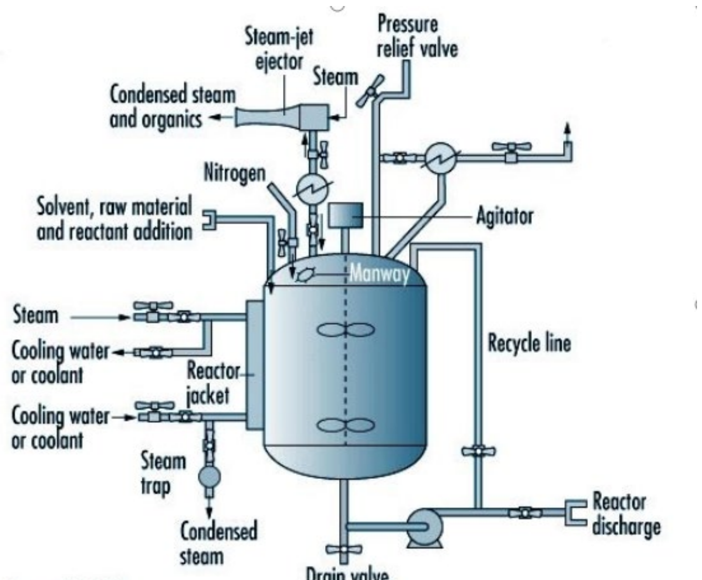
Heart of chemical reaction



Exothermic reaction



Endothermic reaction



Source: EPA 1993.

The Arrhenius equation

$$k = A\,e^{-Ea/RT}$$

"probability a given collision will lead to reaction"

"number of collisions that result in a reaction (per second)"

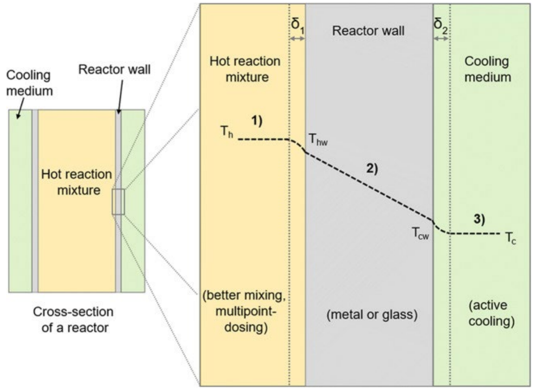
"total number of collisions"

k = rate constant at given temperature
A = "pre exponential factor"
Ea = activation energy
R = the gas constant
T = temperature

Why is it useful?
Depending on situation, can use Arrhenius equatior to solve for:
- activation energy
- rate constant at given temperature

Heat of reaction is key parameter to decide heat will removed or added

Reaction rates are proportional to concentration and to temperature.



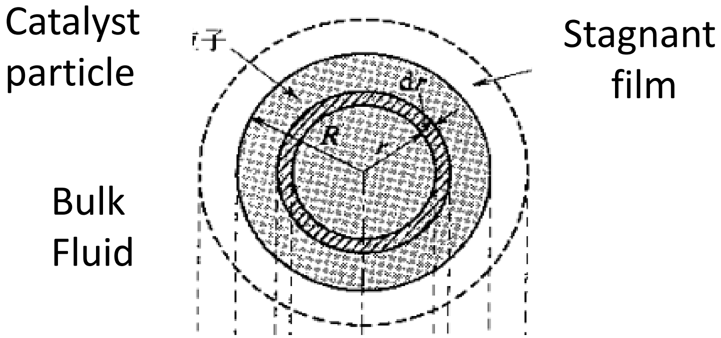
If endothermic reaction, Heat required = reaction temperature + heat of reaction

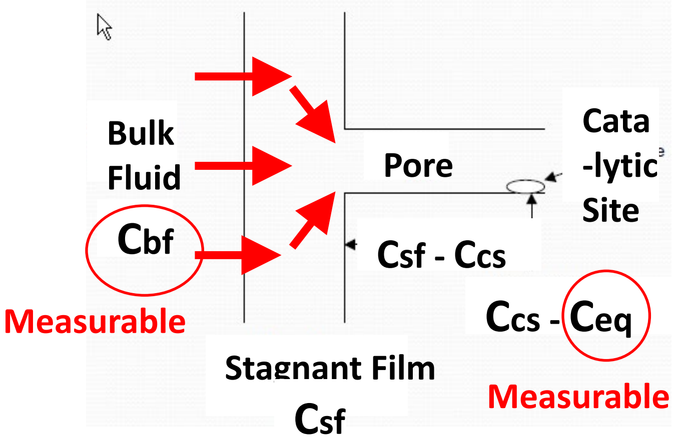
If exothermic reaction, Heat required = reaction temperature + remove heat of reaction

Concept and strategy on up-scaling chemical process for BCG industry

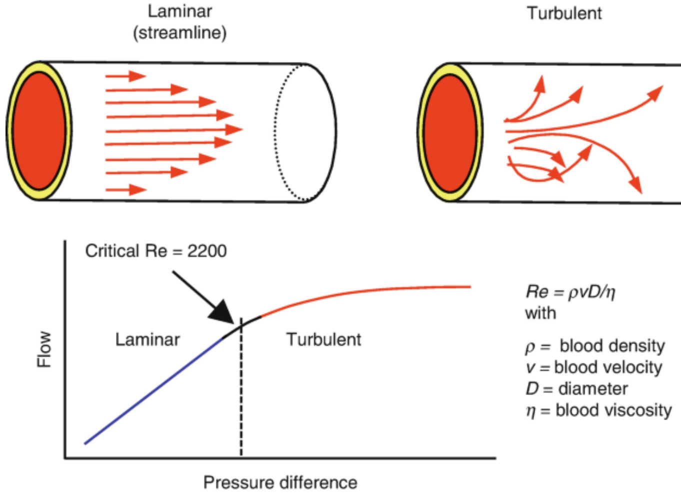
Understand Rate-Controlling Steps

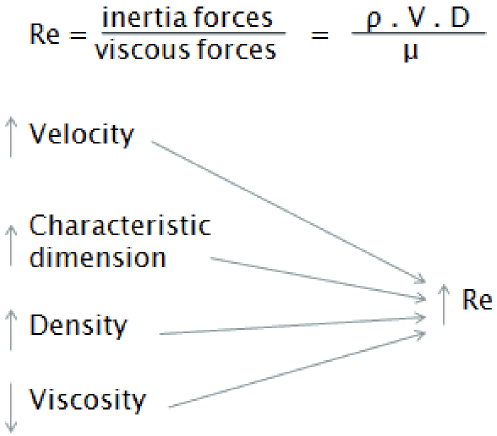
- **Reaction-rate controlled (kinetic controlled)**
  - Low temp region
  - Effectiveness factor = 1
  - Rate $k_{obs} = k$
- **Pore diffusion-rate controlled**
  - Medium temp region
  - Effectiveness factor < 1
  - Rate $k_{obs} = \eta k$ or k/Φ_s
- **Bulk diffusion-rate controlled**
  - High temp region

