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# A highly dynamic, self-organized, bio-economy; it's becoming a serious game

Hugo de Vries

► **To cite this version:**

Hugo de Vries. A highly dynamic, self-organized, bio-economy; it's becoming a serious game. BECY Network Meeting 2015, Sep 2015, Hohenheim, Germany. , 2015, Strategies for Knowledge-Driven Developments in the Bioeconomy. hal-01837479

**HAL Id: hal-01837479**

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Submitted on 3 Jun 2020

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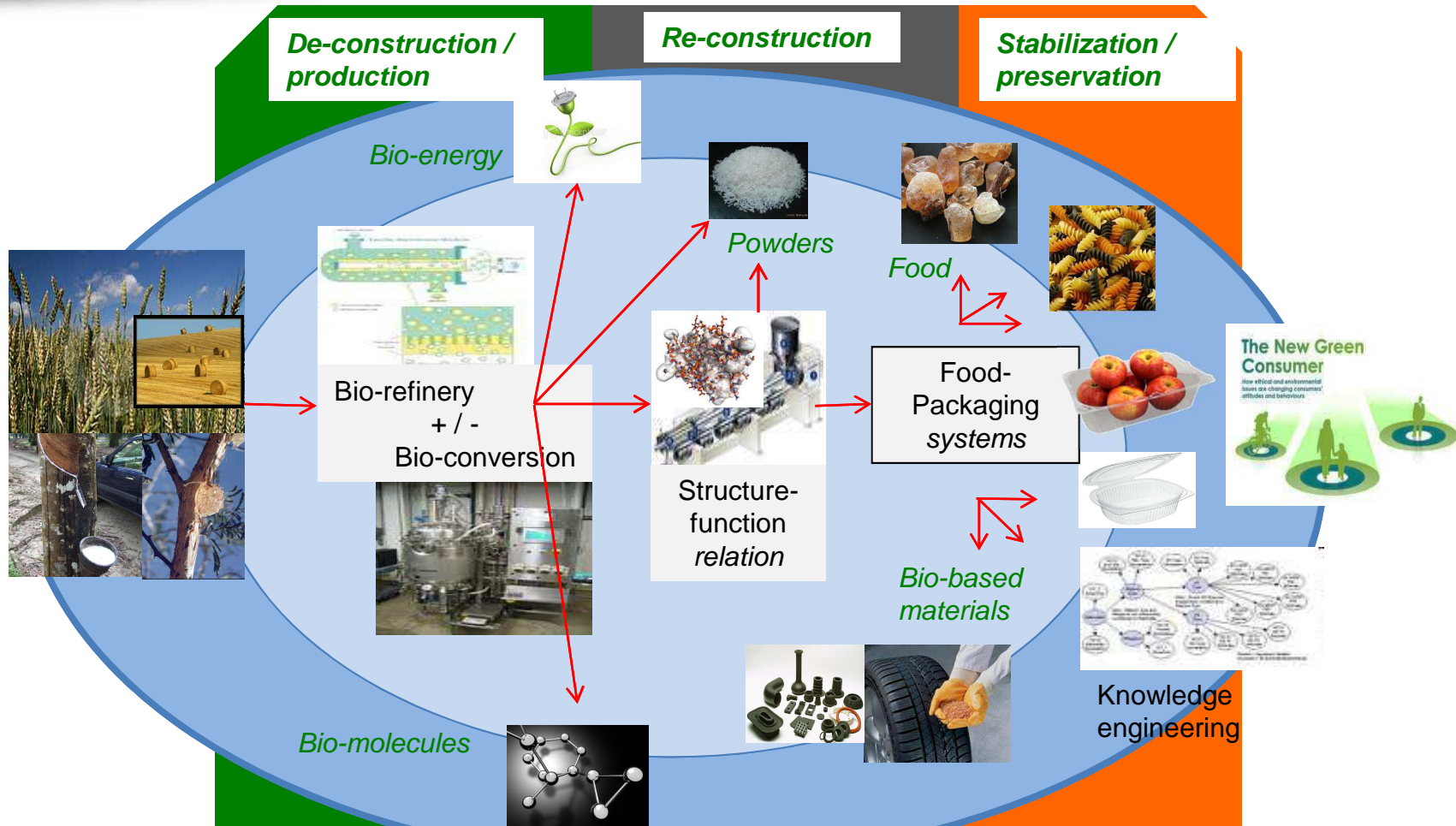
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A highly dynamic, self-organized,  
bio-economy; it's becoming a serious game  
*September 2015, Hohenheim, Bioeconomy seminar*  
*Hugo de Vries, director UMR IATE*



# Where do I come from? The research domain of IATE



**MISSION: integral & well-balanced use of available plant- and microbial resources for food & bio-molecules, bio-materials and bio-fuel**

## Context:

- Viable planet and reduction of fossil fuels

>>>> transition towards  
a bio-based society

- Food security: the rich versus the poor  
AND the food versus fuel 'battle'

>>>> transition to a fair, ethical and well-  
balanced society

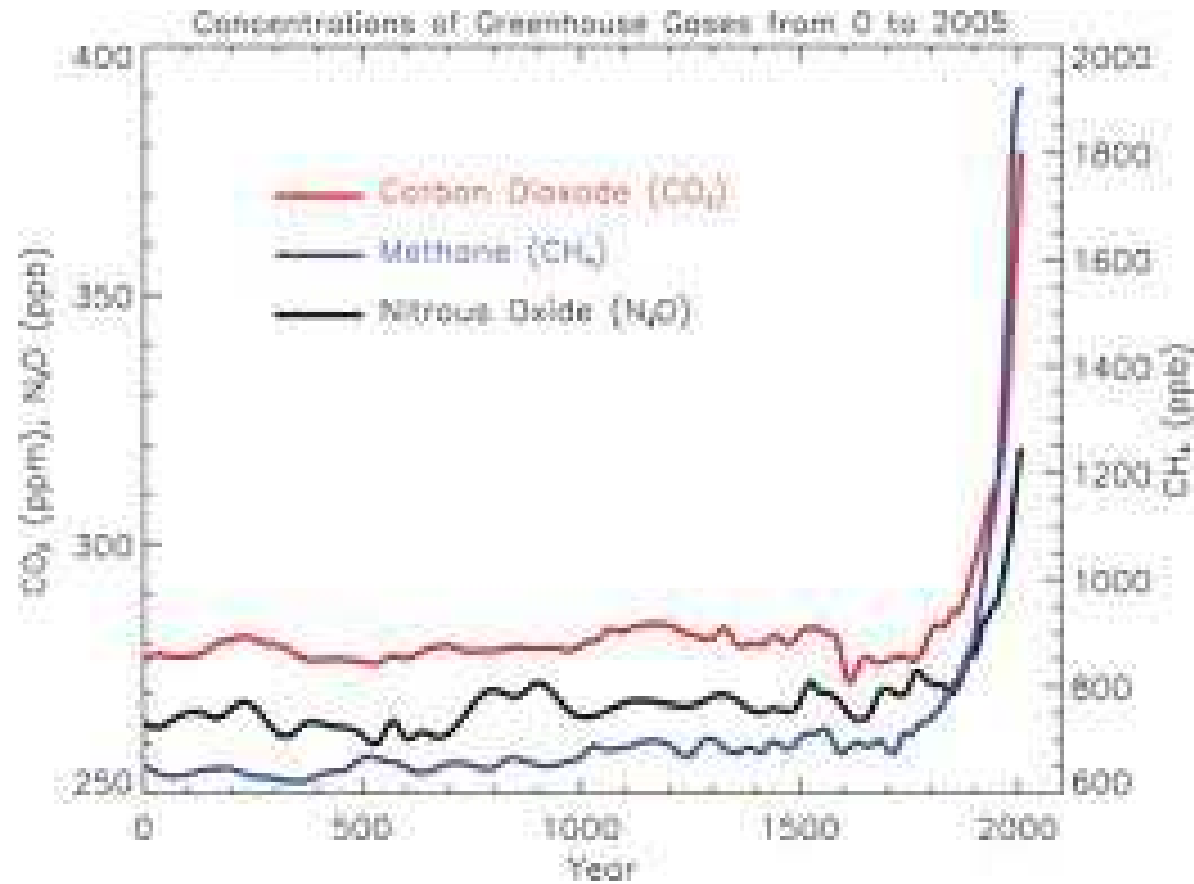
*It is becoming a serious game*



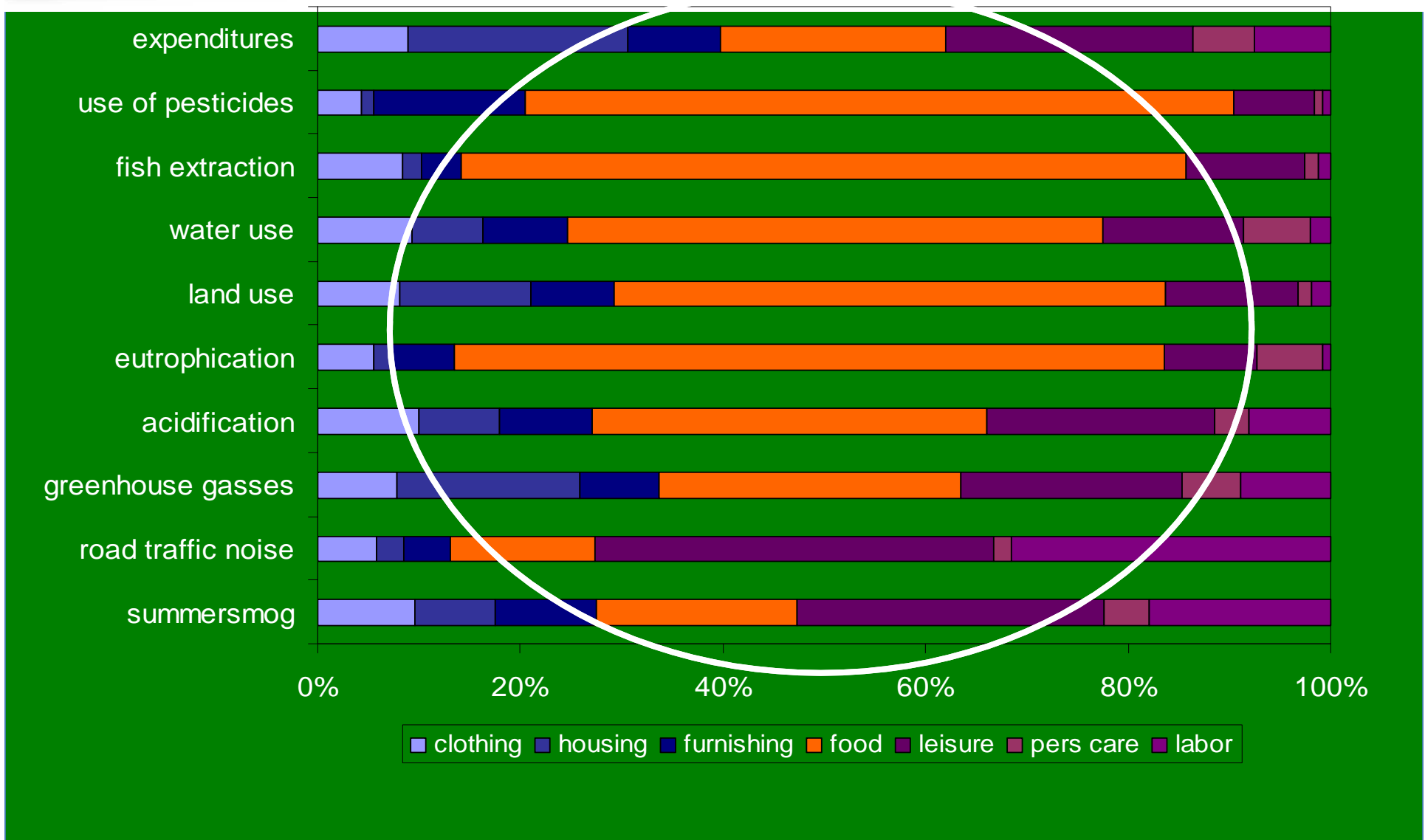
Status

What is the current  
status?

# What is the current status?



# What is the current status?



# What is the current status?



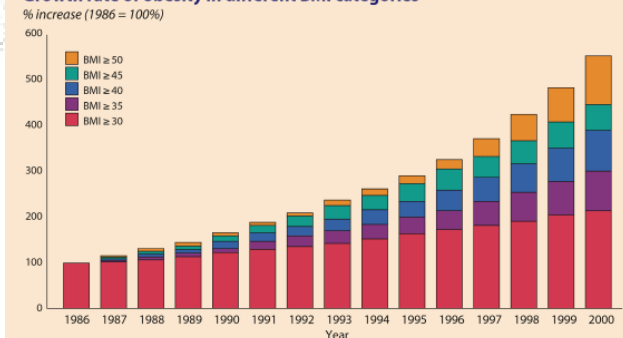


# What is the current status?

## We are facing extremes, that tend to become more extreme



**Growth rate of obesity in different BMI categories**



Source: Sturm R. Increases in clinically severe obesity in the United States, 1986-2000. *Arch Intern Med.* 2003;163:2146-2149.

