Economics to CO2 conversion to PolyHydroxyAlkanoate (PHA)

14 June 2022

Jean-Luc DUBOIS

Arkema

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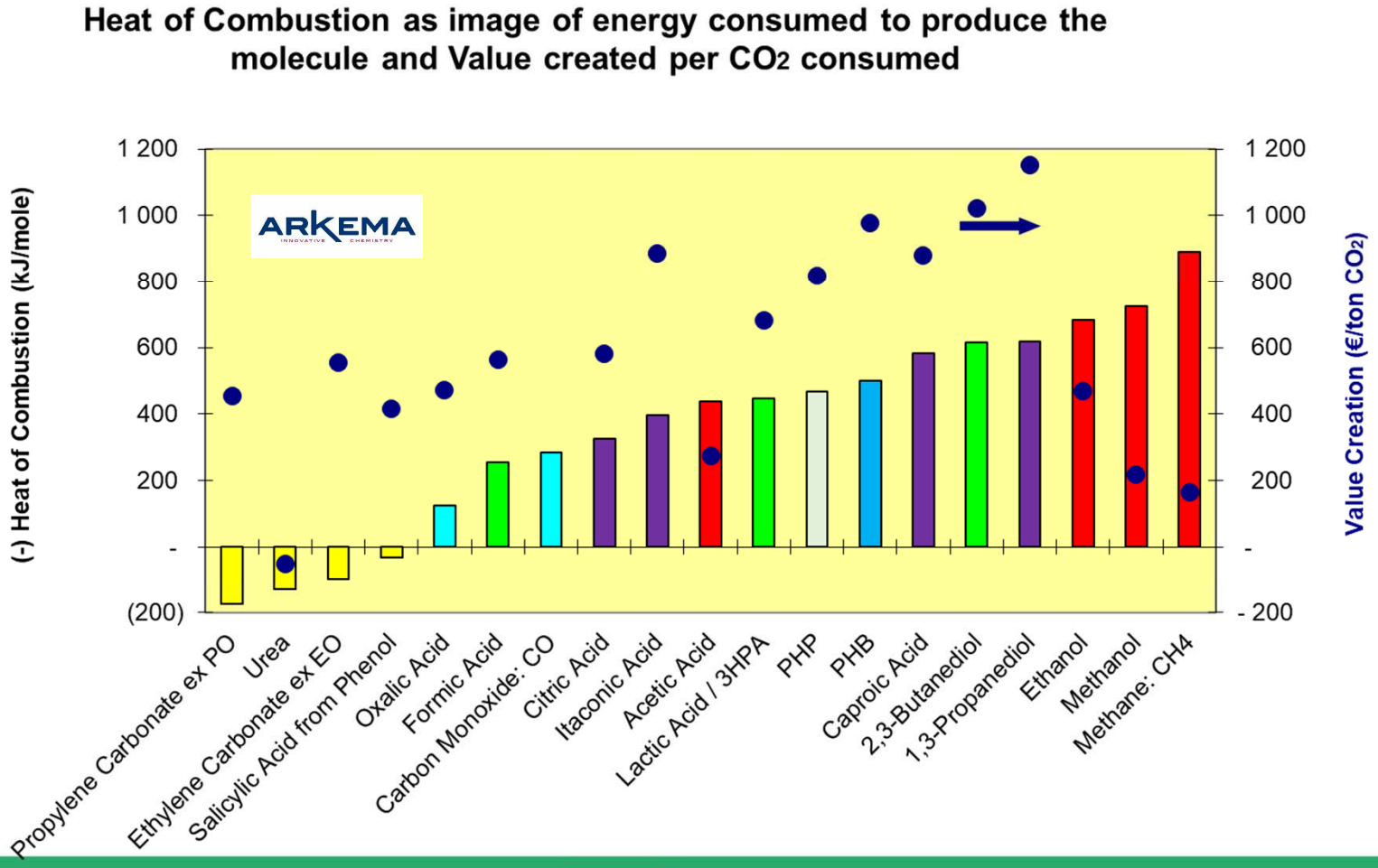
TARGET PRODUCT SELECTION



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CO_2 Emission Allowance value

