NOVAMONT, THE BIO-BASED MATERIALS, AND ITS EXPERIMENT OF SYSTEM-BASED ECONOMY

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EUROBIOREF Summer School
Castro Marina 23 Sep 2011

Novamont
Living Chemistry for Quality of Life.

PRESENTATION ITEMS

- NOVAMONT BACKGROUND
- BIOPLASTICS AND BIOBASED MATERIALS
- PRODUCTS AND SYSTEMS
- STARCH BASED POLYMERS
- NOVAMONT TECHNOLOGIES, EVOLUTION OF THE BIOREFINERY INTEGRATED IN THE LOCAL AREAS

NOVAMONT: THE ORIGINS (1989)

FERRUZZI

MONTEDISON

MONTECATINI

(DONEGANI INSTITUTE)

NOVAMONT

(R&D CENTER)

ERIDANIA

BEGHIN SAY

(VILVOORDE

RESEARCH CENTER

INTEGRATION OF CHEMISTRY, AGRICULTURE AND ENVIRONMENT

LIVING CHEMISTRY FOR QUALITY OF LIFE

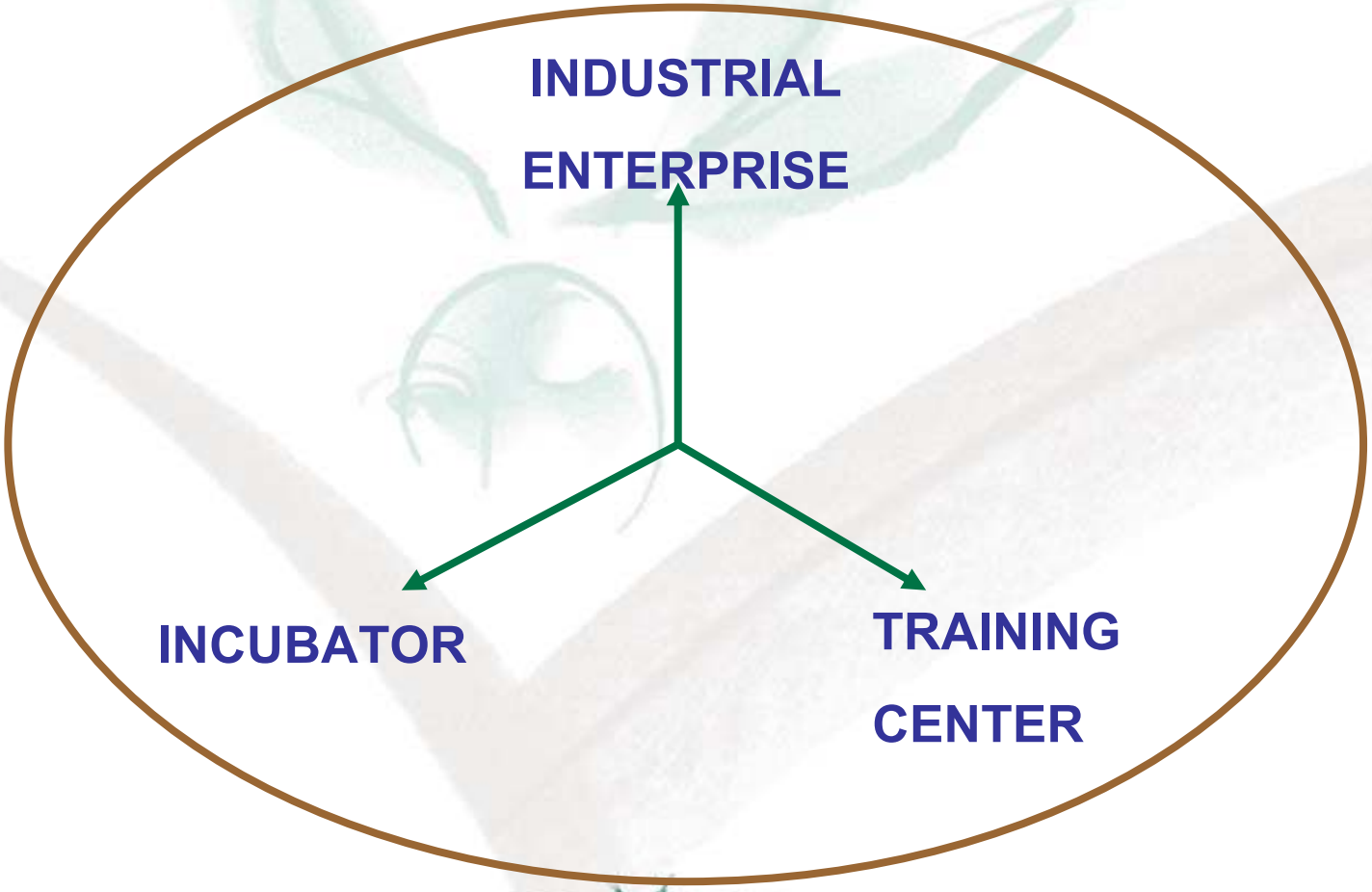
R&D projects:

materials, cobuilders for detergency, biofuel, paper additives, chemicals from hydrocracking