# What is the current status?

Pays du Sud – Pays – du - Nord

**We are facing extremes**



What is the current status?

**We are facing extremes**



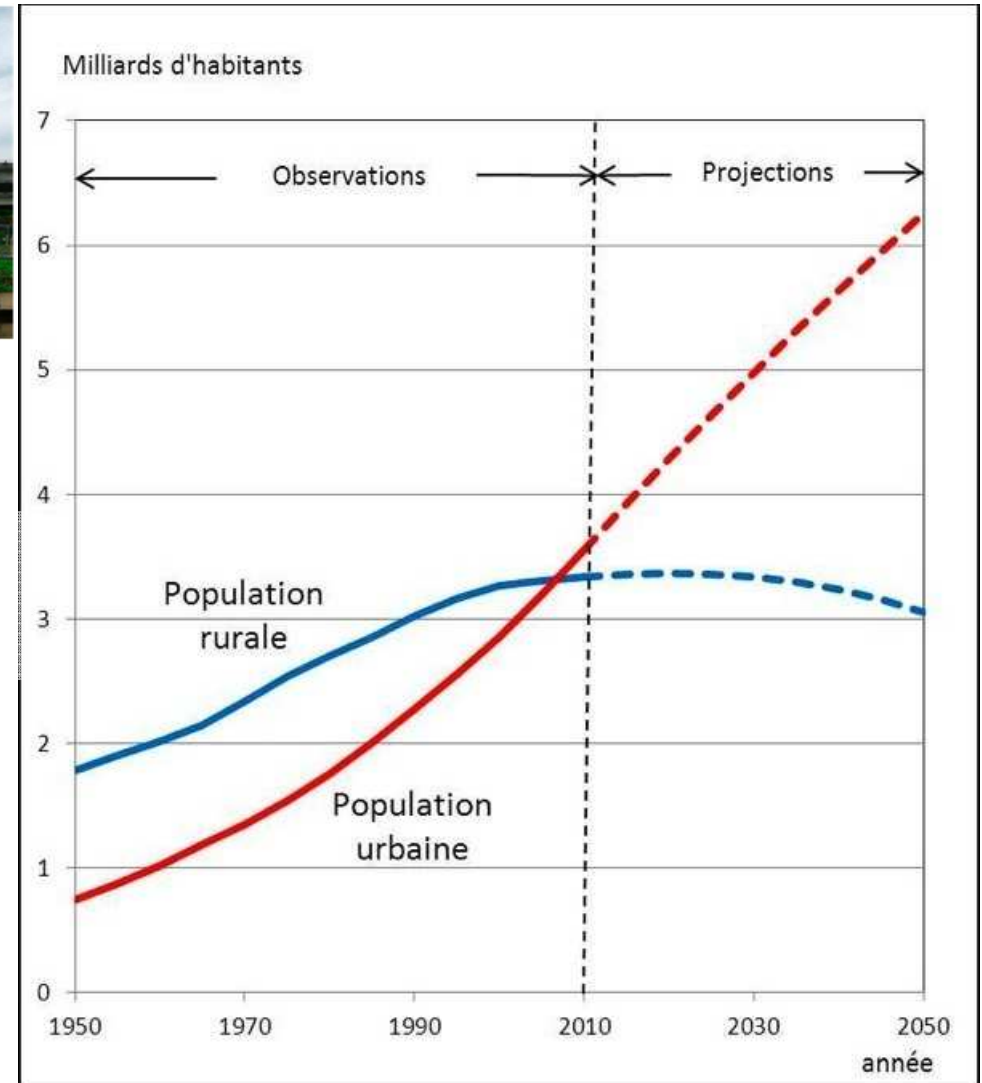
**According to the U.N., a child dies  
from a water-related disease  
every 15 seconds.**



# What is the current status?



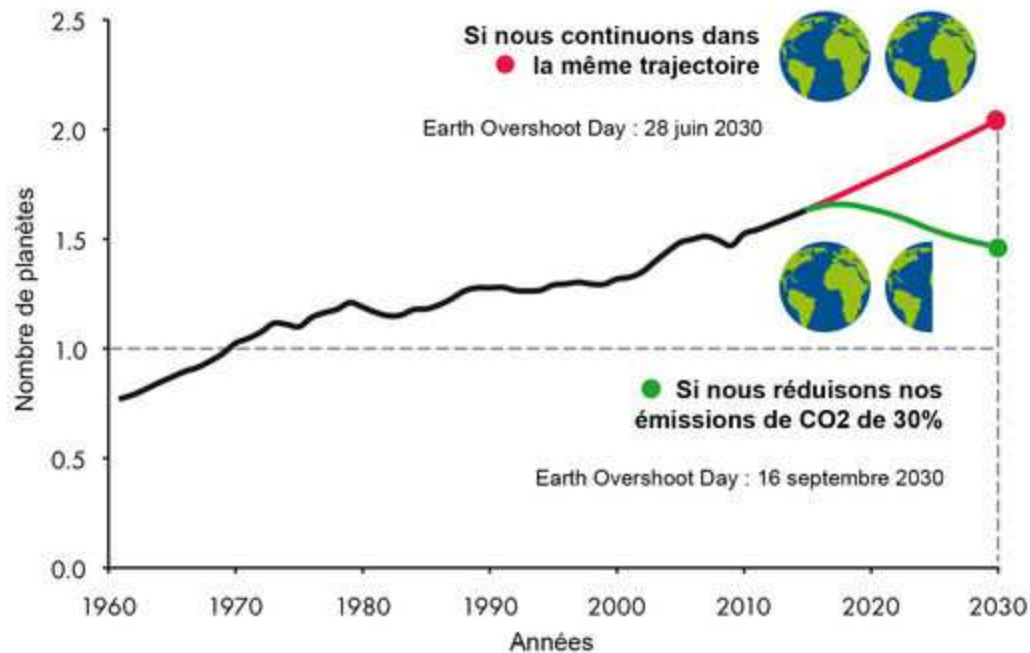
**We are facing extremes**



# These are the consequences Of our way of living

*En moins de huit mois, elle a déjà consommé toutes les ressources naturelles renouvelables que la planète peut produire en un an( Le Monde, 13/08/2015, Global Footprint Network).*

Combien de planètes pour subvenir aux besoins de l'humanité ?



Combien de Chine faut-il pour subvenir aux besoins des Chinois?

CHINE 2.7



Qu'en est-il des autres pays?

FRANCE 1.4



U.S.A 1.9



INDE 2.0



ALLEMAGNE 2.1



GRECE 2.6



G.B. 3.0



EGYPTE 3.2



SUISSE 3.5



ITALIE 3.8



JAPON 5.5



MONDE 1.6

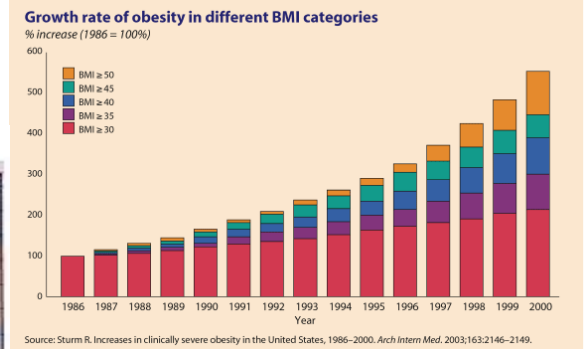
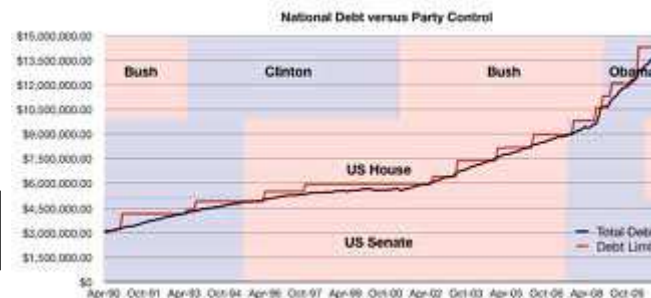
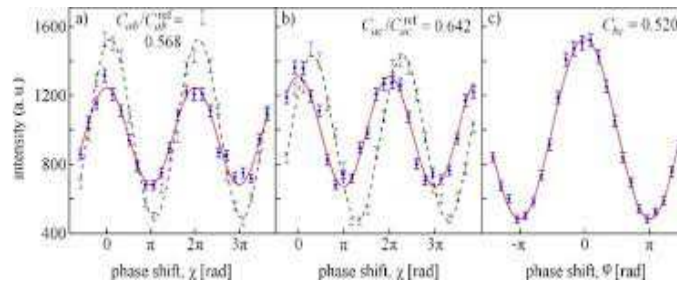
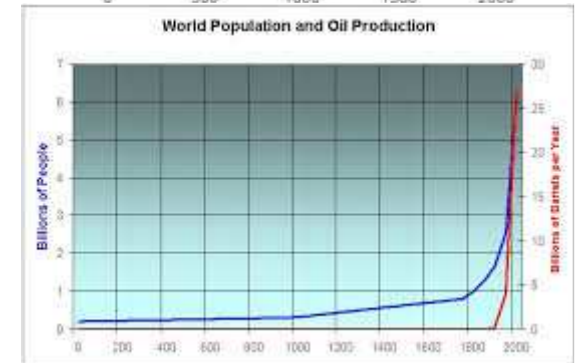
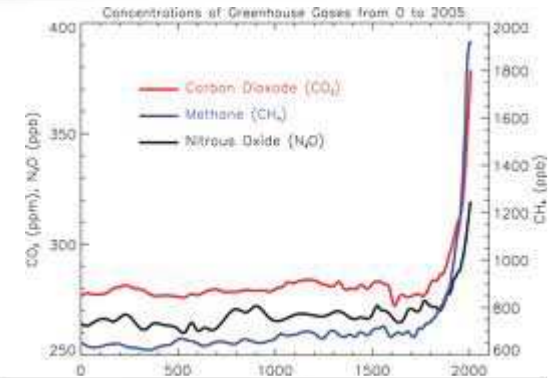


So we can pose the question:  
Where are we currently heading to?

We are currently **extending the expiry date** of our planet.

We are not heading towards a sustainable, circular bio-economy >> better: spiral!

We are not able to take away the uncertainties about a well-balanced society



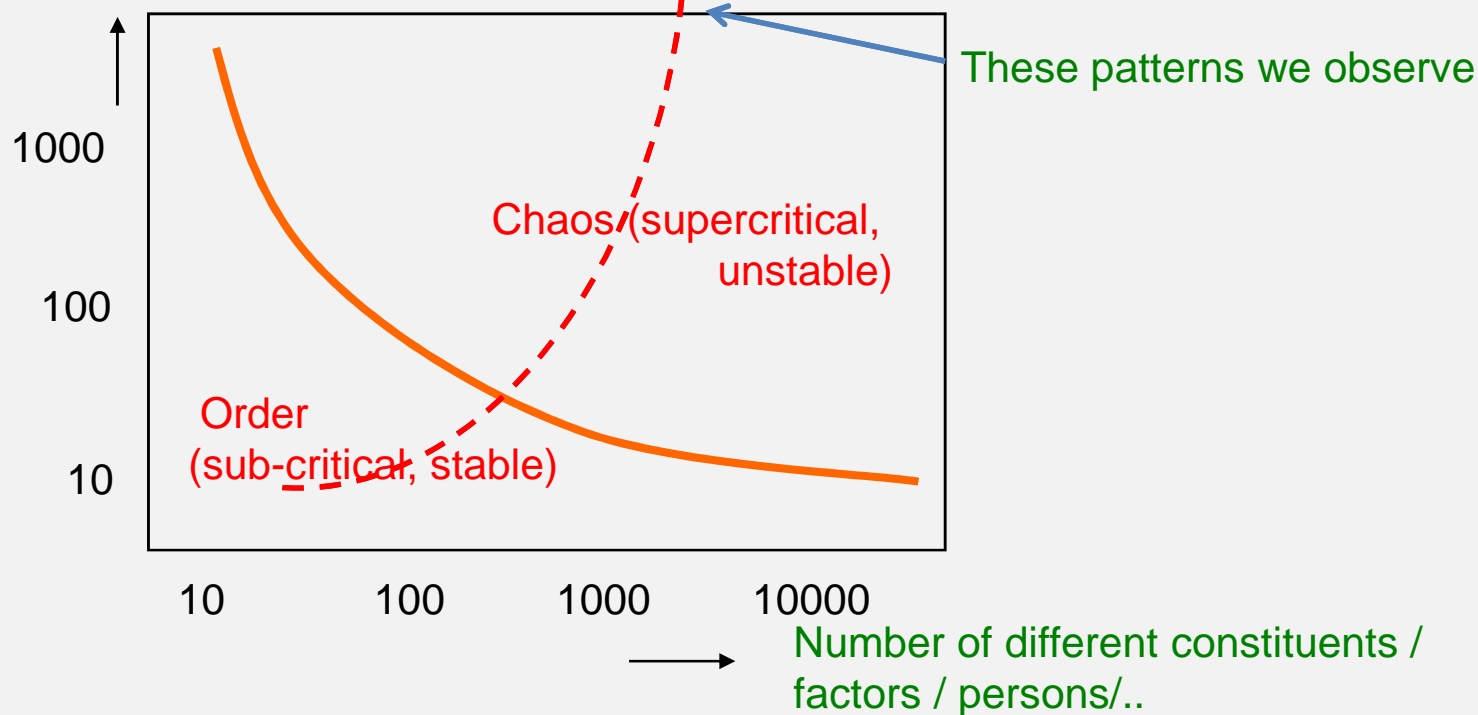
<http://www.worldometers.info/>

Need? Objective? Mission?

