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BIO-COMMODITY REFINING

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Scientific and deputy division manager

INRA

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SEVENTH FRAMEWORK PROGRAMME

FP7 GRANT AGREEMENT N° 241566

A 4-YEAR EU PROJECT

The consortium

- 24 Partners
- 13 Countries
- 5 SMEs
- 4 MNI
- 2000 person-months

The coordinator

- Michael O'DONOHUE
  INRA

Project cost

- Full budget €20 274 484
- EU contribution €13 920 238

Collaborating Institutes

- Institut National de la Recherche Agronomique, France
- Valtion teknillinen tutkimuskeskus, Finland
- Energy research, Centre of the Netherlands, The Netherlands
- Compagnie Industrielle de la Matière Végétale, France
- Chimar Hellas, Greece
- ArkemaNTUAInstitute for Energy and Environmental Research Heidelberg, Germany
- Katholieke Universiteit Leuven, Belgium
- Syra, France
- lSYNPO, akciová společnost, Czech Republic
- WUR-A&F, The Netherlands
- Chalmer's University of Technology, Sweden
- Latvian State Institute of Wood Chemistry, Latvia
- INRA Transfert, France
- The Energy and Resources Institute (TERI), India
- Oy Keskuslaboratorio - Centrallaboratorium Ab, Finland
- CAPAX environmental services, Belgium
- Royal DSM N.V.The Netherlands
- nova-Institut *Gmb,* Germany
- Institut für Umweltstudien - Weibel & Ness GmbH,Germany
- Huntsman, Belgium
- World-wide Fund for nature, Scotland/India

BIOCORE'S CONTEXT

The driving questions and challenges behind biocore

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TOUGH CHALLENGES

- **EU 2020 goals (directive 2009/28/EC)**
  - 20% renewable energy
  - 10% biofuels in the transport sector
- **The G8 (Aquila, 2009) has announced ambitious 2050 goals**
  - Reduce GHG emissions by 80 - 95% in order to maintain global warming below +2°C

SOLUTIONS?

- **Possible options**
  - A massive increase in biofuels
  - Vast improvements in energy efficiency
  - A move towards a zero carbon transport network
  - A massive increase in R&D and PPP
  - A fast transition towards a bio-based economy

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LIVING WITH FINITE RESOURCES

- **World biomass resources are abundant, but limited**
  - Approx 1400 Mha arable land[1]
  - A further 70 – 138 Mha[1] could become available
    - 200-390 Mt extra grain (rice or wheat)[2] or 10-15% increase
  - 3-10 Gt[3] cereal residues produced annually
  - Roundwood production 2 Gt

- **Food must always be a priority**
  - 9 billion to feed in 2050
  - Biorefining must obey the maxim ‘Food and Fuel’ not ‘Food or Fuel’
  - Better to use lignocellulosic biomass

[1] FAO figures
[2] Assuming approx 2.8 t/ha (average); EU27= 5.23 t/ha
[3] Estimate accounts for highly variable data

LEARNING TO USE EVERY DROP

Oil refining is an interesting paradigm

- All oil fractions are valorized
- Non-energetic products generate the highest revenues
- Both fuel and chemicals are produced

Biorefining should use every last ‘drop’

- A cellulose to fuel concept is insufficient
- Pentose sugars and lignins must be valorized
- Higher value products must be derived from biomass

TECHNOLOGIES FOR THE BIOECONOMY

- **Biotechnology wil be a key driver (Suschem report)**
  - Energy efficiency
  - Lowered environmental impact
  - High catalytic diversity

- **Chemistry will continue to play a pivotal role**
  - Proven technologies and processes
  - Cleaner reactions inspired by REACH and principles of green chemistry

- **Integrated processes using both biotechnology and chemistry will become frequent**
  - Smart integration will be critical for efficient biorefinery processes

