

Closed Loop Chemistry ***From Waste to Wealth*** ***using*** ***Green Chemistry***

James Clark

Green Chemistry Centre of Excellence
University of York, UK

www.greenchemistry.net

Research

Industry

Networking

Education



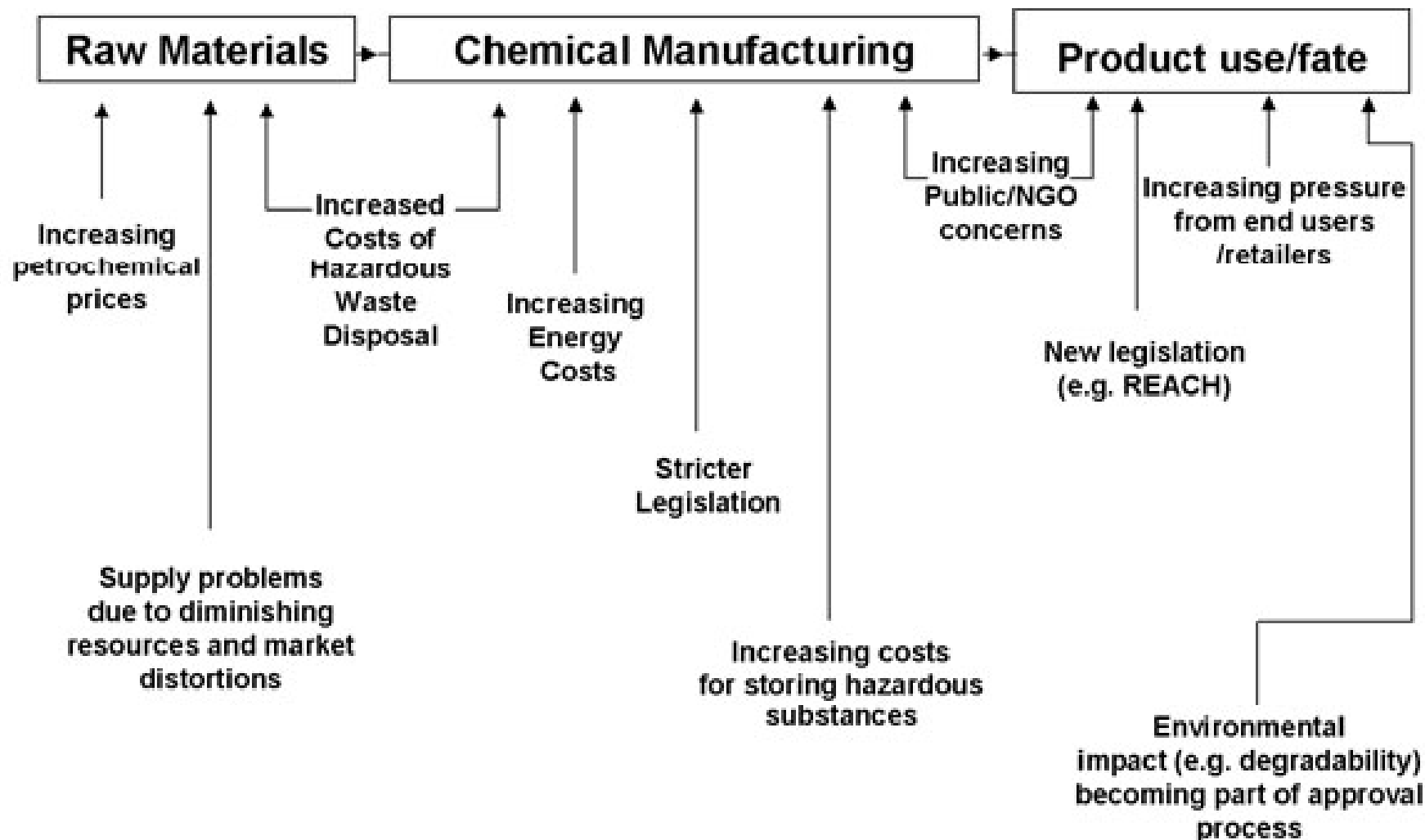
www.greenchemistry.net

Benefits of the Chemical Industry



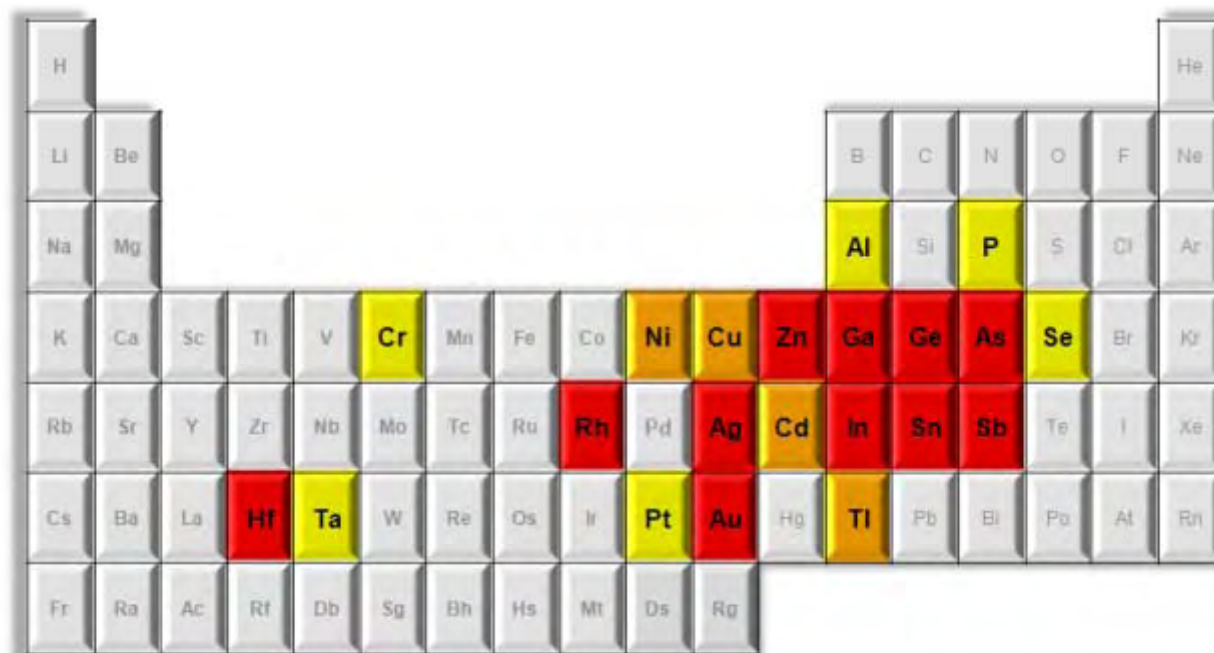
Yet everybody hates chemicals!

Pressures on the Chemical Industry Across the Lifecycle

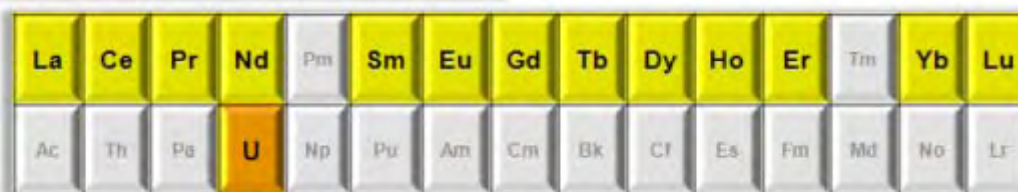
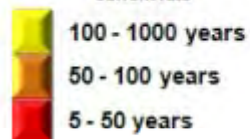


We are running out of key elements

Elemental unsustainability



NUMBER OF YEARS LEFT
If continued to be consumed at
current rate



Research

Industry

Networking

Education

So much ends up in waste



Research

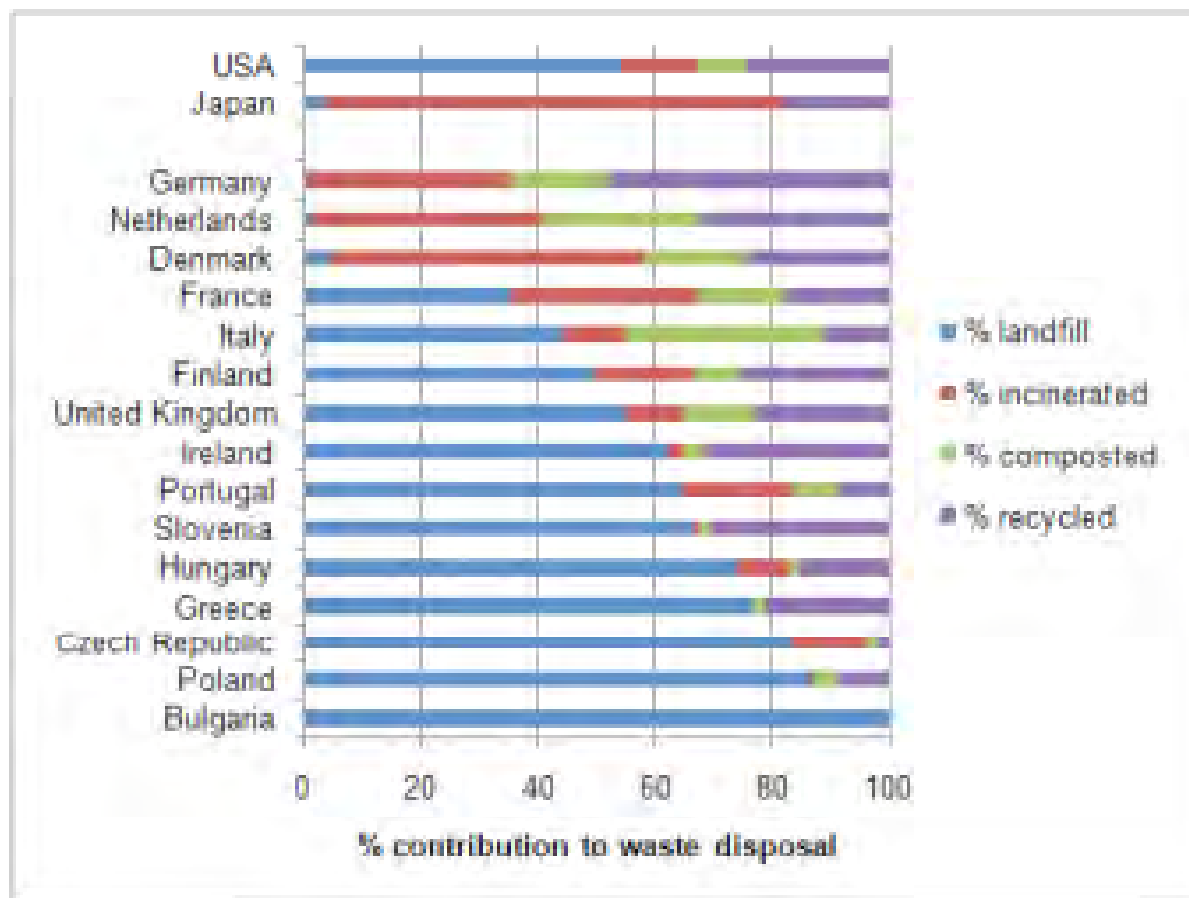
Industry

Networking

Education



What do we do with our waste?