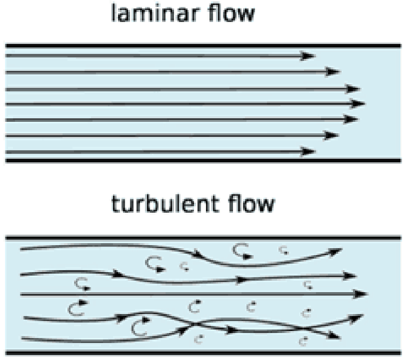




Understand Hydrodynamic

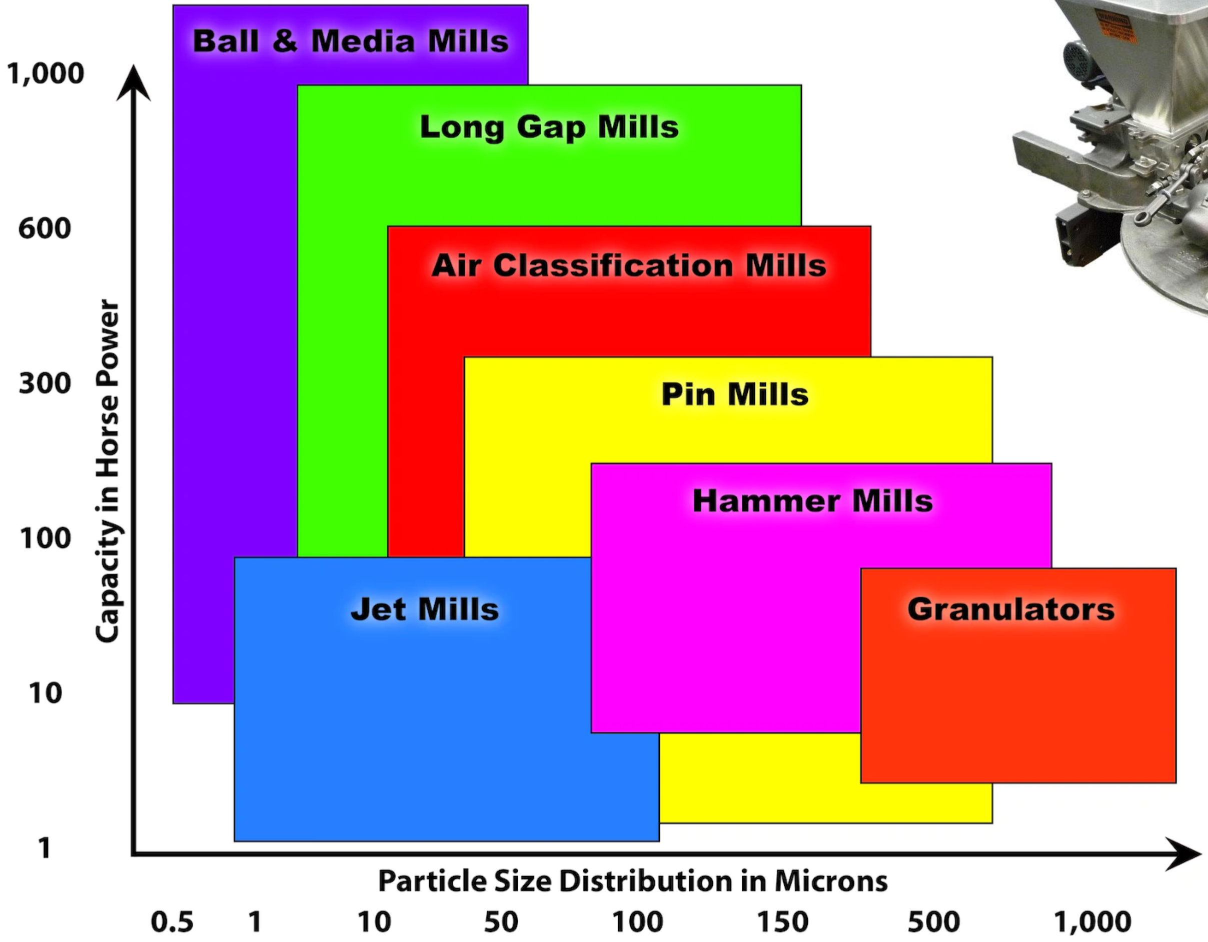




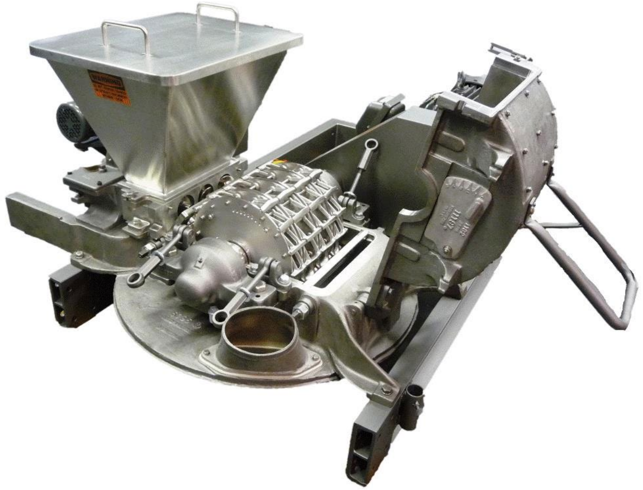


Instrument and industrial equipment for process scaling up

Milling Machine

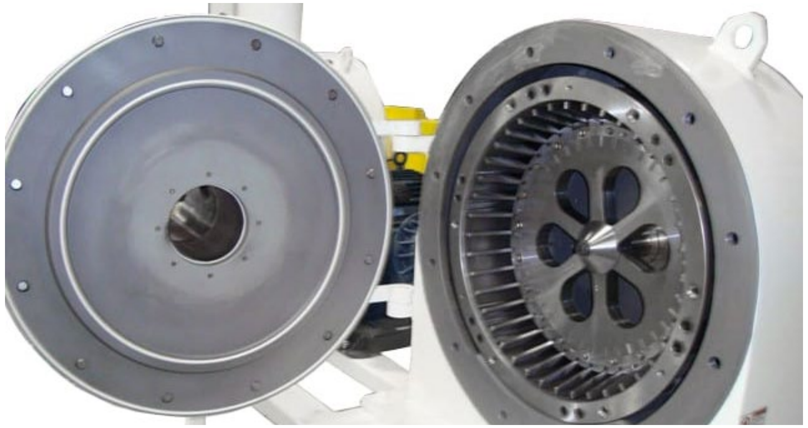


MIKRO PULVERIZER® HAMMER & SCREEN MILL



Choosing the Right Mill System

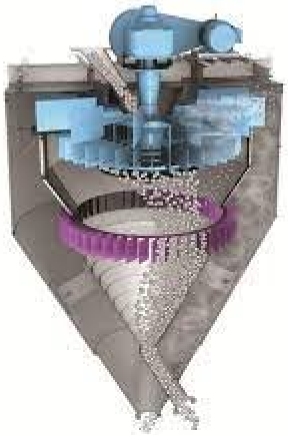
- What is the Material
- What Are the Application Requirements?
- Which Machine Do I Need?
- Is It a Small Scale Process, or is the Plan to Scale Up?
- Safety and Exposure: What Safety Mechanisms Might Be Needed?
- What are Your Cleaning and Sanitation Requirements?