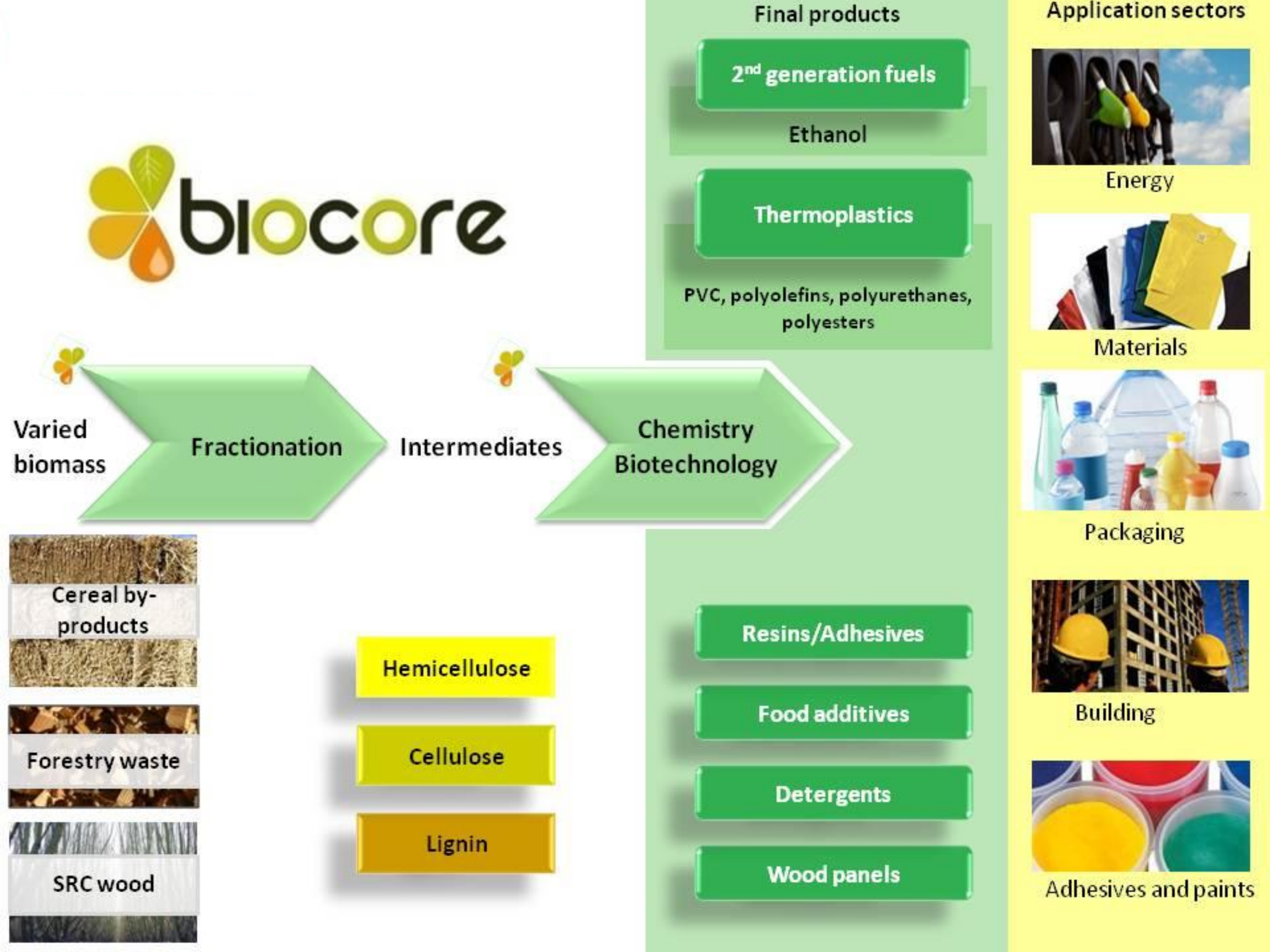
BIOREFINERIES, MAN AND HIS ENVIRONMENT

- **Biorefineries must be sustainable and produce new or renewed industrial activity in Europe and create new opportunity in India**
  - Regional approach with medium scale industrial units
  - Links to existing industrial activities (e.g. sugar refineries and paper mills)
  - Biorefining should be a new driver for agriculture

- **Biorefineries must be robust**
  - Various feedstocks
    - allowing for different geographical locations
    - allowing for seasonality effects

BIOCORE'S AIMS AND STRUCTURE

Expected results and the way to achieve them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Final products
2nd generation fuels
Ethanol
Thermoplastics
PVC, polyolefins, polyurethanes, polyesters
Application sectors
Energy
Materials
Packaging
Building
Adhesives and paints
Varied biomass
Fractionation
Intermediates
Chemistry Biotechnology
Cereal by-products
Forestry waste
SRC wood
Hemicellulose
Cellulose
Lignin
Resins/Adhesives
Food additives
Detergents
Wood panels

KEY FEATURES OF BIOCORE

Take home messages about the project

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AVOIDING COMPETITION WITH FOOD SUPPLY

A multi-feedstock concept

- Cereal crop residues
  - Abundant (3-5 Gt produced per annum worldwide)
    - 100 -600 Mt[1] in India
      - on-field burning still common practice
      - Approx 23% is actually available
- Forest products
  - Hardwood products and residues
- Dedicated short rotation coppice
  - Potential for high yield (8-15 t/ha)
  - Use of marginal or polluted land
  - High expectations (up to 140 Mt per year for Europe[3])

[1] based on Gadde et al, 2009 and Felby and Bentsen, 2008
[2] based on Fischer et al, 2007 and other estimates
[3] IEA 2050 scenario

OPTIMIZED EXTRACTION OF BIOMASS COMPONENTS

- **CIMV Organosolv**
  - Uses a formic : acetic acid solvant system (generation of peracids)
    - Dissolves lignin and hemicelluloses
  - Multi-biomass
    - Hardwood
      - SRC woods (with bark)
    - Cereal coproducts
      - Wheat
      - Rice straw
      - Maize cane
    - Dedicated energy crops

- 100 kg/h biomass
- In operation since 2006
  - >50 runs completed

THREE PLATFORM INTERMEDIATES

Cellulose and glucose

Pentose sugars

Lignins

MAKING IT WORK……………EVERYWHERE

- **Account for the many issues that will form the framework of biorefinery implementation**
  - Environment?
    - Plant, animal and microbial biodiversity
    - Landscape
    - Soil quality
  - Economy
    - Employment
    - New markets and products
  - Society
    - Rural development
    - New policy

