

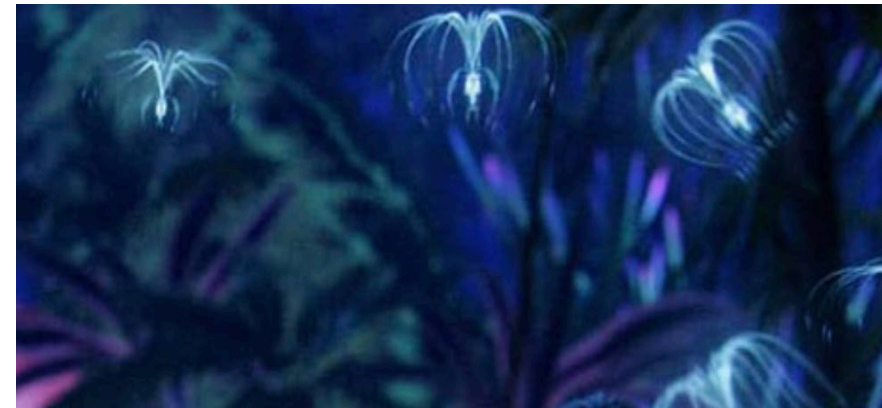
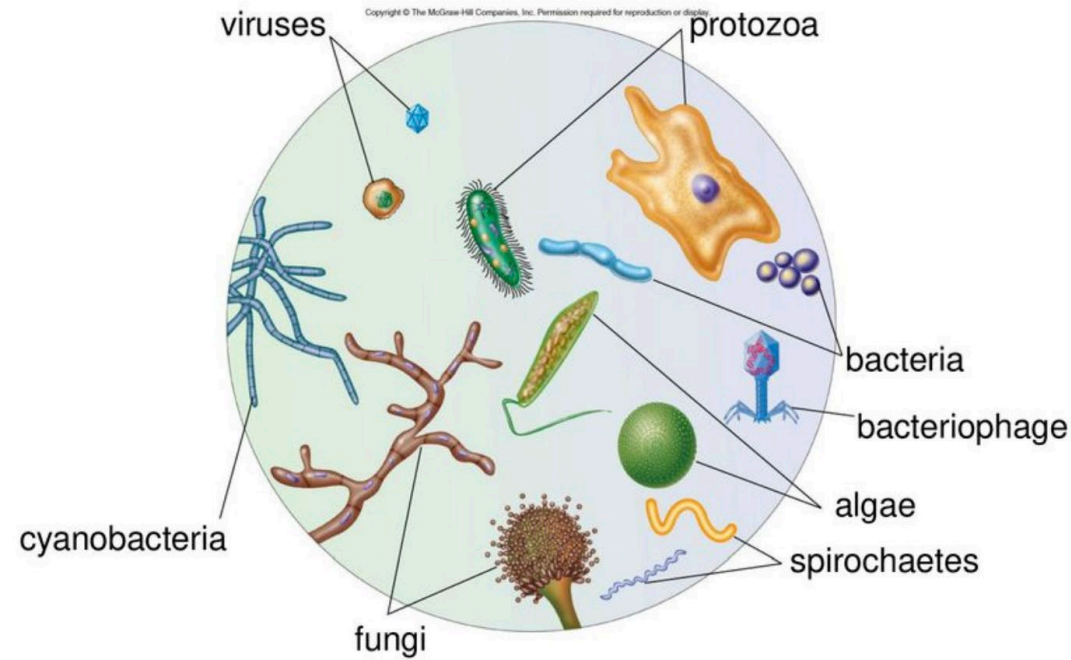
# Microbial Biotech for Feed and Food for the Future



Willy Verstraete

# The microbial world

Viruses /Bacteria /Yeast /Fungi /Protozoa/Algae



- They communicate and connect
- They are very efficient
- They are 99.9999% positive

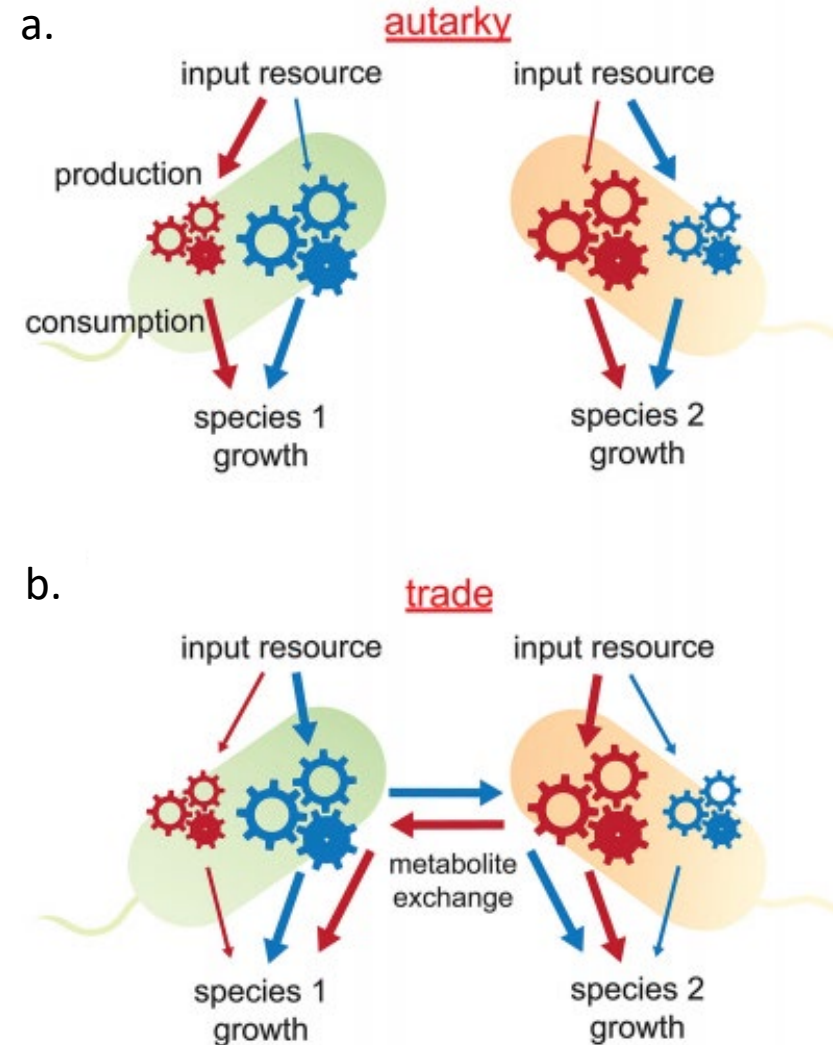
Central Feature :

THE MARKET ECONOMY is also applicable to THE MICROBIAL WORLD

Economists studying microbial metabolism  
(Tasoff *et al.* 2015)

By trading with one another, microbes clearly grow better!  
Each part of the process is done with more accuracy and efficiency by multiple species compared to a single species.

Sounds evident / ...yet ....