What a waste!!



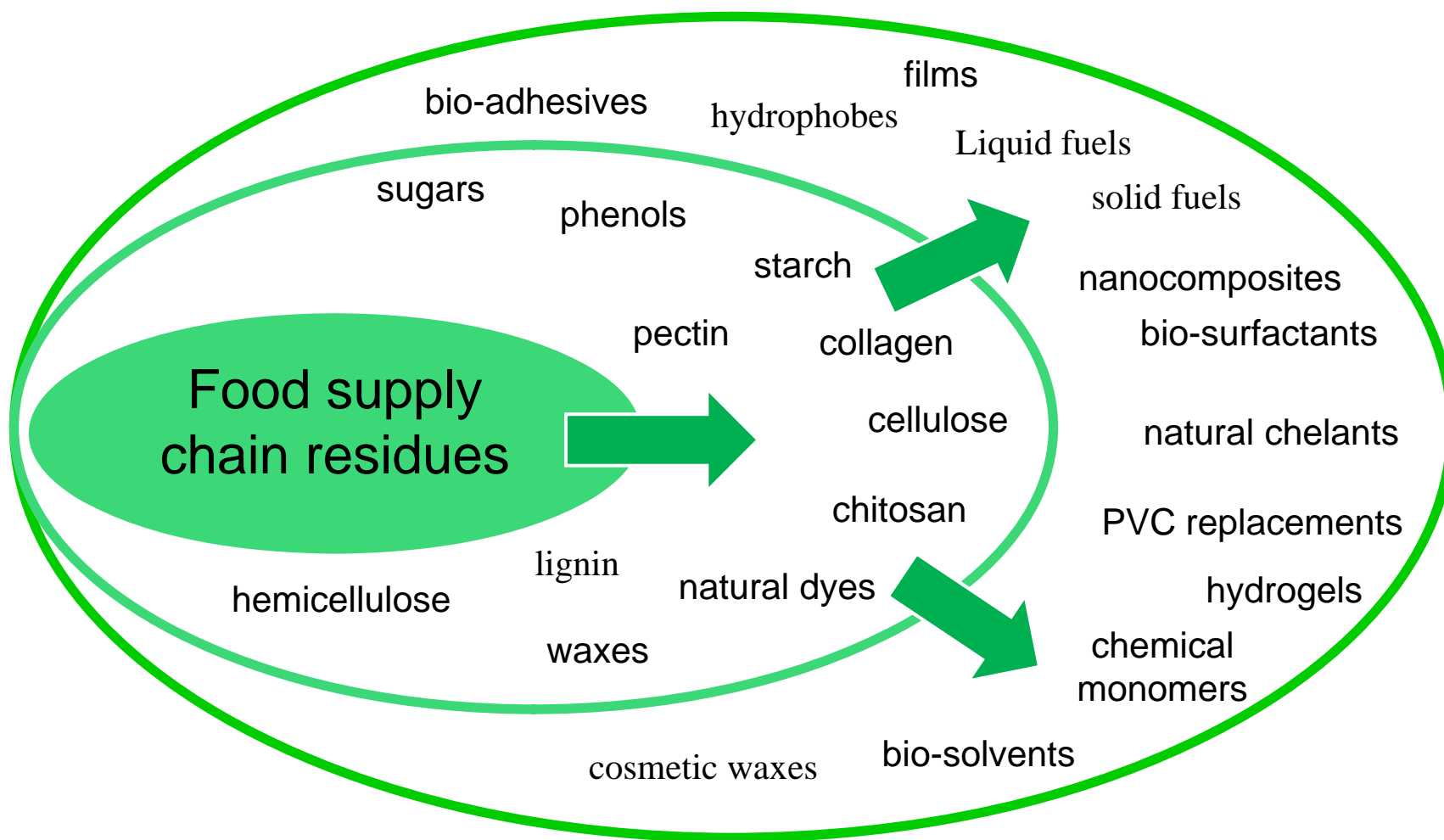
Waste is tomorrows resource



*We need to encourage the greater use of
chemically rich waste as a resource*

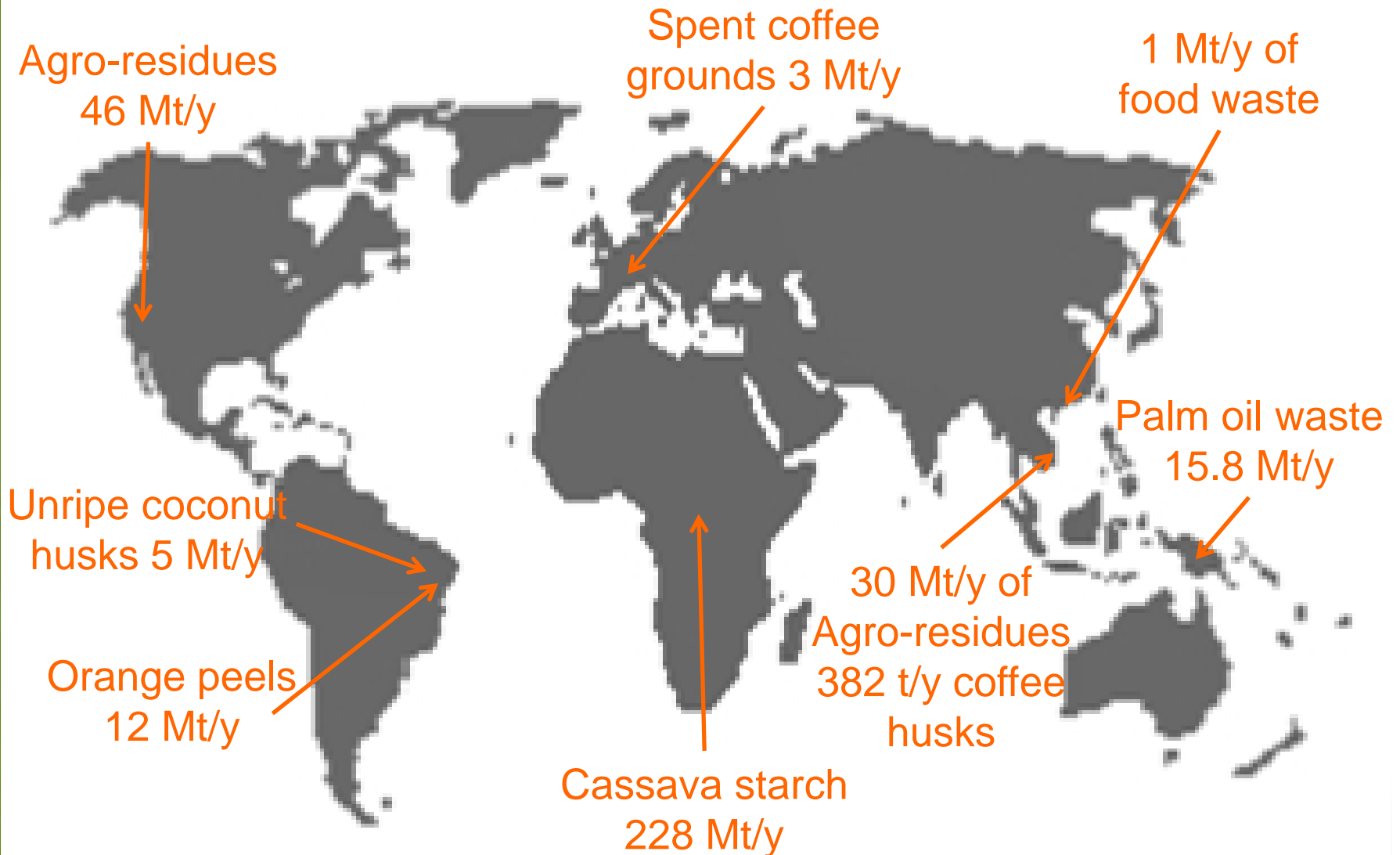


Chemicals from food waste



- Research
- Industry
- Networking
- Education

A world of possibilities...



- Research
- Industry
- Networking
- Education

Sustainable sources of Carbon

*Over 90% of organic chemicals are based on petroleum feedstocks
- this is not sustainable*