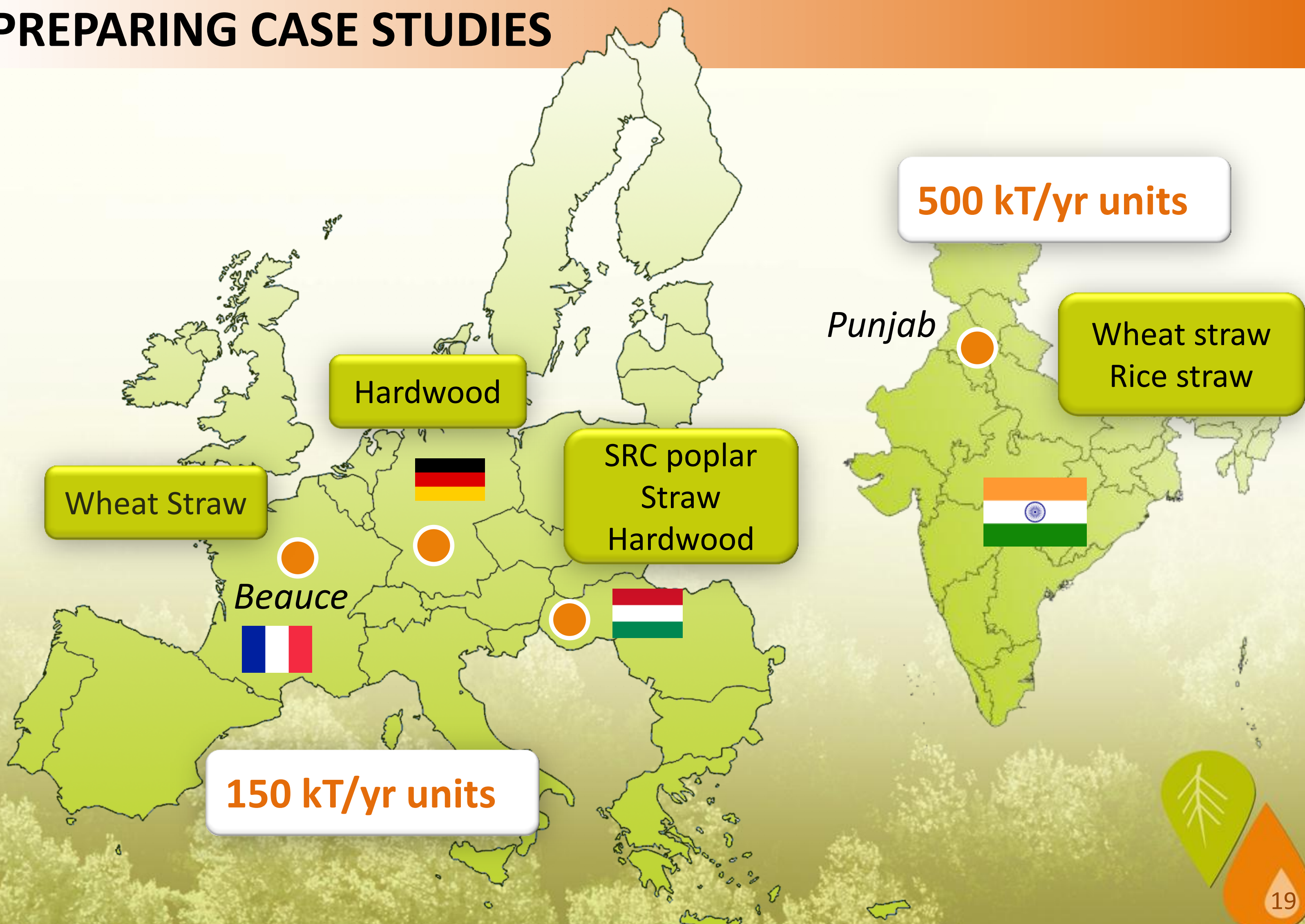
MAIN ACHIEVEMENTS

Highlights of the project’s progress

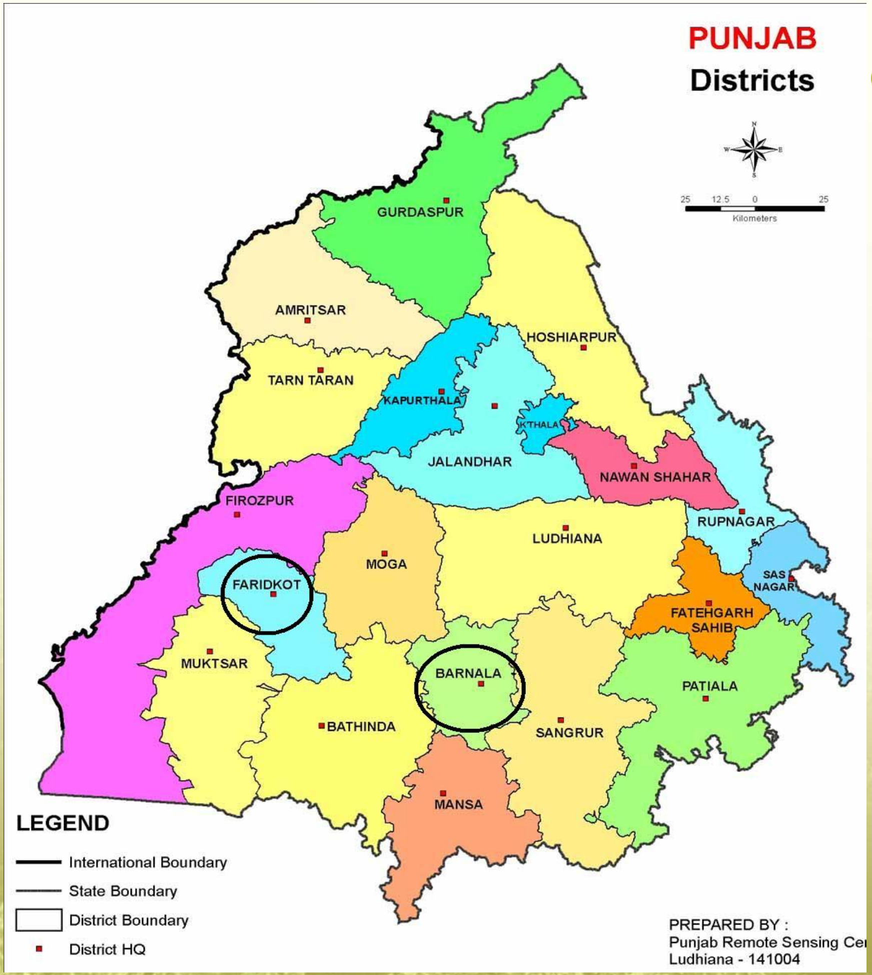
BIOMASS SUPPLY

- **Aggregation of existing data reveals that:**
  - Europe can readily supply 35 Mt per year of ag-residues
  - Up to 50% (17.5 Mt) of potentially harvestable straw residues are located in 3 countries: Germany, France and Ukraine
  - Potentially harvestable hardwood in Europe is located in France, Germany, Italy, Poland, and Romania (2.5 to 5.5 Mt per country)
  - Certain Indian states can supply both wheat and rice straw
    - Favourable climatic conditions allow for two crops per season
  - Central and Eastern Europe present best potential for SRC poplar