Instrument and industrial equipment for process scaling up

Milling Machine

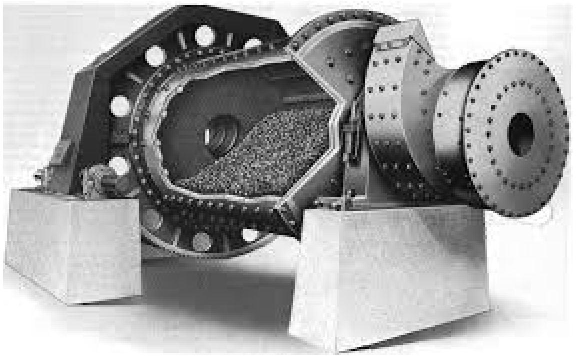
Fluidized bed jet mill



Air Classifier for Cement,

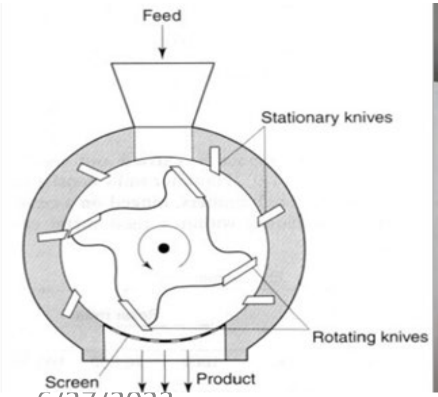
Hammer Mill

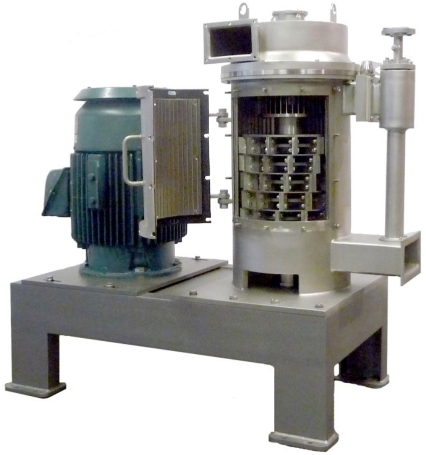
Pin Mill



Ball Mill

Cutting Mill





Mikro LGM ® Long Gap Mill –
Hosokawa Micron Powder Systems

Microfluidizer

Instrument and industrial equipment for process scaling up

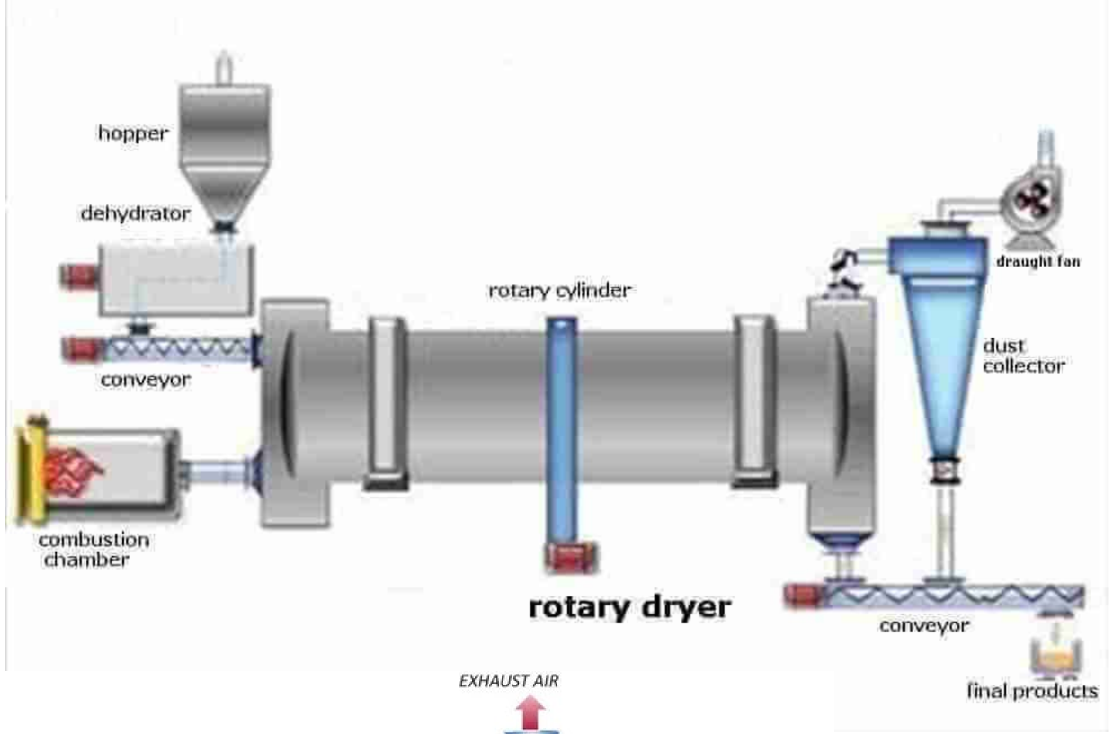
Type of Dryer

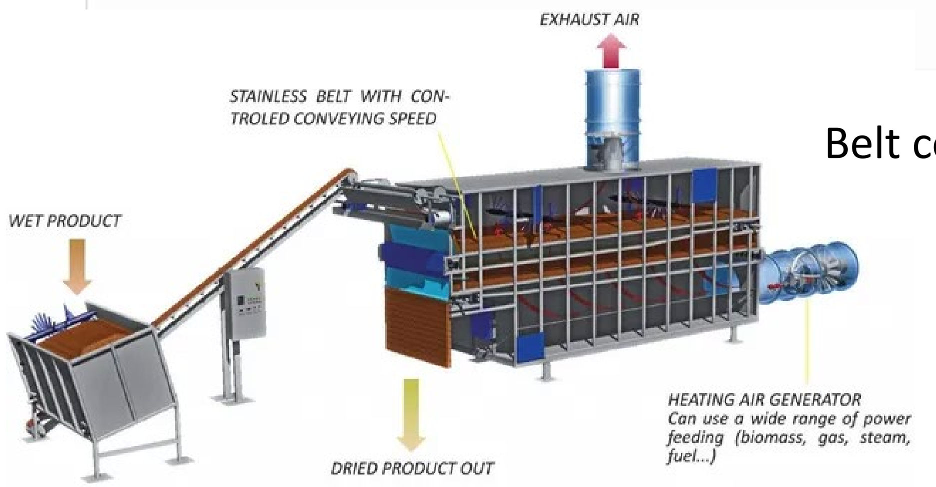
Tray Dryer or Vacuum

- Air Flow
- Air Temperature
- Depth of Tray
- Moisture Probe
- Drying time

Fluidized Bed Dryer

- Air Flow Rate
- Air Temperature
- Air Humidity
- Optimum Load
- Drying time





Belt conveyor dryer

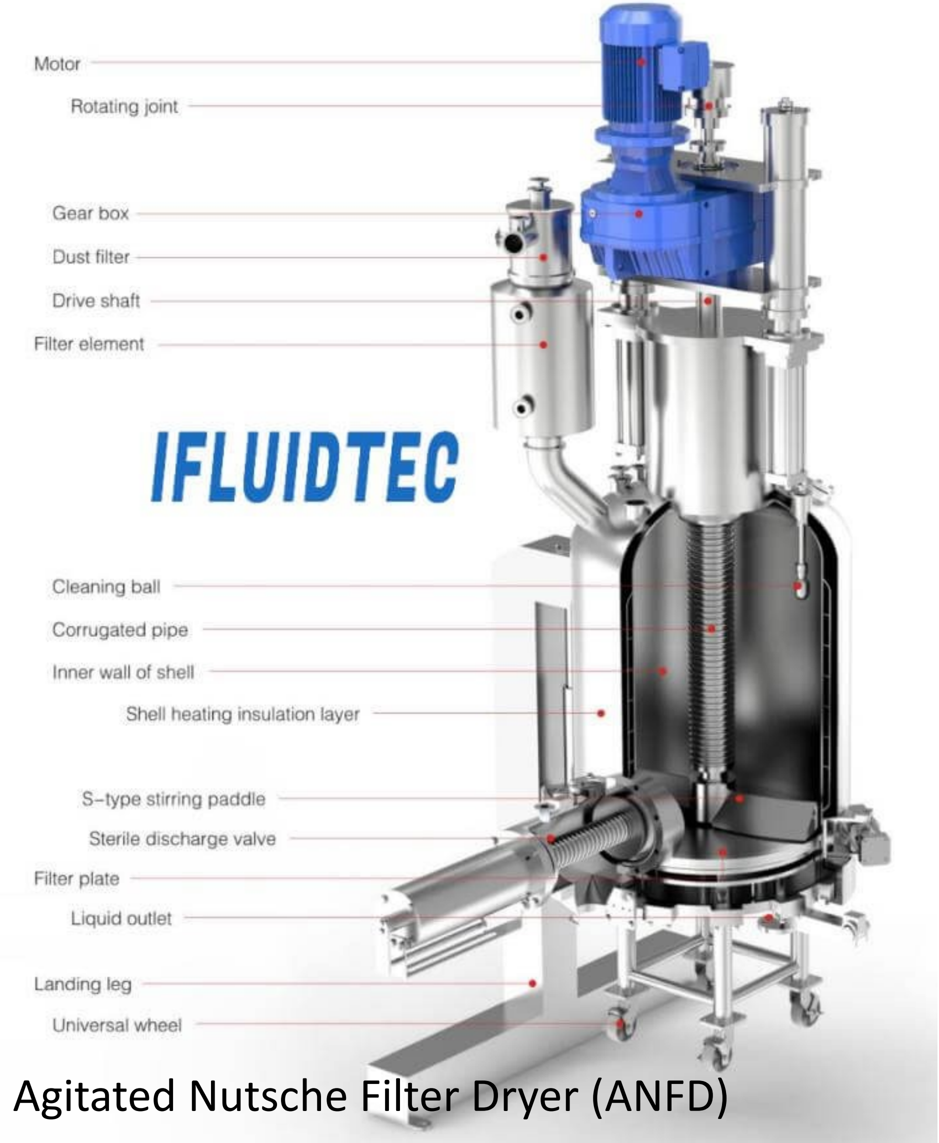
Instrument and industrial equipment for process scaling up

Type of Dryer

Spray Dryer

Rotary Cone vacuum dryer (RCVD)

Rotary Vacuum Paddle Dryer (RVPD)



Agitated Nutsche Filter Dryer (ANFD)

Instrument and industrial equipment for process scaling up

Conclusion Instrument & Equipment process scaling up

- ✓ *Available equipment & instrument selection (Practical)*
- ✓ *Use old fashion equipment (Conventional)*
- ✓ *Conventional energy source (Steam, Electrical)*
- ✓ *Low worker & easy operation (Less to do by human)*
- ✓ *Adjustable parameter (Wide range)*
- ✓ *Understand hydrodynamic regime (Heat &Mass transfer)*
- ✓ *Understand chemical reaction (Heat of Reaction & Kinetic)*

Concept and strategy on up-scaling chemical process for BCG industry

Scale up team for industrial approach

1. *Marketing Team, (Problem Provider)*
   - *Who will buy our sustainable technology? Why? What value does the technology bring to potential customers?*
2. *Researcher Team, (Solution Provider)*
   - *develops new process and determines key process information such as reaction rates, phase interactions and operating temperatures and pressures.*
3. *Engineer Team, (Potential Provider)*
   - *takes key process information from chemist and develops a safe design that includes vessel dimensions, materials of construction, specifications for mechanical equipment, hydraulic calculations and process control/instrumentation philosophies.*

What are the main skills needed to scale up chemical processes?

https://www.quora.com/What-are-the-main-skills-needed-to-scale-up-chemical-processes

Chemist not chemical engineer

How I've seen new processes successfully scaled up generally follows this pattern:

