BIOECONOMY MAIN CHALLENGES: AN OECD PERSPECTIVE

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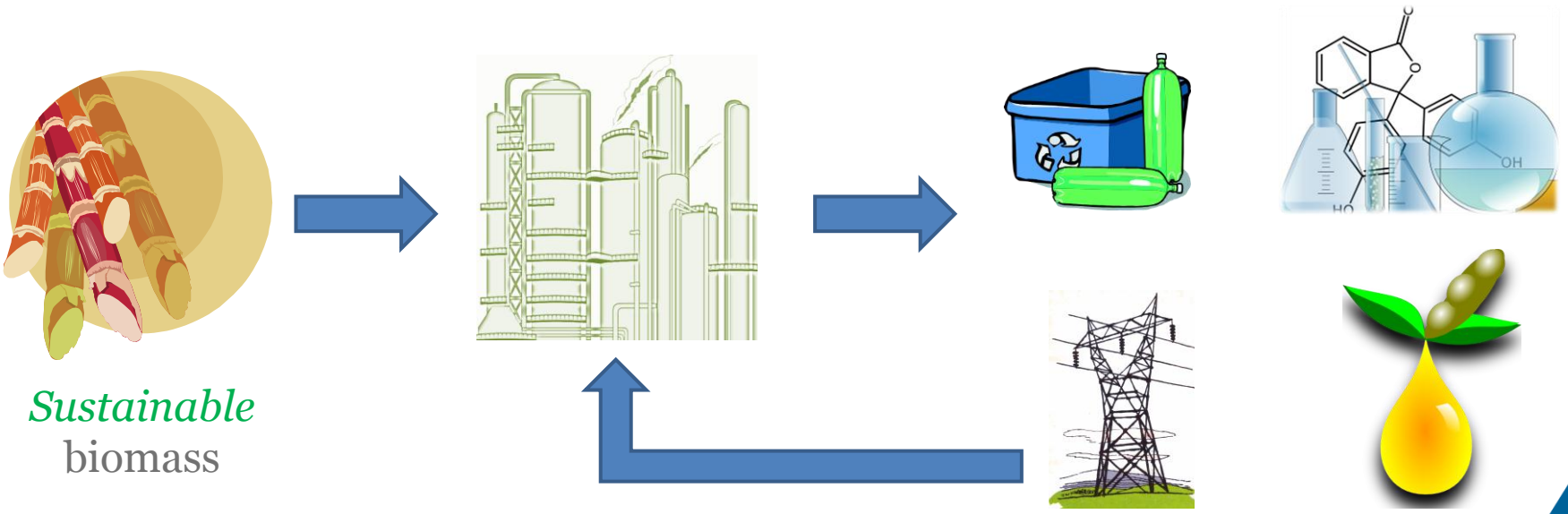
OECD
BETTER POLICIES FOR BETTER LIVES