From chaotic  
back to  
self-organized, dynamic systems

# We need to get better insights in our complex system(s)

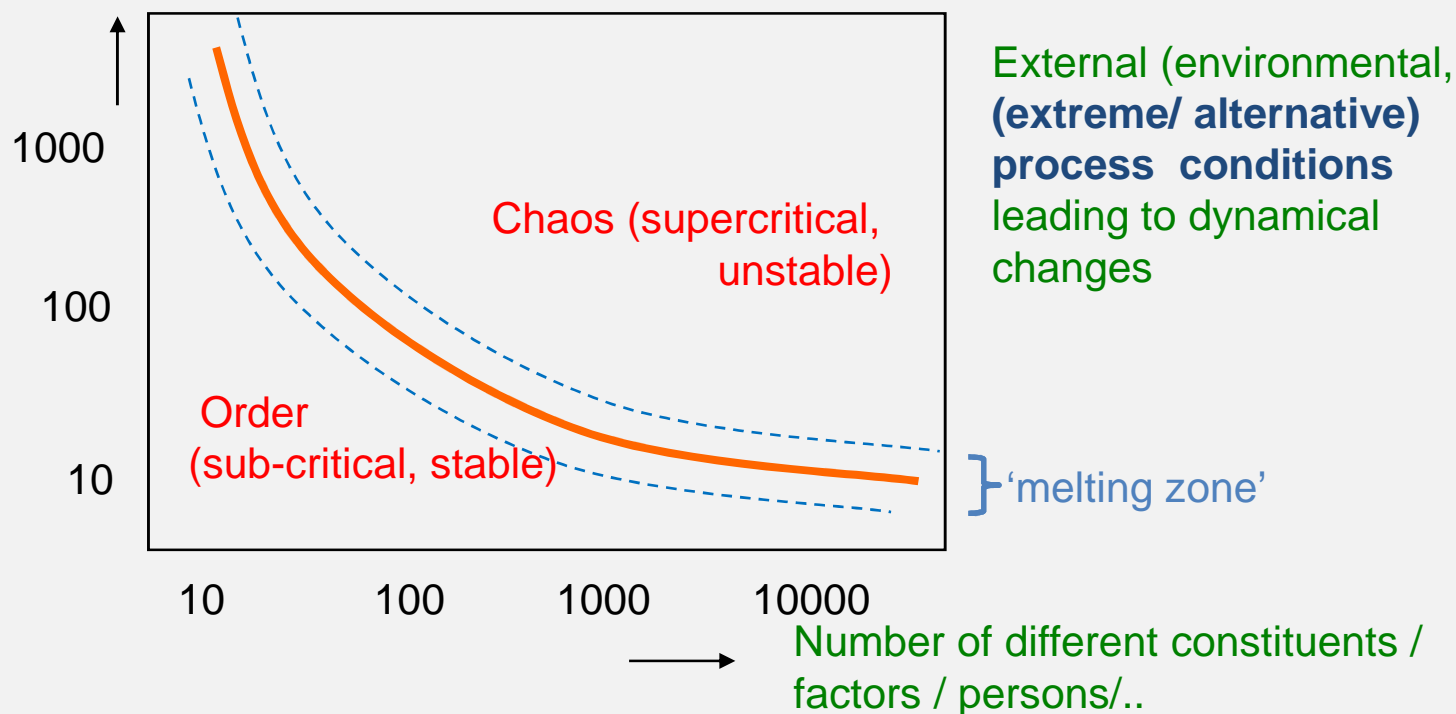
Interactions between (external) constituents (in e.g. biomatter) /factors/..





# We need to get better insights in our complex system(s)

Interactions between (external) constituents (in e.g. biomatter) /factors/..



And in our bio-economy transition?



In a transition towards a bio-based economy

We are dealing with numerous highly complex systems (questions)

# We have to deal with (only some examples given)

- What are the relationships between structure-function-environment in the plant and the bio-based product stages?  
(natural rubber has superior quality as compared to synthetic rubber; after decennia of research no clue!?)
- How to design sustainable ways of utilizing 100% of our resources, including all its (functional) constituents?  
(local, competitive small-scale bio-refinery concepts, ..)
- What new business concepts are needed for that?  
(industrial ecology, agriparks, ..)
- Do we understand the perception of consumers/users?  
(products based on current waste streams, accepted? > a neurophysiological approach needed)
- How to deal with the paradox 'using a sledgehammer/elephant to crack a nut'?  
(our engineering actions are in general at a scale that is 100.000 higher than of the action required (e.g. opening a sulphur bridge in a molecule, or over-dimensioned storage facilities, or cooking with water) > how to understand the impact of changing processing conditions on biomatter)

What to do?

Deepen our insights in the complex systems

*Trying to recognize features of rigid,  
dynamic and chaotic behaviour*

*'Steering' systems to become self-organized  
and dynamic*

*Some examples from functionalization of molecules, towards functional  
fractions, combined fractions (incl co-products), via development of new  
product-structures and diverse products, towards full business parks  
and global systems*

# Functionalizing biomolecules

Reduction of number of modifications and energy use

## SOURCES VÉGÉTALES

Feuilles, fruits, épices...

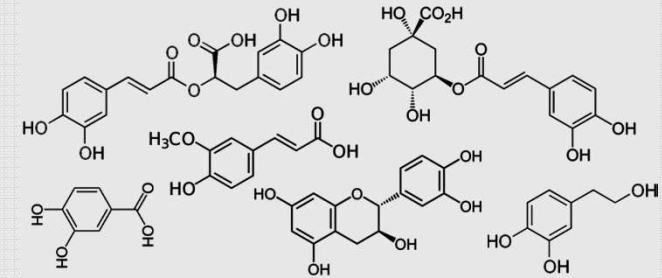


Extraction

Purification

## COMPOSÉS PHÉNOLIQUES

Acides phénoliques, flavonoïdes...



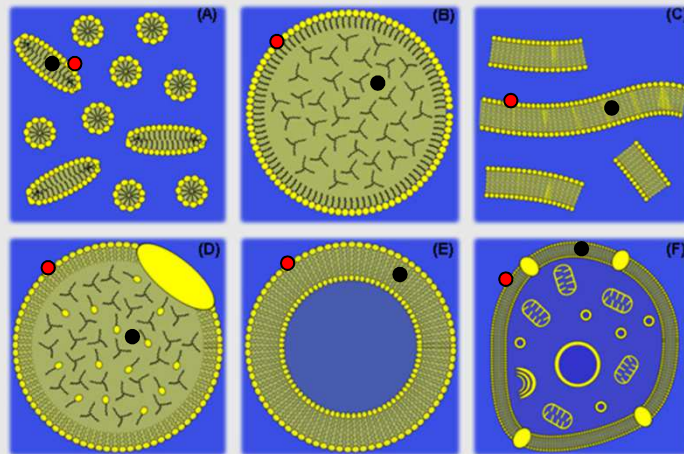
And e.g. enormous sources of galactolipids, nearly not used today

Lipophilisation

Milieu

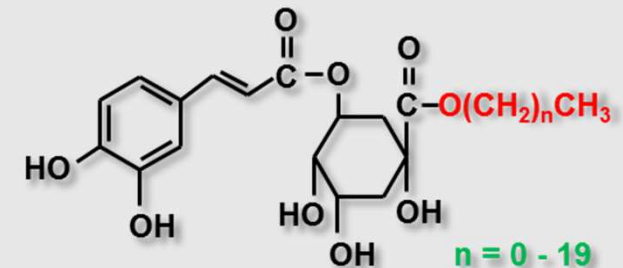
Catalyseur

Synthon  
lipidique



Evaluation  
Structure / Activités

(Aox, antimicrobienne...)



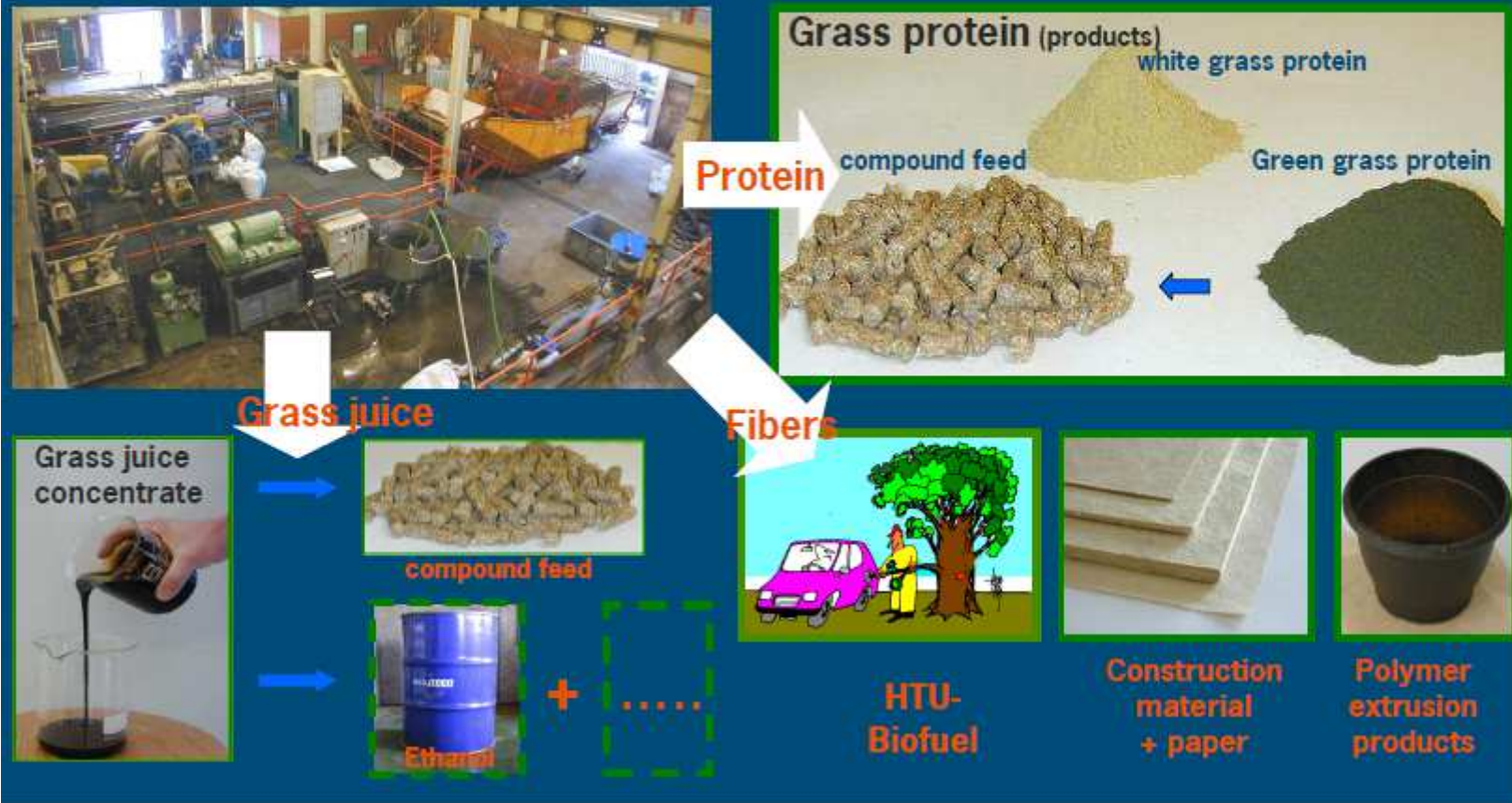
## SYSTEMES D'ETUDE

Emulsions, liposomes, bactéries, cellules

## PHENOLIPIDES

**TOMORROW: grass not only for cows**

**Pilot biorefinery line Foxhol (Groningen)  
(Prograss Consortium)**



# Bio-refinery concept feasible

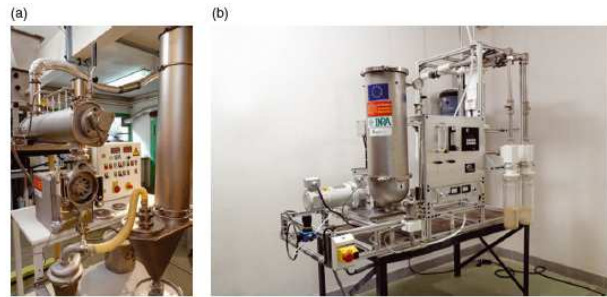


Figure 5. Pilot equipments for cryomilling (a) and electrostatic sorting (b) at INRA-IATE.