1. **Chemist researches and develops new process and determines key process information such as reaction rates, phase interactions and operating temperatures and pressures.**
2. **Chemical engineer takes key process information from chemist and develops a safe design that includes vessel dimensions, materials of construction, specifications for mechanical equipment, hydraulic calculations and process control/instrumentation philosophies.**
3. From this design, some fairly detailed capital and operating cost estimates can be established which allow for a green/red light decision.
4. Assuming a green light, mechanical, electrical and civil engineers are brought on to complete the detailed design.
5. Equipment is procured and construction contractors and specialty tradespeople are brought in to put the thing together.

The key to projects is getting the right people on the project at the right time to do the right thing. I've seen quite a few people try to skip straight from step 1 to step 5 and just build the thing because they don't want to spend money on the design and end up with a product that is unusable because it doesn't meet code, doesn't work properly, is unsafe and/or runs way over budget.

My advice is to figure out what you can do with the training you have. Find the right people with the right training to do the other jobs

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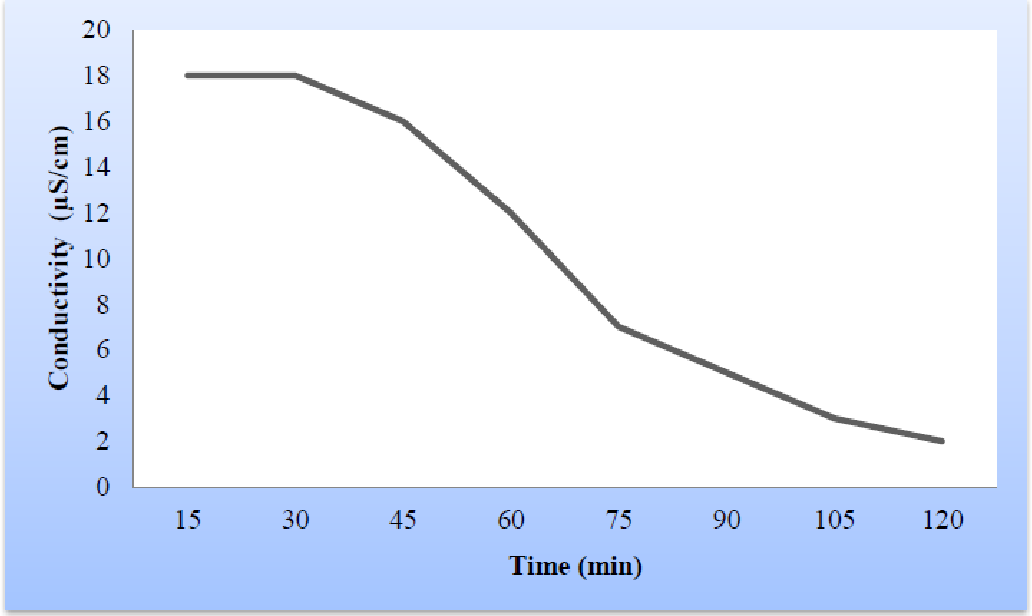
Case study I BCG strategy from Laboratory to Production Scale

1. Determination of virgin paper production feasibility from bagasse

The materials used included bagasse, NaOH, Na2S, a blender, hot plate, set of sieves, an oven, plastic dish, sponge, nylon cloth, and water. 30g of bagasse was weighed on an electronic balance. 3g of NaOH and 3g Na2S were added to a large glass beaker containing 500 ml of water and the resulting mixture was stirred.. The paper was left on the tray on top of the nylon cloth and left to dry overnight at 70°C.

2. Determination of residence time for virgin papering (Rate Limiting Step)



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3. Determination of virgin paper biodegradability and Other Standard

the biodegradability and over which the paper 227.3 days will remain in an aerobic environment. This is done by measuring reduction in mass as a function of time that the paper is exposed to micro bacteria (Table 3). The paper is estimated to be fully degraded after 7.6 months. The results showed that the paper is biodegradable thus production of virgin paper from bagasse is a green solution to environmental and pollution management.