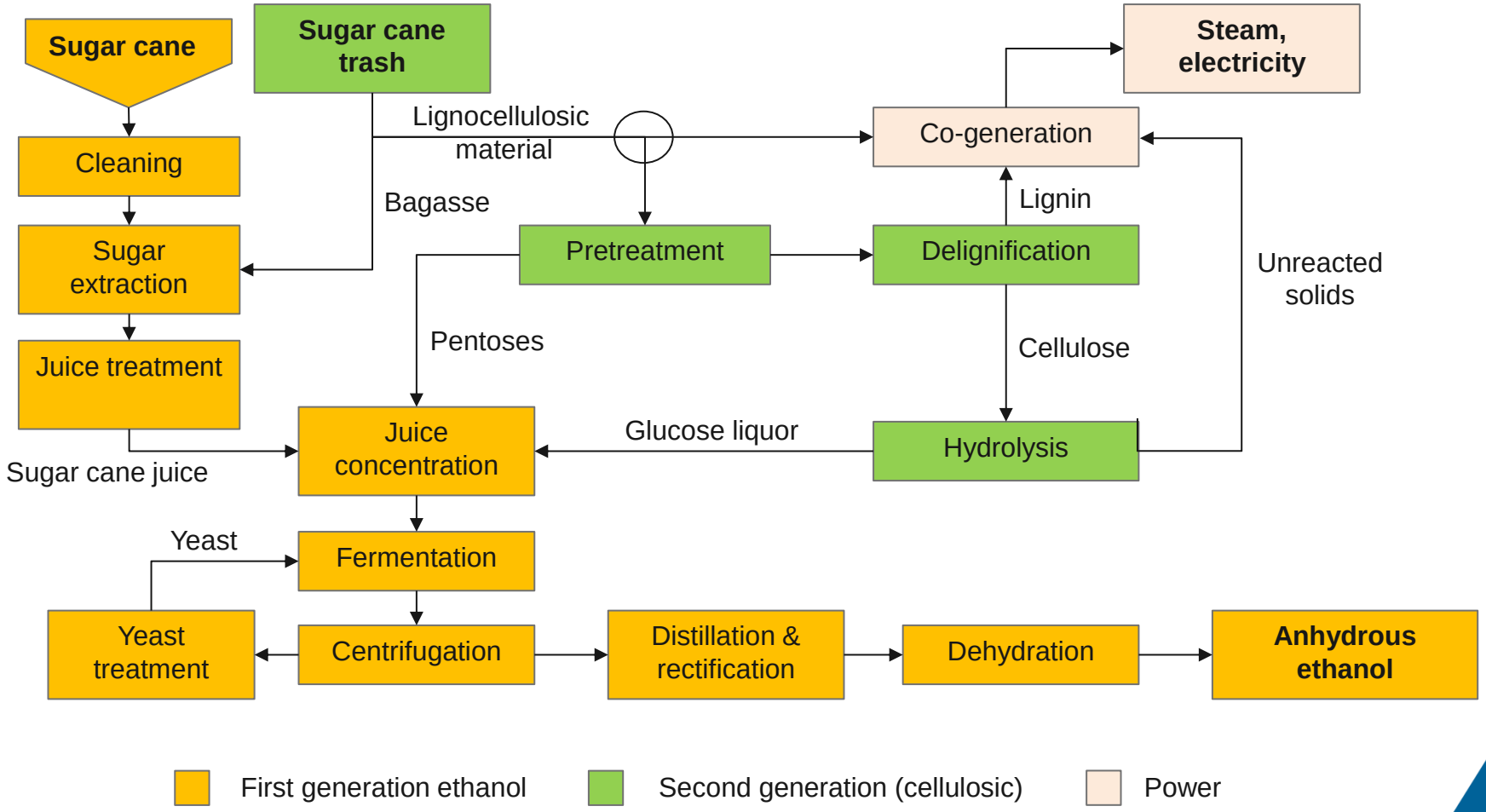
What is a bioeconomy ?

- **Decouple economic growth from environmental degradation**
- In particular the need to **drastically cut GHG emissions**
- Biotechnology can be responsible for 2.7% of GDP in the OECD countries
  - This excludes the contribution from biofuels
- Biotechnology will be used in the development of all pharmaceuticals and most new varieties of large market crops



The Bioeconomy to 2030: Designing a Policy Agenda (2009)

Next generation Brazilian ethanol mill ?



Dias et al. (2013). *Applied Energy* 109, 72–78.

Industrial Biotechnology and the bioeconomy

A Bioeconomy for Europe[1]

"*Significant growth is expected to arise from sustainable primary production, food processing and industrial biotechnology and biorefineries, which lead to new bio-based industries, transform existing ones, and open new markets for bio-based products. New high skilled jobs and training options need to be developed to meet labour demands in these industries…*"

US National Bioeconomy Blueprint[2]

This envisaged "*a previously unimaginable future*" in which two of the categories of new materials are:

(i) "*ready to burn liquid fuels produced directly from CO2 and*;