PREPARING CASE STUDIES

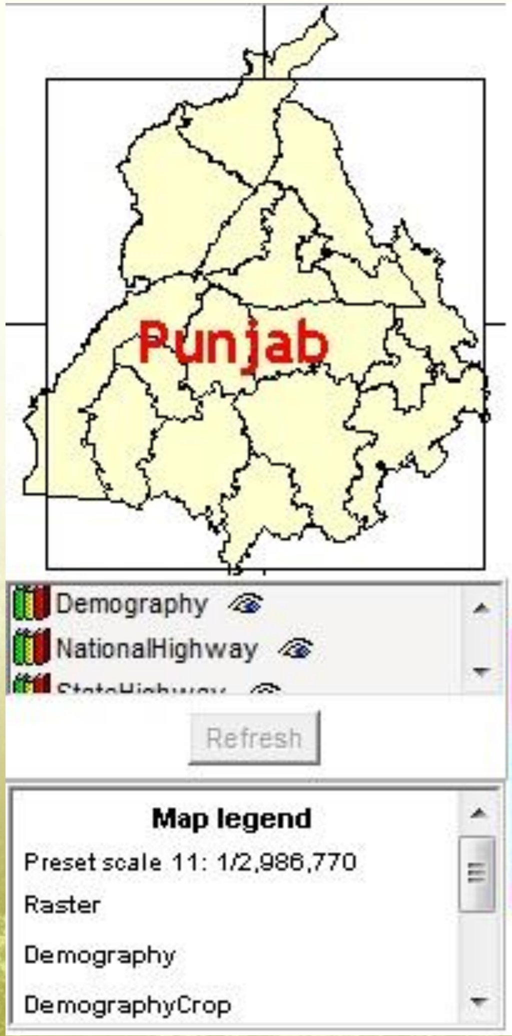


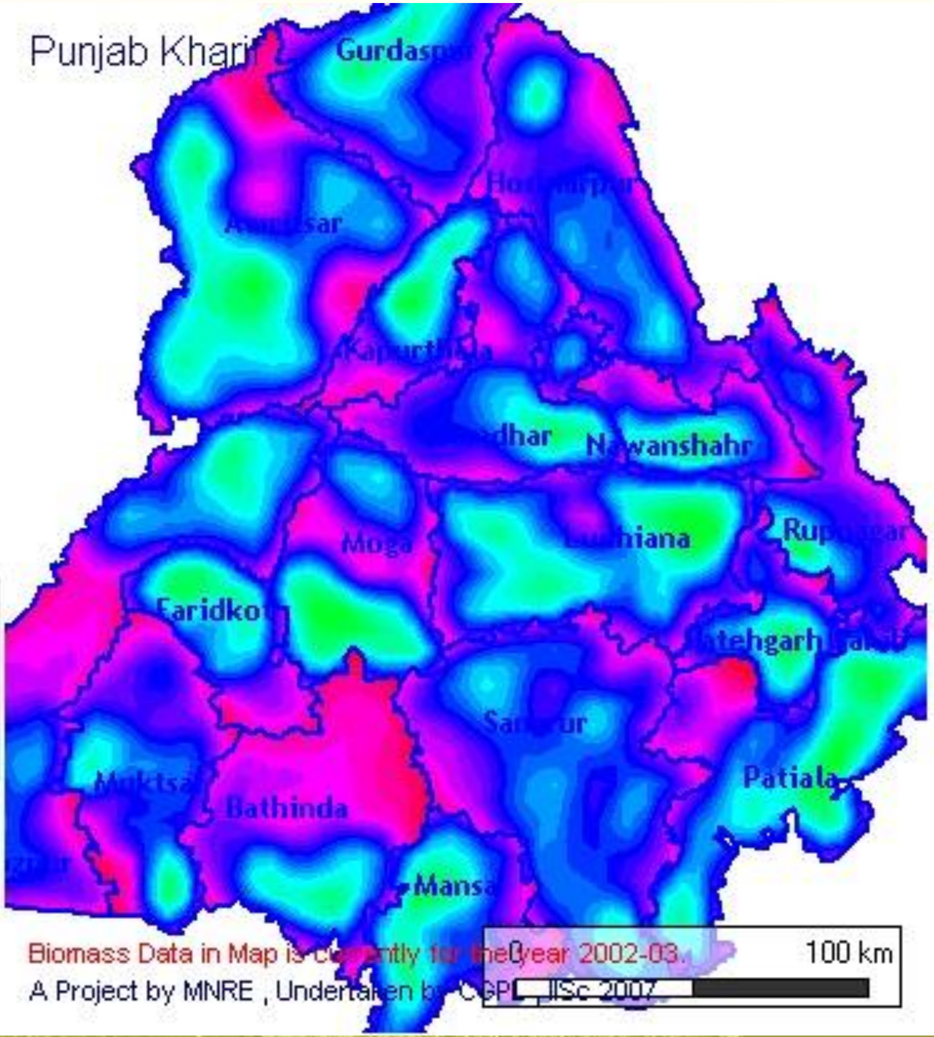
INDIAN CASES STUDIES



- Locations for biorefinery
  - Barnala (Sangrur): Planned raw material requirement - 500000 ton of DM per annum
  - Faridkot : Planned raw material requirement - 150000 ton of DM per annum

BIOMASS AVAILABILITY





BIOMASS ATLAS OF INDIA , 2003-04 (MNRE, GoI)

- Barnala (Sangrur)
  - 29,92,000 tons of agro biomass surplus in Sangrur
  - Existing supply chain of small entrepreneurs – Paper industry
  - Neighboring districts – (Mansa, Ludhiana, Patiala) 51,63,000 tons of agro Biomass Surplus

- Faridkot
  - 913000 tons of agro biomass surplus
  - Large landholdings in Malwa region + Sirhind Canal
  - Neighbouring district- (Firozpur, Bhatinda, Moga) - 68,73,000 tons of agro Biomass surplus

Impact of Bio-refinery

- No direct/indirect change in Land use pattern with/ without LC biorefinery
- Employment to locals
- Decrease in straw burning from 90% to 10% (2025)
- Health benefits due to bio-refinery (reduced straw burning – sent to biorefinery)
- One ton of burned straw yields 3kg of particulate matter, 60kg of CO, 1460kg of CO_2, 199kg of ash, 2 kg SO_2. – Health issues in post harvesting season. (Gupta et al(2004))
- Total annual welfare loss in terms of health damages due to air pollution caused by the burning of rice straw in rural Punjab amounts to ₹76 millions. (Kumar & Kumar (2010): CREDI) - Avoided