Table 3. Biodegradability results on virgin paper from bagasse

Sample	Initial mass, M_1(g)	Final mass, M_2(g)	Difference in mass, $M_1 - M_2$	$\frac{M_1 - M_2}{M_1}$	BD (%)
1	3.78	3.74	0.04	0.010	1.10
2	3.65	3.61	0.04	0.010	1.10
3	3.74	3.68	0.06	0.016	1.60
4	3.60	3.52	0.08	0.022	2.20
5	3.56	3.50	0.06	0.017	1.70

4. Determination of the effect of various pulping chemicals on the cooking rate

Table 2. Effect of various chemicals on the pulping of bagasse paper

Experiment	NaOH	Na_2S	Na_2CO_3	Result
1	Absent	Present	Present	The bagasse could not be mechanically pulped by the blender
2	Present	Absent	Present	A greyish mixture of unreacted bagasse and pulp was obtained
3	Present	Present	Absent	The bagasse took a long time to react with vigorous stirring periodically
4	Present	Present	Present	The bagasse was chemically weakened and easily mechanically blended

The purpose of NaOH is to degrade lignin and that of Na2S is to fasten the cooking reactions and to decrease cellulose degradation caused by NaOH

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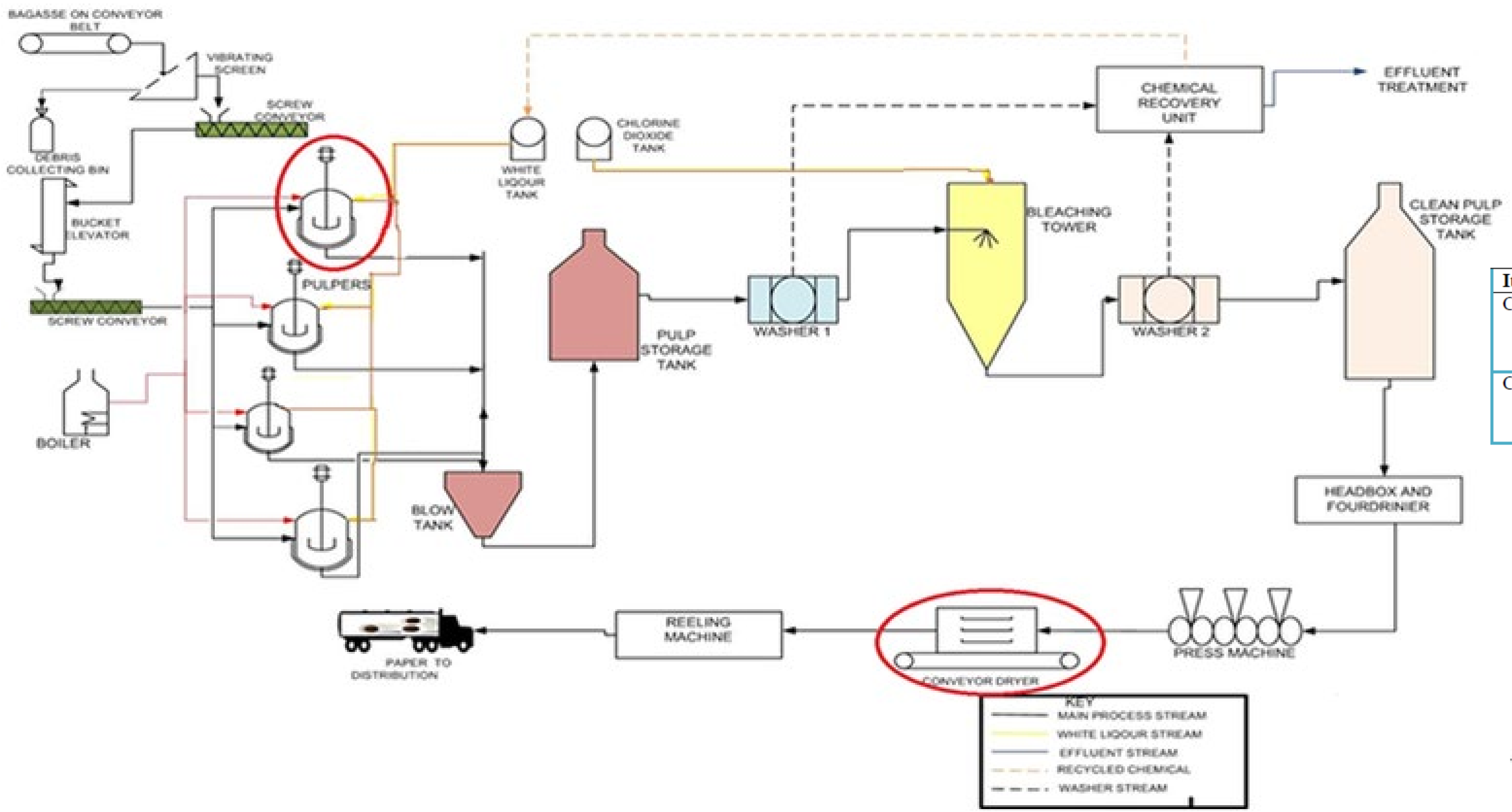
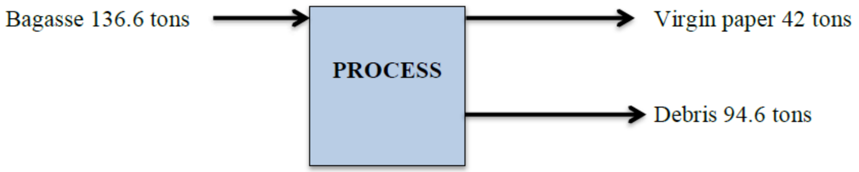
5. PROCESS DESIGN DESCRIPTION





Mass Balance summary per day

Energy balance summary

Item	Heat in (MJ/ batch)	Heat Out (MJ/ batch)
Continuously stirred batch pulper	19 441	2700
Conveyor dryer	16 485	1 833

Production Scale

JGSEE

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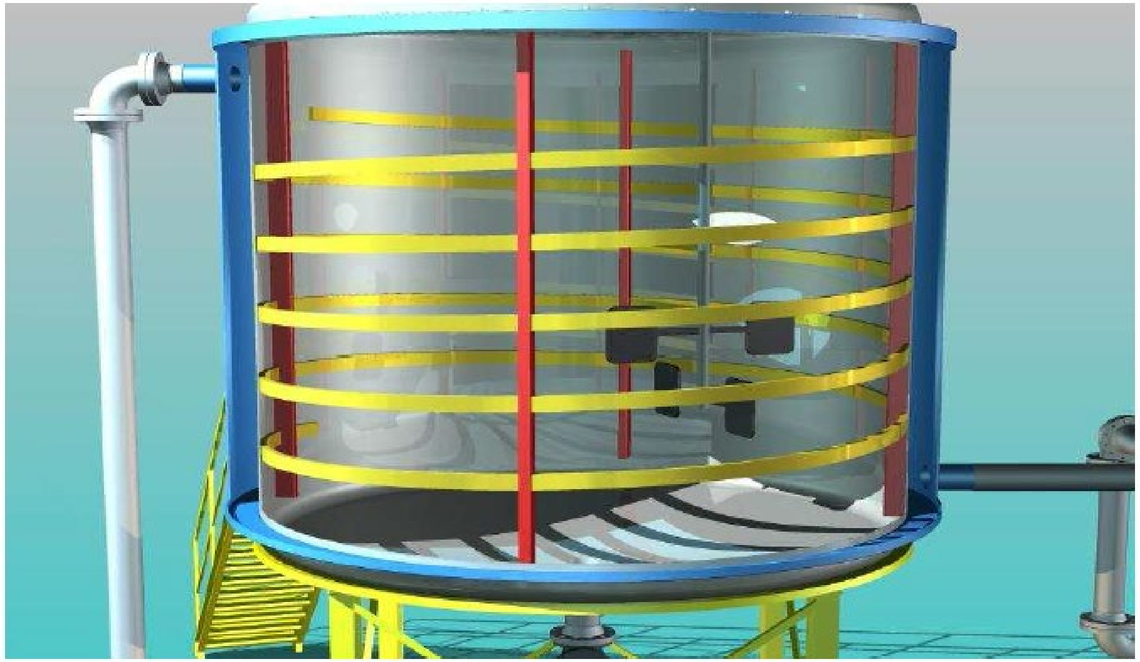
6. EQUIPMENT DESIGN
- Stirred batch pulper design