Research

Industry

Networking

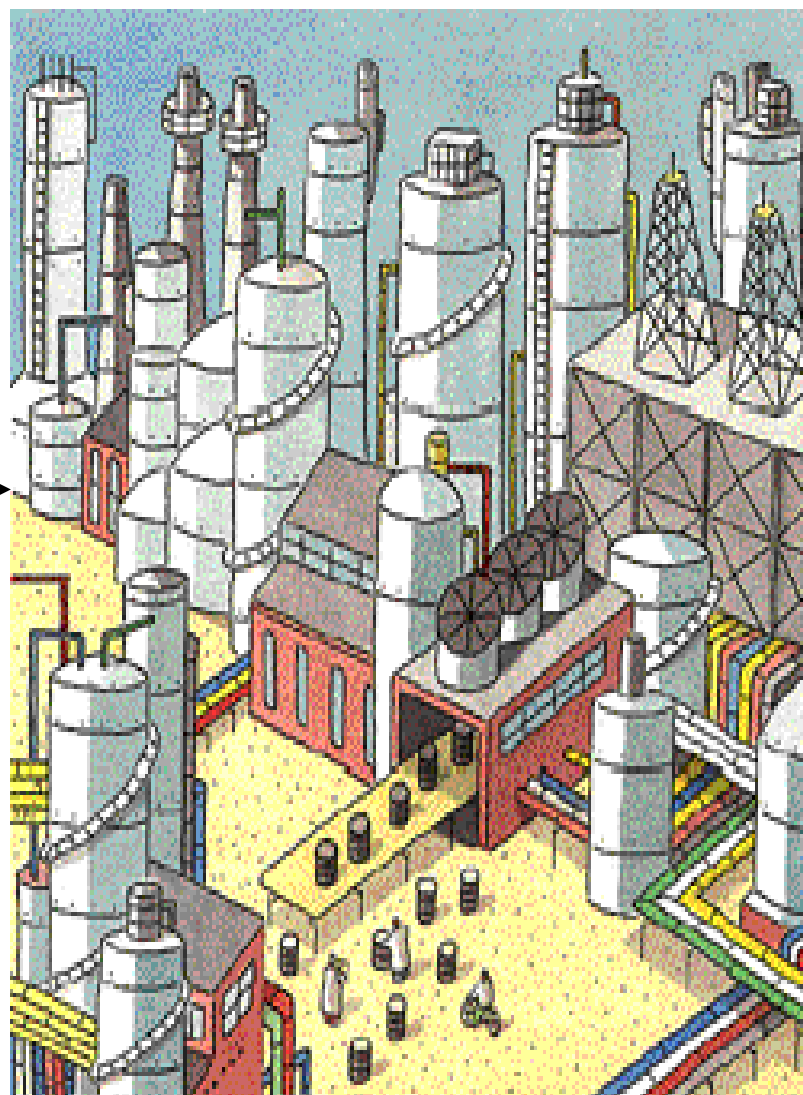
Education



Petroleum Refinery



Petroleum
feedstock

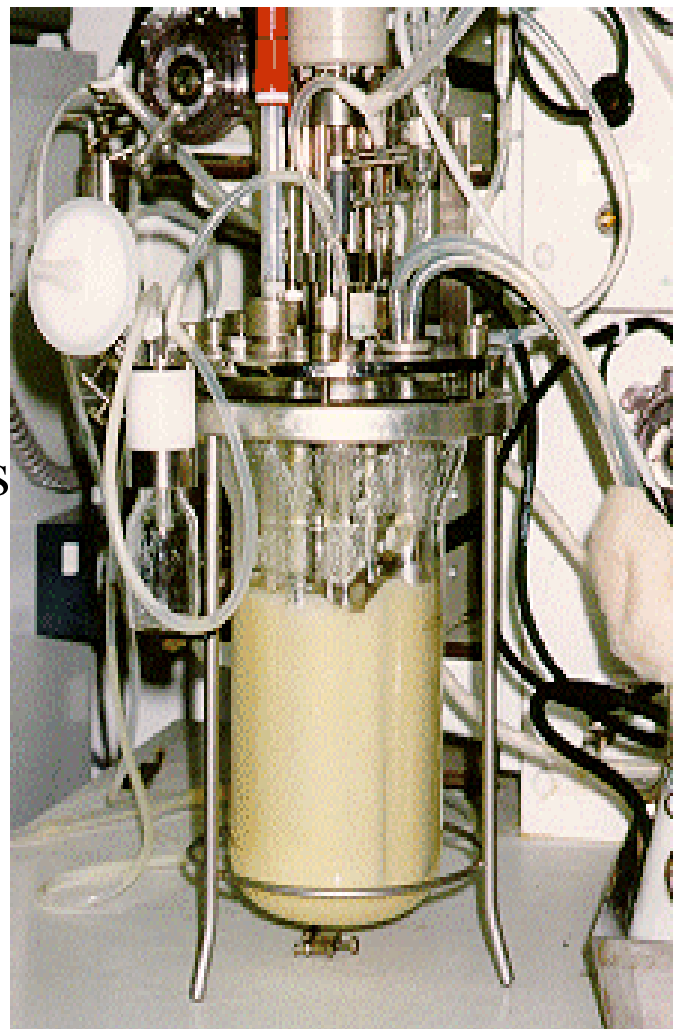


- Fuels
- Solvent
- Bulk chemicals
- Plastics
- Fibres
- Fine chemicals
- Oils



Bio-refinery

Biomass



→ Fuels



→ Solvent



→ Plastics



→ Bulk chemicals



→ Fine chemicals

→ Fibres



→ Oils



Research

Industry

Networking

Education

Don't use food quality feedstocks!!

It's not just about how safe the product is....
Or how clean the manufacturing is.....
Or how sustainable the feedstocks are

**We need to introduce
Green Chemistry
concepts and practices
across the supply chain(s)**

Research

Industry

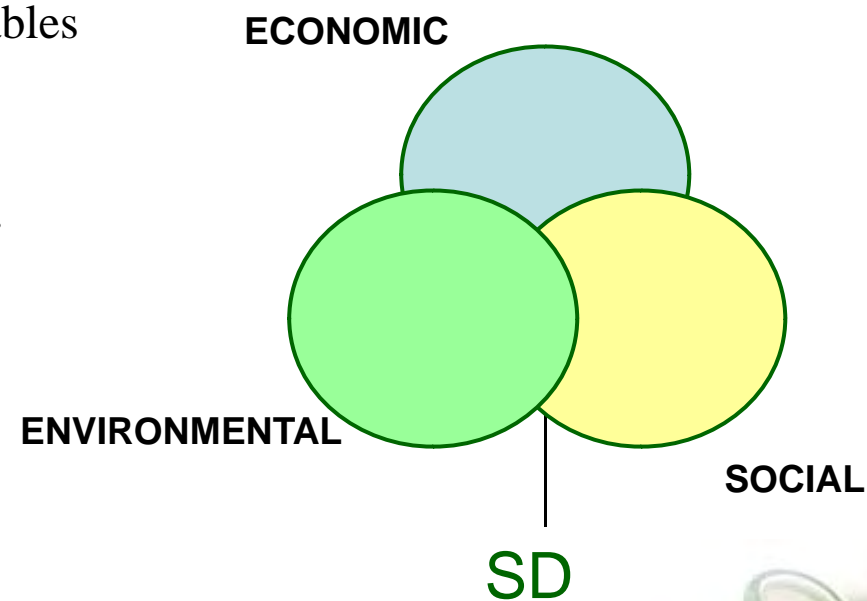
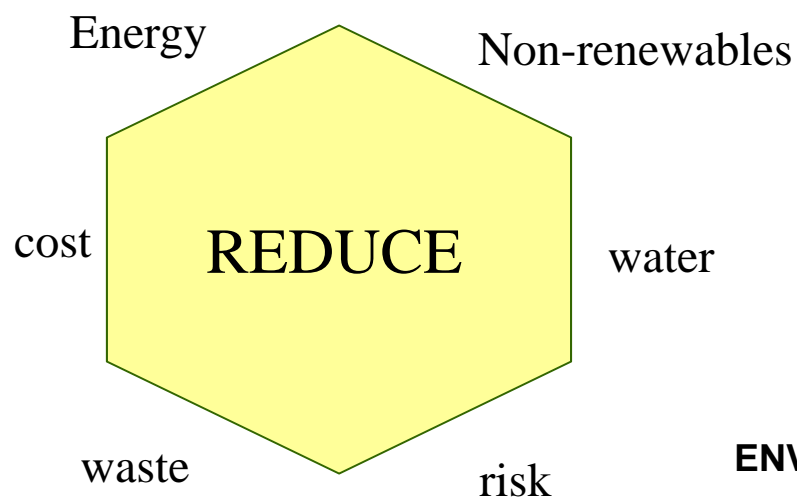
Networking

Education



What is Green Chemistry?

Sustainable Development and Business

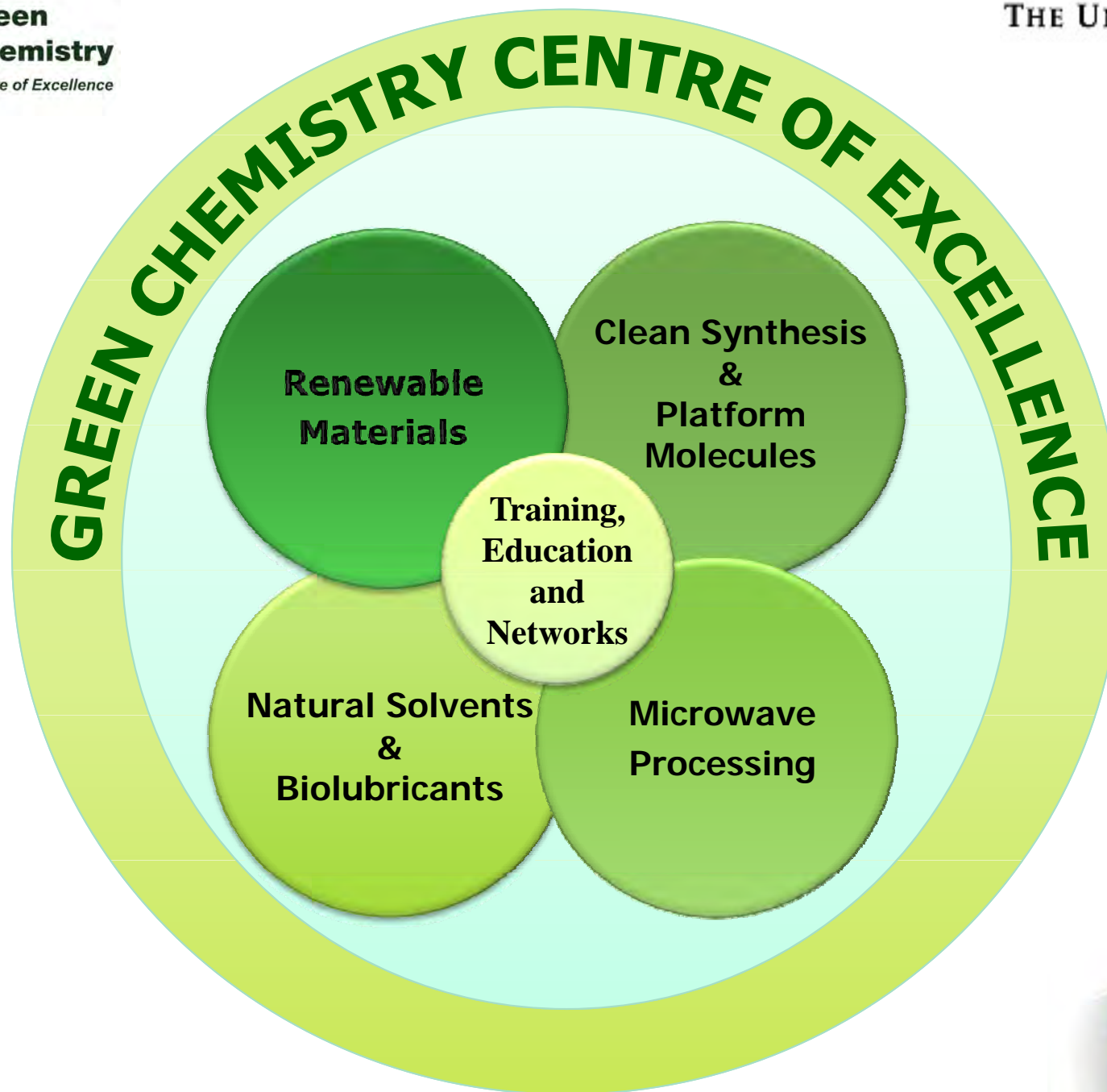


Research

Industry

Networking

Education



Research

Industry

Networking

Education





Biomass

including food and agro-wastes

CHEMICAL POTENTIAL

Extractables

(secondary metabolites from straw)

Materials

(primary metabolites – starch, cellulose)

Bulk Chemicals

((Bio)chemical processing of bulk materials/residues)