1994: CONCENTRATION JUST ON MATERIALS; CREATION OF NOVAOL, DEDICATED TO BIOFUELS

1996: NOVAMONT ACQUIRED BY BANCA INTESA-SANPAOLO (ex COMIT) AND OTHER INSTITUTIONAL SHAREHOLDERS

NOVAMONT TODAY

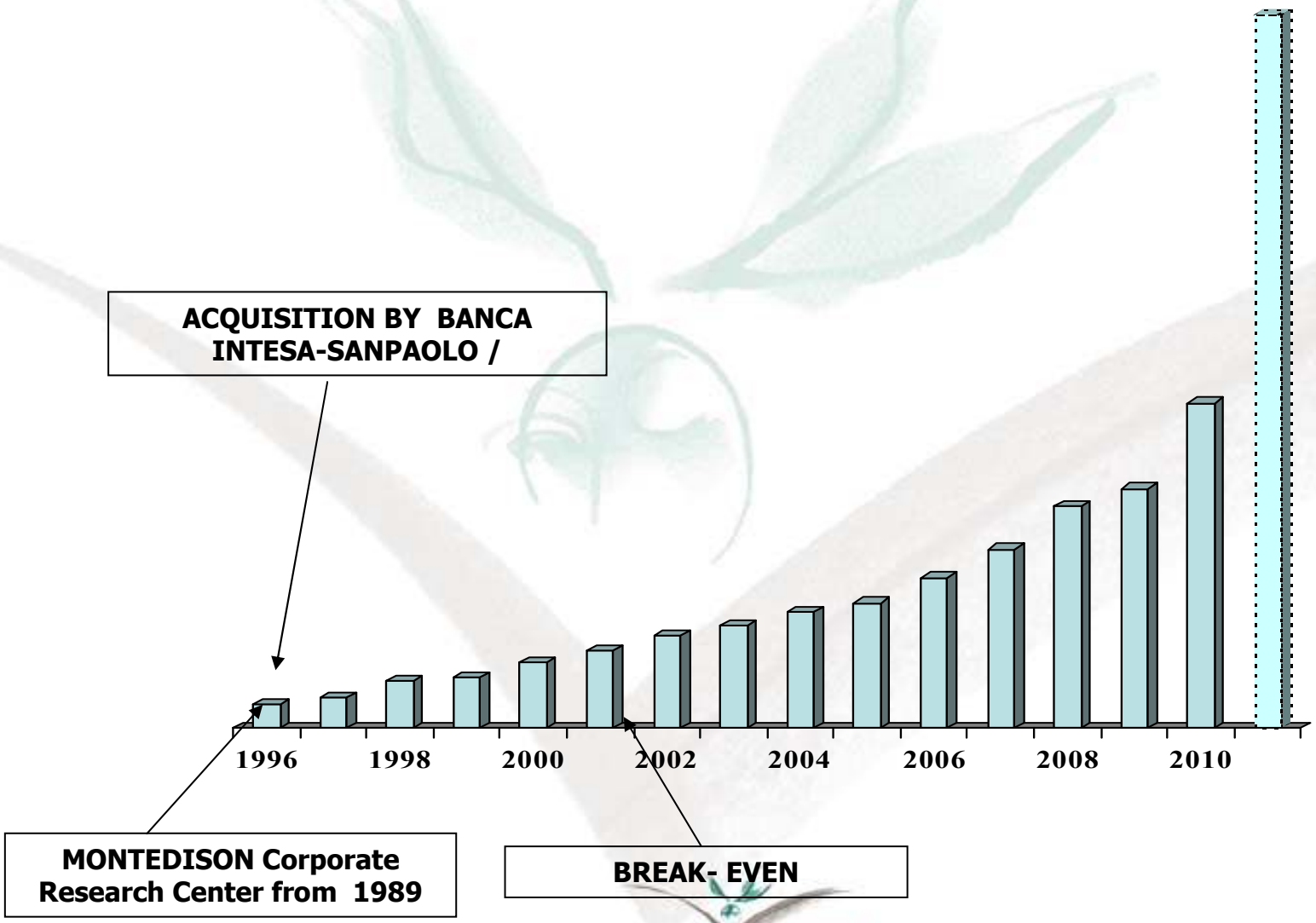


NOVAMONT PROFILE AS AN ENTERPRISE

- **PIONIER AND A MARKET LEADER IN THE SECTOR OF BIODEGRADABLE MATERIALS FROM RENEWABLE RESOURCES**
- **TAILOR-MADE MATERIALS FOR A WIDE RANGE OF INDUSTRIAL APPLICATIONS (Mater-Bi trade-mark)**
- **STRONG PATENT PORTFOLIO** (more than 120 articles, >90patents (800 cases), >100MlEuro of investment, 10 awards).
- **RESEARCH AND DEVELOPMENT AS THE DRIVING FORCE OF NOVAMONT'S INDUSTRIAL DEVELOPMENT (>6% of turnover , more than 20% of the human resources dedicated to research)**
- **SIGNIFICANT HISTORICAL GROWTH TREND OF REVENUES, WITH STEADY IMPROVEMENT IN OPERATING PERFORMANCE .**

Awarded by EPO and EU as "Inventor of the year 2007" for the 1992 – 2001 patents on bioplastics and industrial achievements

Novamont: growing trend



NOVAMONT AS A TRAINING CENTER

Training Center in the key areas of the company business for the most important stakeholders (staff, young and expert researchers, customers, universities, associations, civil servants) with the aim of sharing values, knowledge, technical skills that anticipate future needs

This commitment manifests itself through a series of collaborations which foster the integration of training courses with the skills and know-how and values of Novamont

MORE THAN 160 LEARNING PROGRAMMES ATTENDED IN NOVAMONT SINCE 2000

- **RESEARCHERS FROM ITALY, EU, ALL OVER THE WORLD**
  - **IN COLLABORATION WITH PARTNERS FROM THE PUBLIC AND THE PRIVATE SECTOR**

UNIVERSITIES AND ACADEMIC PARTNERS

EUROPEAN COMMISSION (*MARIE CURIE FELLOWSHIPS*)

REGIONAL AND LOCAL INSTITUTIONS

NATIONAL INSTITUTIONS (MINISTRIES)

BANKING FOUNDATIONS

RESEARCH CENTRES

HIGH SCHOOL AND UNIVERSITY INTERNSHIP PROGRAMMES

TRAINING PROGRAMMES FOR EARLY STAGE RESEARCHERS AND PhD STUDENTS

MASTER OF SCIENCES IN "BIOTECHNOLOGIES FOR BIOPLASTICS"

CUSTOMERS/ CIVIL SERVANTS

BIOPLASTICS CAN BECOME A POWERFUL DEMONSTRATIVE CASE OF RELEVANT DIMENSIONS FOR SUSTAINABLE DEVELOPMENT AND CULTURAL GROWTH

- REDESIGN ENTIRE APPLICATION SECTORS
- AFFECT THE WAY RAW MATERIALS ARE PRODUCED THROUGH INTEGRATION OF ENTIRE AGRO-INDUSTRIAL CHAINS
- MODIFY PRODUCT'S USE AND DISPOSAL
- EXTEND THE EXPERIMENTAL ACTIVITY OF RESEARCH LABS TO LOCAL AREAS
- DEFINE RELIABLE STANDARDS

Bioplastics Definition

- Compostable plastics certified according to EN13432 and based on renewable and/or non renewable resources

  Examples : (starch blends, PLA,PHA,cellulosic materials, specific synthetic polyesters…)

- Standard Polymers produced on the basis of renewable resources

  Examples : specific polyesters based on bio-propanediol, specific polyamides from castor oil, PE or PVC based on bio-ethanol

Bioplastics and biodegradation

- To assess an universally acceptable definition of biodegradability is a difficult task but neverthless it is essential to avoid confusion and misunderstandings
- Depending on the background of the definising organisation and their particular interests many different definitions have been adopted and even more important are the criteria for calling a material biodegradable.
- A demonstrated potential of a material to biodegrade doens not say anything about the time frame in which this occurs nor the ultimate degree of degradation

As examples….

- LDPE degrade slowly to CO2 (0,35% in 2.5 years) : Should it be considered biodegradable?
- Polyolefin-Starch blends rapidly loose stenght, disintegrate and visually disappear if exposed to microorganisms but the polyolefin fraction will neverthless persist in the environment. Can these materials be called biodegradable?

Bioplastics and biodegradation

Since early 90's a huge debate among experts and all relevant stakeholders begun and a general agreement was obtained concerning the following key points:

- **For all practical purposes of applying a definition, material manufactured to be biodegradable must relate to a specific disposal pathway (composting, sewage treatment denitrification, anaerobic sludge treatment)**
- **The rate of degradation has to be consistent with the disposal method such to avoid accumulation**
- The ultimate end products of a material manufactured to be biodegradable are CO2, water and minerals
- The intermediate products include biomass and humic materials
- Materials must degrade safely and not negatively impact on the disposal process or the use of the end product of disposal

Biodegradability is a functional feature of a product and become an useful property only if it occurs in specific conditions and timing

Bioplastics and biodegradation

- Since 1994 up to 2000 CEN worked on European Commission Mandate to develop a compostability norm for packaging waste The norm was published as EN 13432

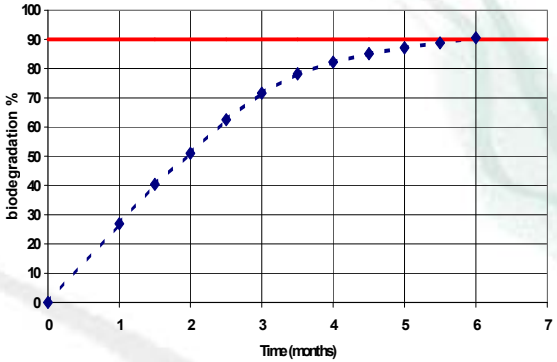
- The EN 13432 industrial standard has been upgraded in 2001 as EU harmonized norm giving to it a higher juridical value e and compliance with this standard is required to claim that a product is compostable in the European marketplace.