Stirred batch pulper with cross section showing position of agitator

Table 5. Stirred batch pulper design specifications

CHEMICAL ENGINEERING DESIGN	
Number required	4
Height	4.34 m
Nominal diameter	2.17 m
Volume	16 m^3
Nominal pulper thickness	0.022 m
Number of heating coils	8.4
Design pressure	1 167 kPa
Jacket thickness	0.30 m
Material of construction	Carbon steel
MECHANICAL ENGINEERING DESIGN	
Weight of contents	1 876 kN
Maximum bending moment	21.3 kNm
Maximum compressive stress	1.931 kN
Wind load	1.572 kN

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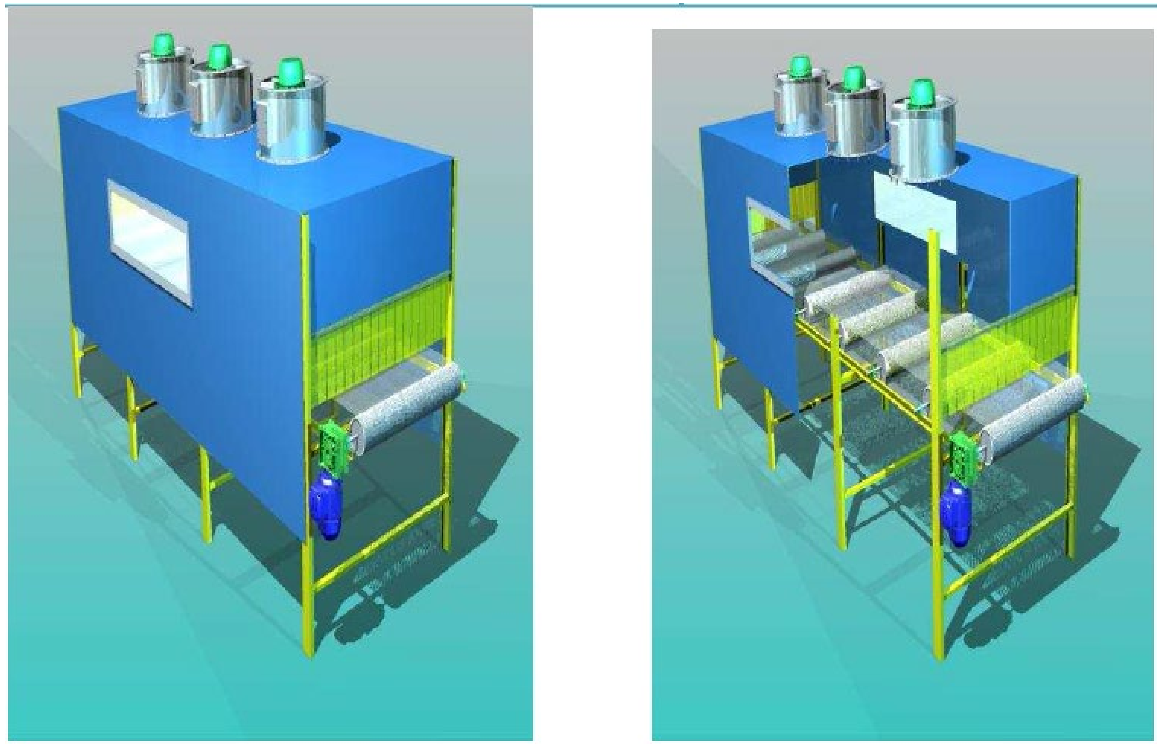
6. EQUIPMENT DESIGN
- Conveyor dryer design

CHEMICAL ENGINEERING DESIGN	
Number required	1
Function	Drying of wet paper web into virgin paper
Operation	Continuous
Number of heater-fans	3
Area	18.14 m^2
Length	4.77 m
Slicing width	3.8 m
Height	3.8 m
Volume of dryer	69 m^3
Operating temperature	205°C
Operating pressure	1 atmosphere
MECHANICAL ENGINEERING DESIGN	
Feed weight on belt	6.2 N
Maximum tensile stress on belt	137 N
Creep strength	581 kN

Dryer rates are high because of the large area of contact and short distance of travel for the internal moisture. Conveying-screen dryers are fabricated with conveyor widths from 0.3- 4.4m sections. The important parameters that were calculated are the volume, area, slicing width, height, length, conveyor speed of belt, powerrequired by blower and heater-fan.



Conveyor dryer (a) South east view, (b) Section view

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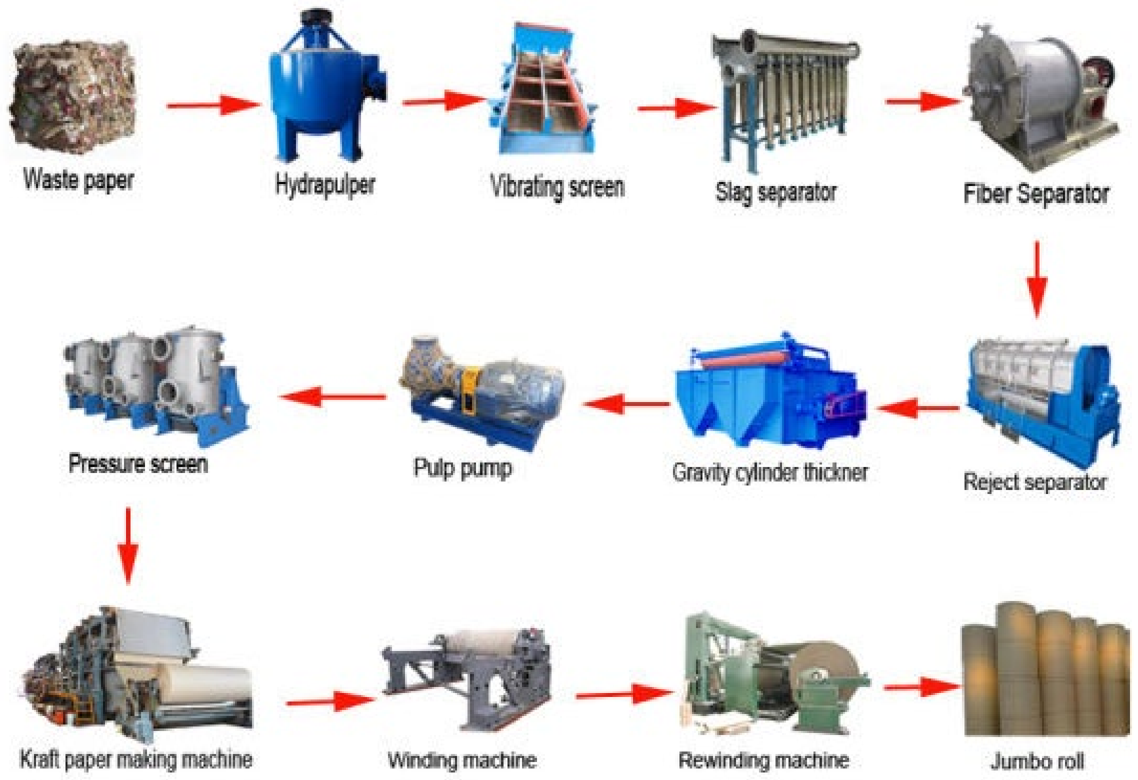
6. EQUIPMENT DESIGN
- Sizing major equipment