EUA Futures
07/06/2022

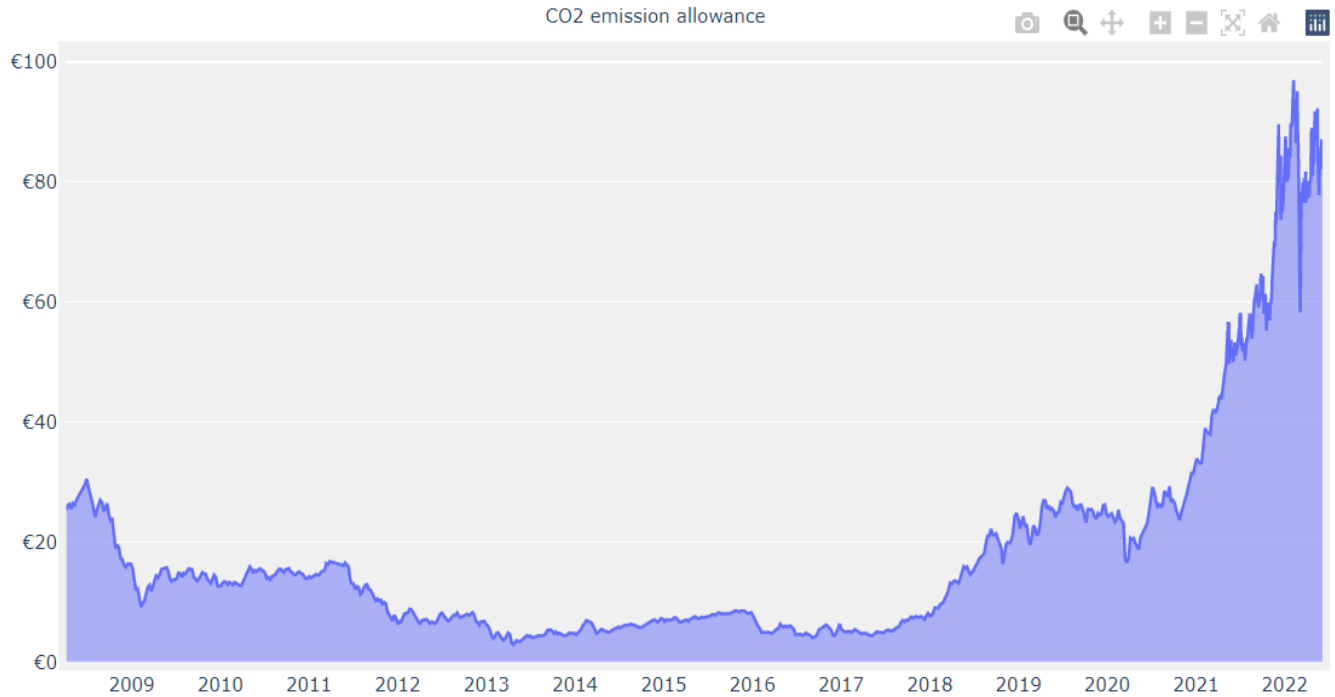
€82.11

DEC 23
€84.95

DEC 24
€89.24

DEC 25
€96.65

Source



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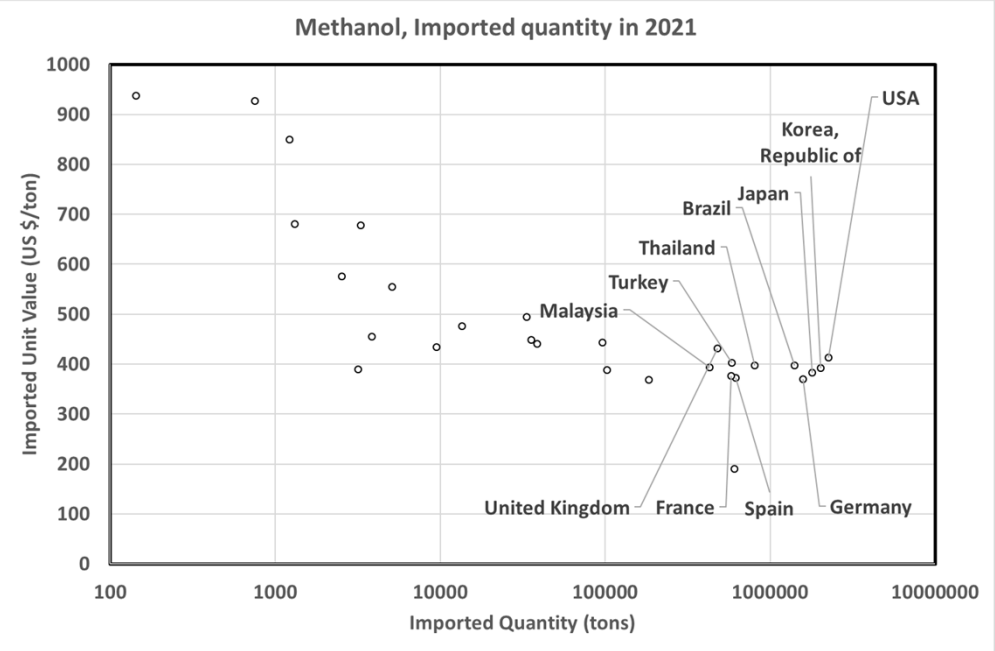
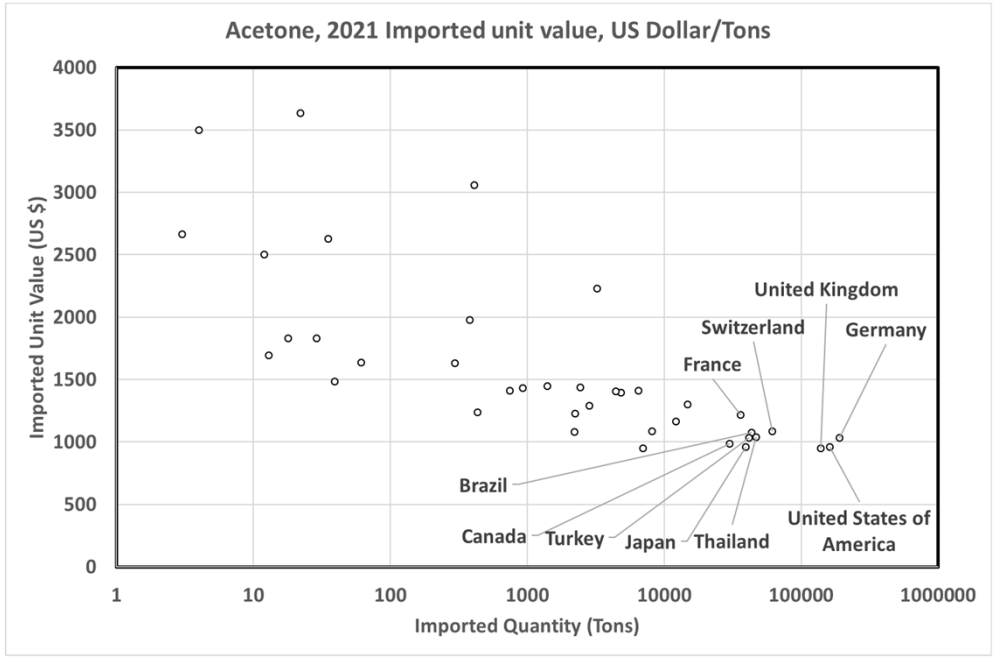
Methodology for the selection of the most promising targets