- The Norm specifies and combines tests, criteria and pass levels in terms of

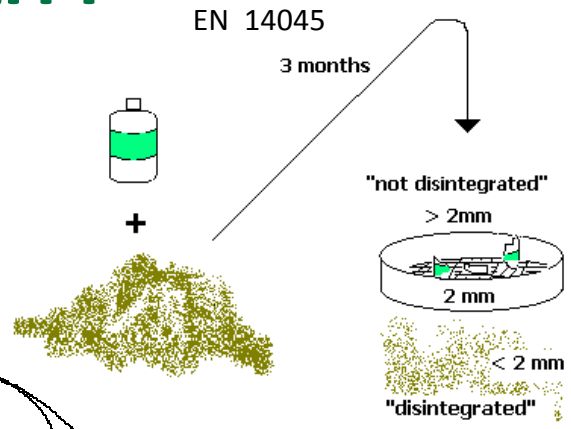
  - Material characteristics
  - Biodegradation
  - Disintegration
  - Compost Quality

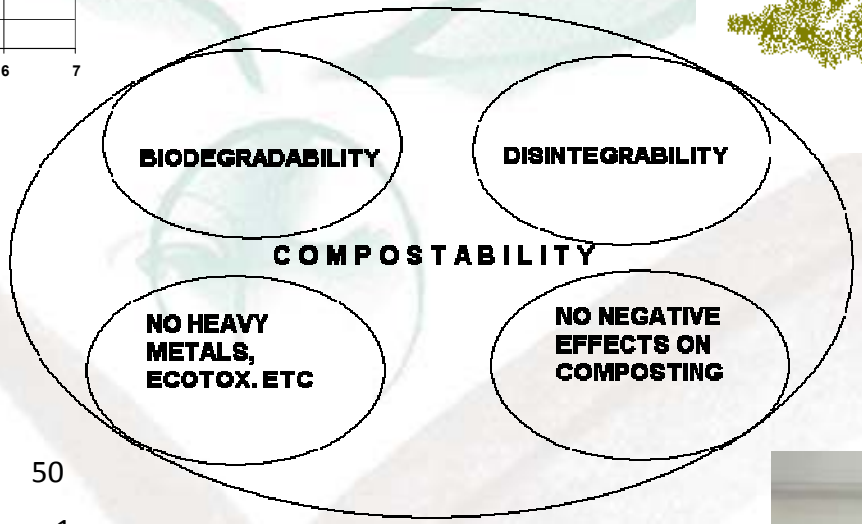
COMPOSTABILITY

ISO 14855



EN 14045





EN 13432

Zn	150	Cr	50
Cu	50	Mo	1
Ni	25	Se	0,75
Cd	0,5	As	5
Pb	50	F	100

Plant growth test

ENVIRONMENTAL IMPACT OF BIO-BASED PLASTICS

- BIO-BASED PLASTICS ARE NOT NECESSARILY AT LOW ENVIRONMENTAL IMPACT

  (crops, processes, performances for the specific applications, density …)

- EVALUATION OF THE ENVIRONMENTAL IMPACT OF SPECIFIC PRODUCTS / APPLICATIONS (LCA) WITH A "CRADLE TO GRAVE" APPROACH

ATTENTION TO END OF LIFE IN A SYSTEM'S LOGIC

THE BIODEGRADABILITY OF BIOPLASTICS
When is it important?

- RECYCLING IS UNPRACTICAL OR NOT ECONOMICAL
- BIODEGRADABILITY AS FUNCTIONAL PROPERTY
- REAL RISK OF DISPERSION IN THE ENVIRONMENT
- IT IS A POLLUTANT OF FOOD AND YARD WASTE

UNEP

UNITED NATIONS ENVIRONMENT PROGRAMME

Marine Litter: A Global Challenge

Ocean Conservancy

Regional Seas

GPA

Marine Litter: A Global Challenge

Prepared by
Ljubomir Jeftic, Seba Sheavly, and Ellik Adler

Edited by Nikki Meith

April 2009

Ocean Conservancy

Regional Seas

GPA

Marine Litter: A Global Challenge

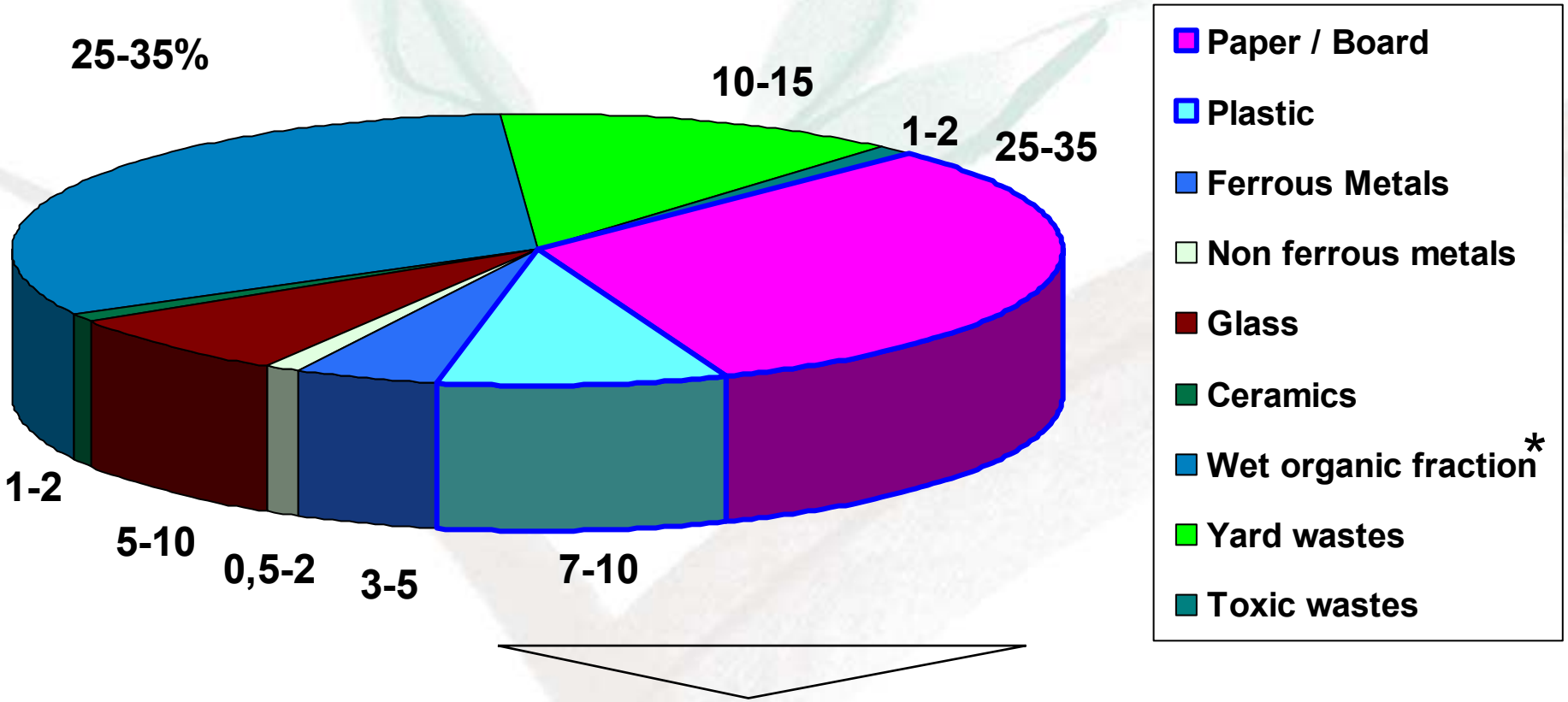
Report April 2009

Table 4. 'Top ten' marine debris items – ICC global (1989-2007 combined)

1989-2007 'Top ten' marine debris items – global ICC totals		
Debris items	**Number of items**	**Percent of total**
Cigarettes/cigarette filters	25,407,457	24.6
Bags (paper & plastic)	9,711,238	9.4
Caps/lids	9,398,977	9.1
Food wrappers/containers	9,191,575	8.9
Cups/plates/forks/knives/spoons	7,426,964	7.2
Beverage bottles (plastic) <2 litres	5,684,718	5.5
Beverage bottles (glass)	4,991,860	4.8
Beverage cans	4,796,554	4.6
Straws, stirrers	4,508,085	4.4
Rope	2,215,329	2.1
Total debris items	**103,247,609**	**80.7**

Source: Compiled from annual ICC data reports, Center for Marine Conservation/Ocean Conservancy (1989-2007).