ADDING VALUE

TECHNOLOGIES

Benign Extraction Methods

Separation/Purification

Green Chemical Transformation

Selective Fermentation

Controlled Pyrolysis

Extraction Technology

(Bio)platform molecules

Green Chemistry/technology

Expansion Methods

Green Chemical Modification

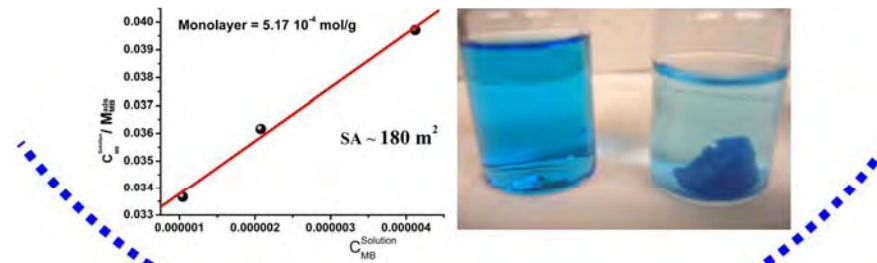
Composites



- Research
- Industry
- Networking
- Education

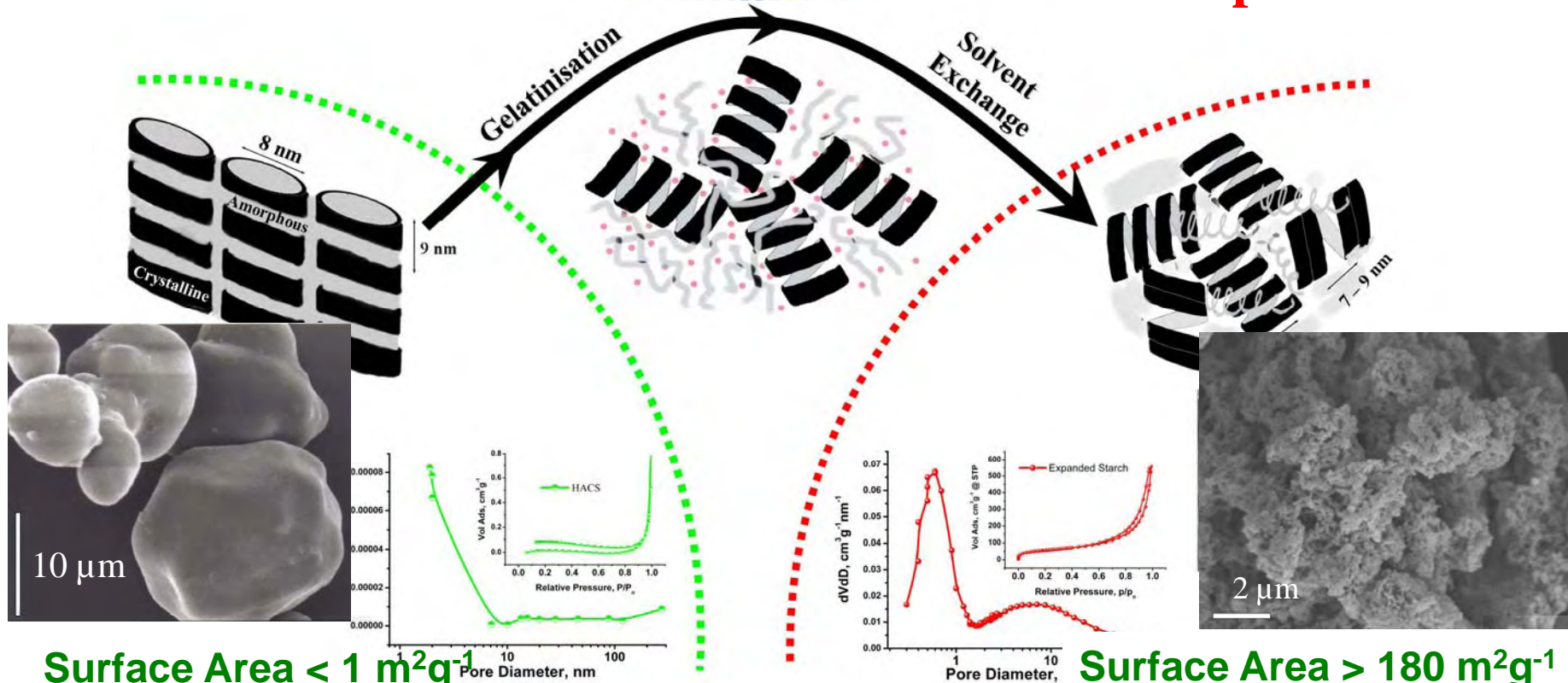
Food waste....

Porous polysaccharide-derived materials



Native Starch

Expanded Starch



Surface Area < 1 m²g⁻¹
Pore Volume < 0.002 cm³g⁻¹

Surface Area > 180 m²g⁻¹
Pore Volume > 0.5 cm³g⁻¹

STARBONS®

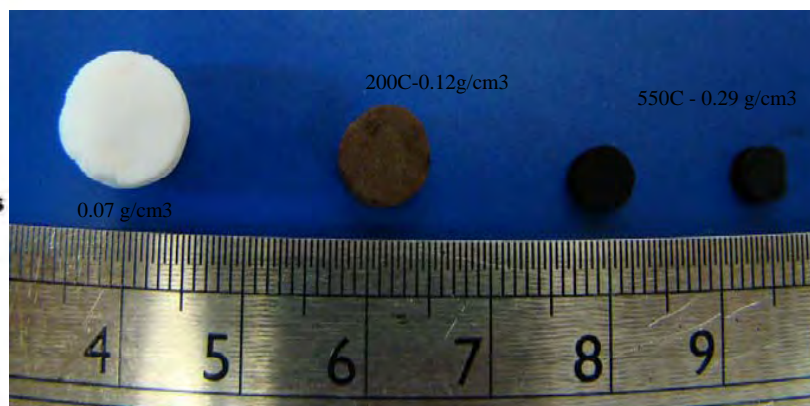
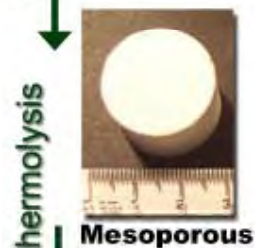
An exciting new class of carbonaceous materials

Properties

Applications

- Separation media
- Catalysis
- Absorbency
- Water purification
- Fuel cells

- Adjustable surface energies and polarities
- High mesoporosity and surface areas
- Readily functionalisable with acid/base/metal functionality
- Excellent solvent stability
- Good chemical and heat resistance
- Controllable electrical conductivity
- Formation of composites and blends
- Particulate/ monolithic forms

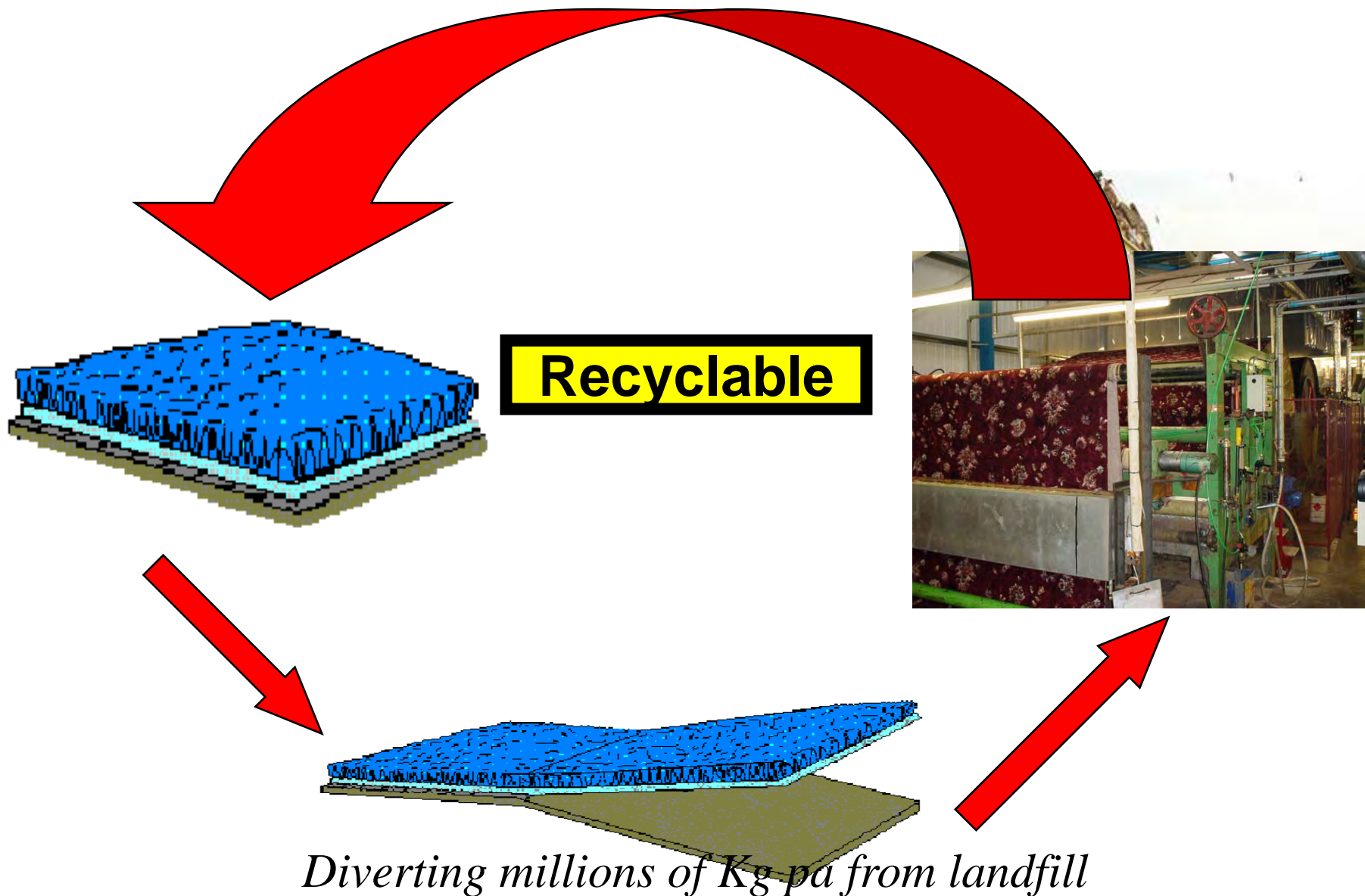


- Research
- Industry
- Networking
- Education



Making use of food wastes.....