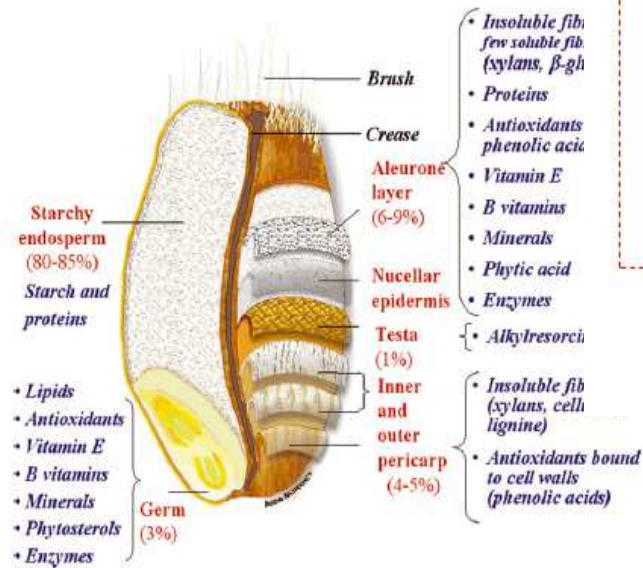
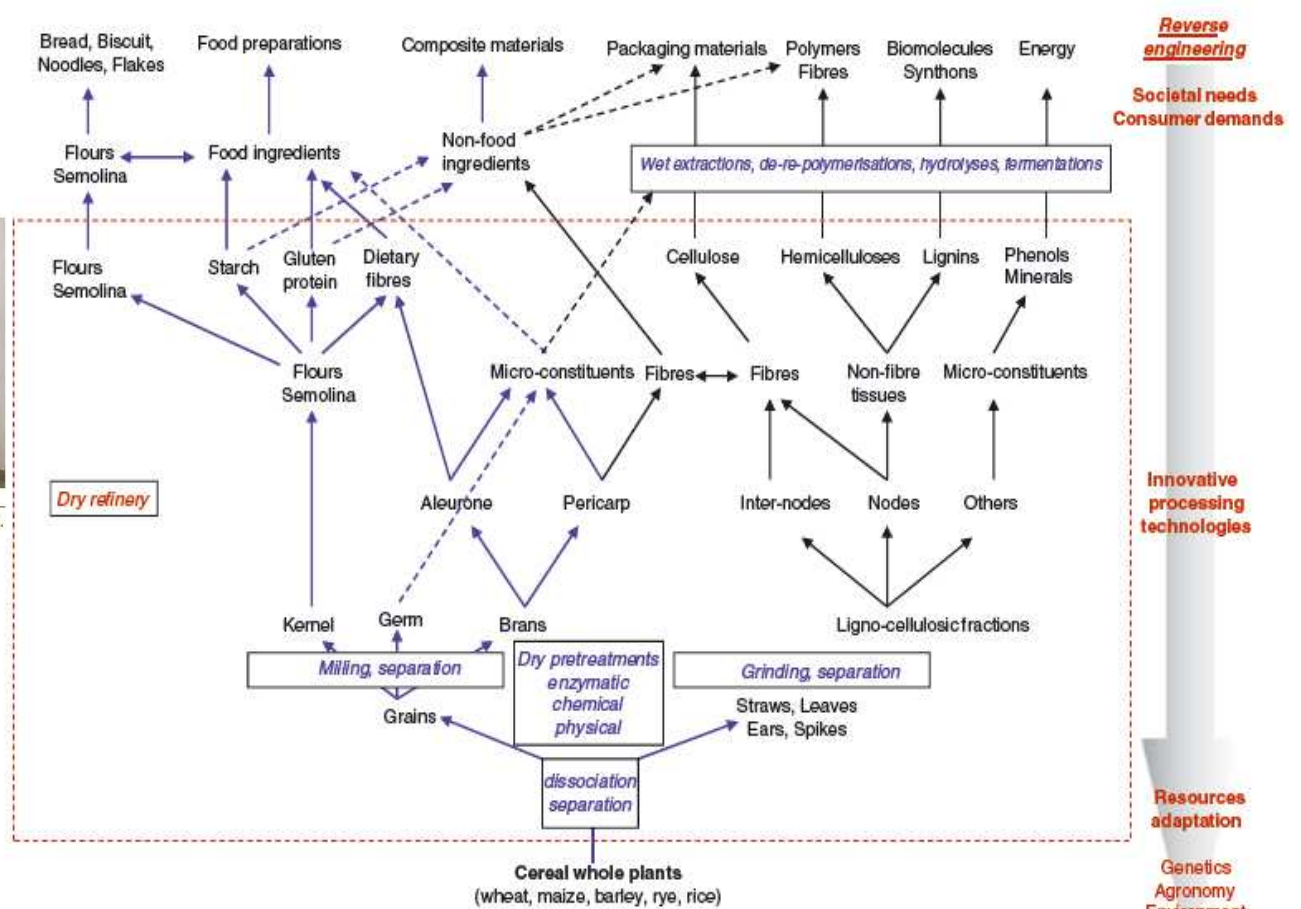


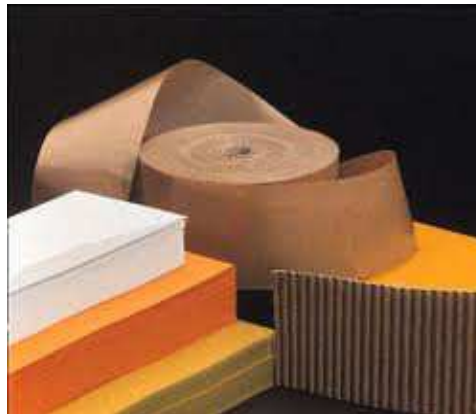
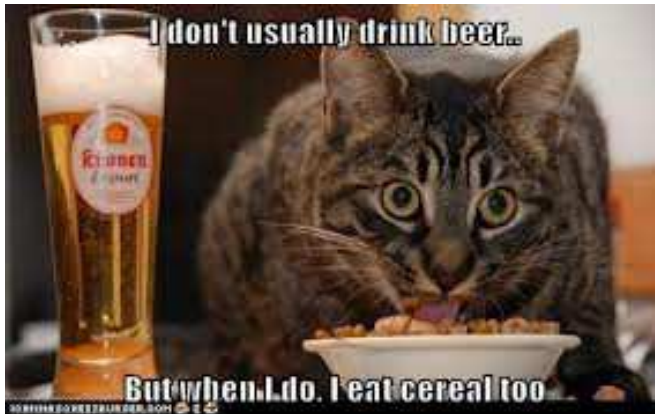
Figure 3. The wheat grain and its components (adapted from Surget & Baron<sup>54</sup> and Hemery *et al.*<sup>55</sup>).



Ref. Abecassis, de Vries, Rouau, 2013, in *Biofuels, bioproducts, biorefinery*

# Bio-refinery: a variety of Cereal Products:

*THINK food and NON-food; reversed chain*

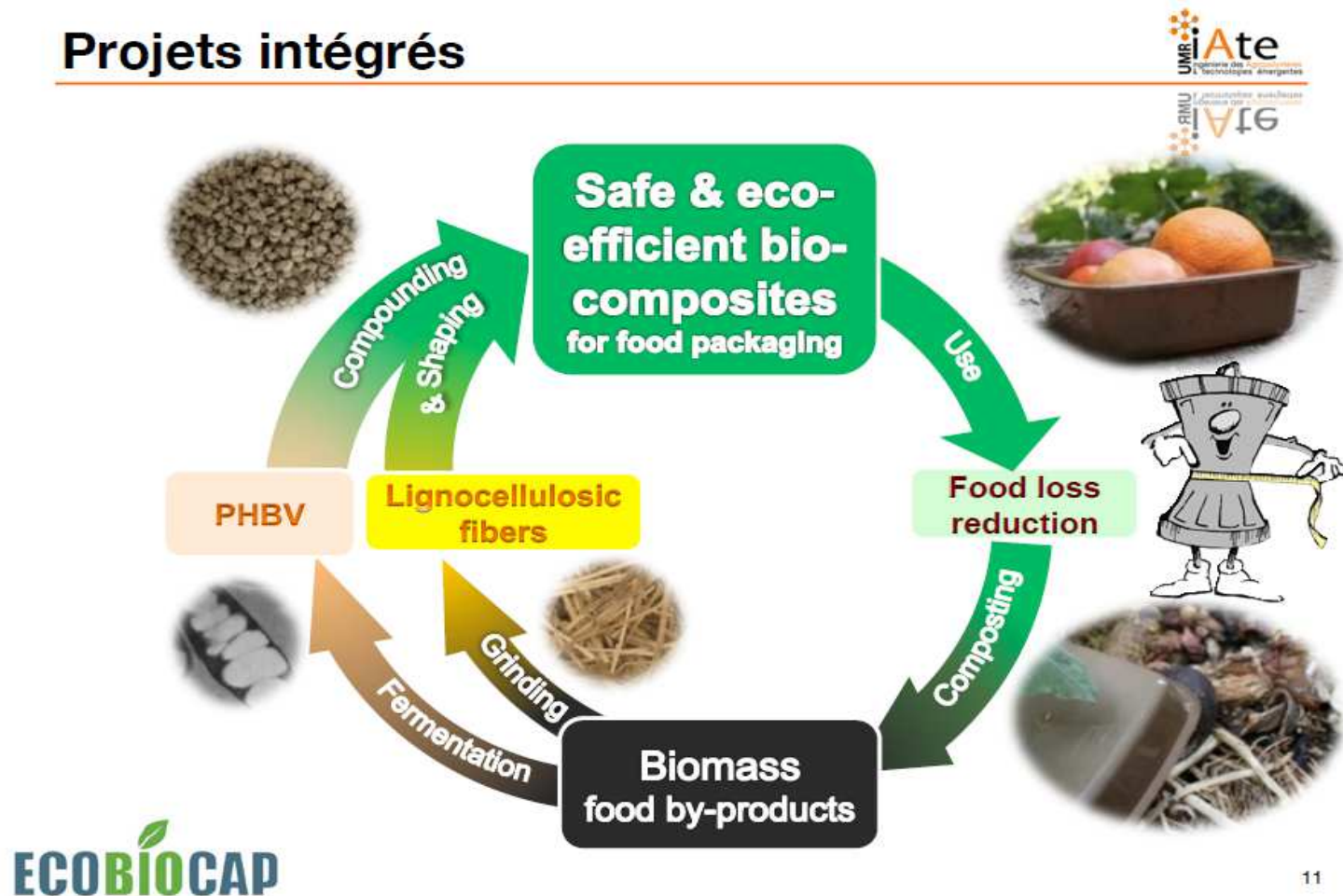




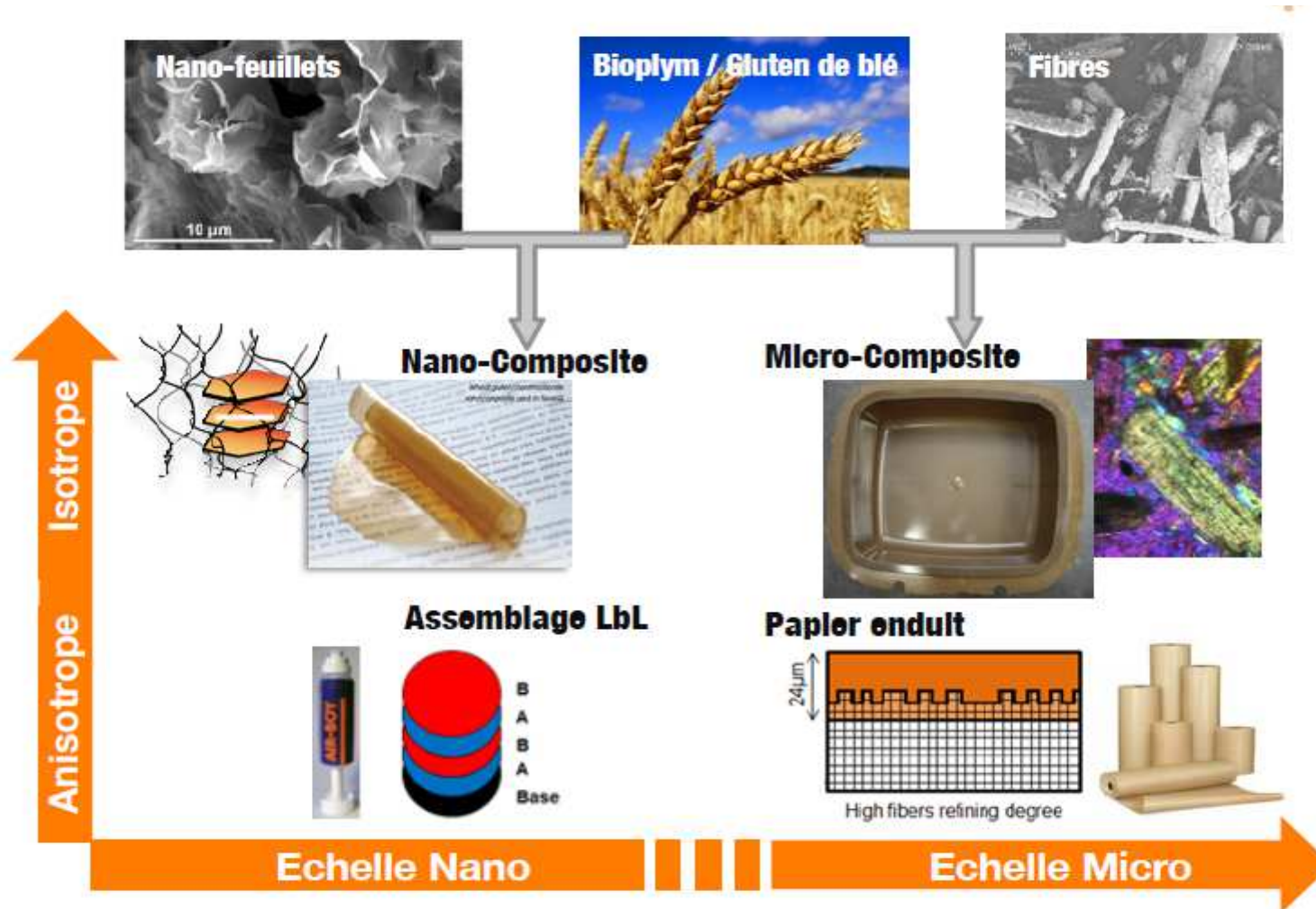
# From functional molecules towards functional fractions and their utilization

EcoBioCAP will provide the EU food industry with **customizable, ecoefficient, biodegradable packaging solutions** with direct benefits both for the environment and EU consumers in terms of food quality and safety.