SOLID WASTE COMPOSITION IN EUROPE
(Average value per inhabitant: 500 Kg/Year)



More than 40% of solid waste can be composted

** Food, Vegetable, Fruit*

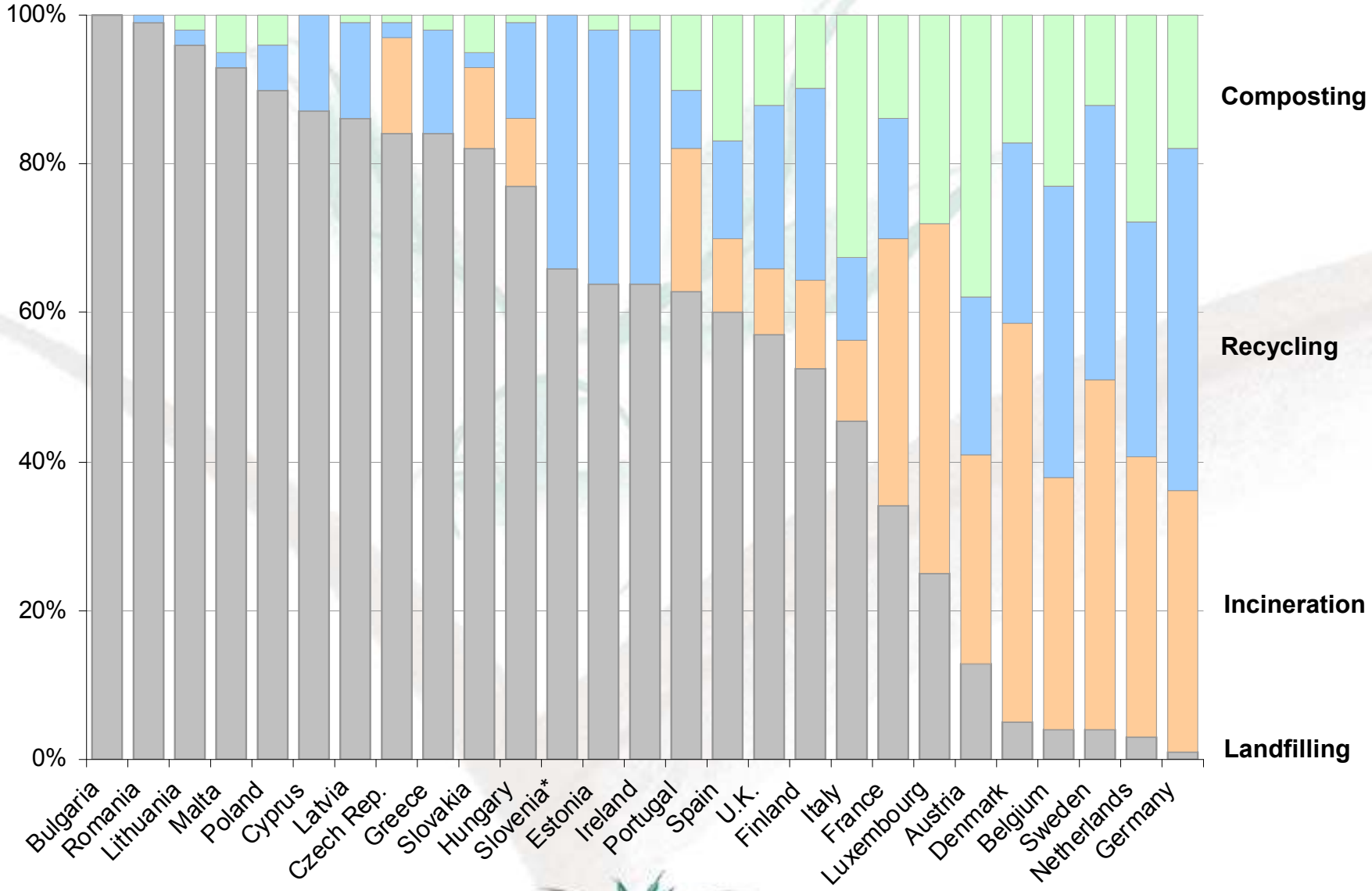
BACKGROUND ON ORGANIC WASTE

- **Potential to reduce CO2 emissions of between 74 and 94 Mlton, 11% of the European emissions reductions targets by 2020.** (German Federal Ministry of Environment)

- **Landfill Directive aim to reduce organic waste of at least 65% by 2016 with reference to 1995**

ERRMA March 2008 report

Waste management options in EU27 (breakdown)



Source: EUROSTAT, 2007 (data EU27 year 2005)

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* Slovenia, recycling includes composting

ENVIRONMENTAL IMPACT OF SYSTEMS
An example

Catering meals with disposable cutlery

SCOPE OF THE STUDY

Evaluate the environmental consequences of using three different disposable cutlery in fast food restaurants, town festivals etc.

Different cutlery allow different waste treatment systems

An *heterogeneous* waste is generated.

- The mixed heterogeneous waste is eventually landfilled and/or incinerated.
- The separation of non biodegradable and biodegradable components is in line of principle feasible but with a very low percentage of probability