# The choice to make

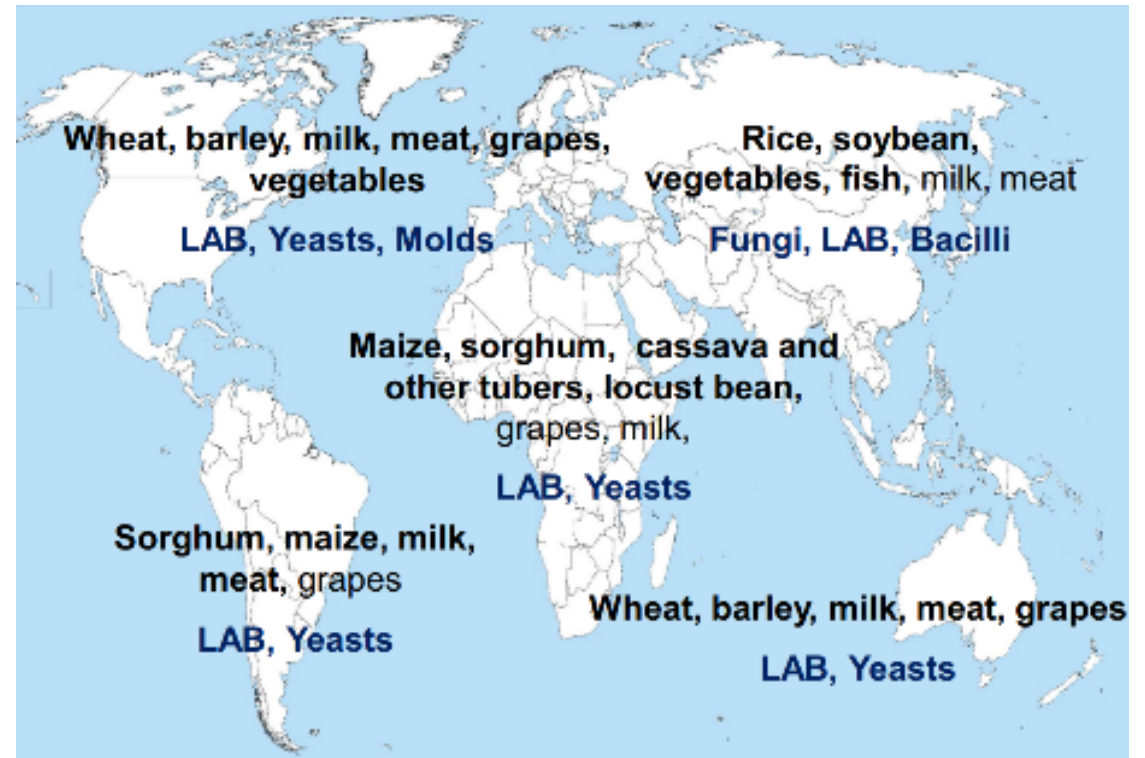
Mixed culture microbiology / spontaneous fermentation /terroir fermentation // “nature’s best practice NBP “ fermentation

## Lambiek bier

Lambiek is een streekbier uit de Vlaamse vallei in België. Het wordt nu ook buiten deze regio's bereid en is buiten deze streek verkrijgbaar.



“ Beer / Wine/ Kombucha/Choucroute / Cheese....“



**THE MICROBIOME !!**

<https://doi.org/10.1111/1541-4337.12520>

# The choice to make

Conventional industrial fermentation

Precision microbiology

Precision fermentation



Malus :

Complex / high Capex  
Often low in efficiency

Bonus :

Certainty –Deterministic



# Warren Belasco 2006 : “Meals to come”



Be very aware of the ongoing duality :

- a) Malthus related thinkers / **dystopian mindset**  
the limits of growth

People are programmed to DISTRUST

- b) Marquis de Condorcet related thinkers / **utopian mindset**  
the techno-cornucopian approach

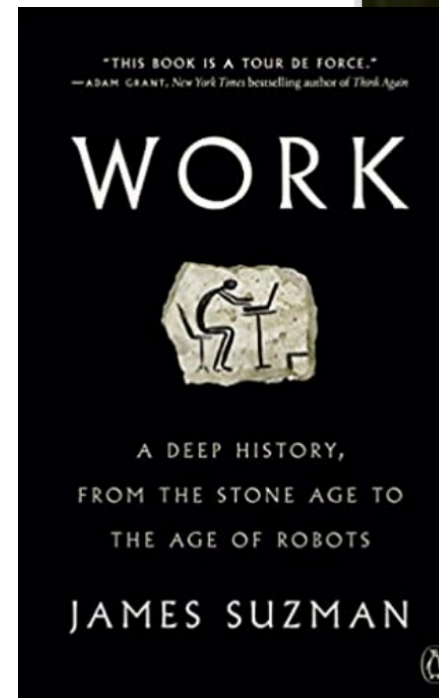
The sky is the limit : microbial food / synthetic meat ...

# Current mindsets :

Plants directly as food : in case we all become vegetarians

we get 10 x more space for 'wild ' plants; they are of value for the health of our ecosystems

We create far too much entropy ;  
we must become much more efficient  
with our resources ; certainly  
in our feed and food production



# Current urgent issues

- Energy supply : We must think 'renewable'
- **Nitrogen** = MAJOR player in the global warming  
1 kg reactive N = 2 L fossil fuel by the Haber Bosch process  
4% of all fossil fuel goes to N fertilizers
- Every person needs some 100 g quality protein per day = 14 g reactive Nitrogen per day  
**= 200 L fossil fuel equivalent per year**

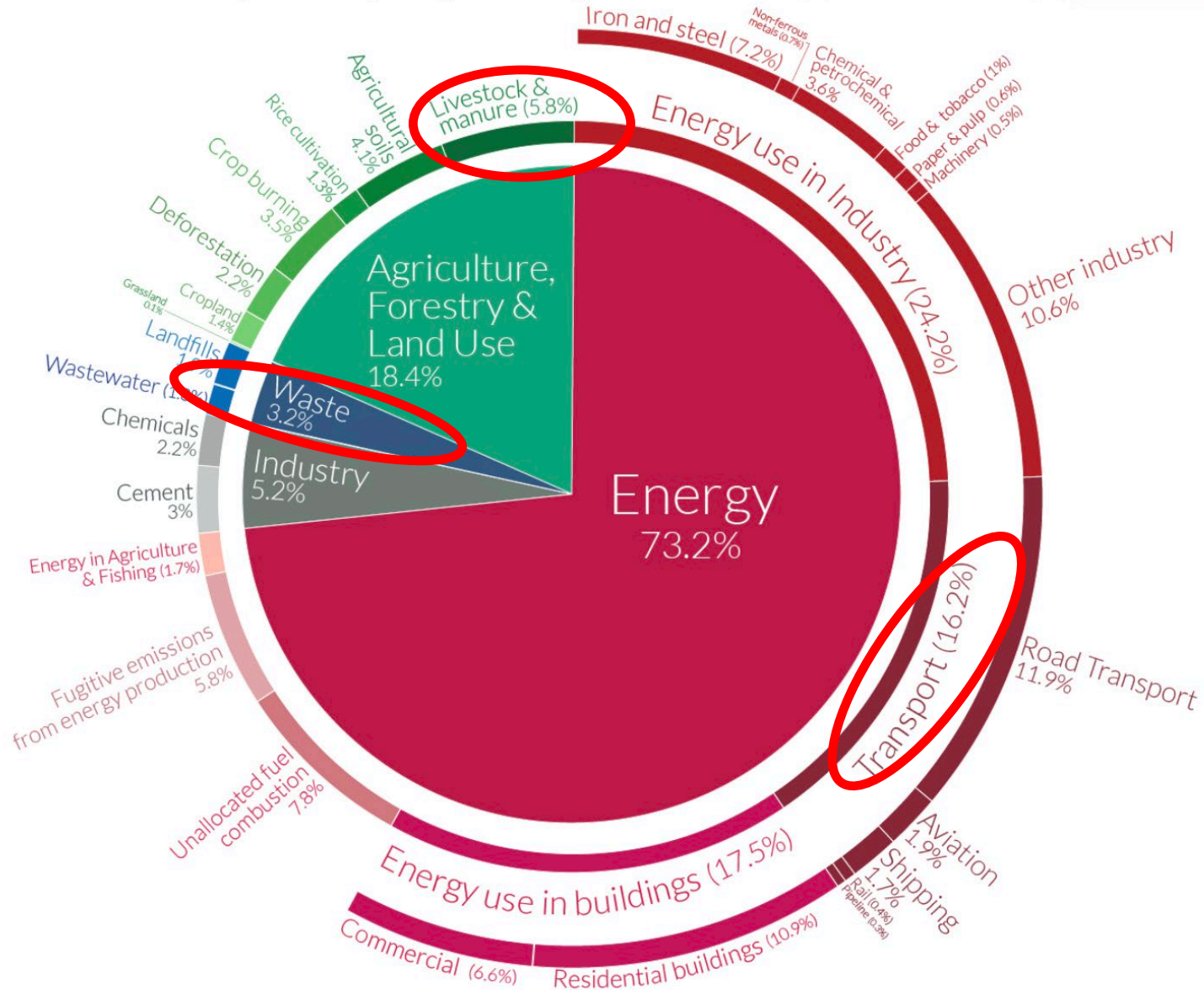
**Timmermans to end EU climate 'contradictions'**