## Projets intégrés



# Relations structure /transfer



# Alternative resources and products



'meat alternatives on basis of new plant and insect protein sources

> Developing new fibrous foods utilizing new processing tools and process intensification pathways



**>>> here is a real opportunity, also for developing countries?**



# Stabilization of products and Down-scaled novel technologies



## STEW COOKED IN MINUTES THE SUSTAINABLE BREAKTHROUGH IN FOOD PREPARATION

With the Nutri-Pulse® e-Cooker® stew can be prepared in a few minutes, with better retention of the original nutrients and an exquisite taste. e-Cooking® technology is also ideal for preparing other types of meat as well as fish, vegetables and potatoes.

IDL Netherlands B.V. developed this technology which uses Pulsed Electric Field (PEF) to cook food. Stew does not need to simmer for hours, but is instead ready after only a few minutes within the e-Cooker. The origin of the technique lies in research for mild preservation techniques for fruit juices and other liquids, whereby 'cold pasteurisation' with pulsed

electric fields is used to better preserve the flavour, smell, colour and taste of the juice in comparison with traditional heating processes. Govert van Oort, Owner-Manager of IDL Netherlands B.V., wondered whether this technique could also be applied to the preparation of solid foods (uniform heating and controlled) and his idea proved to be a big success.

OMVE NETHERLANDS B.V. IDL Netherlands B.V. is business partner of OMVE Netherlands B.V. OMVE is a leading company specialised in high-quality, small-scale liquid process equipment for laboratory and pilot applications. The advanced processing equipment simulates both existing and new industrial processes at the highest level and a large number of trials can be carried out in less time



necessary to make the car meat and can contain of meat, fish and vegetables chewable, edible and digestible. The disadvantage of this method is that during sustained heating this can cause the loss of some valuable nutrients. The Nutri-Pulse e-Cooker ensures a homogeneous preparation process; this means that no heat is brought from the outside to the inside of the food, but instead the necessary heat is created in the food itself. Electrical pulses pass through the food and cause electroporation of the cells. In combination with pulsed ohmic heating, the food is cooked evenly on the inside and the outside, and prepared very quickly at a relatively low temperature and with low energy usage. The pulse duration, number of pulses and pulse strength can be adjusted very accurately so that the

very low energy usage and treats the raw materials very gently. In addition, it increases the quality of the food by preserving more nutrients, more initial moisture of the product, more smell, colour, structure and taste. The food enables fresh produce to be prepared in a very short time (just a few minutes) and opens up opportunities for the development of new dishes. The preparation process with the Nutri-Pulse e-Cooker is safe (no hot surface) and, because of homogeneous heating, the food is also microbiologically safe to make.

APPLICATIONS Hans Roelofs, Innovation Director at IDL Netherlands B.V., reports that the feasibility study on the use of PEF technology for cooking painted a very positive



'Advantages are low energy usage, nutrient preservation, improved quality, and significant time and space savings'

Innovation  
by Cees Goettsch/Hans Roelofs

picture. IDL has received good comments from the culinary world including from Jonnie Boer from restaurant Librije in Zwolle (NL). With the e-Cooker, IDL has won the 'Cooks Innovation Trophy' in 2011. Together with Top Sport Restaurant and InnoSport-Lab\* Papendal (NL), which has expertise in the field of nutrition and sport, IDL is working on the project 'e-Cooking-Voeding-Sport'. This project examines the possible impact e-Cooking\* can have on the sporting performance of individual athletes. Practical tests are soon to be carried out in the Top Sport Restaurant's open kitchen. Caterers, hospitals and companies in the food industry have already shown an interest in this new technology which, in addition to its benefits such as low energy usage, nutrient preservation, improved quality and time savings, can also deliver significant space savings.

HERE AND NOW IDL Netherlands B.V. develops surprising technological concepts from idea to the market. The company's guiding principle is 'People, Planet, Prosperity'; and it chooses to focus on technologies that add real value to society.

Meanwhile IDL has applied for and received several patents for e-Cooking. Van Oort sees a great future for the technology: "The principle of e-Cooking is in line with all the focal points of the agrifood sector such as sustainable food and energy. Consider the growing world population and the impending food shortage. It is important that whatever people eat contains as many nutrients as possible." Roelofs adds: "e-Cooking can also provide a solution to malnutrition for patients in hospitals and care homes. They will get tastier food, which can be offered at any time thanks to the quick cooking time. Also looking across borders at developing regions, where there is often food available but not enough power to prepare it properly. The Nutri-Pulse e-Cooker uses so little energy that, in the near future, it should become possible to power it with a truck battery."

[www.innovation-xl.com](http://www.innovation-xl.com)

Sustainability >> also in the kitchen?

<http://www.innovation-xl.com/en/nutripulse.html>

# Agri-business parks

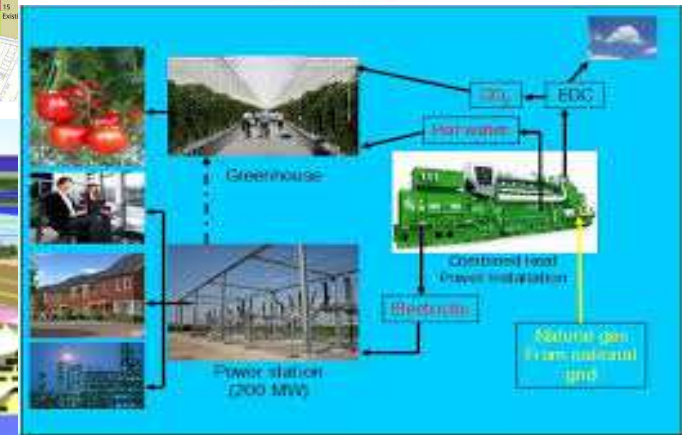
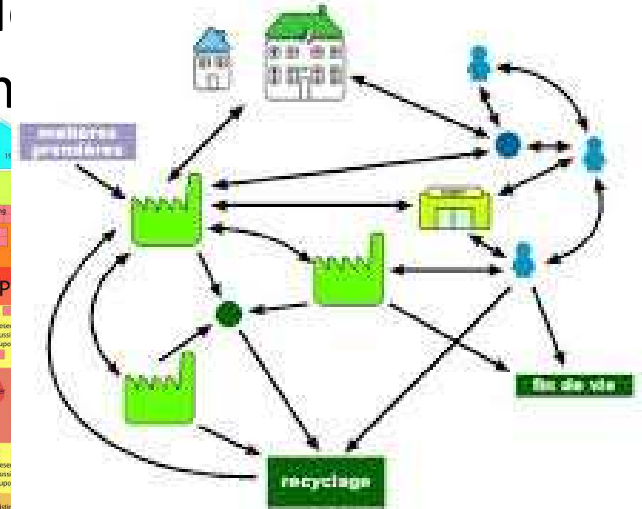
At larger scale, a group/cooperative of a wide SMEs could be competitive in valorizing biomass in the most efficient ways for multiple products

*THUS creating value on site*

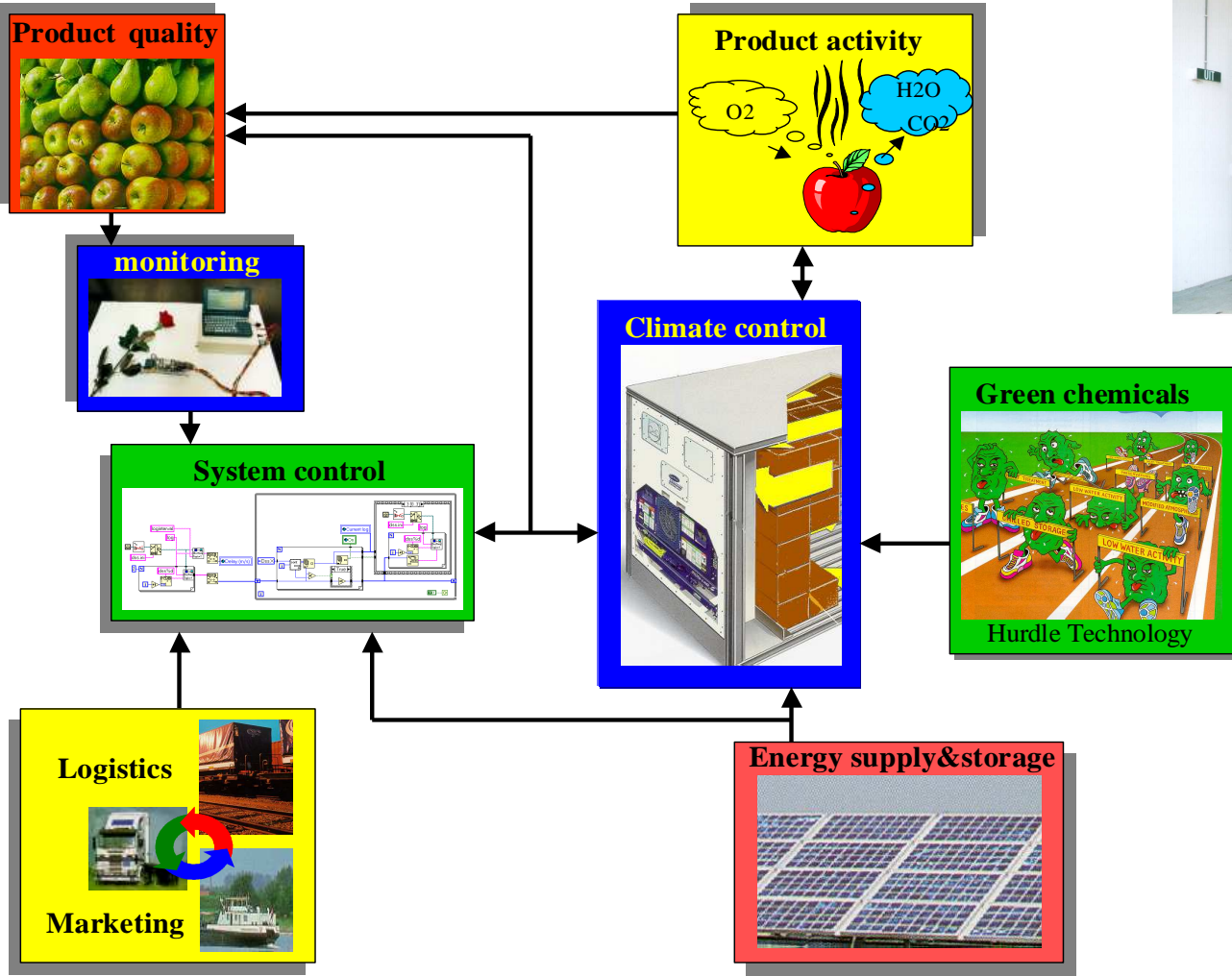
- Greenport concept: profit by integration of agricultural production, processing & trade
- Local/regional clustering of different production chains, to utilize waste, residuals, heat or other streams