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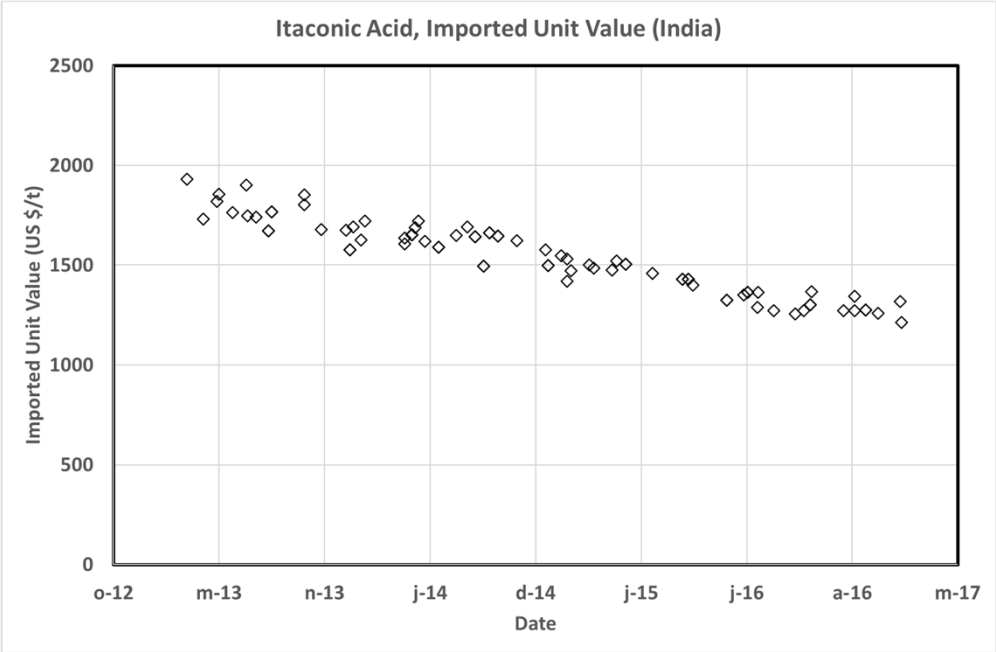