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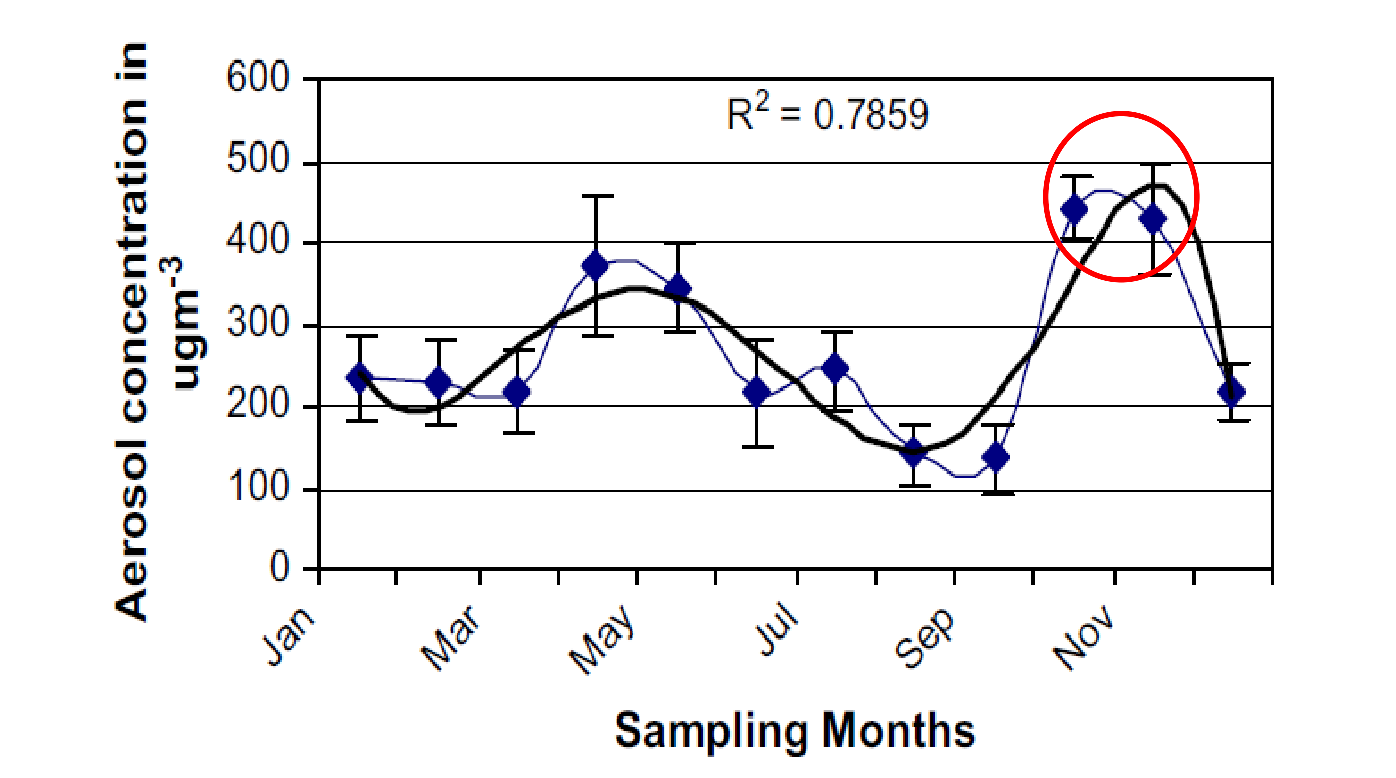
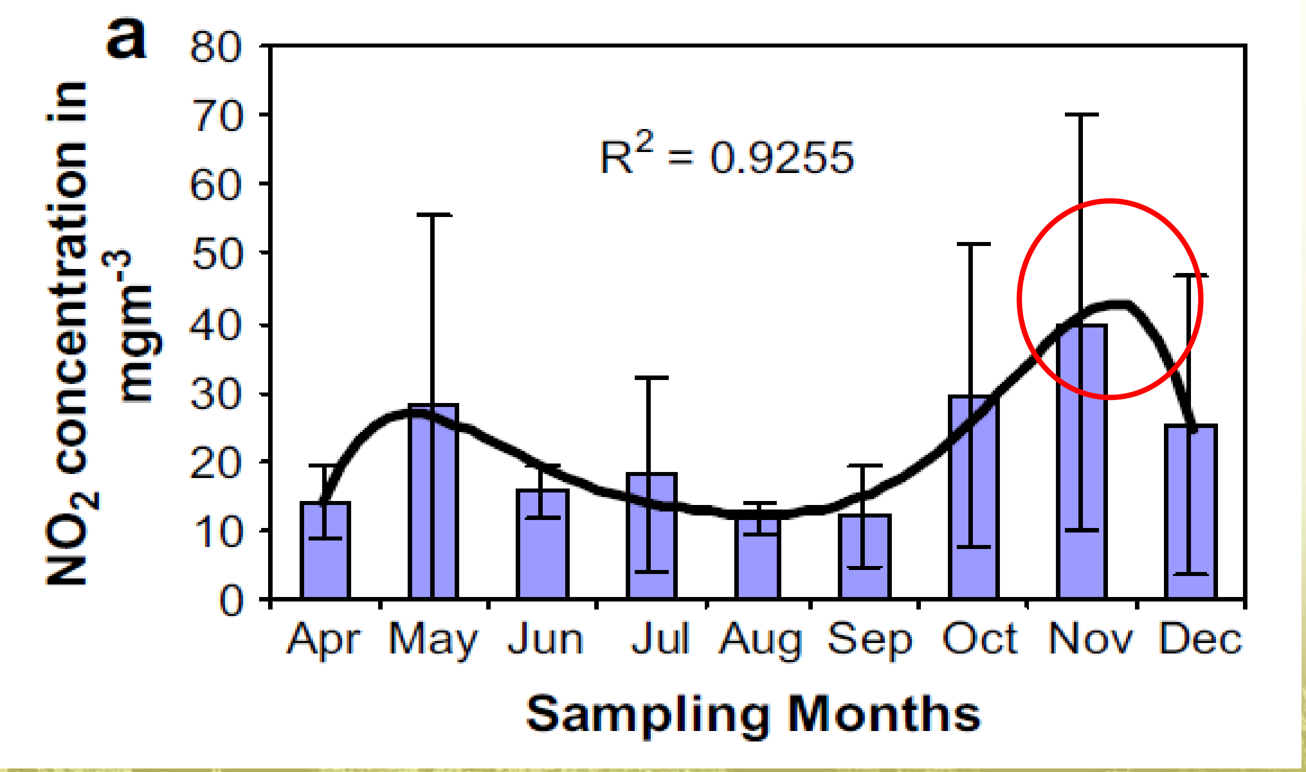
Straw burning -Pollution

- Study done in Patiala, S.K. Mittal et al (2009) measured monthly average value of ambient air quality.
- Red circle represents Paddy harvesting season