Écologie industrielle : de nouveaux flux de matières et de biens



# An energy-zero transport container concept?

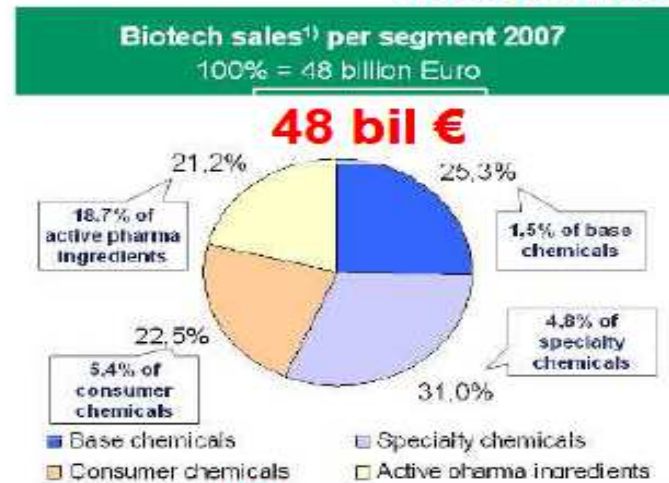


Status

*We have the means to  
better valorize and  
improve our quality of  
life*

# There is a market!

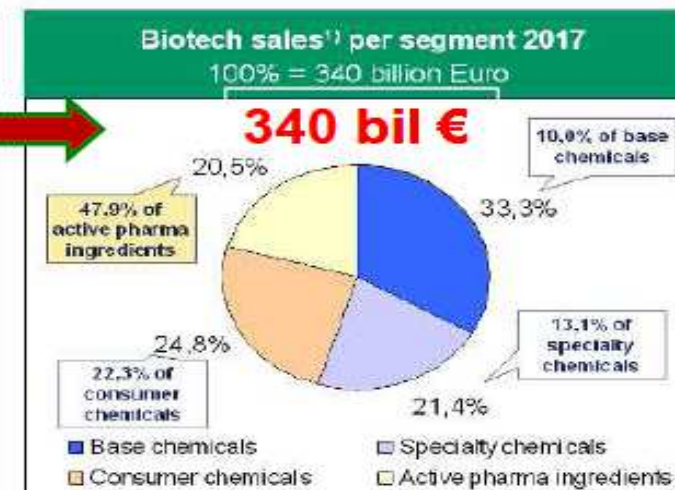
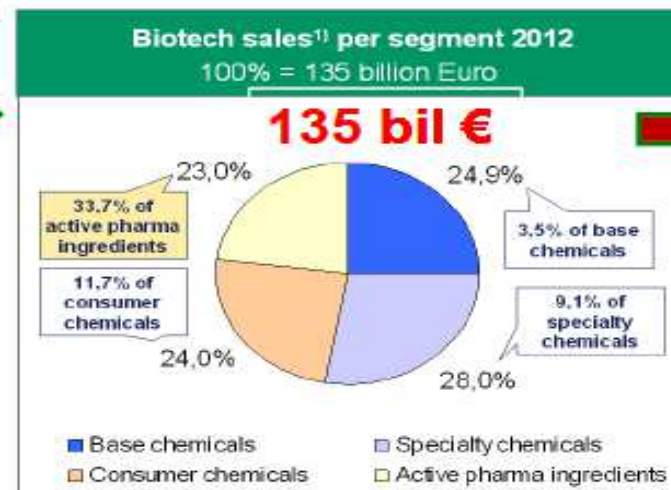
## Improved competitiveness by biowaste feedstocks & bioprocessing



### Sales of biobased products

**2007: 48 bil € (3,5% of total chemical sales)**  
**2012: 135 bil € (7,7% of total chemical sales)**  
**2017: 340 bil € (15,4% of total chemical sales)**

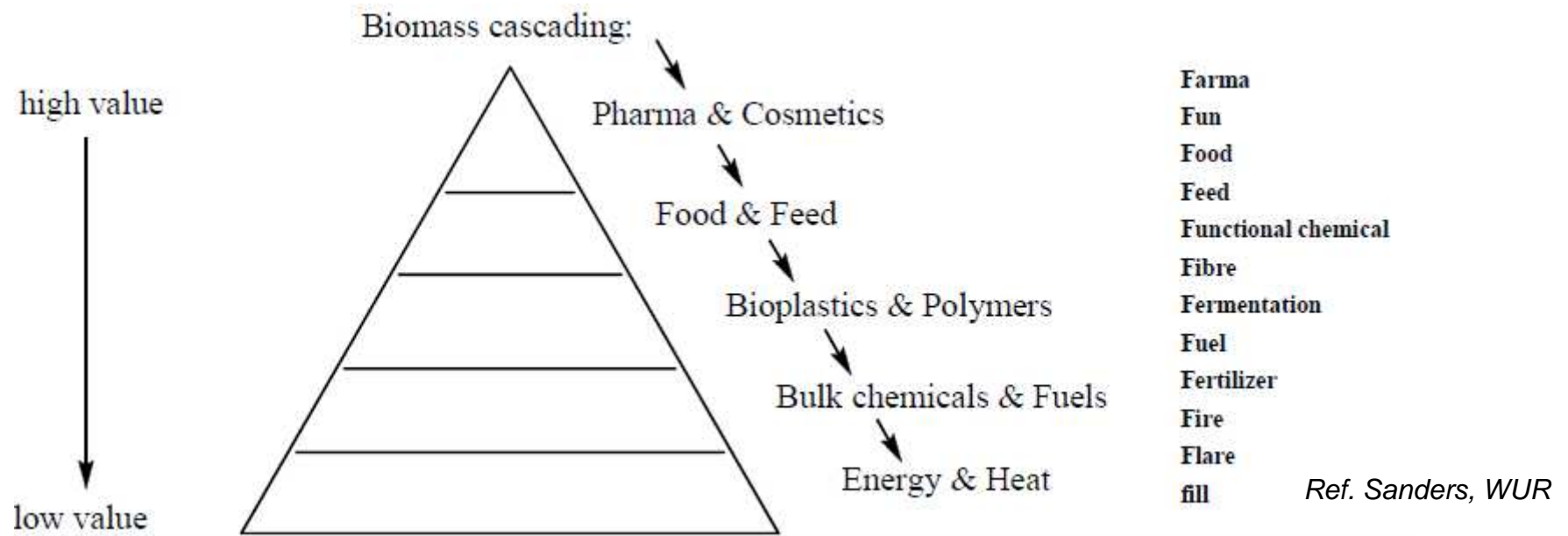
*G. Festel (EFIB 2009, Lisbon, October 2009; OECD workshop, Vienna, January 2010)*






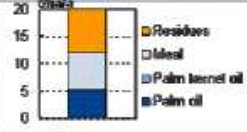

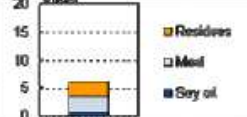

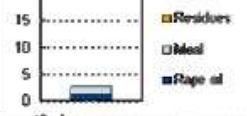

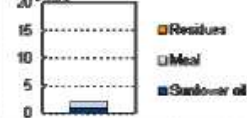
There are multiple,  
combined, options!


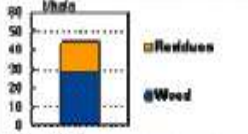

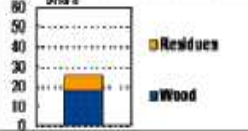
We can make use of the real value of biomass?







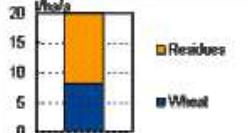

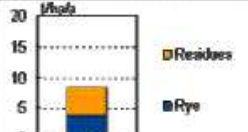

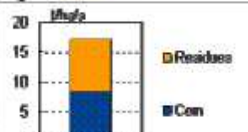

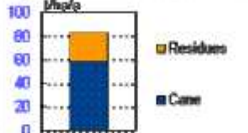

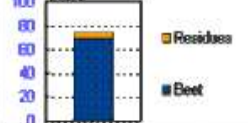
*e.g. lignin is nearly not valorized, proteins in grass idem, brewer spent grains idem, co-products for cereals idem, etc. etc.*

**Only for some we have substantial residues to valorize, for others not!**

| Feedstock   | Crop yield kg/ha/a (fresh) | Oil yield kg/ha/a                    | Meal yield kg/ha/a                         | Residues kg/ha/a   | Fractions  |
|---|----------------------------|--------------------------------------|--|--------------------|--|
|  Palm oil  | Fruit 12000                | Palm oil 5000<br>Palm kernel oil 320 | Palm pulp meal 6000<br>Kernel seedcake 680 | Empty bunches 8000 |  |
|  Soybean   | Seed 3400                  | 800                                  | 2800                                       | 2500               |  |
|  Rapeseed  | Seed 2500                  | 1000                                 | 1500                                       |                    |  |
|  Sunflower | Seed 2000                  | 800                                  | 1200                                       |                    |  |

| Feedstock   | Wood yield kg/ha/a (fresh) | Residues m <sup>3</sup> /ha/a | Chemical composition (of dry matter)  | Fractions   |
|---|----------------------------|-------------------------------|---|---|
|  Eucalyptus ssp. | 14000-28000                | 8300-16400                    | Cellulose 40-60 %<br>Hemicellulose 20-35 %<br>Lignin 15-35 %<br>Extracts 1-20 % |  |
|  Pine ssp.       | 1800-17500                 | 800-7800                      |   |  |

| Feedstock  | Yield kg/ha/a (dry) | Chemical composition (of dry matter)   |
|--|---------------------|--|
|  Microalgae (open pond)             | 1000-3000           | Protein 6-79 %<br>Carbohydrates 4-64%<br>Lipids 1-40 %<br>Nucleic acid 1-6 % |
|  Microalgae (open photobioreactors) | 5000-6000           |  |
|  Macroalgae                         | 45000               |  |

| Feedstock  | Crop yield kg/ha/a (fresh) | Residues kg/ha/a   | Fractions   |
|--|----------------------------|--|---|
|  Wheat        | 8000                       | 11800  |    |
|  Rye         | 3800                       | 4400   |   |
|  Corn       | 8160                       | 8700<br>Type Stalk MC Share d.w.<br>Leaf 70-75 50<br>Cob 20-25 20<br>Husk 50-55 20<br>45-50 10 |  |
|  Sugar cane | 58000-88000                | 24000-37000  |  |
|  Sugar beet | 69300                      | 4700   |  |