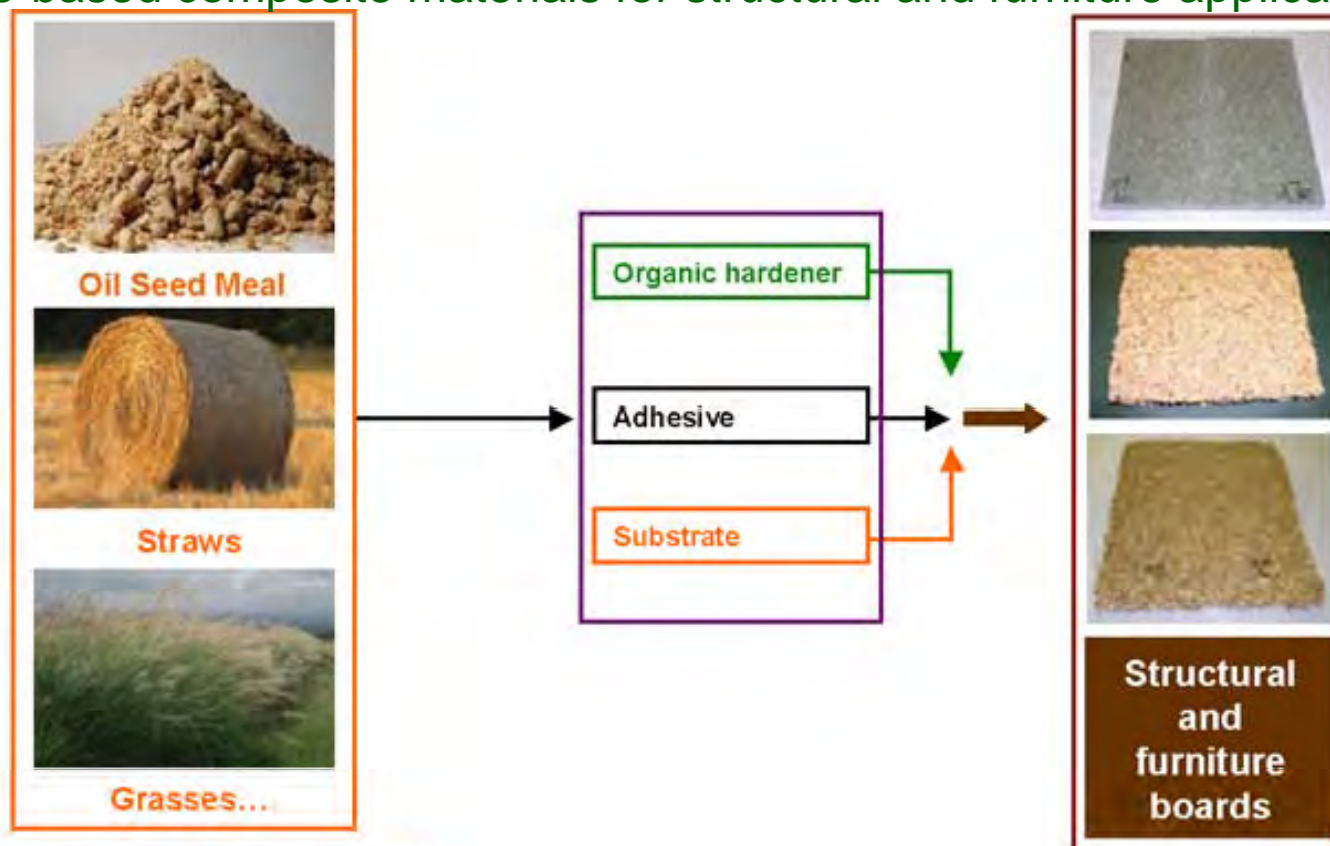
Switchable adhesives for carpet tiles (InterfaceFlor)



More uses for food waste and for ashes.....

Bio-silicates (B&Q)

Bio-based composite materials for structural and furniture applications



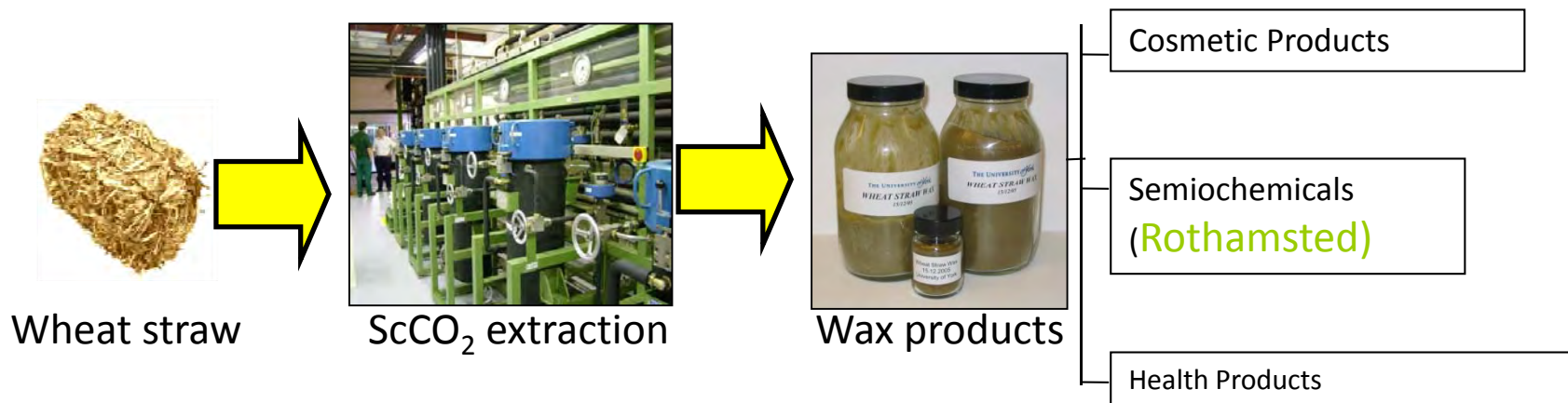
Agricultural and related residues

*Future construction materials based on
100% green and sustainable components*



Eco-waxes

Charles Jackson Farms - Botanix - Croda - L'Oreal - Processum



“Natural” products are very desirable...they need to be:

- *derived from natural resources*
- *extracted using “natural” solvents (H₂O, EtOH, CO₂)*
- *modified only by “natural” methods (biocatalysis)*



Making your process *greener*

Chemical manufacturing is largely based on chemistry that is complex, energy-, solvent-, and water-intensive and produces a lot of CO₂ and considerably more (often hazardous) waste than product

Research

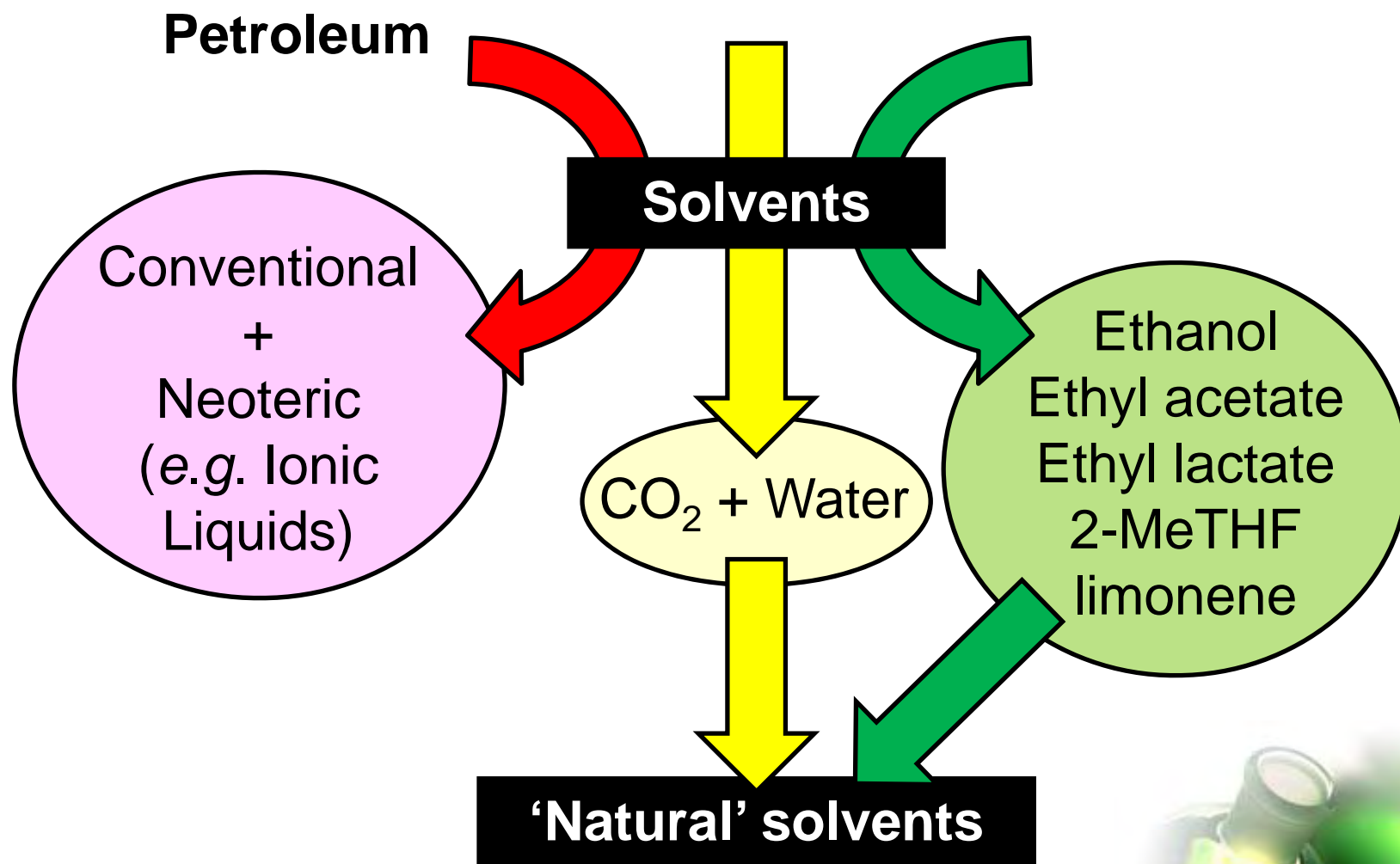
Industry

Networking

Education



Greener Solvents



Research

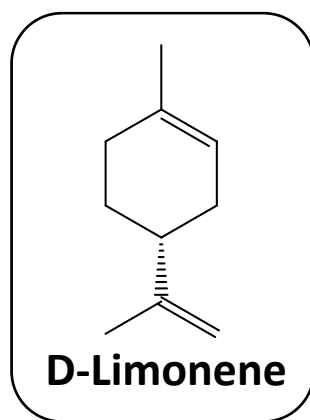
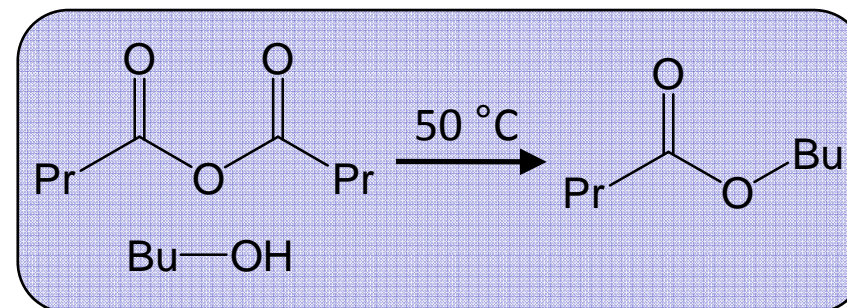
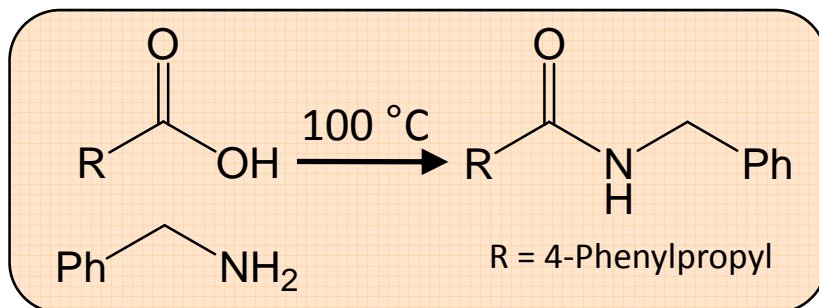
Industry