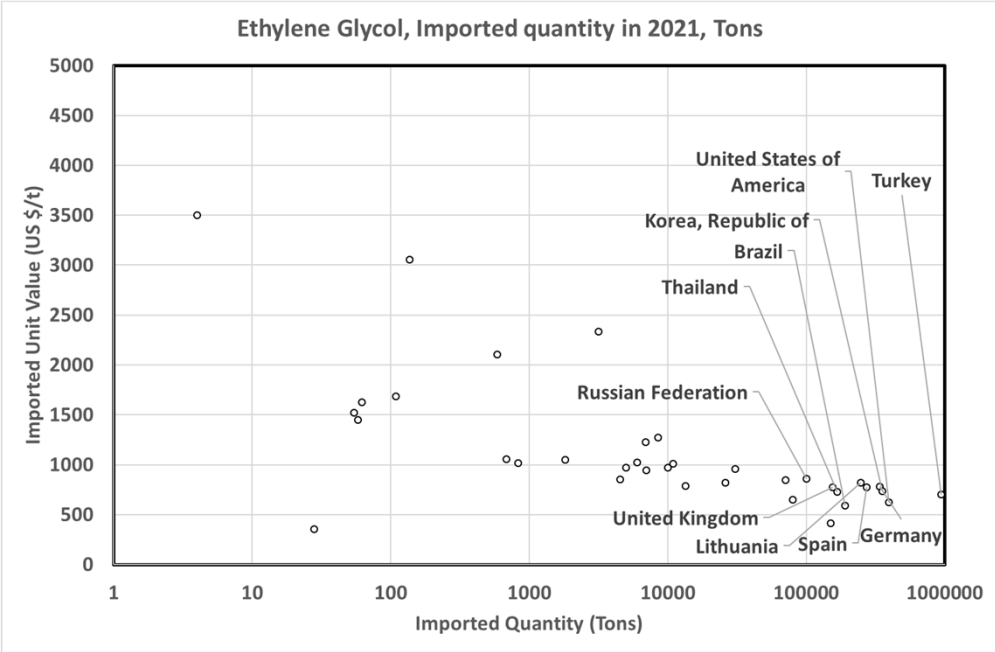

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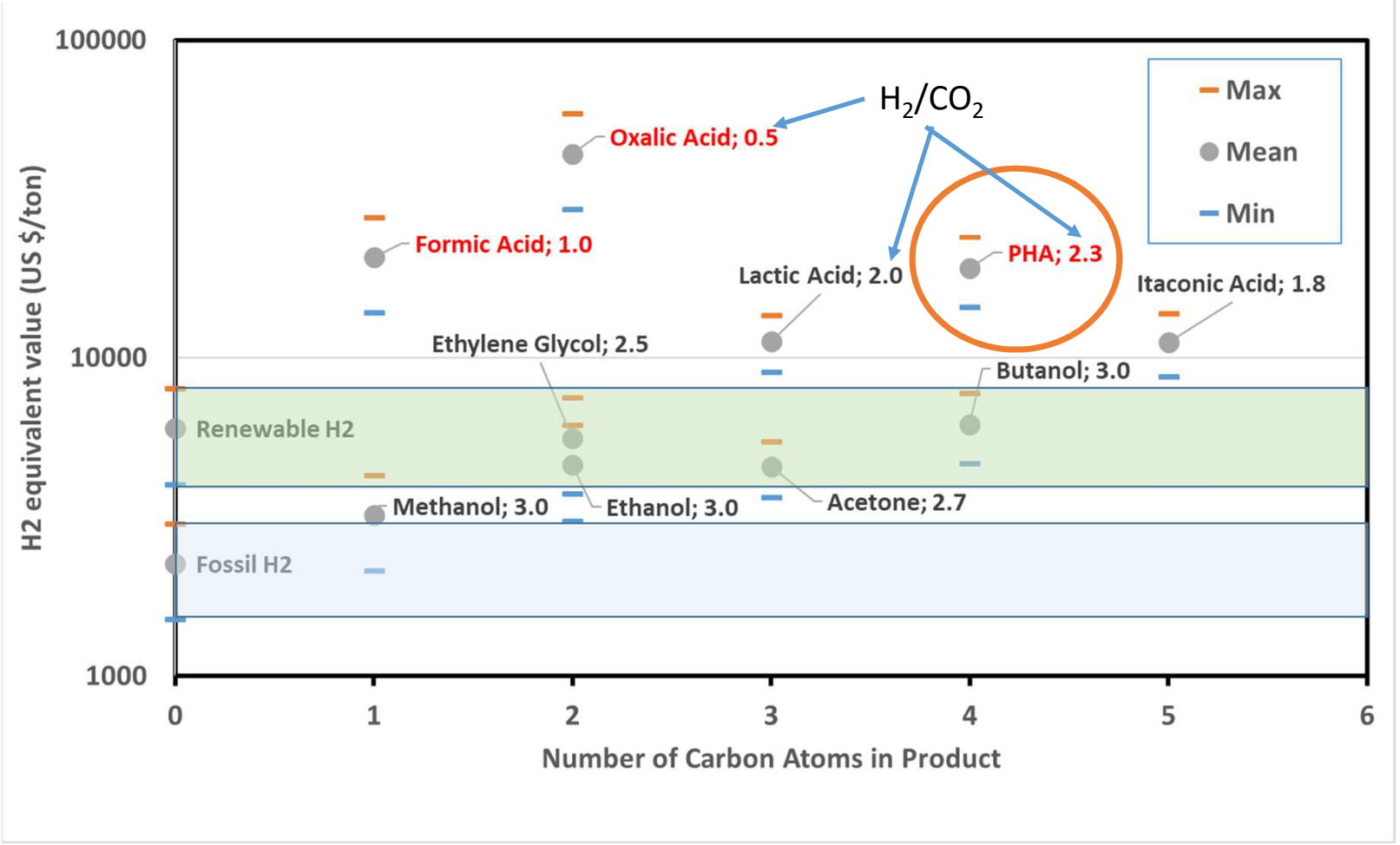
Hydrogen equivalent value



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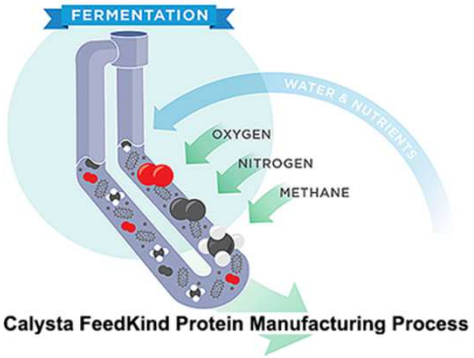
Industrial Scale Gas fermenters: 4 different technologies

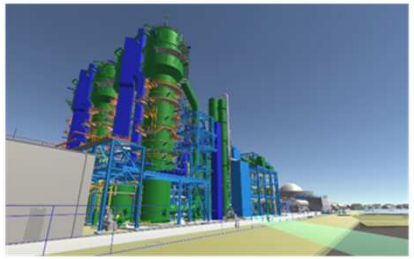
INEOS Gas (CO/H_2) fermenter
(Idled)
Ethanol

Calysta Gas (CH_4) fermenter
Proteins



Calysta FeedKind Protein Manufacturing Process

Lanzatech/Shougang
Gas ($CO/H_2/CO_2$) Fermenter
Ethanol



Lanzatech/Arcelor Mittal
(under construction)
Ethanol

Unibio Gas (CH_4)
Fermenter
Proteins

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Industrial Scale Gas Fermentation processes: 3 – 6000 $/t product

	Ineos Bio	Calysta	Lanzatech	Unibio	Coskata
Location	USA	China	Belgium	Russia	USA
Product	Ethanol & Electricity	Proteins	Ethanol	Proteins	Ethanol
Feedstock	Biomass to Syngas	Methane	CO	Methane	CO
Capacity product	24 kt/y 8 MW	20 kt/y	63 kt/y	6 kt/y	118 t/y (pilot/demo)
CAPEX	130 M$ (2011)	80 M$ (2020)	180 M$ (2020)	35 M$ (2016)	25 M$ (2008)
Technology	Stirred tank / Bubble column	Loop reactor	Jet Loop reactor	U-loop	

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Monte Carlo Simulation of Process economics for PHAs