# Global greenhouse gas emissions by sector

This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO<sub>2</sub>eq.



## GREEN HOUSE GASES

Energy: 73% of which 16 % transport

Waste(water) treatment : 3.2 % of which 1% is related to urine N ( N<sub>2</sub>O production )

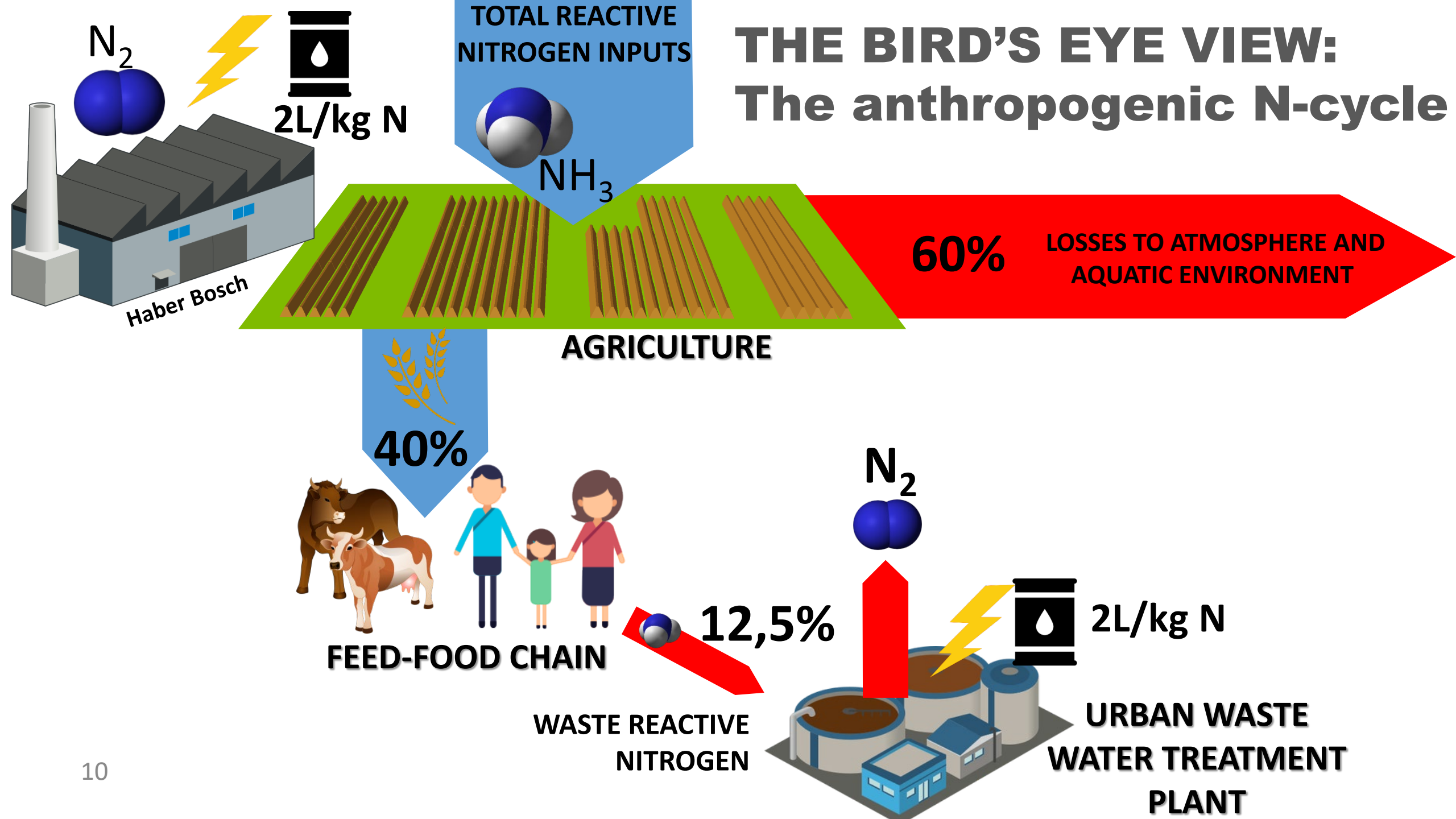
Agriculture 18% of which 5,8% animal husbandry and manure

## NITROGEN IN GLOBAL WARMING (AMMONIA & N-OXIDES)

CA 10 % !!! N<sub>2</sub>O

Part of animal meat in global warming  
Ca 5-15%  
(Pikaar et al. 2023)

# THE BIRD'S EYE VIEW: The anthropogenic N-cycle



# COP 27 in 2022

- Antonio Guterres



*“ We ride on a highway to the climate hell “*

– Feed and food production should reflect on how to **IMPROVE** !!

# Microbial Biotech



## The strengths :

- **TOP Speed & Yield :**

doubling time : hrs

yield : 1Kg carbohydrates – aerobic metabolism – 0,3 - 0,4 Kg cell dry weight

of which 70-90% can be protein ( optimal amino acids & highly digestable )

Food Conversion Factor: cattle /pigs/poultry/fish : 4-8

dairy products : 8-13

insects : 10

microbes : 0,2-0,4 !!!