Food scraps

B&C foam

B&C mug

B&C cutlery

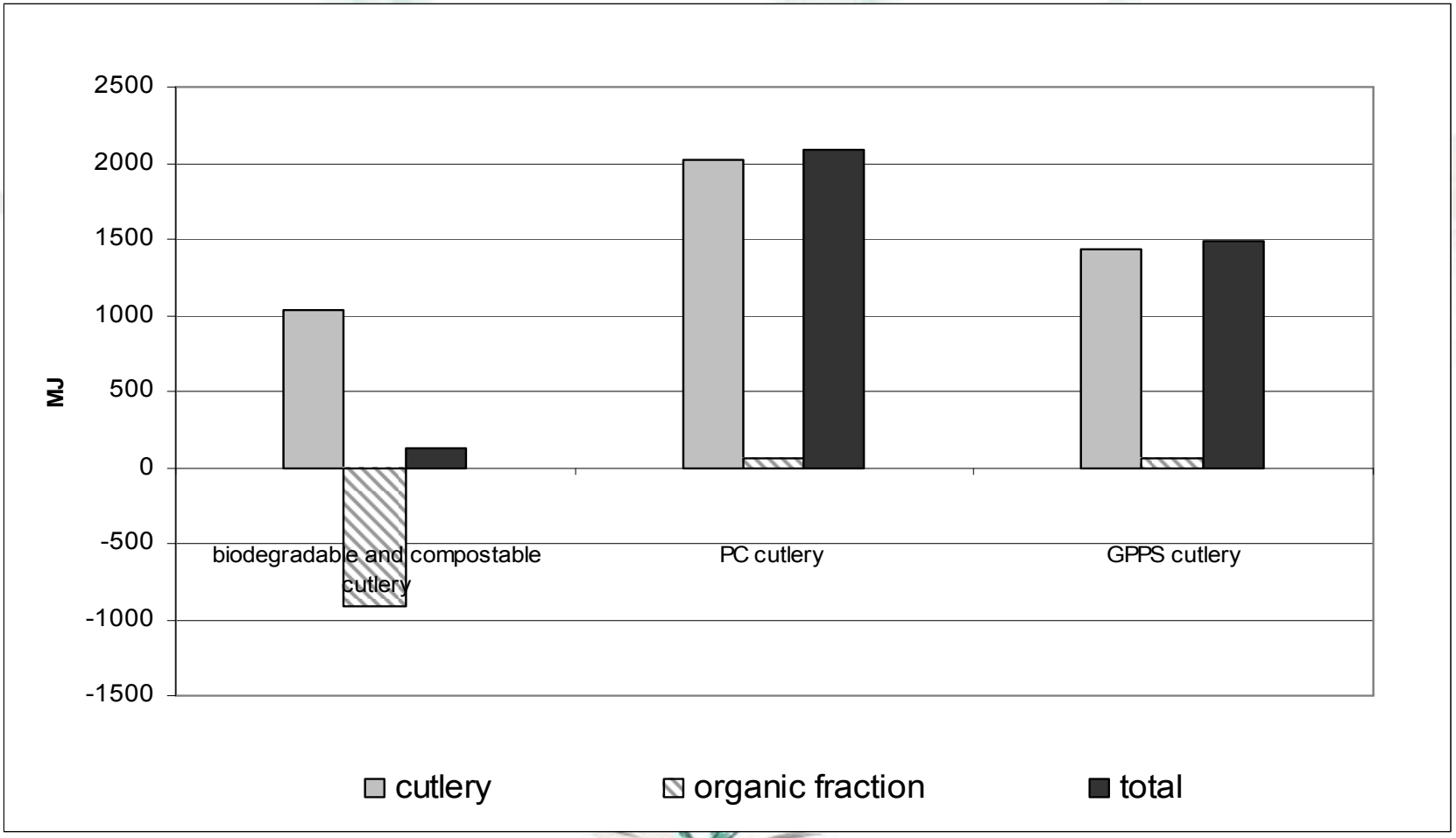
An *homogeneous* waste is generated

- **B&C plastic waste**
- **Food waste**

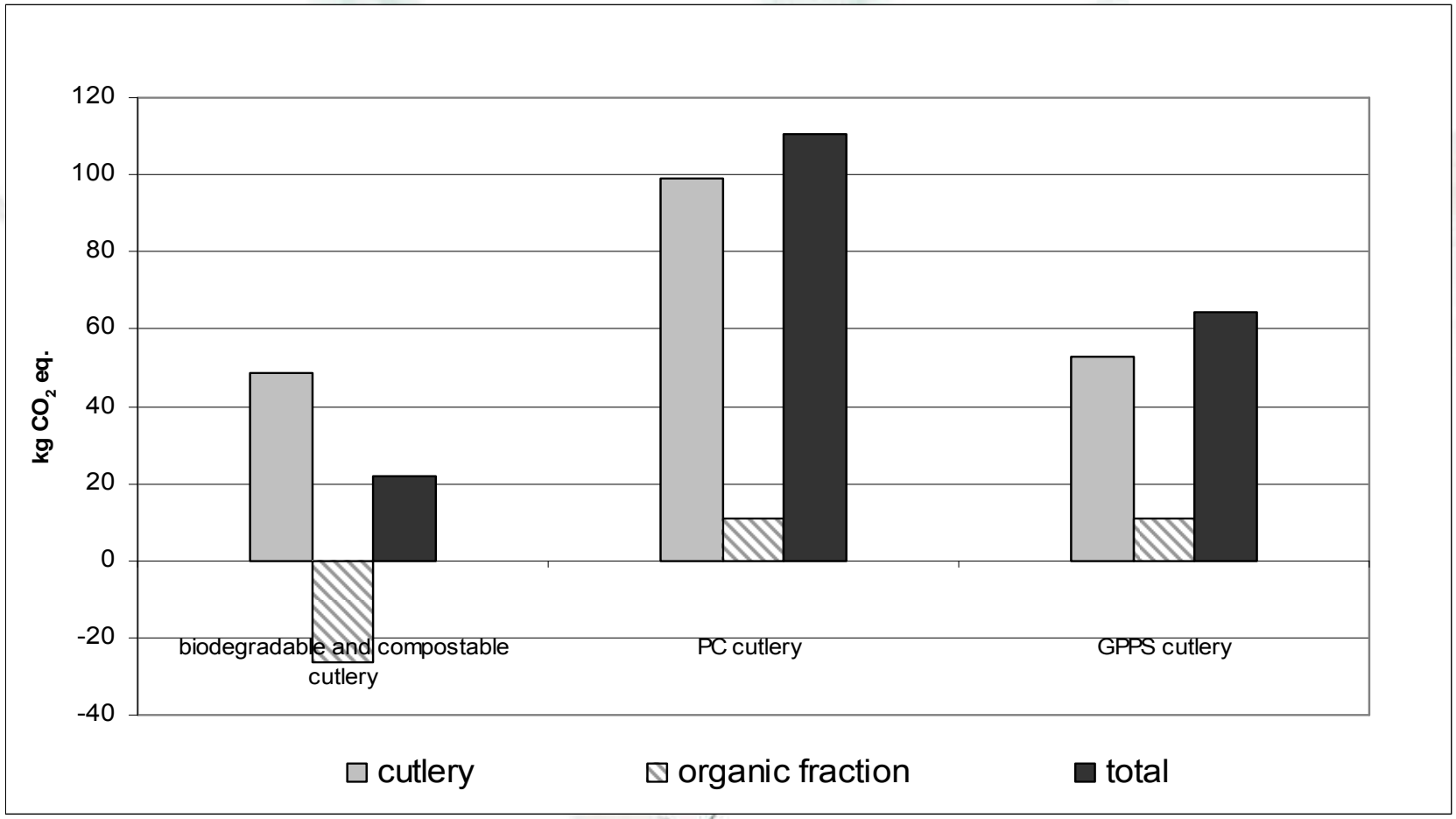
Both fractions are compostable and can be collected as a whole *homogeneous* fraction

The homogeneous waste can be recycled by means of organic recovery, i.e.composting or anaerobic digestion followed by composting. Compost is a valuable soil improver.

Non renewable energy (MJ) produced by serving 1000 meals either with B&C or with traditional plastic cutlery



Greenhouse gases produced by serving 1000 meals either with B&C or with traditional plastic cutlery.



LCA ANALYSIS: CONCLUSIONS

- A key issue for a reliable evaluation of the environmental impact of a product is to focus the attention on the effect that such product will have on complex system/s of far bigger impact than the single product itself.

- When the functional unit is selected on the bases of products and not on systems LCA can be very misleading.

THE RAW MATERIALS FOR BIOPOLYMERS AND CHEMICALS

CORN, WHEAT, POTATO ETC.

OLEAGINOUS CROPS

BIOMASS

CELLULOSE → CELLULOSE DERIVATIVE rayon, cellulose acetate, etc.