Table 7. Specifications for sized equipment

BLOW TANK	
Volume	3.54 m^3
Diameter	1.44 m
Height	2.16 m
Material of construction	Carbon steel
BLEACHING TOWER	
Volume	3.5 m^3
Diameter	1.14 m
Height	2.16 m
Material of construction	Stainless steel
STORAGE TANK	
Volume	11.4 m^3
Diameter	2.58 m
Height	3.87 m
Material of construction	Stainless steel



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7. ENVIRONMENTAL IMPACT ASSESSMENT

Table 8. Summarized impacts and mitigation measures for the bagasse to paper plant

Stage	Negative impacts	Positive impacts	Mitigation measures
Construction	Noise and vibrations		Dampening instruments and ear protectors e.g. ear muffs to minimize vibration
	Destruction of natural ecosystem	Construction of access roads and service facilities	Vegetation replacement
	Land pollution		Erection of waste disposal bins on site and frequent litter picking
	Air pollution		Pre-treatment of effluent gases
Operation	Water pollution Air pollution	Continual development of the area	Minimize harmful emissions into water and air by thorough pre-treatment of effluent
Decommissioning	Inability to rehabilitate land Ghost sites creation Unemployment	Facilities can be used for other purposes such as training facility for locals	Train staff entrepreneurial skills

- Environmental legislations and laws; Environmental Management Act Chapter 20:27,
- Atmospheric Pollution Prevention Act Chapter 20:03,
- Zimbabwe National Water Authority Act Chapter 20:25,
- Hazardous Substances and Articles Act Chapter 15:05,
- Forestry Act Chapter 19:05,
- Water Act Chapter20:22,
- Pneumoconiosis Act Chapter 15:08
- Factories and Works Act Chapter 14:08.

According to the environmental impact assessment (EIA), the potential impacts and their mitigation are indicated in Table 8.

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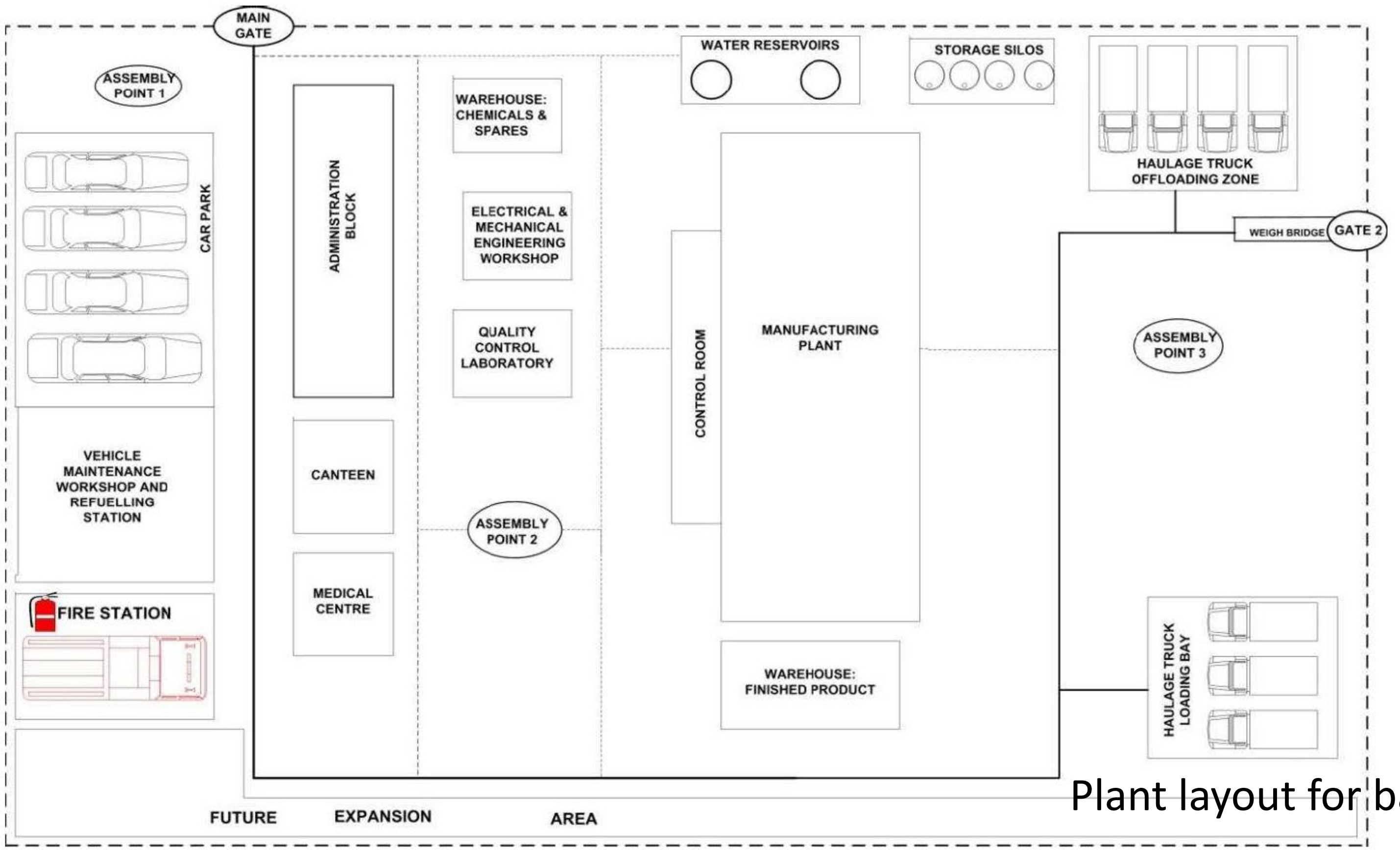
8. SITE SELECTION AND PLANT LAYOUT



Plant layout for bagasse virgin paper processing plant

The principal factors that were considered in the optimum design of the plant layout were the process requirements, convenience of operation, economic considerations (construction and operation costs), and safety of workers and visitors to the site.

Table 9. Description of Chiredzi site

Factor	Description
Plant location	Near outskirts of sugar plantations
Availability of water	Municipal water, dams and/or boreholes, Save, Runde and Mkwasine river.
Population density	Semi-populated
Political stability	Stable
Availability of land	Plenty. The land is generally flat, well drained and has suitable load-bearing characteristics.
Local community considerations	Provision of hospitals, post offices, schools, police stations and other necessary facilities from which plant personnel can benefit.
Labour availability	Unskilled labour available
Market	Marketing area mainly Harare and Mutare.