- In case of 'mixed cultures' : Full use of all components ( starch , pectines, celluloses , ... ) ; they are very adaptive and exhaust all energy sources / **little waste left**

# Microbial Biotech

## The weaknesses :

- Normally no texture – you get a paste of single cells
- Difficult to harvest : 1-5  $\mu\text{m}$  sized
- Needs rapid processing : dewatering / sterilization /...
- Very strict regulatory aspects : EFSA 'novel foods '

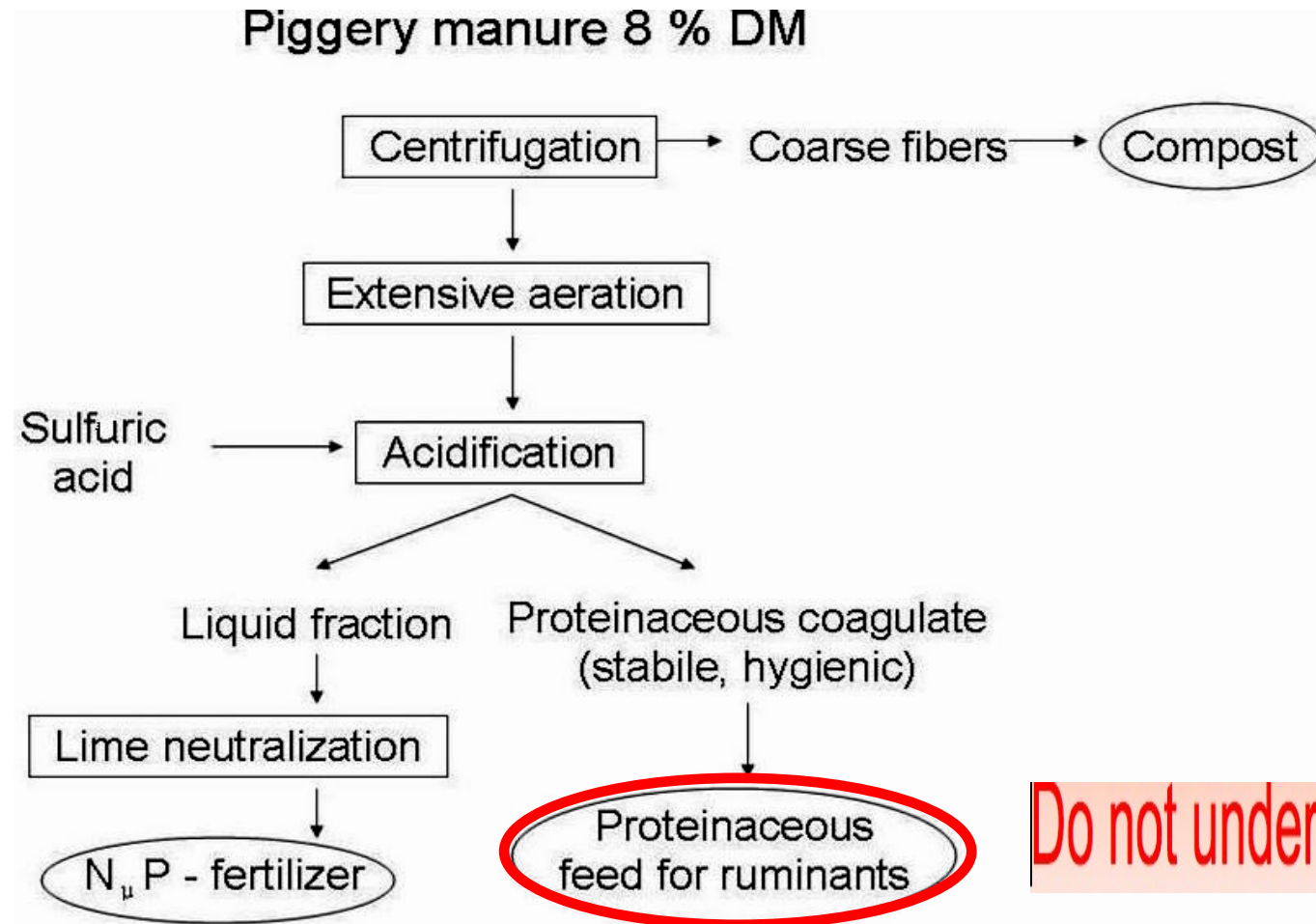


# Overview

- The past: Our personal experiences in Resource Recycling /Feed-Food
- The present: The 'GREEN DEAL'
- The future: The need for education/communication

# Cyclic economy in intensive husbandry 50 years ago

Piggery manure to single cell protein (SCP) to feed  
(Beernem (1974) IWA/R&D prize; LabMET).



Do not underestimate the Tabloids !!

# The past: Our experiences with Recovery

- The year 1985 : The **Rhodospirillaceae** “ fascination “

Short Communications | [Published: January 1985](#)

Chemical control of eucaryotic and blue-green algae in anaerobic photoreactors culturing Rhodospirillaceae

[L. Segers](#) & [W. Verstraete](#)

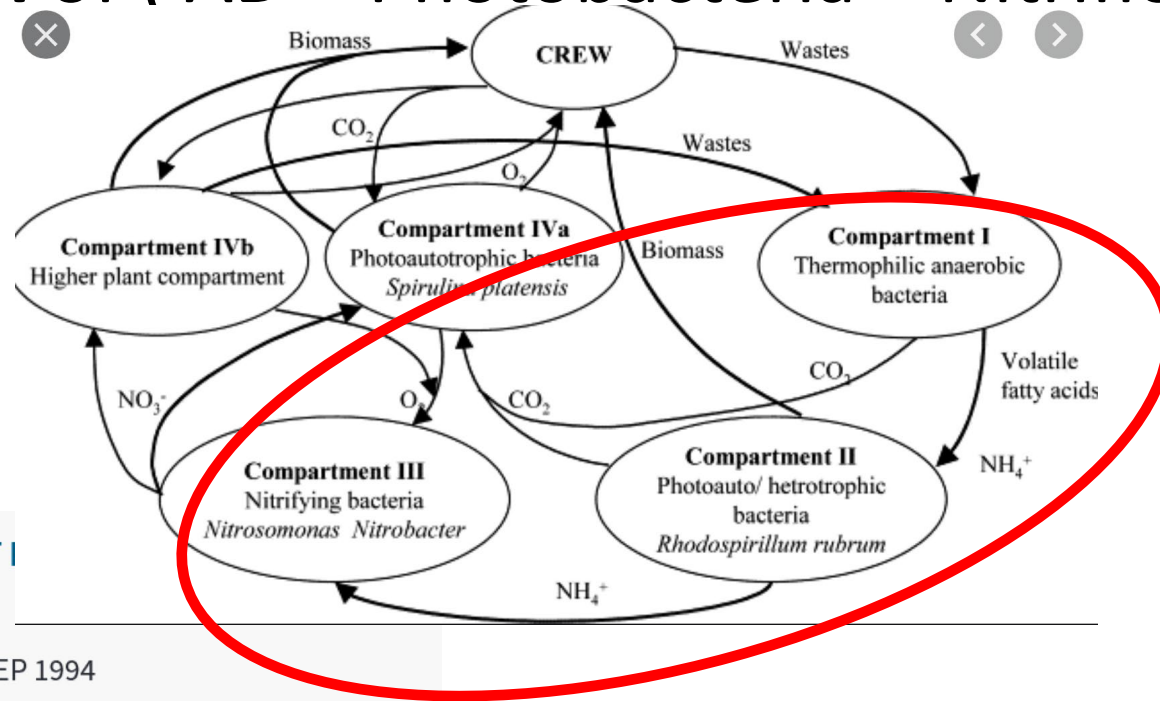
[Experientia](#) **41**, 99–101(1985) | [Cite this article](#)

Take home: Nice new food but ZERO interest at that time



# The past: Our experiences with Recovery

- The 90's :The combi of ( AD + Photobacteria + Nitrifiers) in Melissa



MELISSA IS EITHER AN ECOSYSTEM OR A UNIT I

By: GROS, JB; LASSEUR, C; VERSTRAETE, W

BIOFUTUR Issue: 137 Pages: 35-37 Published: SEP 1994

Take home : In space , we can close the cycle / on our planet : the market economy is as yet reluctant