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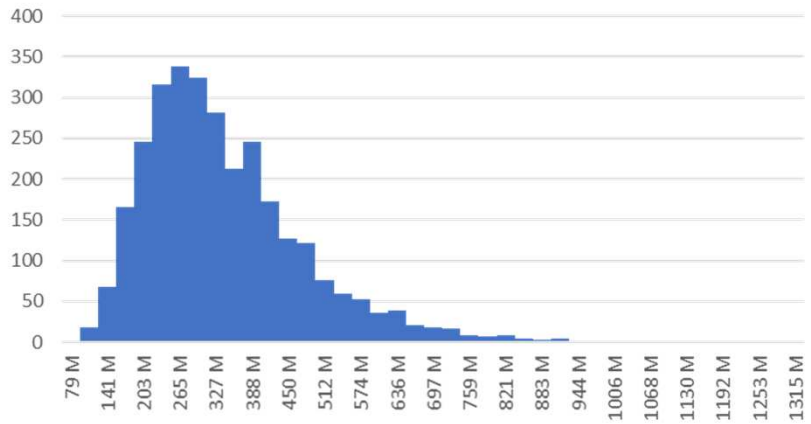
Mass Balance and Investment costs: for 100 000 tons of PHA

Raw Materials	'000 tons
CO2	230
H2	21
Process water	500
NaHPO4	4.5
Metals	0.765
Vitamins	0.115
Ammonium Sulfate	16.1

Products	'000 tons
PHA	100
Cellular Biomass	25

Wastes	'000 tons
Waste Water	500

SUMMARY OF KEY VALUES IN CAPEX	
Chosen ISBL+OSBL @ 50 % proba.	399 000 000
Chosen WORKING CAPITAL	23 000 000
Chosen STARTUP COST	45 000 000
Chosen GRANT & SUBSIDIES	99 000 000
TOTAL	368 000 000



- Energy demand: 15 % of raw material cost
- 7 process steps, Batch process, 3000 simulations

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N°	Name	Type	Parameter 1	Parameter 2	Parameter 3	5%	95%	Shape
1	CO2	GAMMA	k: 25	θ: 2		34.8	67.5	Price distribution of Raw materials
2	H2	LOG-NORMAL	μ: 7.6	σ: 0.12		1640.3	2434.2	Price distribution of
3	Process water (fermentation)	GAUSSIAN	μ: 0.5	σ: 0.1		0.3	0.7	Price distribution of
4	NaH2PO4	GAMMA	k: 156	θ: 16		2176.6	2833.5	Price distribution of
5	NaNO3	LOG-NORMAL	μ: 6.95	σ: 0.14		828.6	1313.3	Price distribution of
6	Metals (oligoelements)	GAUSSIAN	μ: 530	σ: 50		447.8	612.2	Price distribution of
7	Vitamins	GAUSSIAN	μ: 2060	σ: 140		1829.7	2290.3	Price distribution of
8	Ammonium Sulfate	GAUSSIAN	μ: 500	σ: 100		335.5	664.5	Price distribution of

Prices Distributions

- Raw materials, Products and wastes
- H_2: 1640 – 2434 US$/t (long term rH2)
- PHA: 3770 – 5240 US$/t

N°	Name	Type	Parameter 1	Parameter 2	Parameter 3	5%	95%	Shape
1	**PHA**	LOG-NORMAL	μ: 8.4	σ: 0.1		3772.6	5242.1	Price distribution of Products
2	Biomass	LOG-NORMAL	μ: 6.9	σ: 0.1		841.8	1169.7	Price distribution of

N°	Name	Type	Parameter 1	Parameter 2	Parameter 3	5%	95%	Shape
1	Waste water	GAUSSIAN	μ: 1	σ: 0.1		0.8	1.2	Price distribution of Wastes

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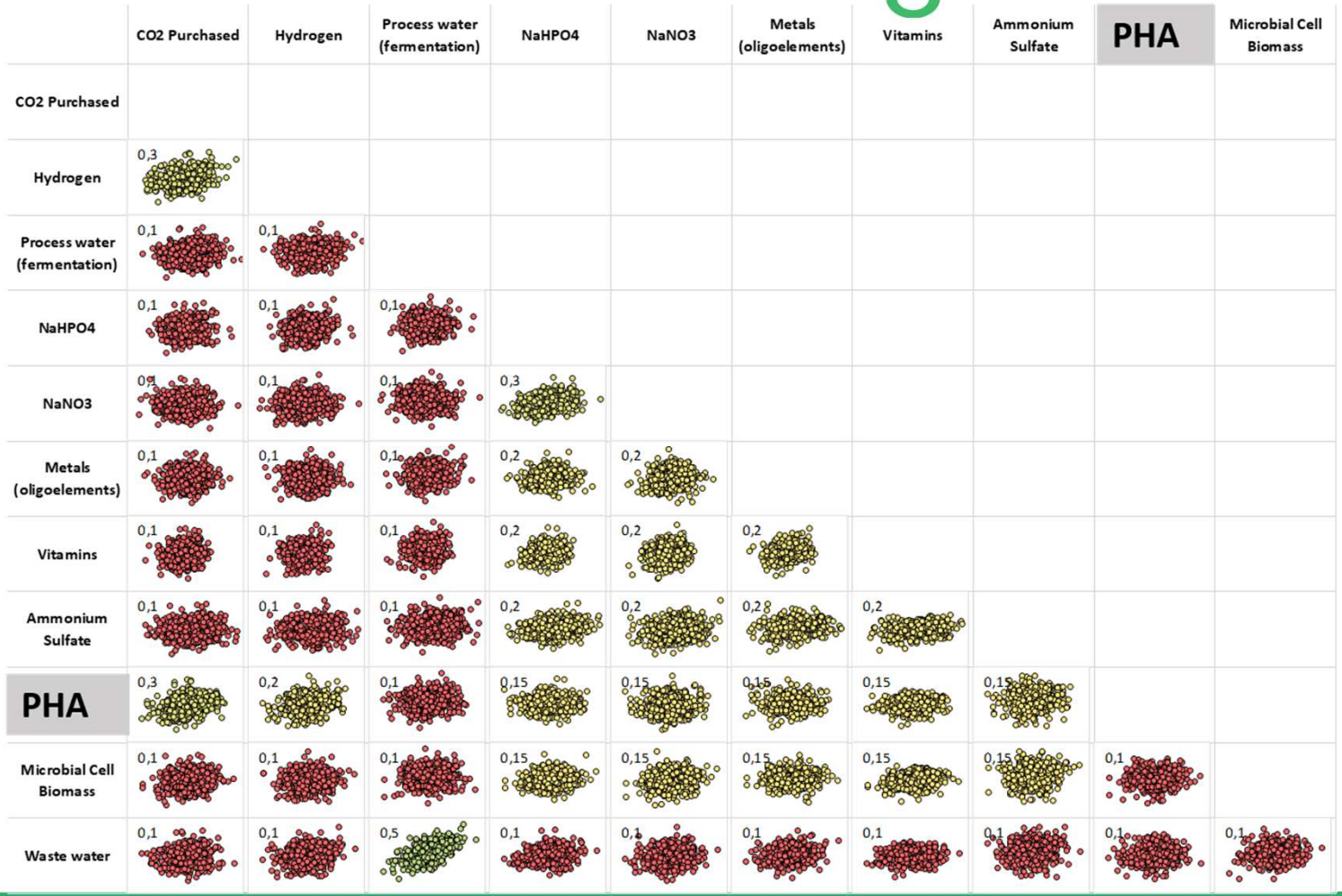
Correlation matrix