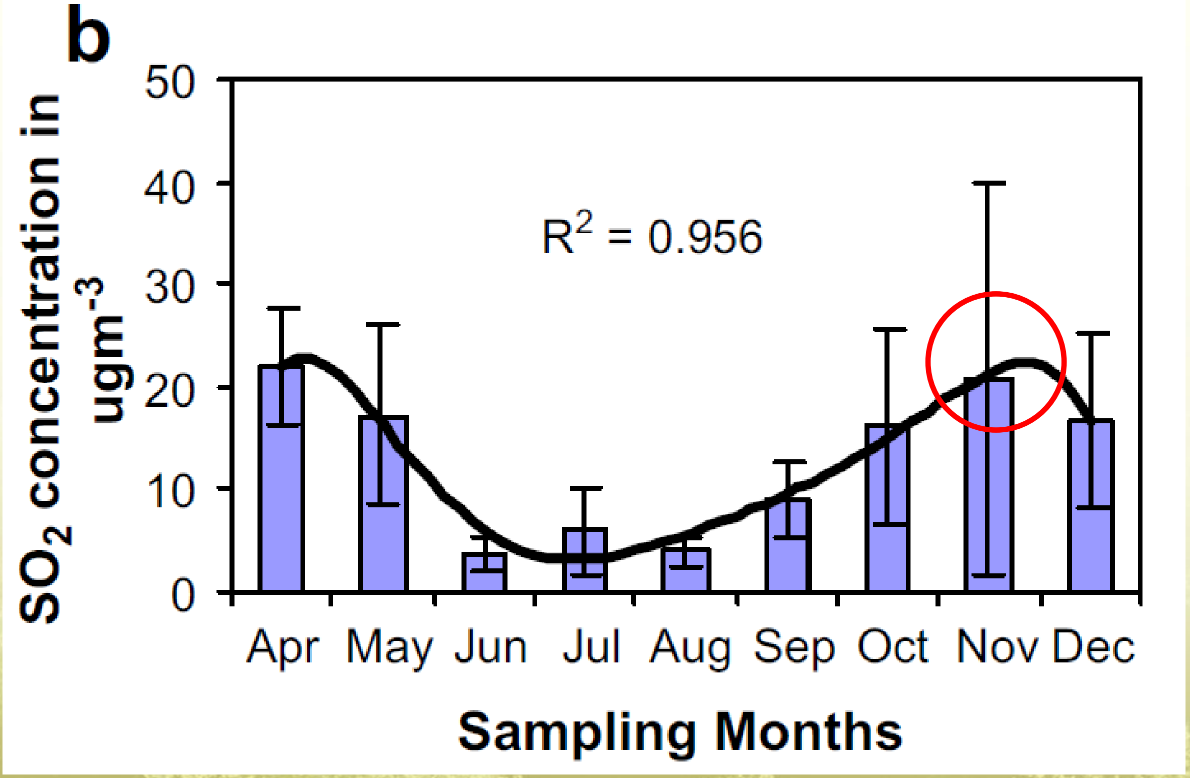


- NO_2 concentration*



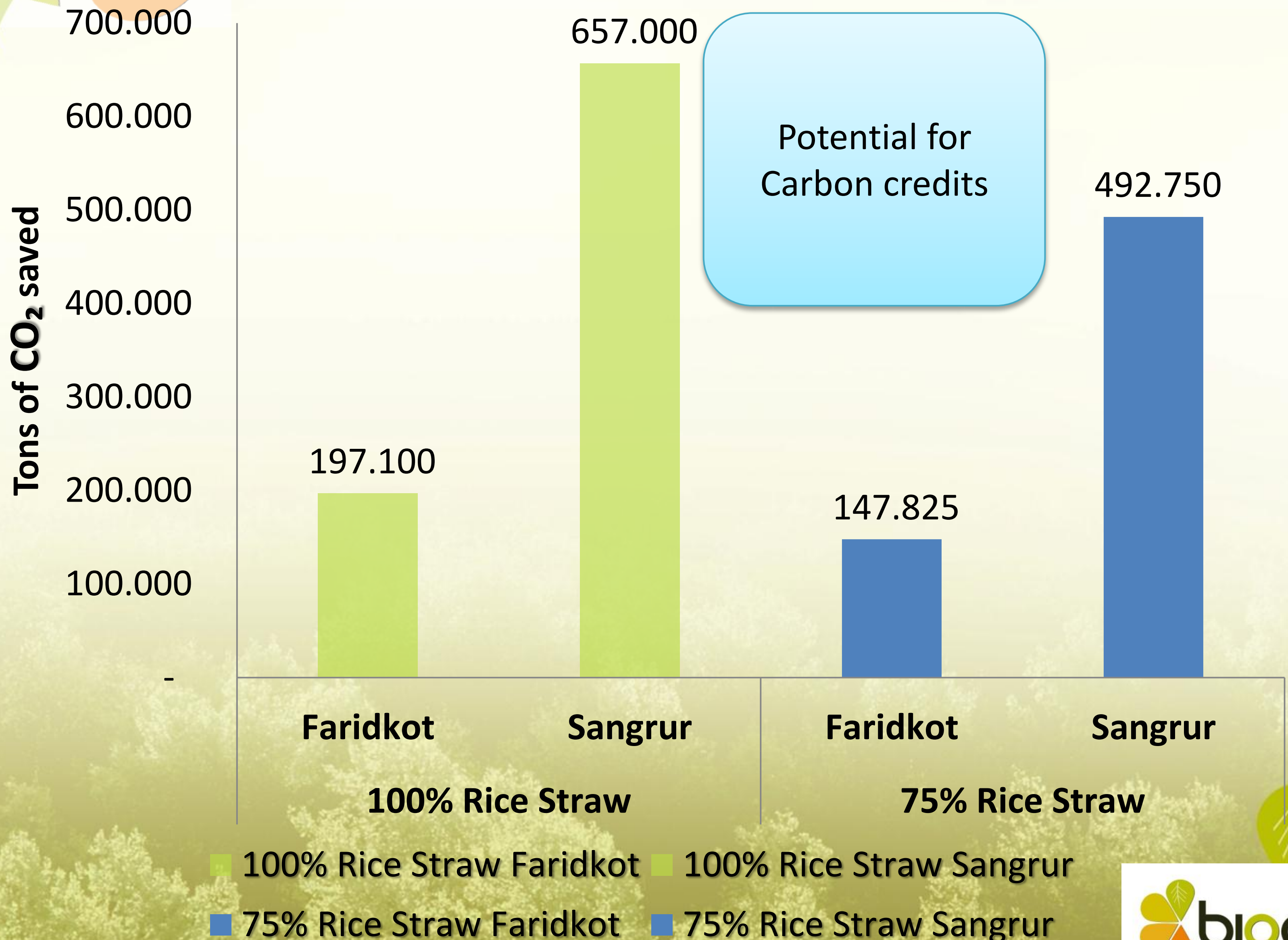
S.K. Mittal et al. / Atmospheric Environment 43 (2009) 238–244