Source: Pöyry

# Of course we need to take into account the overall PPP impact!

Figure 15. Impacts of bio-based vs fossil-based value chains

+ Positive impact  
- Negative impact or risk

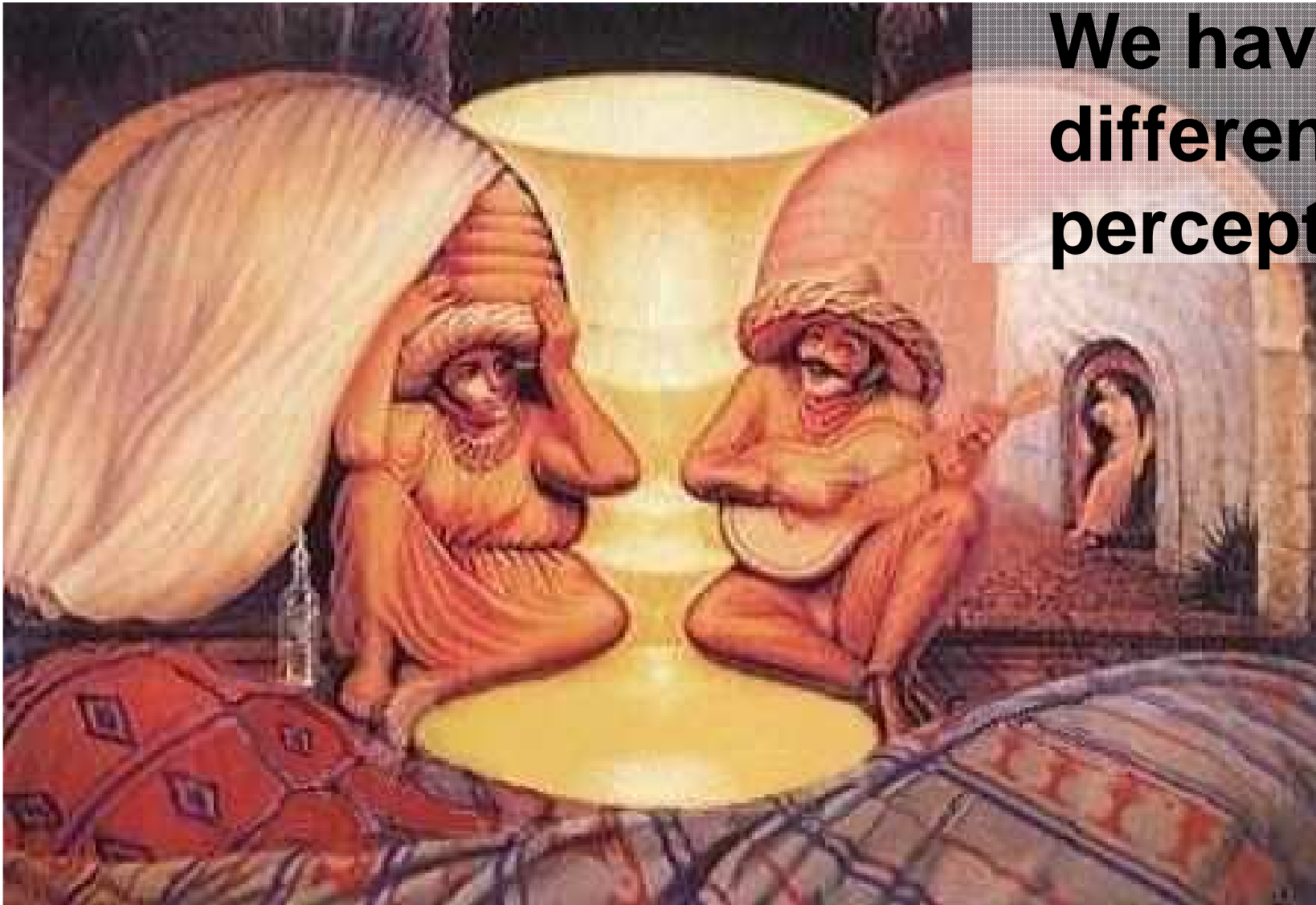
|                       | Raw material sourcing  | Chemical production  | Product use and end-of-life options  |
|-----------------------|--|--|--|
| Environmental effects | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> No hazards in raw material sourcing</li> <li><span style="color: red;">+</span> Decrease in the consumption of non-renewable resources</li> <li><span style="color: red;">+</span> Reduction in biomass-related waste</li> <li><span style="color: blue;">-</span> Risk of eutrophication due to use of fertilizers and plant protection products (not applicable to by-product streams)</li> <li><span style="color: blue;">-</span> Potential contribution of imported biomass to biodiversity losses</li> </ul> | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Reduction in non-renewable energy consumption</li> <li><span style="color: red;">+</span> Reduction in GHG emissions</li> <li><span style="color: red;">+</span> Modernisation of process technology and energy concepts</li> <li><span style="color: blue;">-</span> Increase in water consumption</li> <li><span style="color: blue;">-</span> Increase in particulate emissions from feedstock preparation</li> </ul> | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Less toxic waste</li> <li><span style="color: red;">+</span> Less GHG emissions from waste incineration</li> <li><span style="color: red;">+</span> Biodegradability offers opportunities for composting</li> <li><span style="color: red;">+</span> Recycling possibilities of biobased products</li> </ul>   |
| Social effects        | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Contribution to rural development</li> <li><span style="color: blue;">-</span> Risk of involvement in the GMO controversy</li> <li><span style="color: blue;">-</span> Potential contribution of imported biomass to food insecurity</li> </ul>  | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Contribution to rural development</li> <li><span style="color: red;">+</span> Increasing sustainability and greening of chemical industry image</li> <li><span style="color: red;">+</span> Reduction in VOC emissions improves workforce health and safety</li> <li><span style="color: blue;">-</span> Risk of involvement in the GMO controversy</li> </ul>   | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Decrease in human toxicity</li> <li><span style="color: red;">+</span> Contribution to sustainable development</li> <li><span style="color: blue;">-</span> Risk of involvement in the GMO controversy</li> </ul>  |
| Economic effects      | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Utilisation of wastes and by-product streams</li> <li><span style="color: red;">+</span> Contribution to rural development</li> <li><span style="color: blue;">-</span> Competitiveness of raw materials compared to fossil fuels; possible need for subsidies</li> <li><span style="color: blue;">-</span> Need to develop the logistics of raw material sourcing</li> </ul>  | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Contribution to innovations and European competitiveness</li> <li><span style="color: red;">+</span> Creation of jobs and maintaining production in Europe</li> <li><span style="color: red;">+</span> In some products, savings in production costs</li> <li><span style="color: blue;">-</span> Investment costs</li> <li><span style="color: blue;">-</span> Risks of up-scaling</li> </ul>                           | <ul style="list-style-type: none"> <li><span style="color: red;">+</span> Possible green premiums</li> <li><span style="color: red;">+</span> Market entry in environmentally sensitive markets</li> <li><span style="color: red;">+</span> Reacting on increasing consumer awareness</li> <li><span style="color: red;">+</span> New innovations and products with superior functionality</li> <li><span style="color: red;">+</span> Savings in waste charges</li> </ul> |

And our quality of life!

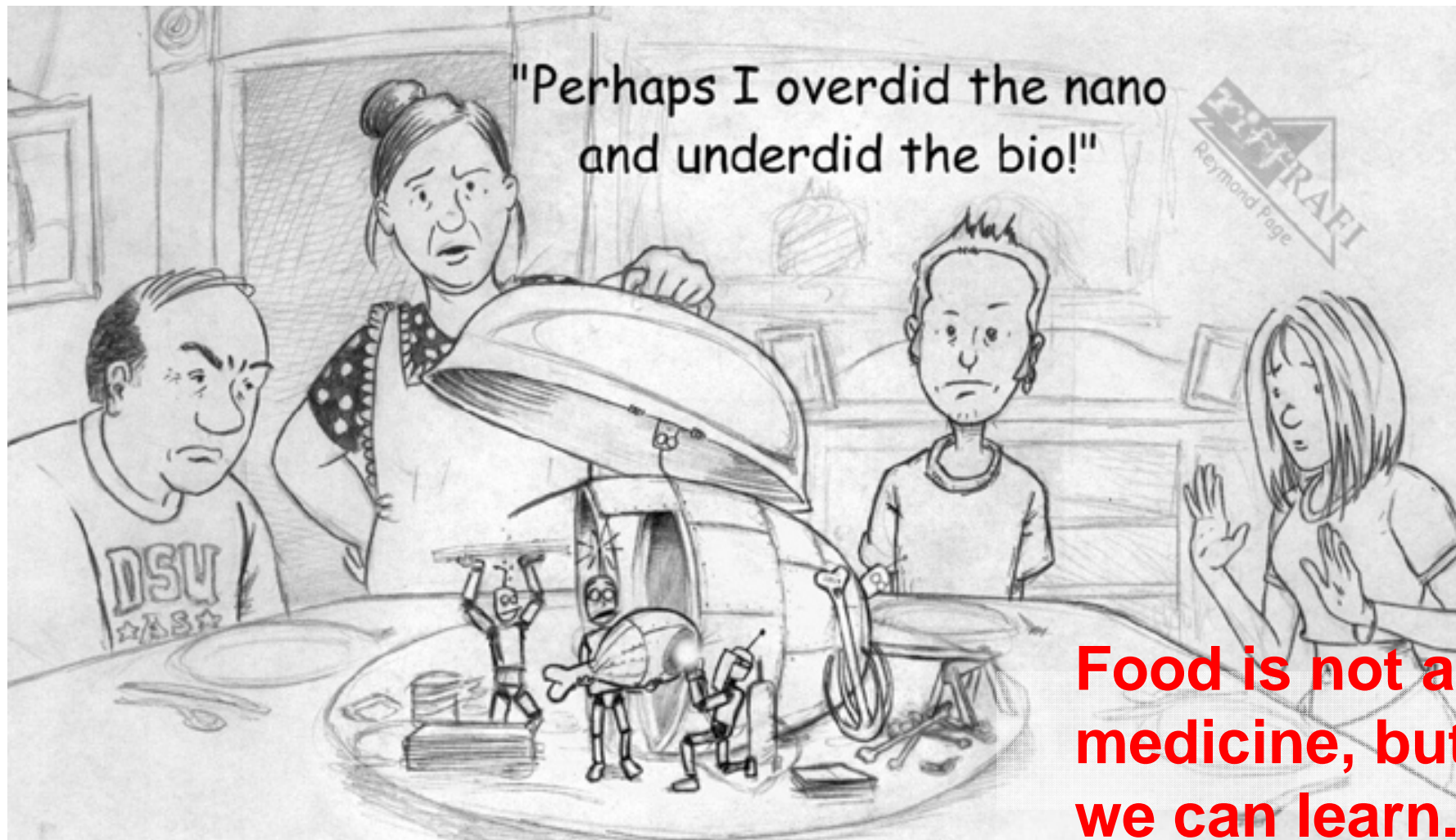


We also need to take  
Into account perceptions:

**We have  
different  
perceptions**



... and dilemmes:



Approach (how?)

Which approaches to reach  
really breakthrough innovations

*(not a factor 10% improvement  
but a factor 10!)*

What are we doing  
*or should do?*



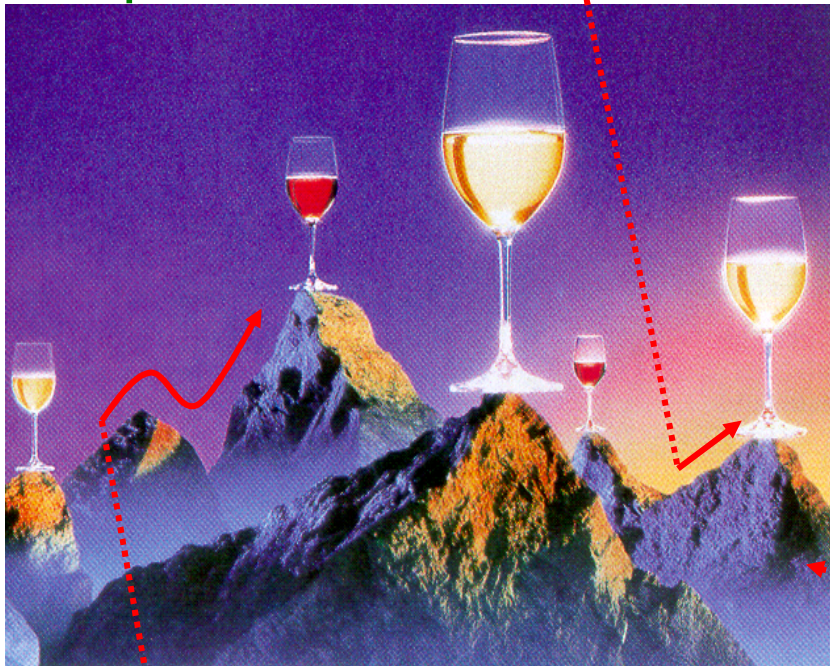
**We need radical innovations based on better understanding of the needs, new scientific ideas, creativity, joint forces, ...)**