Concept and strategy on up-scaling chemical process for BCG industry

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9. ECONOMIC ANALYSIS

Capital cost calculation (Purchased equipment cost)

Table 10. Purchased equipment cost

Equipment	Number of pieces	Unit cost ($)	Total cost ($)
Vibratory screens	1	6 000	6 000
Blow tank	1	11 000	11 000
Pulper	4	10 000	40 000
Blow tank	1	12 000	12 000
Bleaching tank	1	17 100	17 100
Rollers	10	1 000	10 000
Presses	3	1 400	4 200
Paper making machine	1	25 000	25 000
Conveyor dryer	1	26 000	26 000
TOTAL			**151 300**

Table 11. Direct costs

Component	Range %	Selected	Amount $
Raw materials	(10~50) of production cost	20	46 237.28
Operating labour	(10~20) of production cost	15	34 677.96
Utilities	(10~20) of production cost	15	34 677.96
Maintenance and repairs	(2~10) of fixed capital	5	11 559.32
Operating supplies	(10~20) of maintenance	15	1 733.90
Lab charges	15 of labour	15	5 201.70
Patents and royalties	(0~6) production cost	5	11 559.32
TOTAL			**145 647.44**

Table 12. Indirect costs

Item	Chosen %	Cost $
Engineering and Supervision	33 of E	49 929
Contingency	42 of E	63 546
Construction expenses	41 of E	62 033
Contractor's fee	21 of E	31 773
TOTAL		**207 281**

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9. ECONOMIC ANALYSIS

Fixed capital investment

Manufacturing fixed-capital investment represents the capital necessary for the installed process equipment with all auxiliaries that are needed for complete process operation.

FCI = $(207 281 + 145 647.44)
= $352 928. 44
≈ **$353 000**

Working capital investment, **WCI** = 20% of FCI

= 0.2 x $353 000

= **$70 600**

Total Capital Investment, **TCI** = FCI + WCI

= $(353 000 + 70 600)

= **$ 423 600**

Total production cost

This is the sum of the total manufacturing cost and total general expenses. Fixed costs are shown in Table 13.

Table 13. Fixed costs

Component	**Range %**	**Selected**	**Amount $**
Fixed charges	(10~20) of FCI	11	38 830
Depreciation on machinery	10 of FCI	10	35 300
Depreciation on buildings	(2~3) of FCI	2	7 060
Local taxes	(1~4) of FCI	3	10 590
Insurance	(0,4~1) of FCI	1	3 530
TOTAL			**95 310**

The cost of plant utilities is given in Table 14.

Table 14. Power and utilities cost

Utility	**Units / year**	**Cost / unit ($)**	**Total annual cost ($)**
Steam	2 364.70	6.97	16 481.92
Electricity	395 566 kWh	0.15 / kWh	59 335
Water	260 000 m^3	2 / m^3	520 000
TOTAL			**595 816**

Case study I BCG strategy from Laboratory to Production Scale

9. ECONOMIC ANALYSIS

Maintenance and repair costs = 10% of FCI
= 0.1 x $353 000
= **$35 300**

Direct production cost **=** $(595 816 + 35 300 + 95 310)
= $726 426

Plant overhead cost **=** 10% of raw material cost
= 0.1 x $46 237.28
= **$4 624**

Total manufacturing cost, MC **=** Plant overheads + Production cost
= $4 624 + $ 726 426
= **$731 050**

General expenses for the plant are shown in Table 15.

Table 15. General expenses

Item	Range %	Chosen %	Cost $
Administrative costs	2-6 of MC	2	14 621
Distribution and selling costs	12-20 of MC	12	87 726
Research and Development	5-7 of MC	5	36 553
Financing (interest)	0-10 of FCI	10	35 300
TOTAL			174 199

Total Production Cost, TPC =Manufacturing cost + General expenses
=$(731 050 + 174 199)
=**$905 249**

9.3 Profitability analysis
Production capacity per year = 42TPD x 260 days
= **10 920 tons**

Concept and strategy on up-scaling chemical process for BCG industry

Case study I BCG strategy from Laboratory to Production Scale

9. ECONOMIC ANALYSIS

Production cost per unit $= \frac{Total\ production\ cost}{Total\ production}$

$= \frac{\$905\ 249}{10\ 920 tons}$

= \$82.89 / ton

= **\$83 / ton**

Adding a 30% mark up:

Selling price for virgin paper $= \frac{130}{100}$ x \$83/ton

= **\$108**

Total revenue =10 920 ton/ year × \$108 /ton

=\$1 179 360

Gross profit = Total revenue – Total production cost

= \$1 179 360 - \$905 249

= **\$274 111**

Tax paid = 0.3 x Gross profit

= 0.3 x \$274 111

= **\$82 233**

Net profit = Gross profit – Tax paid

= \$274 111 - \$82 233

= **\$191 878**

Return on investment and payback period

ROI $= \frac{191\ 878}{423\ 600}$ x 100%

= **45 %**

PB $= \frac{100}{45}$ x 1 yr

= **2.2 years**

Concept and strategy on up-scaling chemical process for BCG industry

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9. ECONOMIC ANALYSIS

Net present value

A plant lifespan of 10 years was assumed considering the technological advancement and the net present value is indicated in Table 16.

Table 16. Net present value determination

Year	Net Cash Flow ($)	Discounting factor	Present value ($)
0	-423,600.00	1	-423,600
1	191,878	0.909	174,417
2	191,878	0.826	158,491
3	191,878	0.751	144,100
4	191,878	0.683	131,053
5	191,878	0.641	122,994
6	191,878	0.564	108,219
7	191,878	0.513	98,433
8	191,878	0.466	89,415
9	191,878	0.424	81,356
10	191,878	0.38	72,914
Total			**1,181,393**
Net present value			**757,792.85**

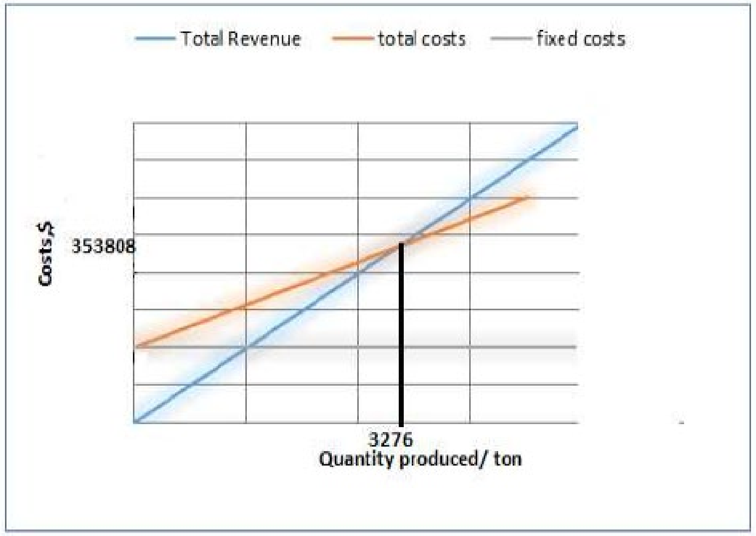
Break even analysis

Number of units needed to break-even point $= \frac{30}{100}$ x 10 920 tons

= 3 276 tons

Break even in monetary terms = 3 276 tons x $108 / ton

= $353 808



Break even chart

Concept and strategy on up-scaling chemical process for BCG industry

Success Case Scale up: Ideal

No Benefit, Return to new concept

Create team
- Marketer
- Engineer
- Researcher

Create Concept
- Improvement
- Decrease Waste
- New Product

Create Mock-up Lab Testing
- Rate Limiting
- Prelim Cost

Prelim TEA
- Product - Feed
- Simple Equipment
- Simple Process

Pilot Proof
- Prototype Product
- Confirm STD
- Potential Process

Production Proof
- Market Survey
- STD testing
- Capacity

Final TEA
- Risk Process
- Partners
- Long terms

BCG for sustainability

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https://interloop.co.th/ministry-sets-up-panel-devoted-to-bcg-economy/