- SO_2



S.K. Mittal et al. / Atmospheric Environment 43 (2009) 238–244

Preventing Emissions from Rice straw burning/ year



MULTI-FEEDSTOCK REFINING

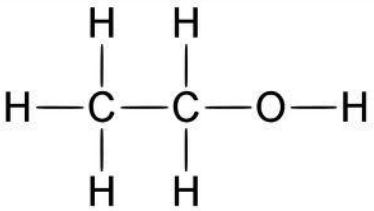
- **CIMV organosolv processing can handle several feedstocks**
  - Rice straw – no process alterations
  - Birchwood and SRC poplar – modification of the residence time and formate:acetate ratio
    - Feasible at industrial scale using a batch mode or by deploying two process lines
    - Bark is not a problem with SRC poplar
    - Hardwood/softwood (90:10) mixture can be processed
  - A promising innovation that will allow the processing of softwood has been identified

PRODUCTION OF BIOETHANOL

CIMV organosolv

SHF with hydrolysis at 60°C

- Near theoretical yields of ethanol
- 150 l batch produced
- Conversion into ethylene underway



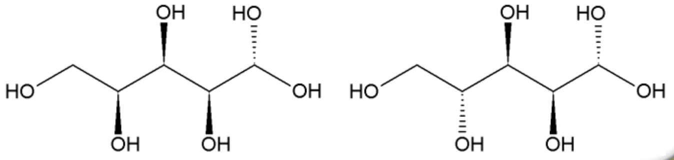
DSM's heat stable cellulases
Industry standard yeast

DIRECT CATALYTIC CONVERSION OF STRAW CELLULOSE INTO POLYOLS

CIMV organosolv

- **One pot method**
  - Yield 90% mol C (% mol C in hexitol per % mol C cellulose x 100)
  - 80 gl-1h-1 (lab scale)
  - Mainly sorbitol (60% mol C) – route to isosorbide

Bifunctional heterogeneous catalyst

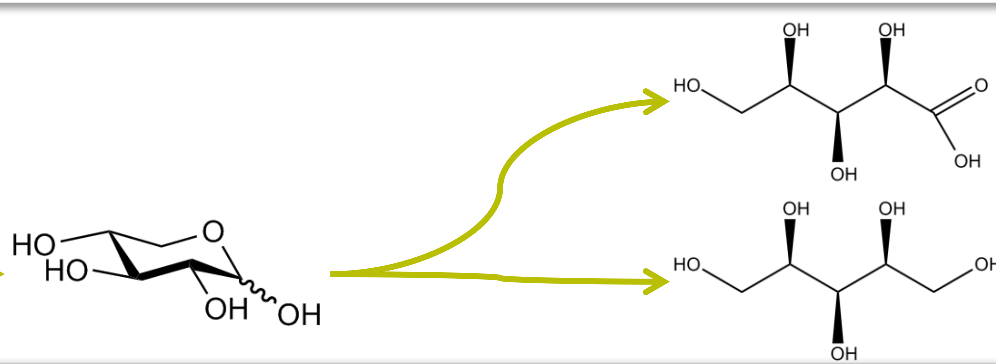


BIOTECH PRODUCTION OF XYLITOL AND XYLONATE

CIMV organosolv

- **Yeast catalyzed conversion**
  - Using pure xylose up to 100 g xylitol l-1 at high productivity (yield 0.85 g xylitol/ g xylose consumed)
  - up to 90 g.L-1 of xylonate
  - Pentose syrup refining is still a challenge

Purification



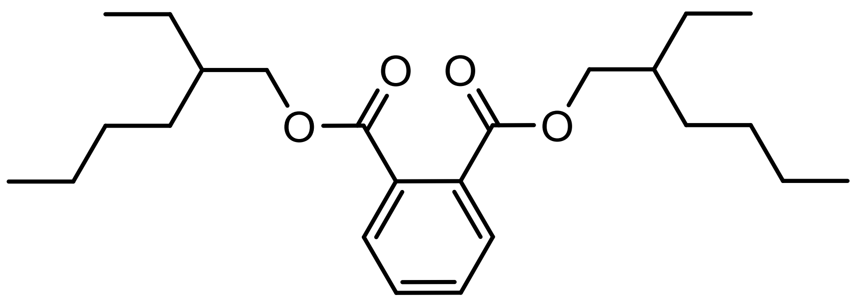
DEVELOPMENT OF LIGNIN-BASED POLYMERS

Lignin reinforcement of thermoplastic elastomer

- Simple fabrication method
- Increased tensile strength and toughness, with surface hardness being significantly increased
- Application for electrical appliances (e.g. cables)

NEW BIO-BASED PLASTICIZERS

- **Di-2-ethylhexyl phthalate (DEHP)**
  - A bio-based plasticizer for PVC



  - Using DEHP, PVC is 30% more flexible

CONCLUSIONS

CONCLUSIONS

BIOCORE

- A concept that addresses a number of grand challenges
- Highly encouraging progress with several highlights after 18 months
- Potential for near-mature industrial technologies in 2014

Thank you!

Stakeholders meeting at Amritsar, India

Acknowledgements to:

- all BIOCORE partners
- the EU Commission for funding