STARCH → DESTRUCTURIZED STARCH, COMPLEXED STARCH, PLA

SUGARS → PHA, CAPROLACTAM, ADIPIC ACID, SUCCINIC ACID, 1,3 PROPANDIOL ETC.

LIGNIN

PROTEINS → AMMINOACIDS

FATTY ACIDS → SEBACIC ACID, AZELAIC ACID, BRASSILIC ACID, DIMERS, LONG CHAIN DIACID AND DIOLOS

STARCH : An example of BIOPOLYMER

- **Starch-based materials**: constituted by starch as it is, with minor modifications either alone or complexed with natural or synthetic biodegradable polymers, such as in the case of Mater-Bi products of Novamont

STARCH : An example of BIOPOLYMER

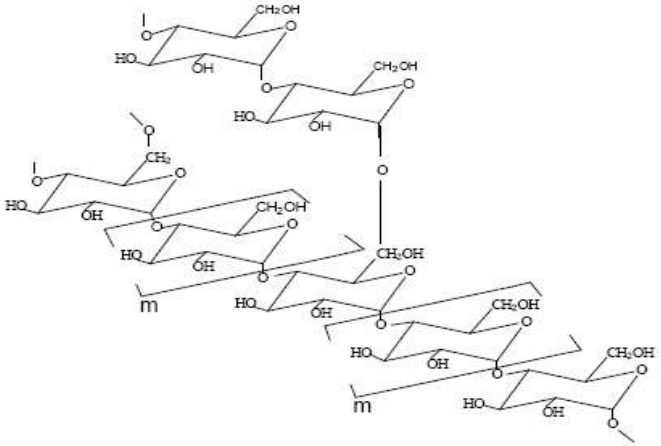


Figure 1: Structure of amylopectin

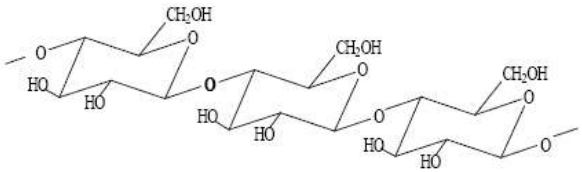
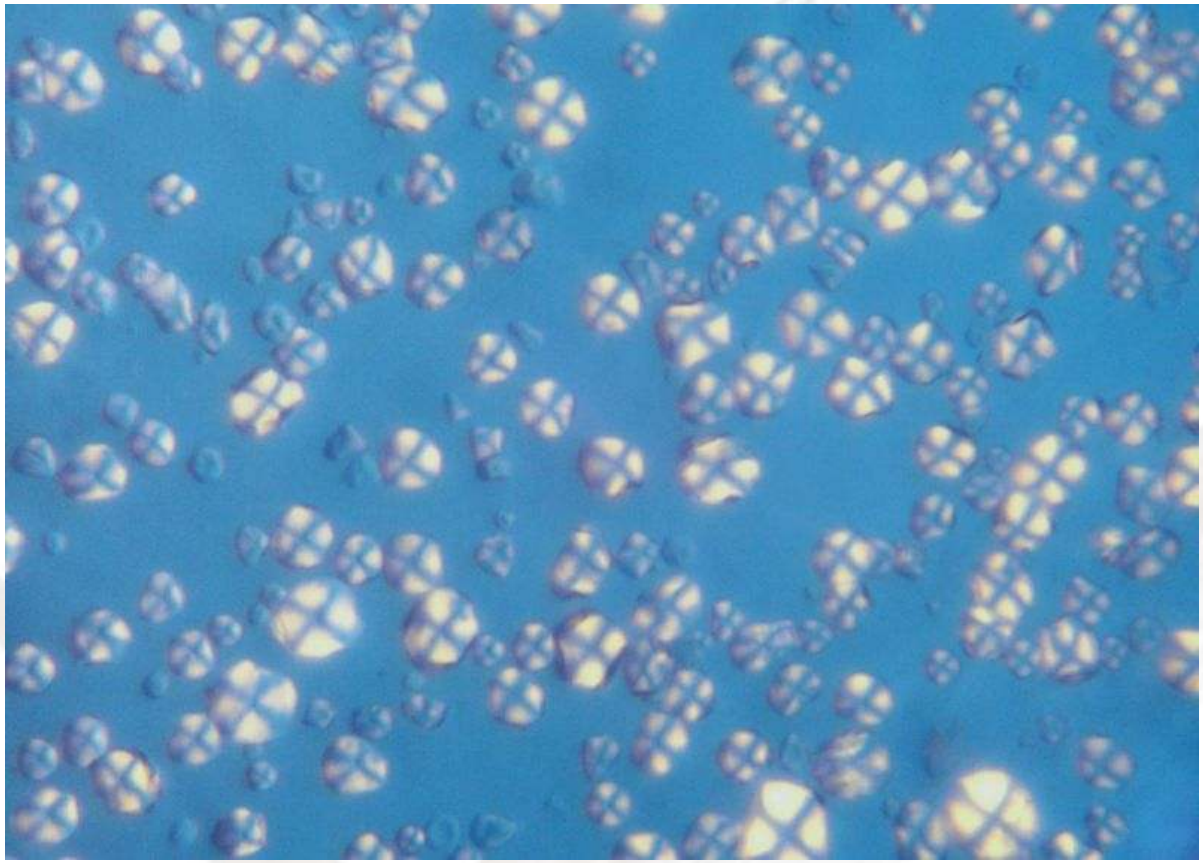


Figure 2: Structure of amylose



- **Microscopy of starch granules** - Each species of plant has a unique shape of starch granules in granular size, shape and crystallisation pattern. Under the microscope, starch grains stained with iodine illuminated from behind with polarized light show a distinctive Maltese cross effect (also known as extinction cross and birefringence).

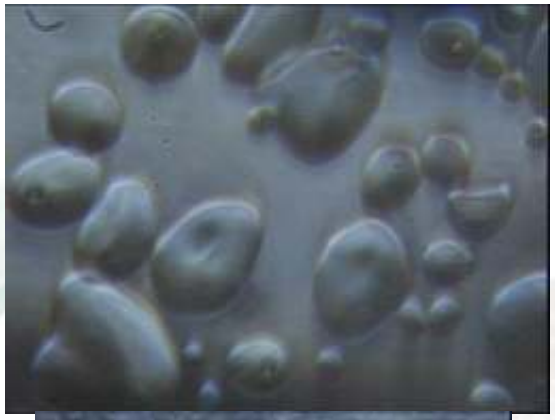
Thermoplastic Starch

- Starch can be destructurized applying sufficient work and heat to almost completely destroy its crystallinity.
- Destructurized starch behaves as a thermoplastic polymer and can be processed as a traditional plastic; when alone, however, its sensitivity to humidity makes it unsuitable for most of the applications.
- The main use of destructurized starch alone is in soluble compostable foams such as loose-fillers, and other expanded items as a replacement for polystyrene.
- Starch can be destructurized and compatibilized with different synthetic polymers to satisfy a broad spectrum of market needs.