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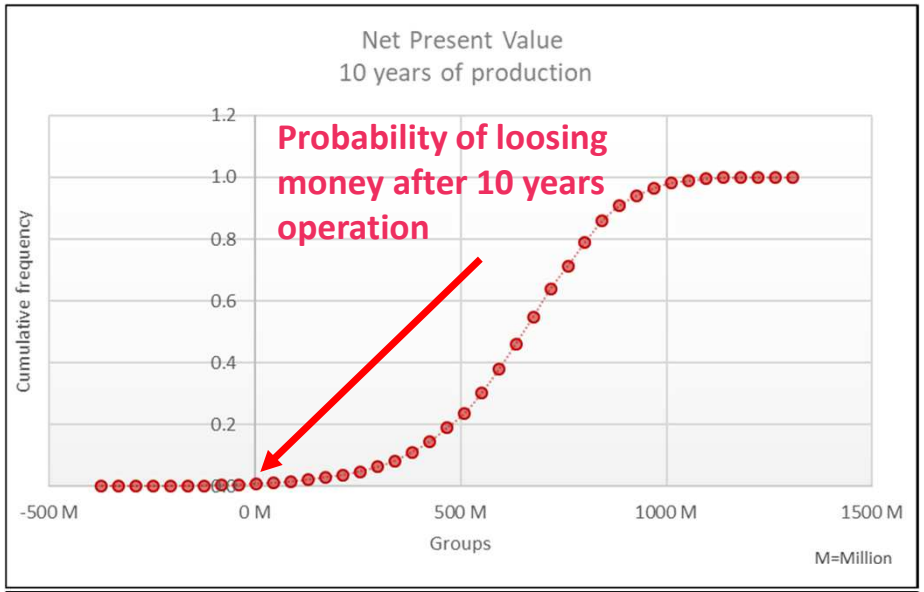
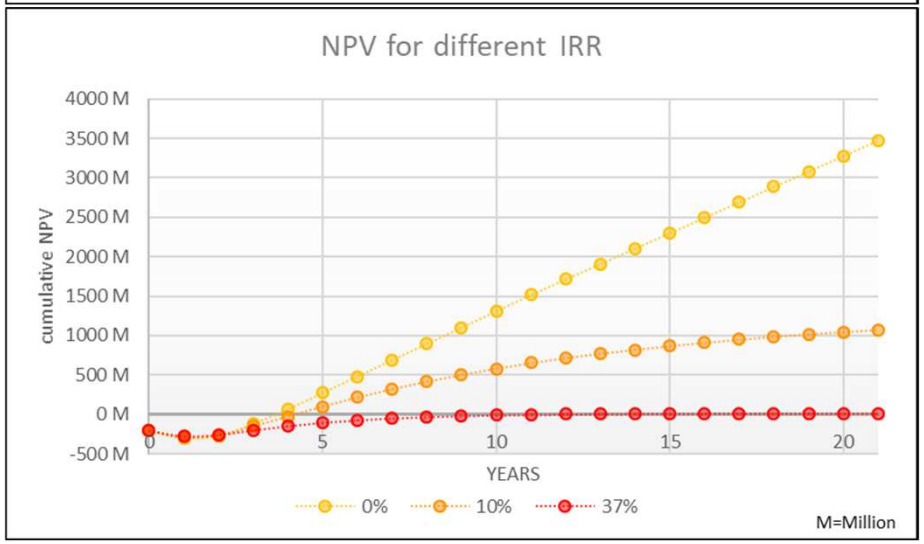
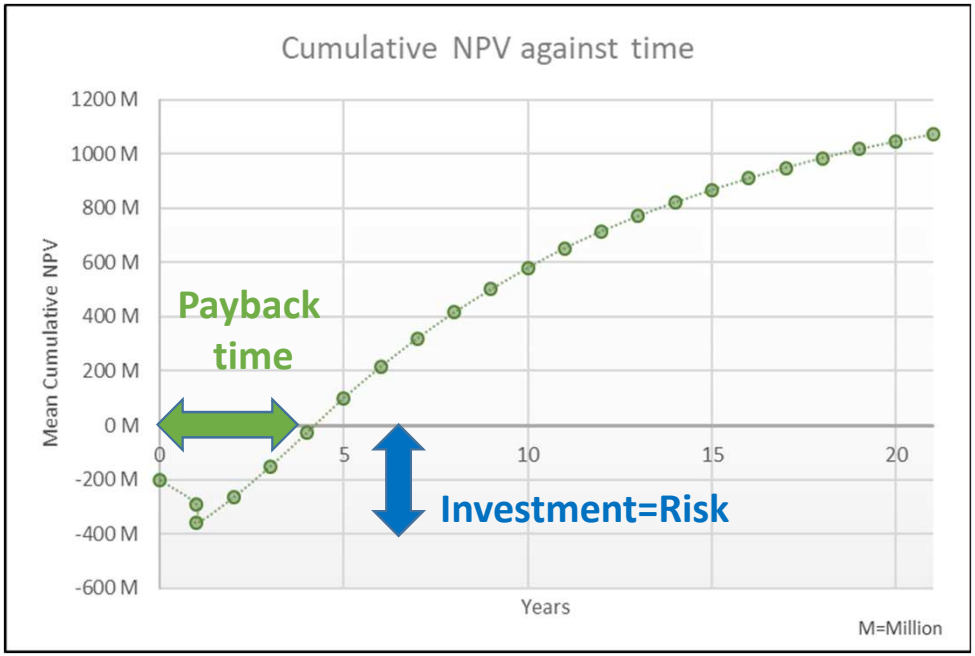