**(technological, organizational, social, economical)**



# Next to optimization *Real innovations*

**Optimisation:** climb mountain where one's base camp sits

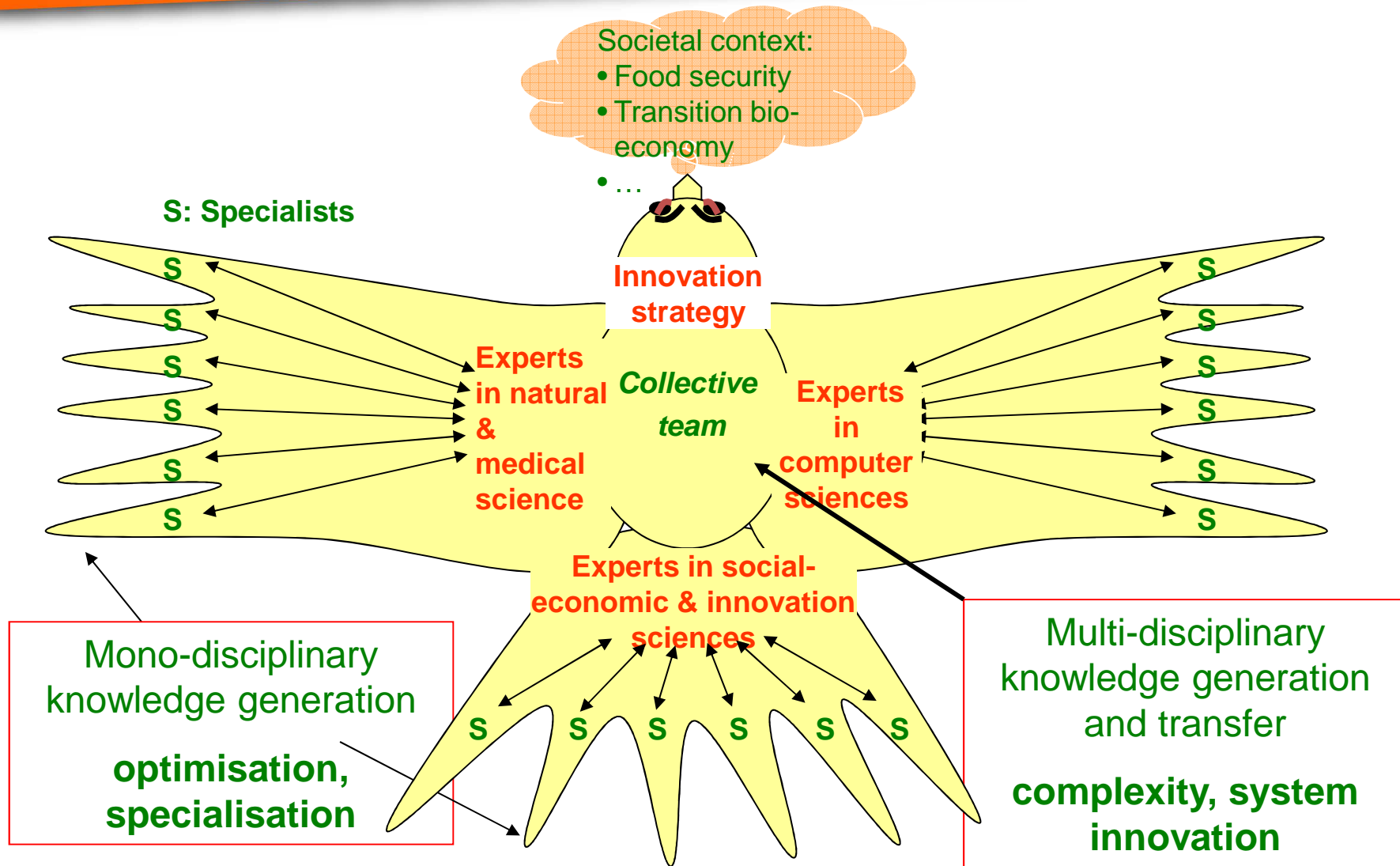


**Re-orientation:** climb a higher mountain in the neighbourhood

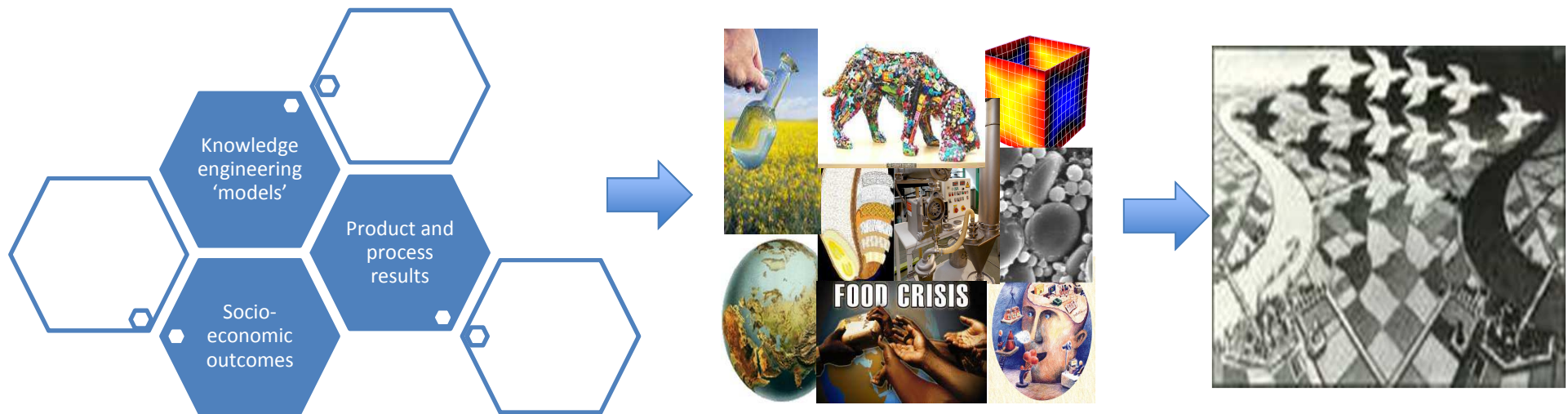


**Innovation:** reshape the landscape

# Tackling complex systems means:



# Lessons for teaching and research:



*We need to go from bricks to an integrated picture*

# My lessons learnt

It is possible, but not easy

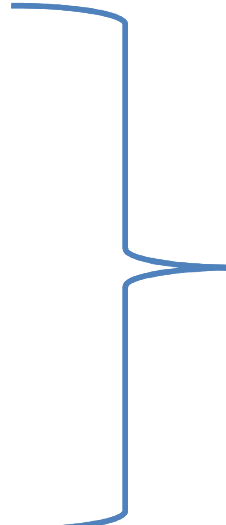
Ready to **C**ook / **C**reate

Ready to **H**eat / **H**urry-up

Ready to **E**at / **E**xecute

Ready to **S**erve / **S**teer

Ready to **S**ore / **S**ustain



But all at the same  
time is like playing

**CHESS**

*If I should be Kasparov, we should learn  
the scholars and students to play chess*

# Lessons learnt, especially regarding the bio-based transition

1. Be passionate by the heterogeneity and not homogeneity of renewable resources: exploit the richness of nature (while maintaining a viable planet)
2. Bio-based society IS NOT (only) a focus on bio-energy from biomass
3. Use the value piramide & quality of life
4. Step away from a synthons approach but start with the functionality and complexity of biomolecules (or functional fractions)
5. Don't think about a single output product but about multiple products and markets (biorefinery)
6. Down think about up-scaling only, also down-scaling counts
7. Include all (side-)effects of a new eco-product
8. AND we should be the research entrepreneurs of tomorrow



ingénierie des Agropolymères  
& technologies émergentes

Thank you very much  
for your attention



Some of the French  
institutions  
involved  
in the transition towards the  
bio-based economy'





**« CEPIA » division**

# **Science and engineering For food and bio-products**

Monique Axelos  
Michael O'Donohue

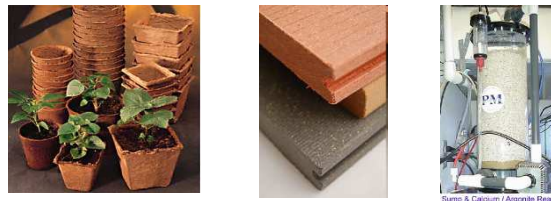


## Genetics and breeding



- Variability
- Plant engineering

## Science and processing



## Consumers

- Health Benefits
- Food Safety
- Sensory Quality
  
- Sustainability of a biobased economy

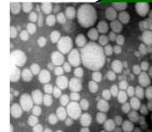
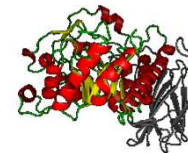
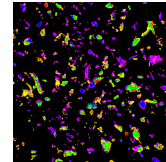
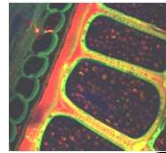
**Foods, Materials, Polymer, Molecule, Energy**

# Integrated approach to construct quality

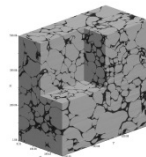
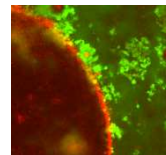
Genetics and breeding

Science and Processing

Consumers



**Composition – process –  
structure - functionality ?**



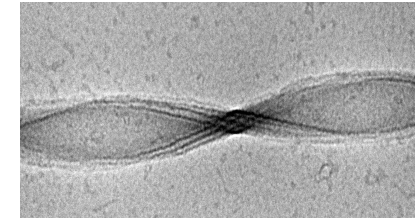
- Health Benefits
- Food Safety
- Sensory Quality
- Sustainability of a biobased economy

- Variability
- Plant engineering

- **Different spatio-temporal scales**
- **Modeling** → **risk assessment**
- **novel technologies**

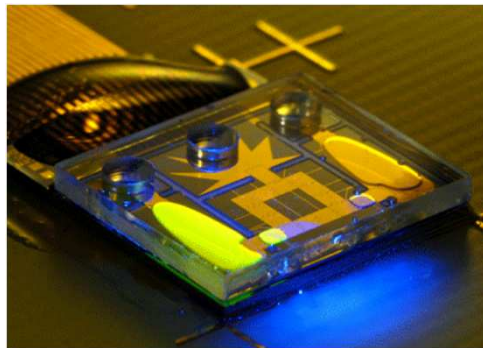


## Topics of interest (1)



### **Nanotechnology: application for biobased applications**

- Design of natural polymer-, protein-, or lipids-based nano devices for smart delivery
- Development of *food* nano-composite
- Nanosensor to detect allergen (high throughput screening)
- Nano-particles in packaging



## **Topics of interest (2)**

**Biocatalysis & (Dry) Bio-refinery**

**Complexity of process-structure-function relationships**

**Vegetable proteins for food and non-food applications**

**.... And many more**



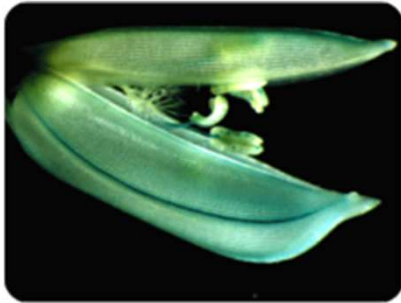
**cirad**

AGRICULTURAL RESEARCH  
FOR DEVELOPMENT

Working  
together for  
tomorrow's  
agriculture

# Research on the appropriate scale

## Three research fields



### •**Biological systems**

Understanding biological systems, from molecule to ecosystem



### •**Tropical production and processing systems**

Analysing farming practices and farming system performance, from plot to farm level

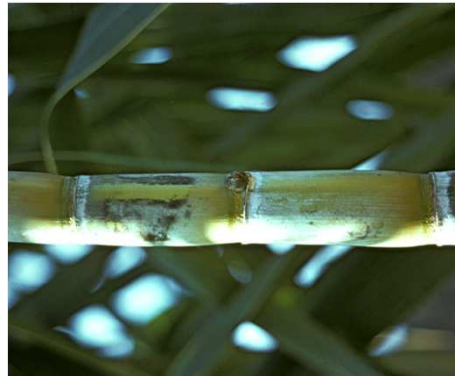


### •**Environments and societies**

Supporting players in rural areas, from a local to a global scale



Fruit and vegetables



Sugarcane



Cocoa



Coffee



Rice



Cotton



Banana and plantain



Oil palm



Animal production



Animal production



Rubber



Forest species

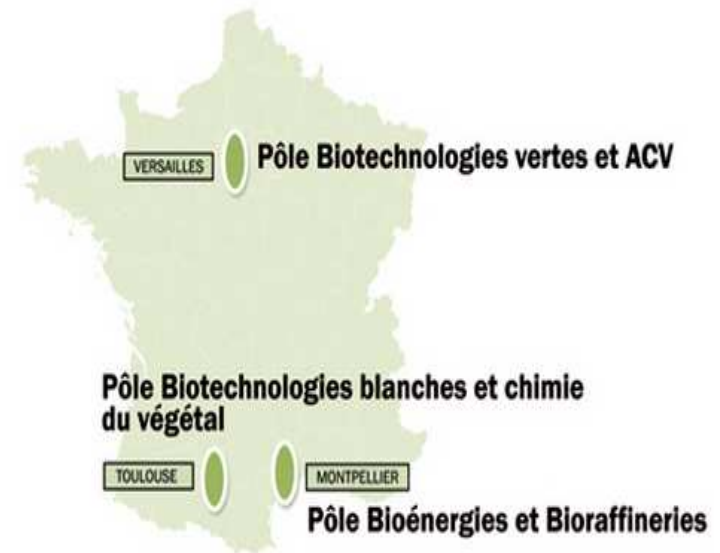




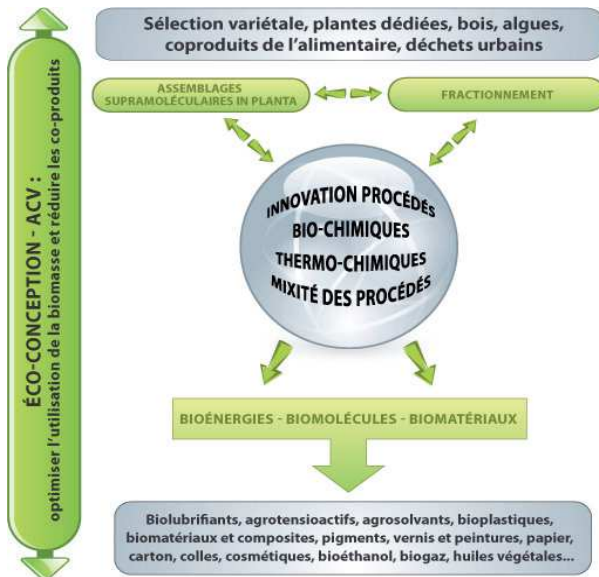
# 3BCAR : une offre de compétences en Carbone bio-sourcée

L'institut Carnot 3BCAR ([www.3BCAR.fr](http://www.3BCAR.fr)) est un réseau structuré de laboratoires de recherche, proposant des compétences pour les entreprises intéressées par la production et les usages du carbone bio-sourcé (**bioénergies, biomolécules et biomatériaux**) selon les principes de la chimie verte et l'analyse de la durabilité.

- **Une offre large :**
  - Plus de 500 chercheurs dans 11 unités de recherche et 3 centres de ressources technologiques.
  - une dizaine de plateformes techniques et un démonstrateur pré industriel, jusqu'à TRL 6.
  - trois pôles géographiques en synergie.



**Spécificité : mobiliser des approches multi-disciplinaires, des végétaux aux propriétés d'usages dans une démarche d'éco-conception:**



## Les marchés

Les producteurs de biomasse et produits agricoles intermédiaires

Les gestionnaires de biens publics

Les entreprises de biotechnologies vertes et blanches

Les producteurs d'énergie

L'industrie chimique

## Les axes de développement des activités

1- Analyse systémique des impacts des modifications liées à l'usage du carbone renouvelable

2- Adaptation de la biomasse à ses nouveaux usages (biotechnologies vertes)

3- Substitution des procédés existants par des procédés biotechnologiques (biotechnologies industrielles)

4- Complémentarité des procédés chimiques et biologiques pour obtenir des fonctions d'usage définies