# The past: Our experiences with Recovery

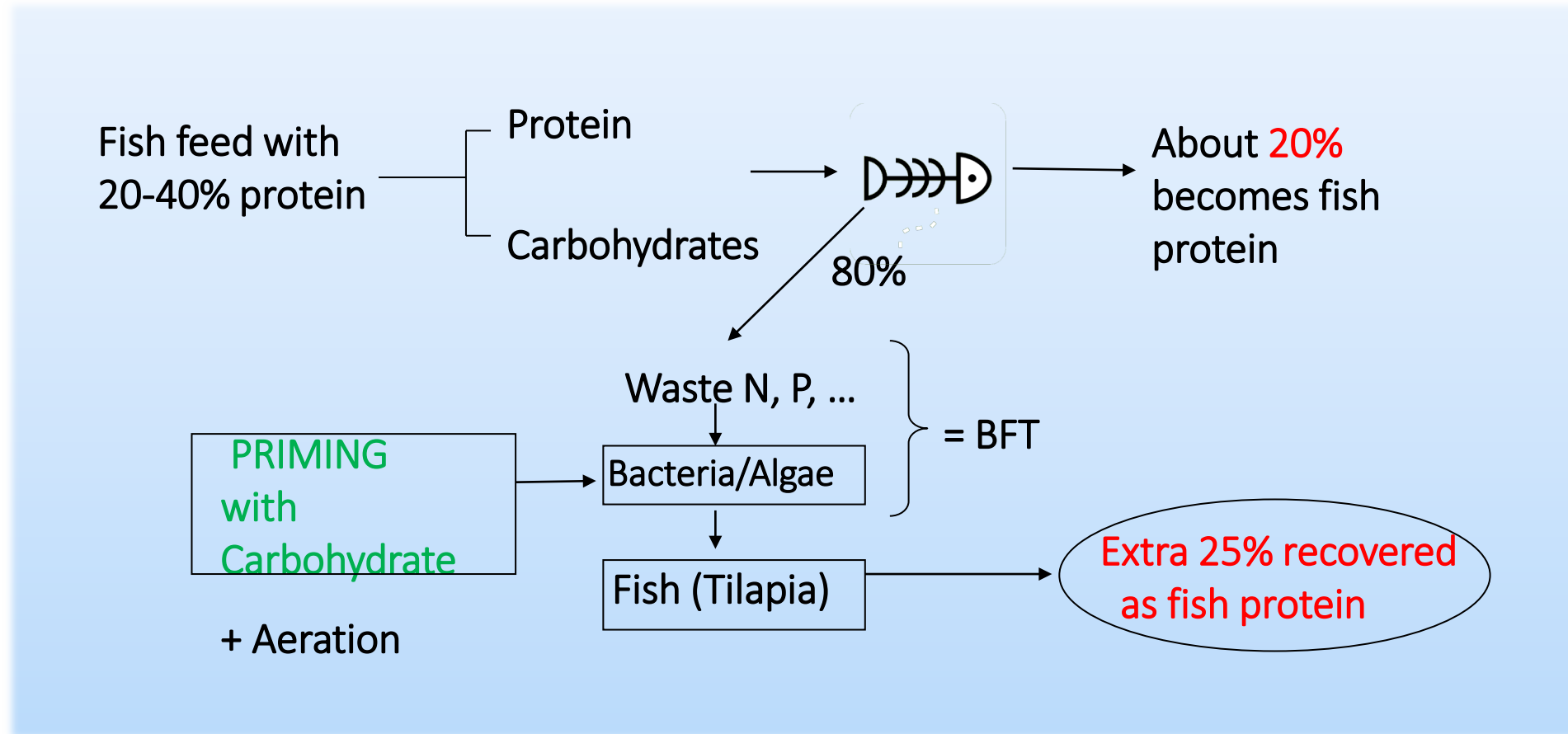
- **The year 2003:** Outcry from Aquaculture : why not in situ **direct upcycling of fish fecal matter** – Sorgeloos -Avnimelech

**The biofloc technology** / Ever since: a growing application



# The Aquaculture BioFloc Technology

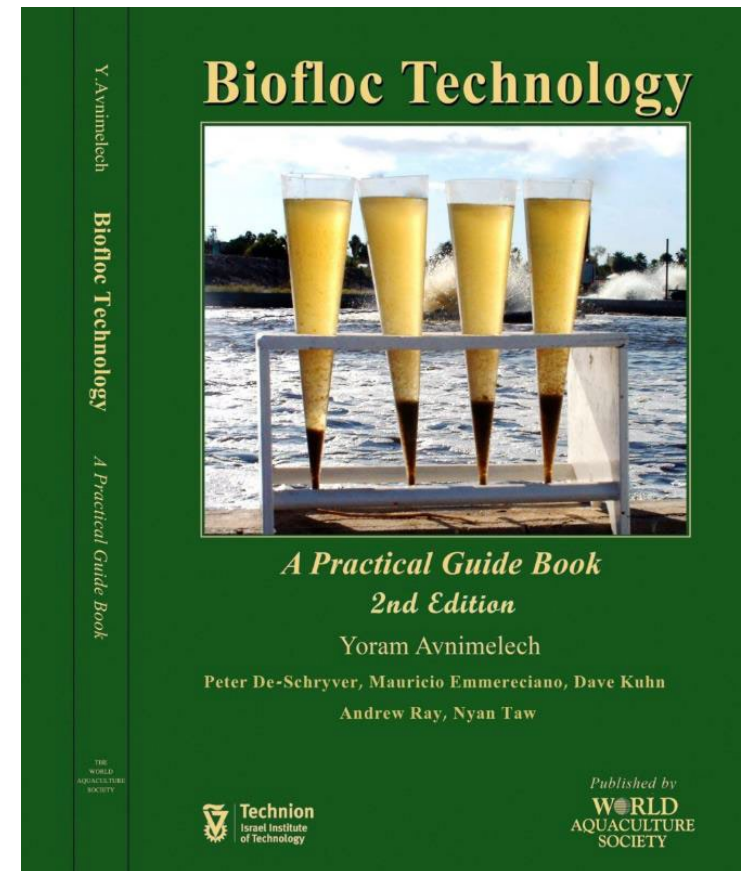
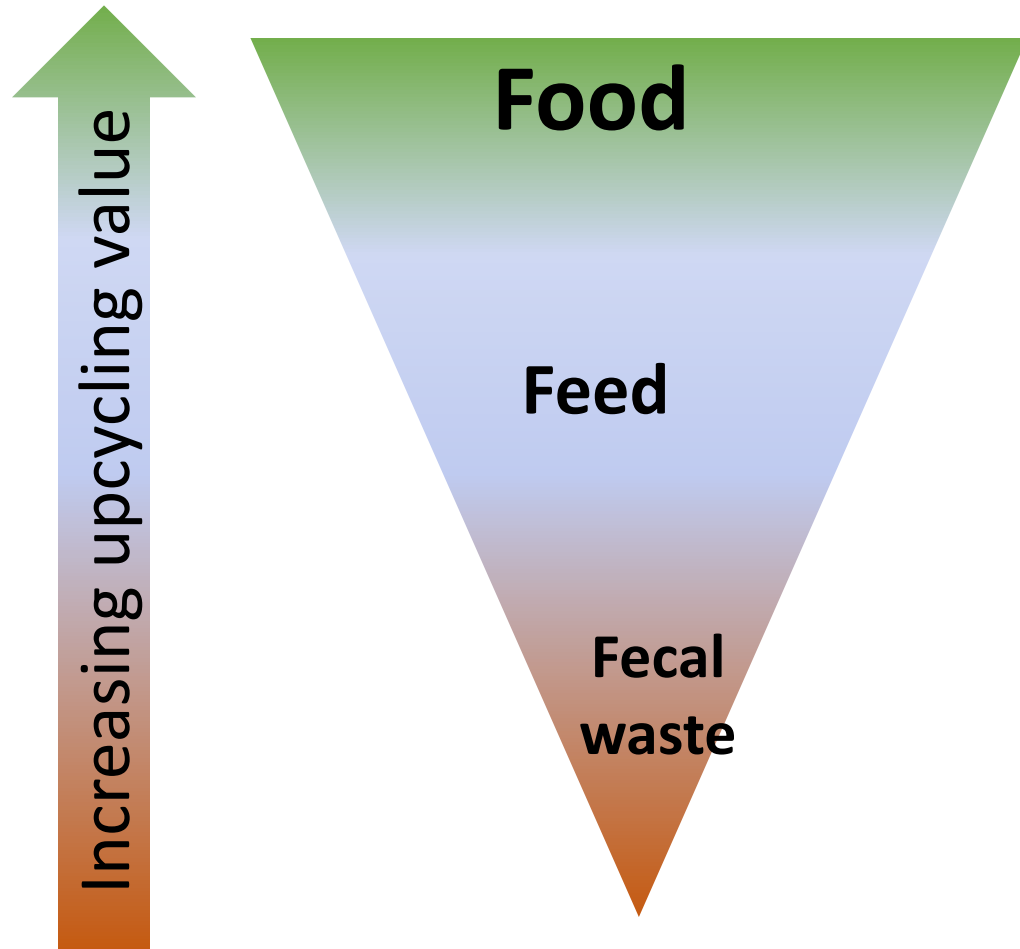
Direct recycling of fecal N as feed in aquaculture