Net Present Value

- Probability of not loosing money
- Payback time: 4 years
- Subsidies repaid in 3 years
- DCFRR: 37 %➔Ok for high Risk



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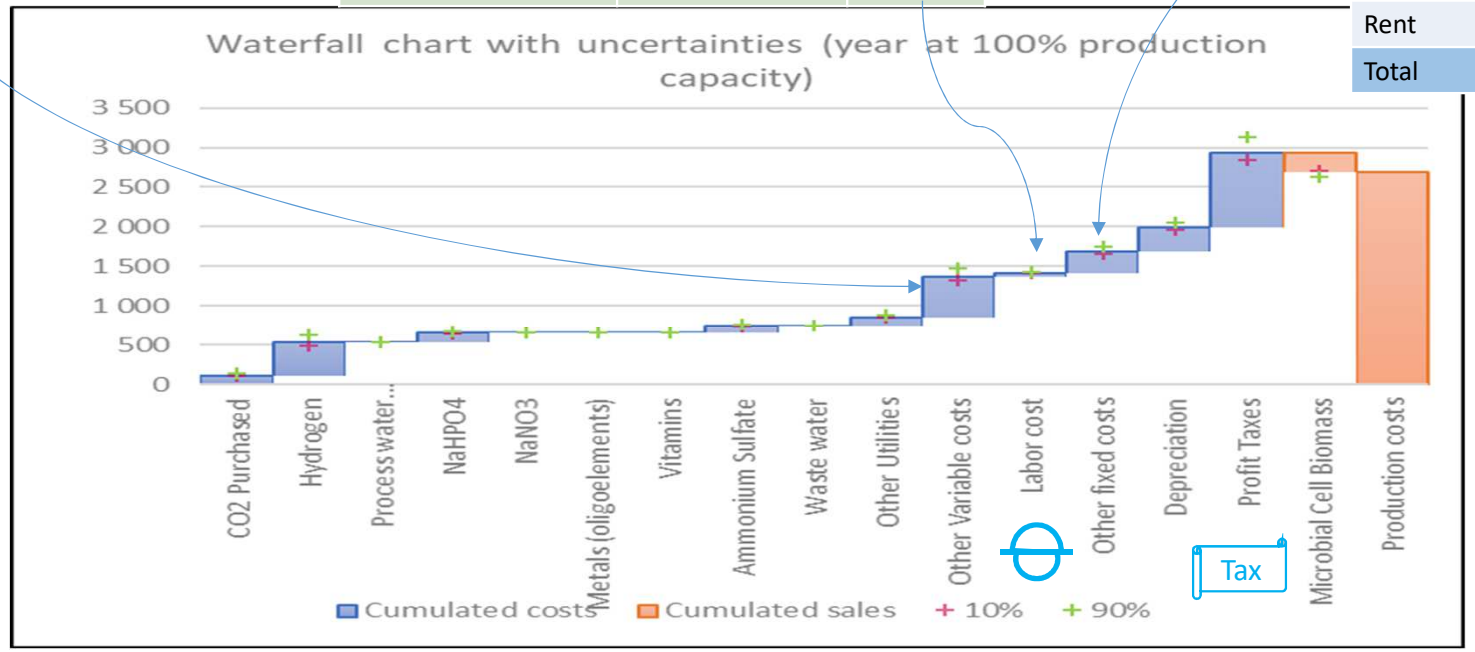
Cost Structure:

(With subsidies). Strategies to make the case more interesting

Other Costs based on sales	Ratio
Royalties	0.03
Distribution and Sales	0.05
Research and Development	0.03
Total	0.11

Labor Cost	Factor	Cost (US $/year)
Operators	7 operators*5 shifts	2100 000
Operating supervision	0.18	378 000
Laboratory Charges	0.18	378 000
Plant overhead	0.60	1260 000
Administration	0.20	420 000

Other fixed cost based on CAPEX	Ratio
Maintenance and Repairs	0.02
Operating Supplies	0.01
Property Taxes	0.02
Financing Interest	0.02
Insurance	0.02
Rent	0.00
Total	0.09