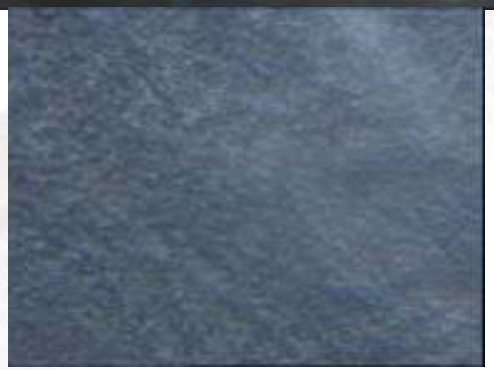
Potato Starch
PL Microscopy

Potato Starch
PC Microscopy

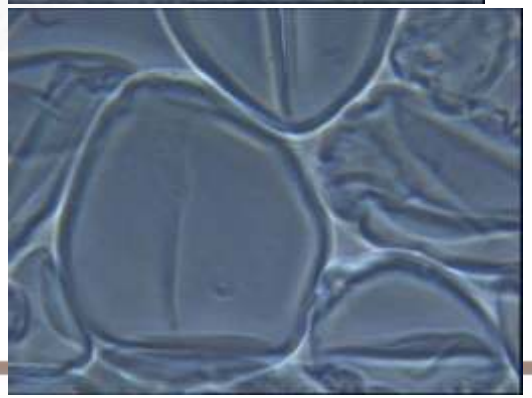
Native



Destructurized
Thermoplastic

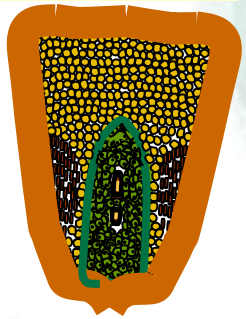


Gelatinized



NOVAMONT'S STARCH/VEGETABLE OILS TECHNOLOGY (MATER-BI – ORIGO-BI)

CORN KERNEL

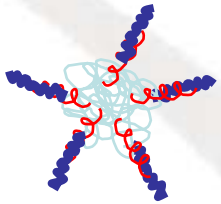


MILLING

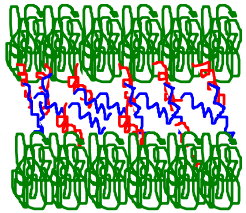
STARCH

DESTRUCTURIZED STARCH
+ CHEMICAL MODIFICATIONS

AMORPHOUS AMYLOSE AND AMYLOPECTINE

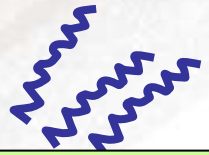


COMPLEXED STARCH (droplet like structure)



COMPLEXED STARCH (layered structure)

+



POLYMERIC COMPLEXING AGENTS

INTERMEDIATES ← VEGETABLE OILS

INDUSTRIAL APPLICATIONS OF MATER-BI

Novamont Technologies- State of Art

2006 SITUATION	COMPLEXED STARCH TECHNOLOGY 1989	2009 SITUATION	2011-2012 SITUATION
INDUSTRIAL PHASE: 20.000 TON	STARCH NANOPARTICLES 1995	60. 000 TON	>100000 ton/year Aprile 2011- January 2012
4 INDUSTRIAL UNDER CONSTRUCTION	2000 POLYESTERS FROM VEGETABLE OILS	4 INDUSTRIAL LINES IN PRODUCTION.	>50000 ton/year March 2011
RESEARCH	1997 MONOMERS FOR POLYESTERS AND INTERMEDIATES	INDUSTRIAL PLANT BASED ON NEW TECHNOLOGY PLANNED TO BE BUILT IN 2011	25. 000 TON → Porto Torres Project
RESEARCH PHASE	2004 TRANSFORMATION OF CO/BY-PRODUCTS IN CO-MONOMERS AND ENERGY	ACTIVATED DIFFERENT PROJECTS AT LOCAL AND INTERNATIONAL LEVEL	
START-UP OF FIELD TESTS	2004 SPECIALIZED OLEAGINOUS CROPS → NEW DEVELOPMENTS	SELECTED OLEAGINOUS CROPS – COOPERATION PROJECTS TO USE ALL THE COMPONENTS. In 2010 START-UP OF FIRST DEDICATED COLTIVATION WITH COLDIRETTI – FEEDING MONOMERS PLANT IN 2012 - first line of lubricants for agriculture ready	BIOMASS 25.000 TON

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BIOREFINERY : MATER BI PRESENT AND FUTURE GENERATIONS

ALREADY INDUSTRIAL PLANT READY IN 2012

GENERATION	MINIMUM RRM C14%	STARCH	NON-FOOD VEGETABLE OIL DERIVATIVE	MONOMERS FROM BIOMASS	TECHNOLOGIES FOR BIOPLASTICS	CHEMICALS
1°	25%	YES	NO	NO	STARCH COMPLEXATION	
2°	40%	YES	YES	NO	•STARCH COMPLEXATION •POLYESTER PRODUCTION	
3°	50%	YES	YES. REDUCED IMPACT	NO	•STARCH COMPLEXATION •POLYESTER PRODUCTION •MONOMER 1	•C9-C13 DIACIDS •C9-C18 MONOACIDS •OTHER CHEMICAL INTERMEDIATES
4°	70%	YES	YES. REDUCED IMPACT	YES	•STARCH COMPLEXATION •POLYESTER PRODUCTION •MONOMER 1 •MONOMER 2	
5°	90%	YES	YES. REDUCED IMPACT	YES	•STARCH COMPLEXATION •POLYESTER PRODUCTION •MONOMER 1 •.MONOMER 2 •MONOMER 3	