(Crab et al., 2007; *Aquaculture* 270: 1-14; *LabMET*;  
(De Schryver et al. 2008; *Water Res.* 42: 1-12; *LabMET*)

From fecal to feed to food !!

This time Full acceptance by the public !



# 2010 --- Upgrading of Carbon /CO2 by Aerobic fermentation to BACTERIAL (1 um ) biomass

## Organotrophic route

- Oxygen
- (Secondary) Organic **Carbon**

## (Recovered) Nitrogen Autotrophic route

- Oxygen
- **CO<sub>2</sub>**
- \* Recovered Nitrogen
- Hydrogen/CO/CH<sub>4</sub>



In-reactor  
**Bacterial Biomass**  
Production

**Open Natural Microbiomes**



**Bacterial  
Protein  
PROMIC**



**Food /Animal Feed**

OR

**Organic Fertilizer  
Necromass**

OR

**Material  
Composites**

# Spontaneous BACTERIAL Protein /Mixed Culture State of the Art

Positive :Top protein quality and technically do-able at 'almost' competitive prices

Neutral : 1um cells are cumbersome to harvest and process (dewater/preserve/ dry)

Negative :Plenty of resistance against 'non-pure' (???) mixed microbial cultures EFSA

*Consider : Top tasty french cheeses produced by open fermentation from raw milk*

At present : Regulatory aspects requiring **total absence** of  
any type of biological 'UNWANTED' species = NO GO !!!

Sofar: There is hope for a future regulatory perspective  
ie absence of rDNA of 'unwanted' microbes could suffice (GMM.pdf)



# Axenic BACTERIAL Protein State of the Art

Positive : well defined outcome

Neutral : 1um cells are cumbersome to harvest and process (dewater/preserve/ dry)

Negative : costs of sterilization / infrastructure / treatment of effluent

At present :

- Industrial production is 'announced' ( Solar Food-H2 /Unibio-CH4/Calysta-Adisseo-CH4 / ....) (Marcellin et al. 2022)
- Critical factors are : costs ( generally of the order of 1,5-2,0 Euro per kg ;Abbadi et al. 2021) + environmental aspects (odour !) + regulatory issues

*Note : Solein grown with CO2 and electricity H2 has received regulatory approval from the Singapore Food Agency 2022*



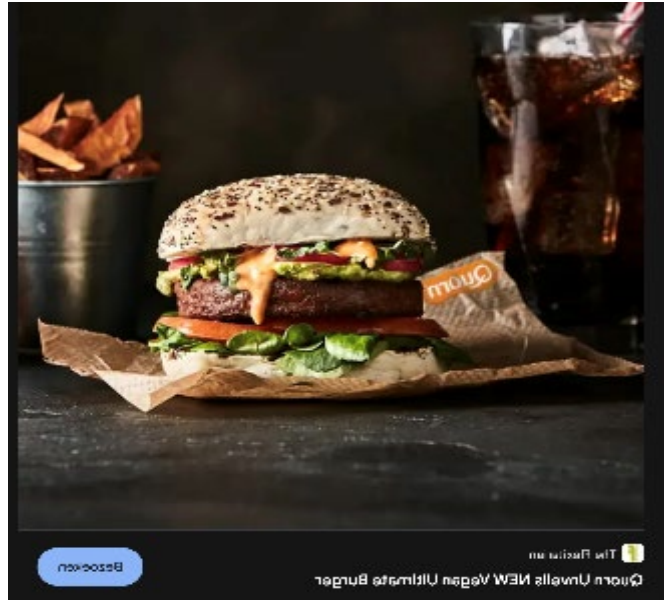
# AXENIC MICROBIAL (>5um) Biomass and AgroFOOD

YES PROVIDED EASY to Harvest & Process and also 'Familiar to the consumer'



How Yeast Is Used in Cooking

YEAST



Quorn Burger-Fungal biomass

FUNGI

Conventional microbial feed and food based on yeast /fungi/algae will increase as part of the 'protein shift' (Pikaar et al . 2023)



Wat is het verschil tussen chlorella en spirulina?

ALGAE



# Overview

- The past: Our personal experiences in Resource Recycling /Feed-Food
- The present: The 'GREEN DEAL'
- The future: The need for education/communication



# Key feature of CYCLIC ECONOMY:

Open naturally evolving mixed cultures =microbiomes

are ESSENTIAL to reach the SDG at reasonable costs

- We need their ‘intelligence ‘ and adaptability eg in various types of water treatment systems !!
- They empower our ‘immunology’ – Bart Lambregt VIB
- EFSA and the regulators should not fear : they, and the risks they represent , can be managed adequately