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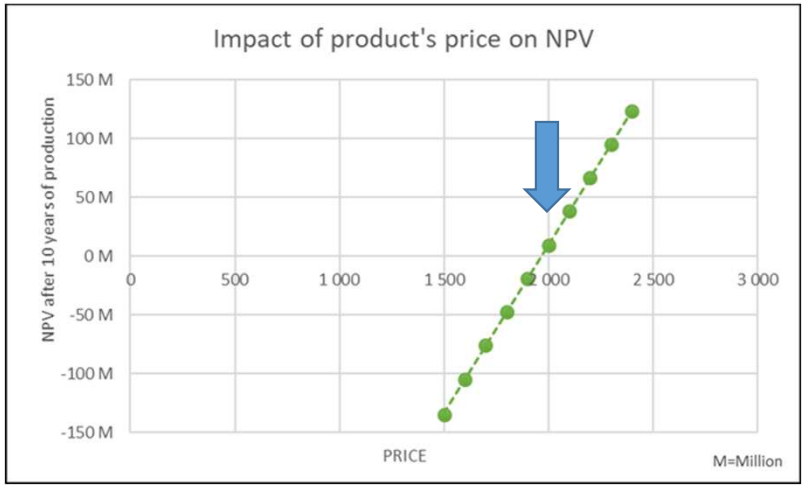
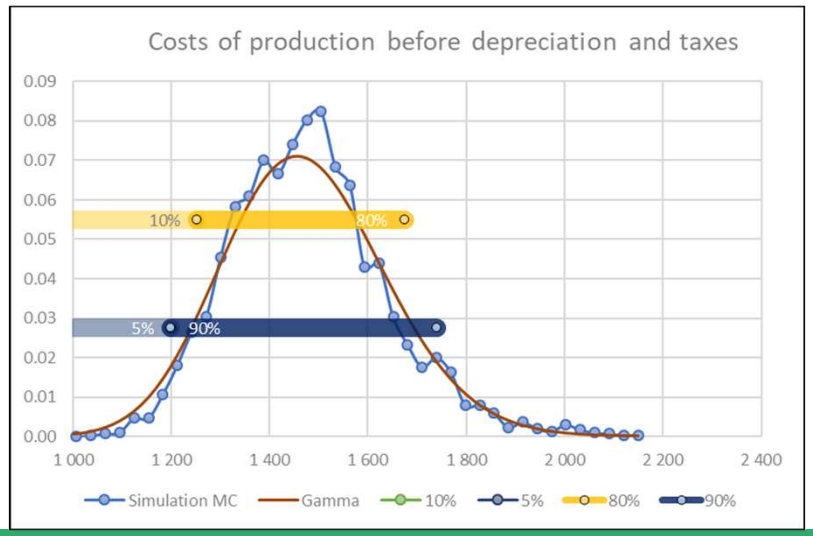
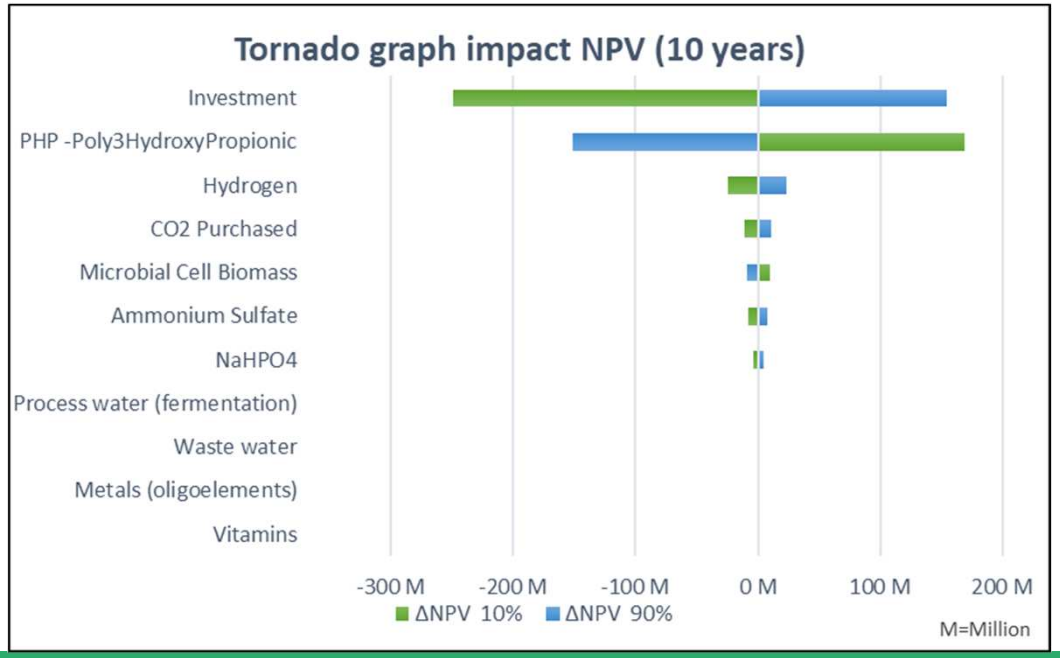
Performance indicators





- PHA needs to be sold above 2000 US$/t
- Key contributors to uncertainty: Capex, PHA sales price



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Conclusions

- Attractive products:
  - Low H_2/CO_2 ratio
  - Low combustion heat
  - Market value depends on location
- PHAs are among the promising targets
  - What is still needed:
  - Technologies for H_2 dissolution, Heat management
  - Appropriate plant size

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Thank You

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