Networking

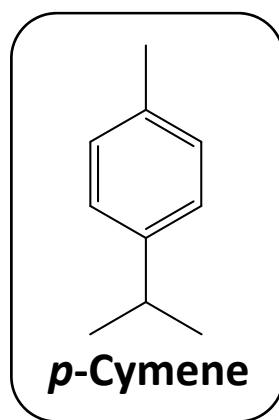
Education



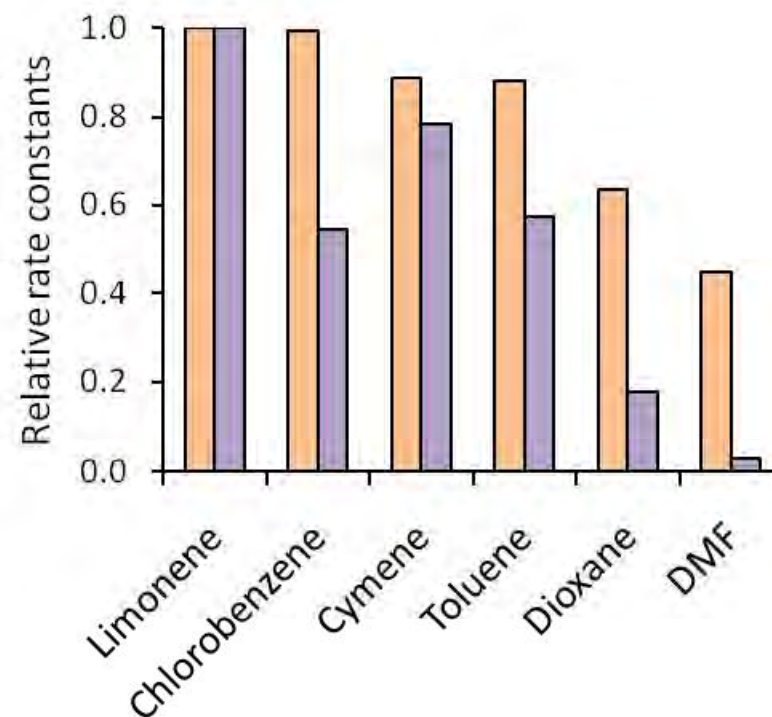
Amidation and Esterification in Bio-Solvents



scCO₂ extraction
↑
Orange peel



O₂ + Pd-γ-Al₂O₃
↑
Eucalyptus oil



Research

Industry

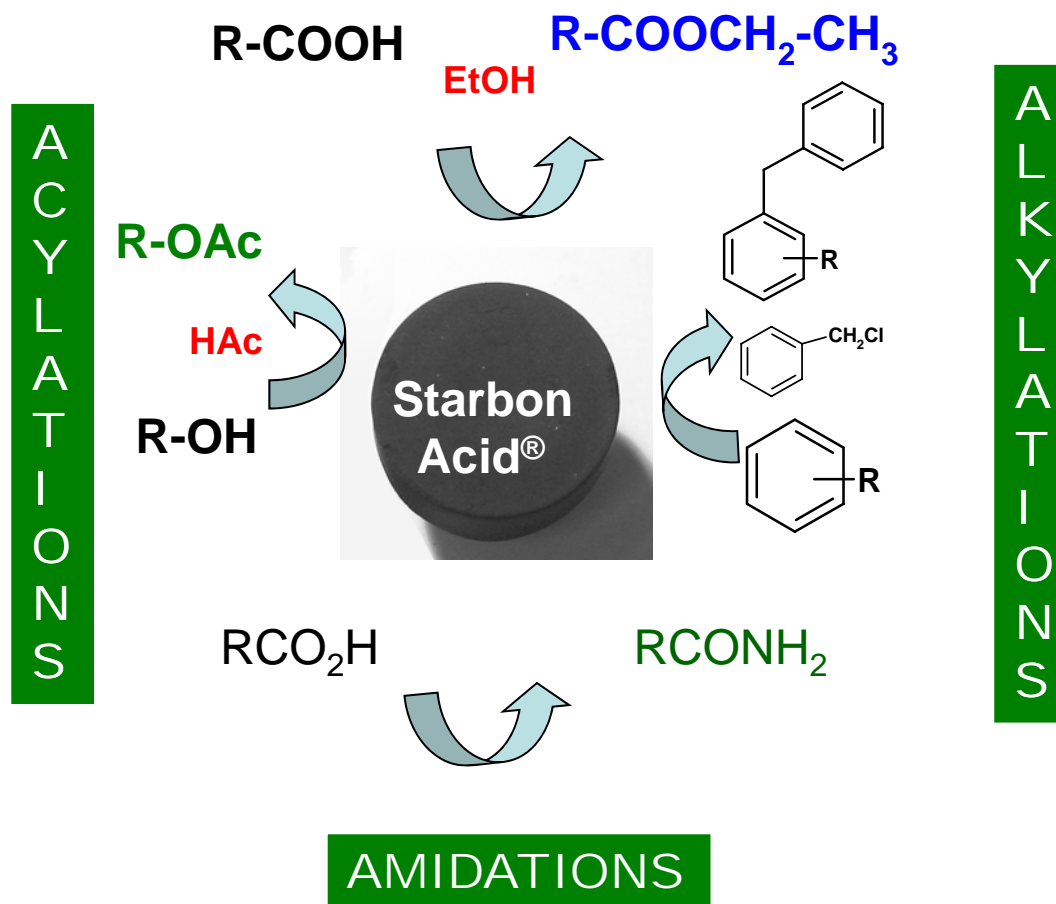
Networking

Education

STARBON[®] ACIDS as catalysts

direct downstream chemistry on fermentation broths

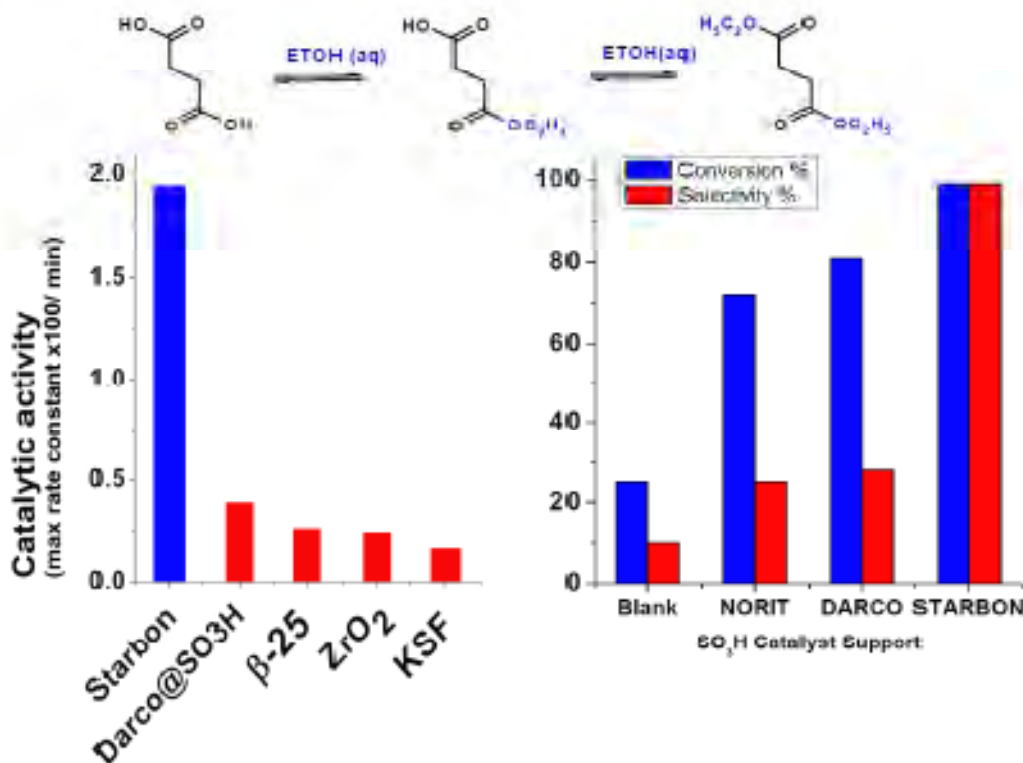
ESTERIFICATIONS



Starbons- a new generation of water-tolerant catalysts

-Acid catalysis directly on fermentation broths

Catalytic activity, conversion and selectivity of STARBON[®] acids in comparison to other solid acids (and supports) in aqueous ethanol esterification of succinic acid

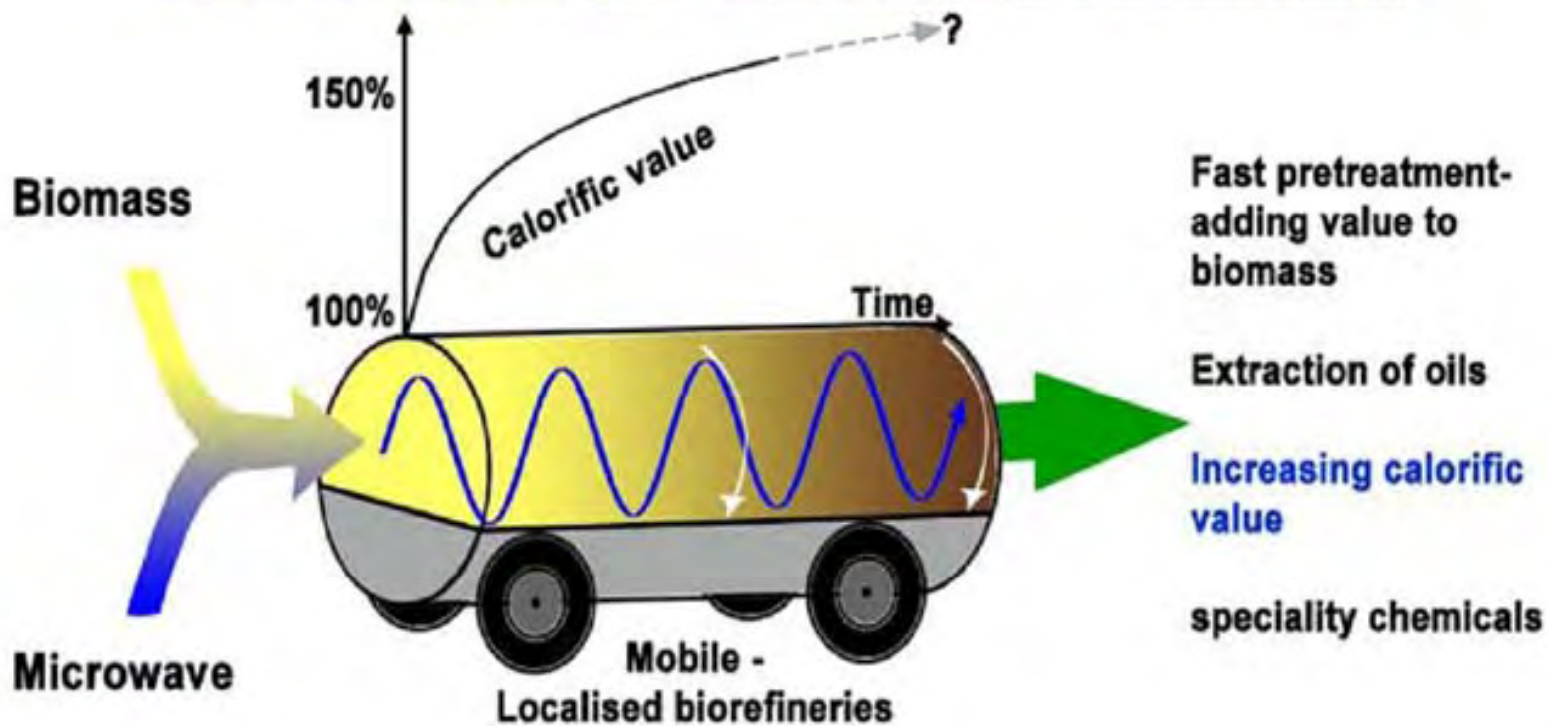


Esterification of succinic acid.