microbial biotechnology



Open Access

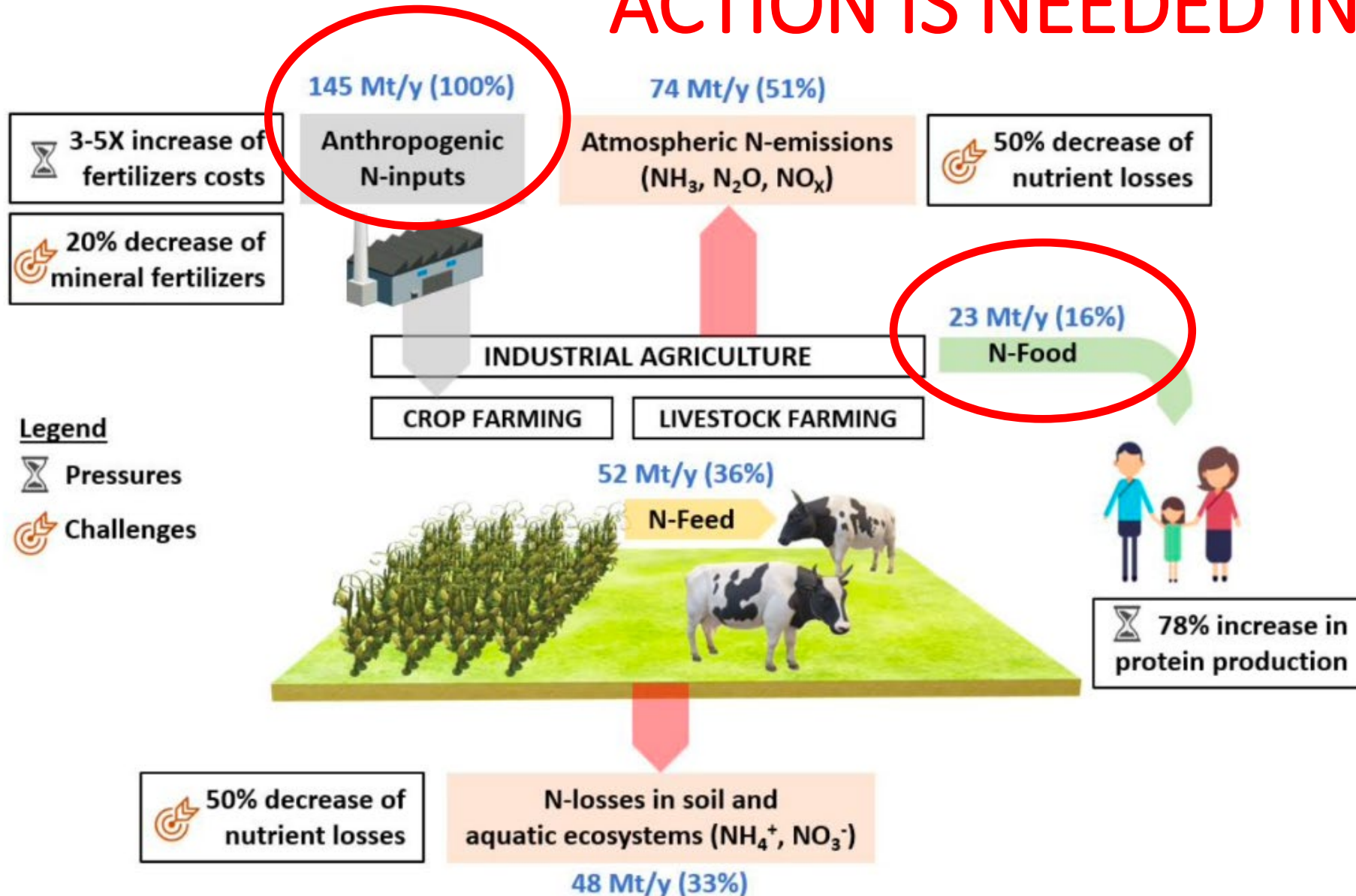
Editorial: Microbial Biotechnology for Sustainable Development Goals | [Open Access](#) |

**Stochasticity in microbiology: managing unpredictability to reach the Sustainable Development Goals**

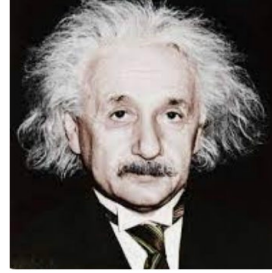
Jo De Vrieze , Thijs De Mulder, Silvio Matassa, Jizhong Zhou, Largus T. Angenent, Nico Boon, Willy Verstraete

First published: 20 April 2020 | <https://doi.org/10.1111/1751-7915.13575> | Citations: 1

# Matassa et al. (2022). - The EU Green Deal **and N ACTION IS NEEDED INDEED**



# NEW & NOVEL :

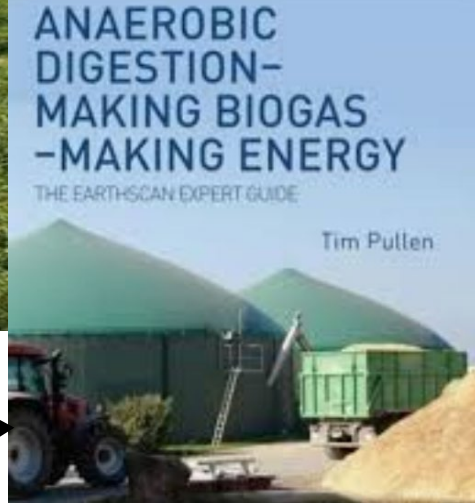


- ➔ • Grasland Based Biorefinery:  
Go for robust and sustainable systems !

Nitrification is the cause of a major part of the N-problems  
Try to fully develop the Biological Nitrification Inhibition (BNI)  
cropping system (Villegas et al. 2020)