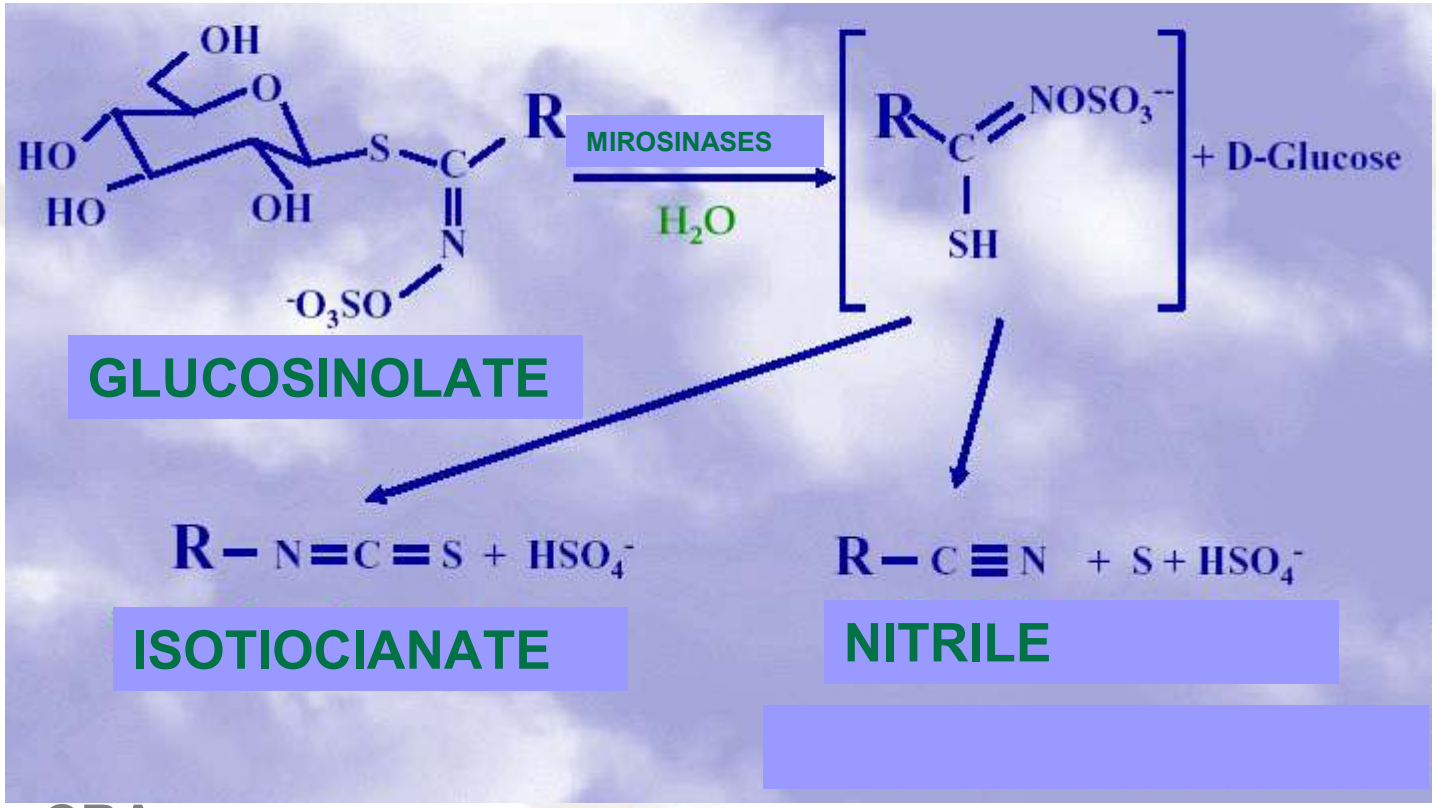
Third Generation : NOVAMONT MONOMERS

- INPUT : VEGETABLE OIL FROM SELECTED OLEAGINOUS CROPS
  - First to start : High Oleic Sunflower Oil from Umbria
- OUTPUT
  - DIACIDS (i.e. Azelaic) as monomers for Novamont Bioplastics
  - MONOACIDS (i.e. Pelargonic Acid) as lubricant, herbicide, starting material for NOBS, …..
  - OTHER CHEMICAL INTERMEDIATES as additive for plastic, rubber, ……

AN EXAMPLE OF USE OF CO/BY PRODUCT: :

THE BIOFUMIGANT EFFECT OF GLUCOSINOLATES-MIROSINASES SYSTEM PRESENT IN BRASSICACEAE

-THE CAKE OF BRASSICACEAS - THE GLUCOSINOLATES-MIROSINASES SYSTEM



LEVEL OF INFESTATION IN ZUCCHINI'S ROOTS AFTER BIOFUMIGATION WITH BRASSICACEAS FLOURS

COOPERATION WITH CRA, TRIUMPH, COLDIRETTI AND NOVAMONT

NOVAMONT MODEL OF BIOREFINERY INTEGRATED IN THE TERRITORY

- COMPATIBILITY / SINERGY WITH FOOD CROPS
- SPECIALIZATION OF NEW INDUSTRIAL CROPS
- ENERGY FROM SCRAPS
- SUSTAINABLE AGRICULTURE WITH VALORIZATION OF HIGH QUALITY COMPOST (CRADLE TO CRADLE APPROACH)
- SYSTEM DRIVEN BY LCA
- ECONOMICALLY SUSTAINABLE

CONTINUOUS INNOVATION IN THE TERRITORY WITH INCREASE OF PRODUCTION EFFICIENCY AND OF QUALITY STANDARDS

Strategies to increase the use of renewable resources

- Midterm – Use of by-products from food, feed and paper industry and Intensification of the integrated production.
- Longterm – Integrated processing of non-food biomass in biorefineries to produce chemicals, biogas, biofuels and bioenergy.
- Development of processes and demonstration in a pilot scale (biorefineries).
- Integration of petrochemical and renewable raw materials in an integrated chemical production site.
- Use of existing infrastructure on chemical sites with coupled product and energy systems and process know-how.
- Integration of biotechnological and chemical processes in an integrated chemical production site.
- Leadership in conversion technologies for renewable raw materials and use of bio-based products.

The Novamont Projects of reindustrialization of Chemical Sites

- Conversion of a polymerization plant in crisis in an efficient Origo-Bi plant (completed- 50000 ton capacity)

- “Green Pole” Porto Torres (just finalized : Matrica)

The "Green Pole" Porto Torres

7 plants with Novamont Technologies to be built in 3 steps, 1 R&D Center, 450 Ml Euro of investments

eni polimeri europa

and

Novamont

in Porto Torres

Step A

1. **MONOMERS PLANT I** (32 kt/a)
2. **BIO LUBRICANTS I** (25 kt/a)

EMPLOEES: ***88***
INVESTMENT: ***about 100 mln €***

Step B

3. **BIOADDITIVES FOR RUBBERS** (30 kt/a)
4. **BIO-FILLERS PLANT** (15 kt/a)

EMPLOEES: ***57***
INVESTMENT: ***about 50 mln €***

Step C

5. **BIO MONOMERS PLANT II** (100 kt/a)
6. **BIO LUBRICANTS PLANT II** (30 kt/a)
7. **BIOPLASTICS PLANT** (120 kt/a)

EMPLOYES: ***126***
INVESTMENT: ***about 300 mln €***

Research Center

- *R&S PROJECT ON BIO MONOMERS*
- *R&S PROJECT ON BIO LUBRICANTS*
- *R&S PROJECT ON BIO ELASTOMERS*

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UP-STREAM INTEGRATION WILL PUSH A NEW DEVELOPMENT OF AGRICULTURE IN SARDENIA

Area da dedicare a coltivazione per integrazione a monte della filiera

- IN RELATION TO STEP 1 RAW MATERIALS WILL BE PRODUCED BY THE OLEAGINOUS CHAIN CREATED IN UMBRIA WITH COLDIRETTI
- AT THE SAME TIME THE EVALUATION OF LOCAL CROPS TO BE OPTIMIZED TO SUPPLY THE NEEDED RAW MATERIALS FOR THE 7 PLANTS HAS BEEN ACTIVATED (PROGRESSIVE USE OF SCRAPS)
- VARIOUS HIGH YIELD CROPS WHICH HAVE THEIR IDEAL HABITAT IN SARDENIA ARE UNDER EXAMINATION

DOWN-STREAM INTEGRATION OF THE CHAIN: AN OPPORTUNITY FOR THE CONVERSION INDUSTRY OF SARDENIA

GENERAL CONSIDERATION ON THE"GREEN POLE" PORTO TORRES

- **THE NEW PROJECT "GREEN POLE PORTO TORRES" IS A GAMBLE WITH THE FUTURE FOR THE WHOLE COUNTRY**
- **THE INITIATIVE WILL BE PUT IN PRACTICE AS FAST AS POSSIBLE TO STRENGTHEN THE LEADERSHIP**
- **CATCHING UP THE OPPORTUNITY OF A RELEVANT PROJECT OF GREEN CHEMISTRY IN ITALY WILL MEAN TO TAKE ADVANTAGE FROM KNOWLEDGE, STRUCTURES AND INFRASTRUCTURES PRESENT IN THE COUNTRY (TECHNOLOGICAL KNOW-HOW, EMPLOYMENT, COMPETITIVENESS OF THE INDUSTRIAL SYSTEM, ENVIRONMENTAL QUALITY)**

BIO-BASED PRODUCTS

SYSTEM'S BASED ECONOMY

Benefits: Increased competitiveness thanks to:
Increased quality of life; lower energy demand & consumption; improved soil, water,& air quality; recyclability, biodegradability/compostability, material/product performance; use of local resources, rural development, new integrated chains, security of resources

polymers; lubricants; solvents, surfactants & other chemicals, pharmaceutical, cosmetics, food additives etc.

via
physical, chemical, biological processes

oils; starch; cellulose; etc.

oilseed crops; cereals; potatoes; straw; wood; waste types

A real sign
of
sustainable development.