Microwave activation of biomass

development of an alternative method of decomposing biomass



Research

Industry

Networking

Education

*One type of future biorefinery
based on single large volume feedstock
and using green chemical technologies
to make a range of products*

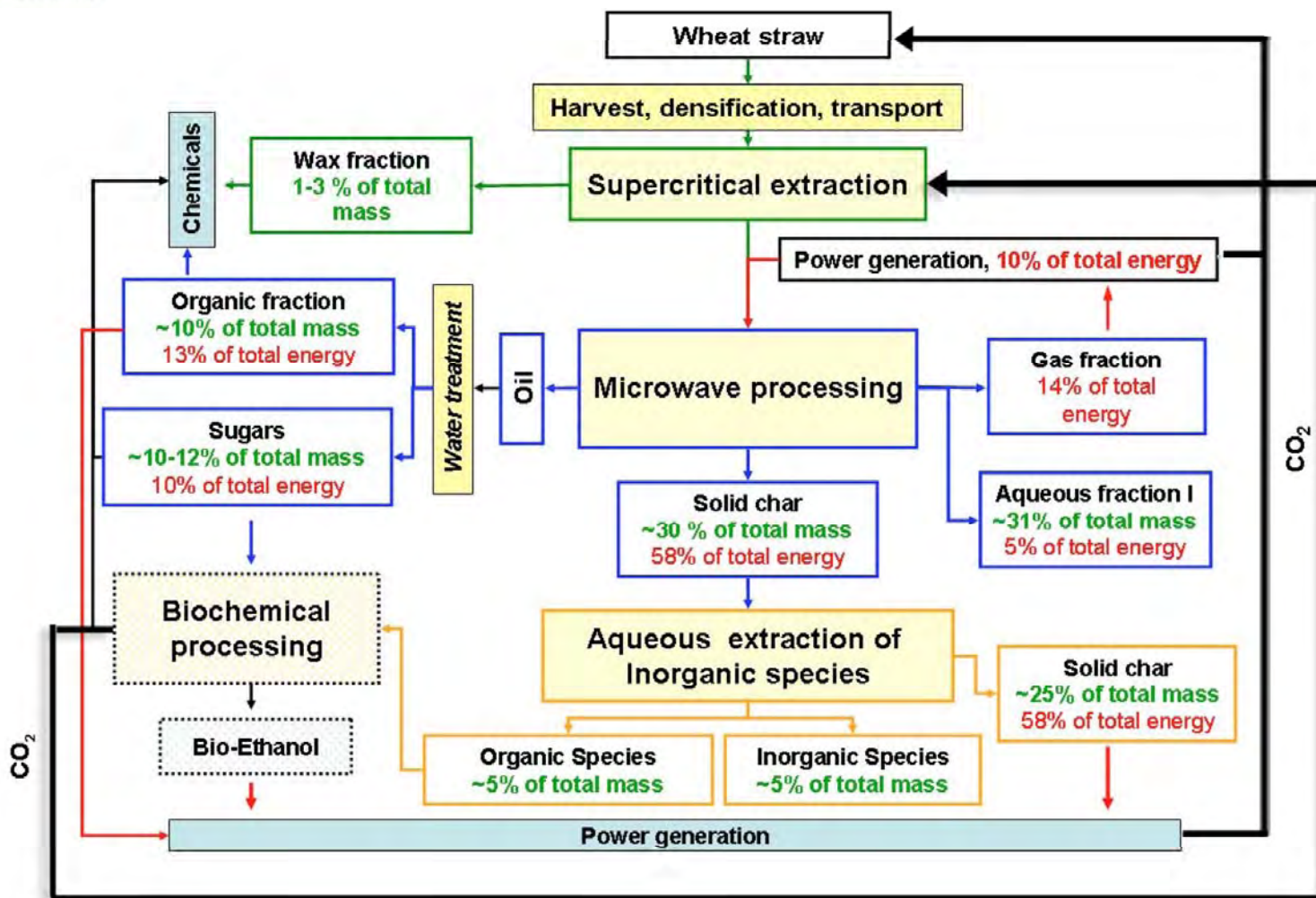
Research

Industry

Networking

Education





- Research
- Industry
- Networking
- Education

Integrated wheatstraw biorefinery

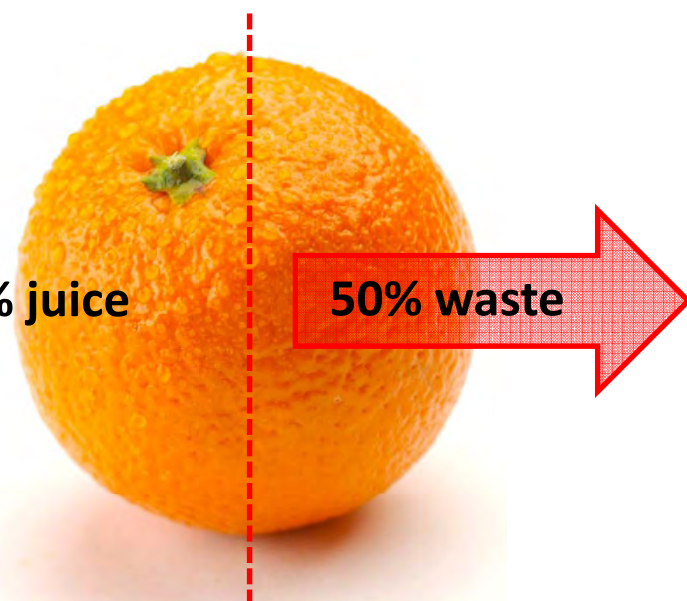


A new OPEC- Orange Peel Exploitation Company

Valorisation of a million ton scale pre-consumer waste to bio-chemicals, bio-materials and bio-fuels.

50% juice

50% waste



8,069,705 T/y
*of waste orange peels
available in Brazil*

BIO-CHEMICALS

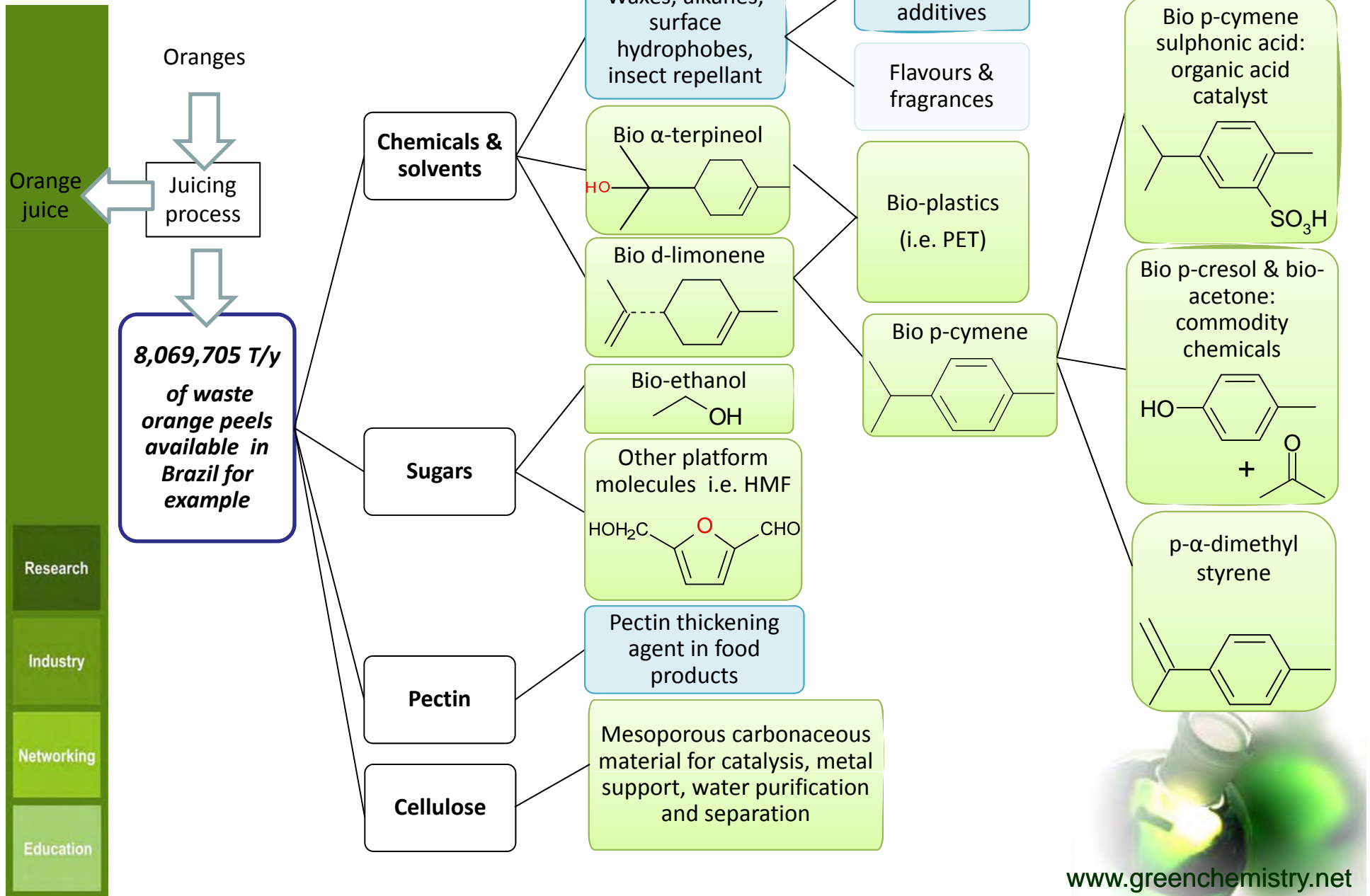
Bio-solvents
Natural fragrance chemicals
Chemical intermediates
acid catalysts

BIO-FUELS

bio-ethanol chars
sugars liquid fuels

BIO-MATERIALS

catalysis
separations water purification



Recent developments in the press:

PepsiCo looks to reuse plant waste

Mar 14, 2011 6:10pm EDT CHICAGO (Reuters)

PepsiCo Develops World's First 100 Percent Plant-Based, Renewably Sourced PET Bottle
PepsiCo Inc is working on ways to reuse waste like oat husks and orange peels.