# New EU Policy: GRASSLAND-BIOREFINERY



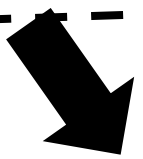
DRINKING WATER



FIBER FERMENTED TO FOOD



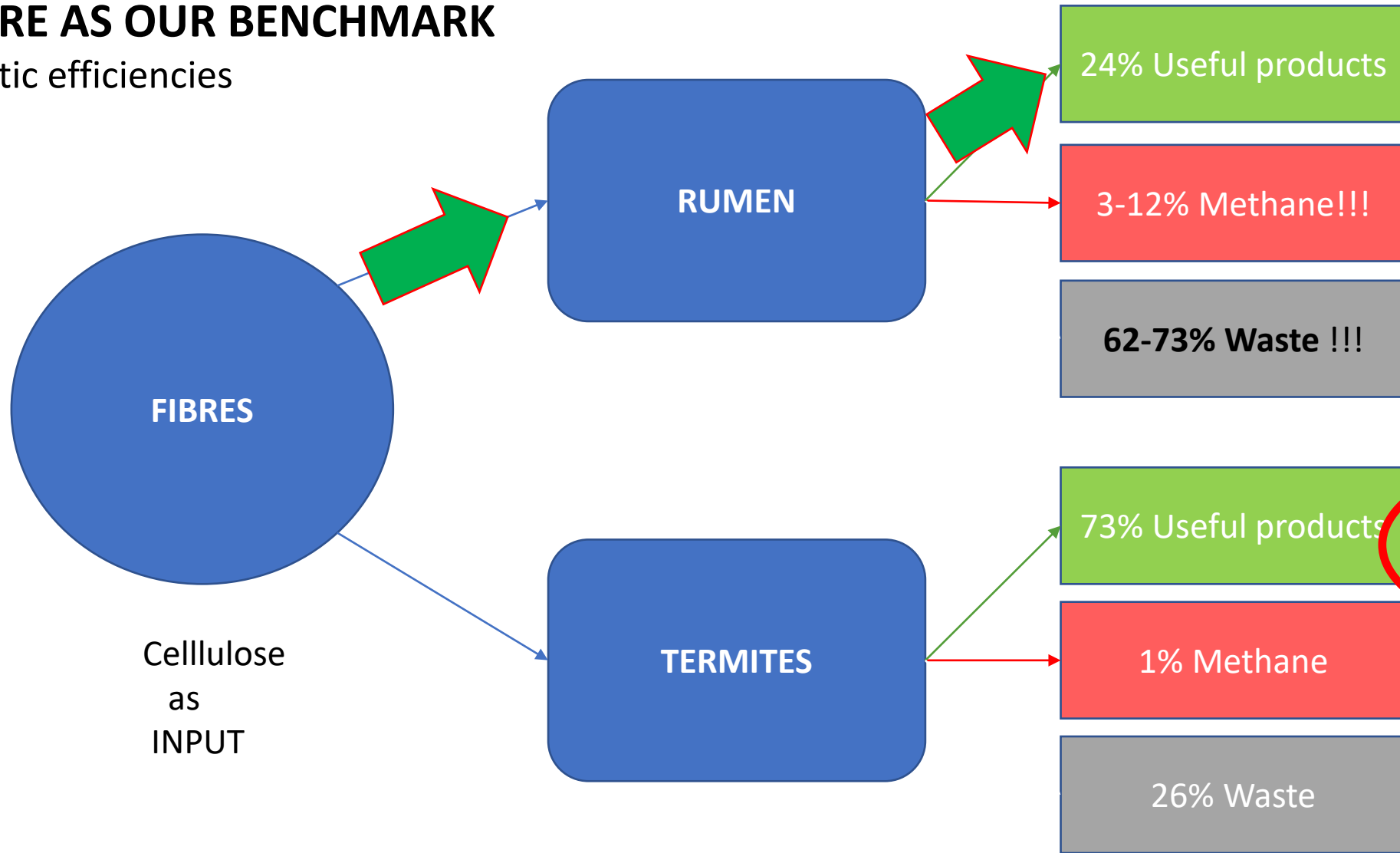
BIOMETHANE





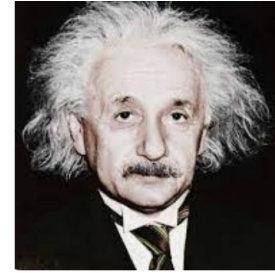
# NATURE AS OUR BENCHMARK

Energetic efficiencies



Can we construct a biorefinery of this type ?

# NEW & NOVEL



- Graslands + biorefinery

Go for robust and sustainable systems

+ **Ferment cellulose to food !!**



- Novel proteins :

Why not implementing Biological Nitrogen Fixation

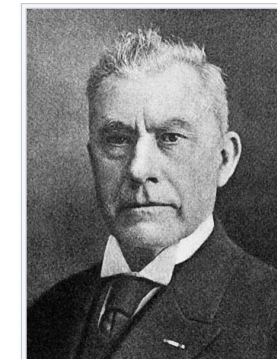
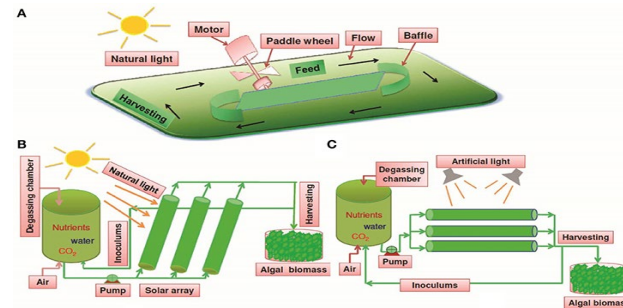


# Biologically Fixed Nitrogen

- Legumes / Soya in Europe : Now promoted as magic in Flanders !!!!
- Spirulina etc : Why not ?
- Fiber and free-living N-fixing bacteria – my chouchou



vib.be - Soja in Vlaanderen



Martinus Beijerinck (1851–1931), discoverer of the genus *Azotobacter*

Note: Orthodox vegetarians should go for bio-N based protein !!!

# Biologically Nitrogen Fixation (BNF)

Be aware , nitrogen fixation comes always at a cost !!!

It takes 2,0 L of fossil fuel equivalent per kg N in Haber Bosch

It takes 20 kg carbohydrate per kg N in root nodule-rhizobia  
( N-fixing soya = minus  $75 \times 20 = 1500$  kg carb equivalent per ha )

It takes 50 kg carbohydrate per kg N in free living aerobic bacteria

Yet , the carbs are 'renewable'

# Overview

- The past: Our personal experiences in Resource Recycling /Feed-Food
- The present: The 'GREEN DEAL'
- The future: The need for education/communication

Upgrading from secondary resources should follow paths in which the consumer has **confidence**:

- a) The involvement of **heat** / fire (CHP, ashes,..)
  
- b) Transition into a **gas phase** (methane, CO<sub>2</sub>, NH<sub>3</sub>, ...)
  
- c) **Change in outlook** (mushroom on horse manure, plants on soil fertilized with feces, ...)



**GO WITH THE CURRENT !!**



# Paris , Microbes and Sustainability

By making microbial protein in reactors , 6% of all land surface now used under intensive agriculture can be 'returned to nature' . This is the total amount land used for agriculture in China (Pikaar *et al.* 2018)

PROPAGATE THE GOOD NEWS



# THE USER / THE REGULATOR

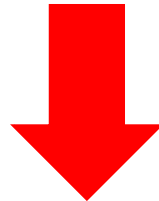
- The illiteracy of the public :

Microbes are generally considered to be a threat:

## Microbio-Phobia

(Timmis *et al.* 2019) We must change this mindset via education

- The regulator tends to demand that every species is documented as if it was a pharmaceutical application / moreover the 'microbiome' should at all instances be constant (EFSA)



Teach / Communicate / Interact !!! with the public & EFSA



# Conclusions on Feed & Food for the Future

With respect to the Paris agreements and the current planetary Climate Issues **Microbial Biotech** has a constantly increasing role to play

We must dare to speak out and take leadership on issues in relation to

- The climate issues ( the N<sub>2</sub>O issue of feed and food proteins )
- The fossil fuel resp bio-based nitrogen fertilizers
- The CH<sub>4</sub> issue of the current plant fiber route



# Conclusions on Feed & Food for the Future

- When dealing with feed and food, the messages of thinkers such as Belasco, Suzman and Attenborough have to be taken serious

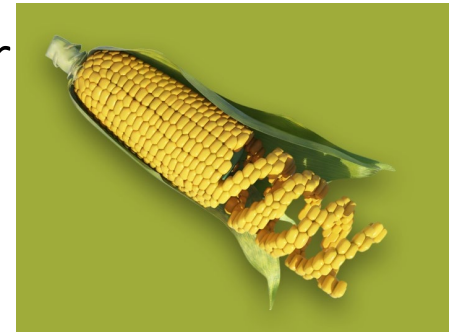
\*There are conservative and progressive consumers / it takes time to convince

“ Go for more simple & strong agro-food -systems “

“Make more land available for ‘ecosystems ‘ and their services

# Conclusions on Feed & Food for the Future

There is a mismatch between the regulator and the innovator  
Twenty years ago , only in the EU : the GMO's got a total  
NO GO!?



Today : the Sustainable Development Goals can not be  
reached  
without the use of clever and efficient 'microbiomes



The current EU regulatory system is hindering progress /  
the EU should think and operate more positively  
about GMO's and also about Microbiomes



# Conclusions on Feed & Food for the Future

The **protein shift**, as part of the NEW DEAL, is a valuable goal.

The way to go is the **FIBER BASED BIOREFINERY** with

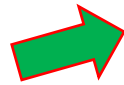
reliable **MICROBIOME BASED FERMENTATIONS**



We all have our 'HOLY GRAIL'



# THIS IS MINE :



PLANT FIBER  
grown  
with BNI and  
possibly with BNF

NOVEL MICROBIOME BASED UPGRADING

VALUABLE FOOD



A close-up photograph of a baby with light brown hair and blue eyes, looking slightly to the left with a determined, almost grumpy expression. The baby is wearing a green and white shirt. The background is a blurred outdoor setting, possibly a beach or park. The word "YES" is written in large, bold, white capital letters with a black outline across the top of the baby's forehead.

**YES**

**WE CAN DO IT!**