Research

Industry

Networking

Education



Microwaving orange peel



Orange peel
Original Mass: 40g. Dry mass: 8.6g

Hydrothermal heating
MW. 800W. 10 min. 200°C



Porous
Cellulose 1g



Sugars 2.2g +
Bio-oil 2.2g +
Pectin 0.15g

Water treatment

Fragrances
Fuels
Chemicals



Research

Industry

Networking

Education

York, the University and Green Chemistry at York

One of Europe's most beautiful and historic cities

❖ **Top 100 World- and Top 10 UK-ranked
University**

University of the Year 2010

❖ **Top 5 UK-ranked Chemistry Department**

❖ **World-leading Green Chemistry Centre
dedicated to creating genuinely sustainable
supply chains for chemical and related products;
-associated activities include Centre for Novel
Agricultural Products (white biotechnology) and
Stockholm Environment Institute**



Research

Industry

Networking

Education



Biorenewables Development Centre
+ New Chair in Green Chemistry
+ New Green Chemistry Centre
+ +.....
= *Green Chemistry @ York*

Research

Industry

Networking

Education



BDC **Biorenewables** Development Centre

Research

Industry

Networking

Education

Project Part-Financed
by the European Union

European Regional
Development Fund



Project Sponsor



*A collaboration between the Green Chemistry Centre
CNAP, FERA and Science City York*



Activity Areas

The Centre's Activities can be groups into 4 areas:

- **Research**
- **Industry** collaboration
- **Education**, including development of teaching and promotional materials
- **Networking** with all chemical stakeholders



Research

Industry

Networking

Education



NORSC

Combining the expertise of the leading Northern England Universities to provide sustainable chemistry solutions to industry

MUSC

The Chemical Industries Association and the Green Chemistry Centre working together to create new green and sustainable supply chains for chemical products



Promoting awareness and facilitating, education, training and practice of green chemistry worldwide



Green Chemistry
Centre of Excellence

Anglo-French collaboration

chemicals from biomass using green chemistry and white biotechnology

Research

In

Net

Education

Green Chemistry and the Consumer

Green chemistry solutions for the retailer and producer

SUSTOIL

The international Network for alternatives to petroleum

Green Chemistry networks worldwide

Greece, Portugal, Cyprus, Japan, USA, Korea, Brazil.....

MSc in Green Chemistry & Sustainable Industrial Technology

Principles & Technologies

Principles, Environmental Impact, Chemical Engineering,
Catalysis for Green Chemistry,
Alternative Reaction Media, Energy,
Clean Synthesis, Renewable Resources,
Greener Products

Supporting Courses

IP, Business Opportunities, Green Chemistry Presentations,
Legislation Presentations and Literature Research

Research Project & Oral Presentation

In collaboration with Industry

T
r
a
n
s
f
e
r
a
b
l
e

S
k
i
l
l
s

Research

Industry

Networking

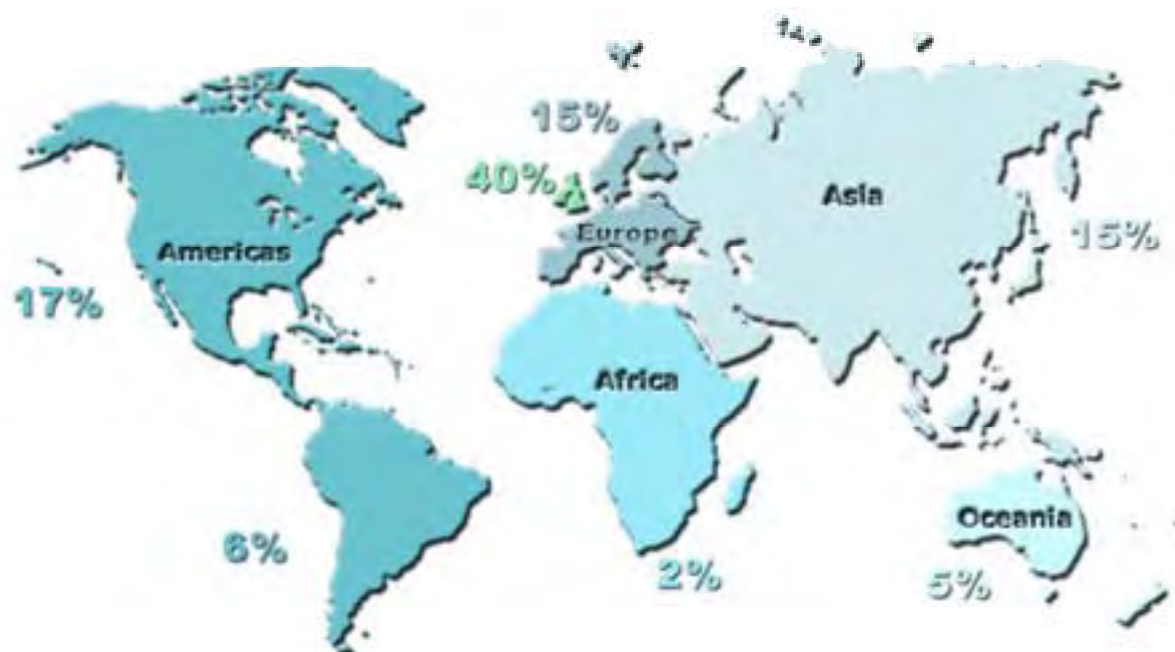
Education



Green Chemistry Network



- Est. 1998 with funding from the Royal Society of Chemistry
- Not-for-profit CLG
- One of the largest international networks of this type in the world
- International membership
- Excellent forum for information exchanges and collaboration



GC&C Networking Projects

Green Chemistry & the Consumer

Engaging the retailers through low technical awareness of greener chemistry



- “Research shows that 80% of the 16 Million people visiting our stores each week want sustainable products”
- “A clear majority (of our customers) want this process to be simplified”
- “Green Chemistry is not only a solution, it is the solution”



Biodegradable Surfactants



Environmentally friendly bitter-taste blockers for drugs



Halogen-free flame retardants

[Mike Barry, Mark & Spencer Head of CSR]

<http://www.rsc.org/chemsoc/gcn/industry.htm#consumer>

We must encourage mechanisms for engaging the (very many) users of the chemical industry



www.greenchemistry.net

Research

Industry

Networking

Education

Pre – HE: Education and Outreach

Aims

- To **excite** young people about **chemistry** and the **positive** impact it can have.
- To **enable** young people to **critically engage** with ideas and solutions

Impacts/areas of work

- lots of projects and funding at key stage 2
- Discovery Days, Countryside Days, Science Days in Primary Schools
- High awareness about environment at young age, interest and enthusiasm
- opportunities at GCSE/A level stage

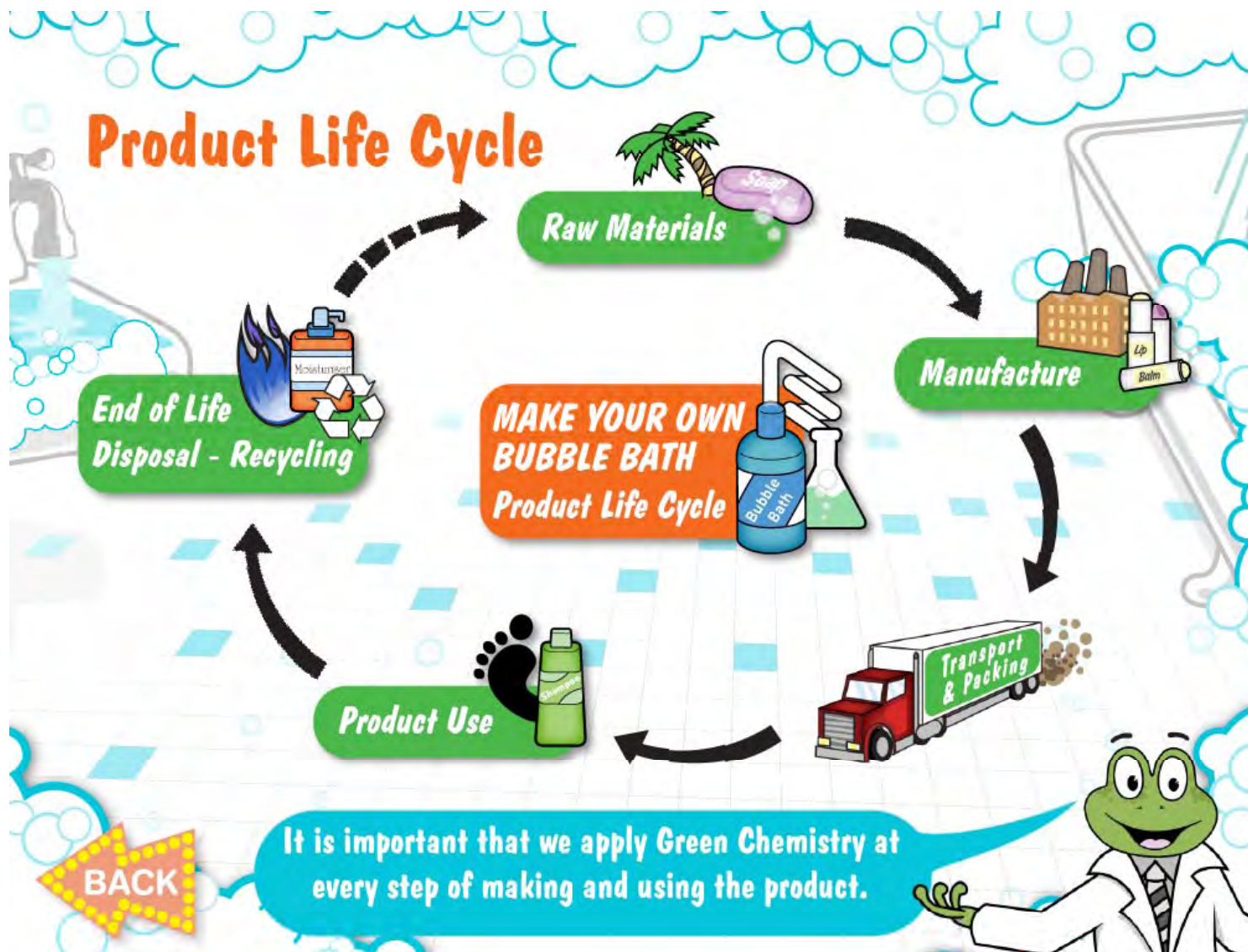


Research

Industry

Networking

Education



Research

Industry

Networking

Education



Research

Industry

Networking

Education

(some of) the York Green Chemistry Centre staff and graduate students

Industry

Education



**Green
Chemistry**
Centre of Excellence

www.greenchemistry.net

Research

Networking