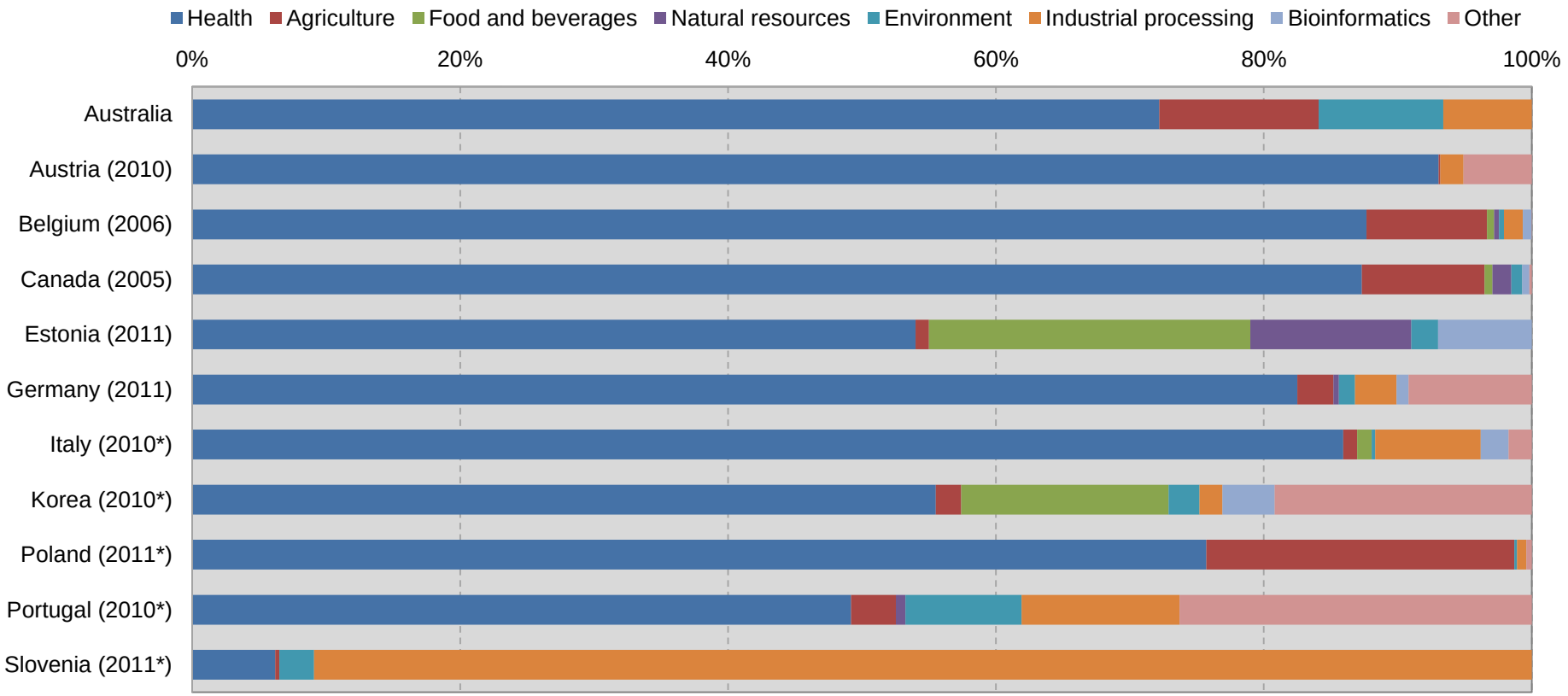
(ii) biodegradable plastics made not from oil but from renewable biomass."

1 EC (2012). Innovating for Sustainable Growth: A Bioeconomy for Europe. COM(2012) 60, final. Brussels, 13.2.2012.
2 The White House (2012). National Bioeconomy Blueprint. April 2012. 43 pp.

Why bio-based production ?

- The products are mainly *substitutions* for petrochemicals and fossil-based fuels
- This makes IB somewhat different from other biotechnology disciplines
- Why substitute ?
  - Energy security
  - Rural regeneration
  - Chemicals competitiveness
  - Climate change
  - GM and synthetic biology

Percentage of biotechnology R&D investments by application (latest available year)



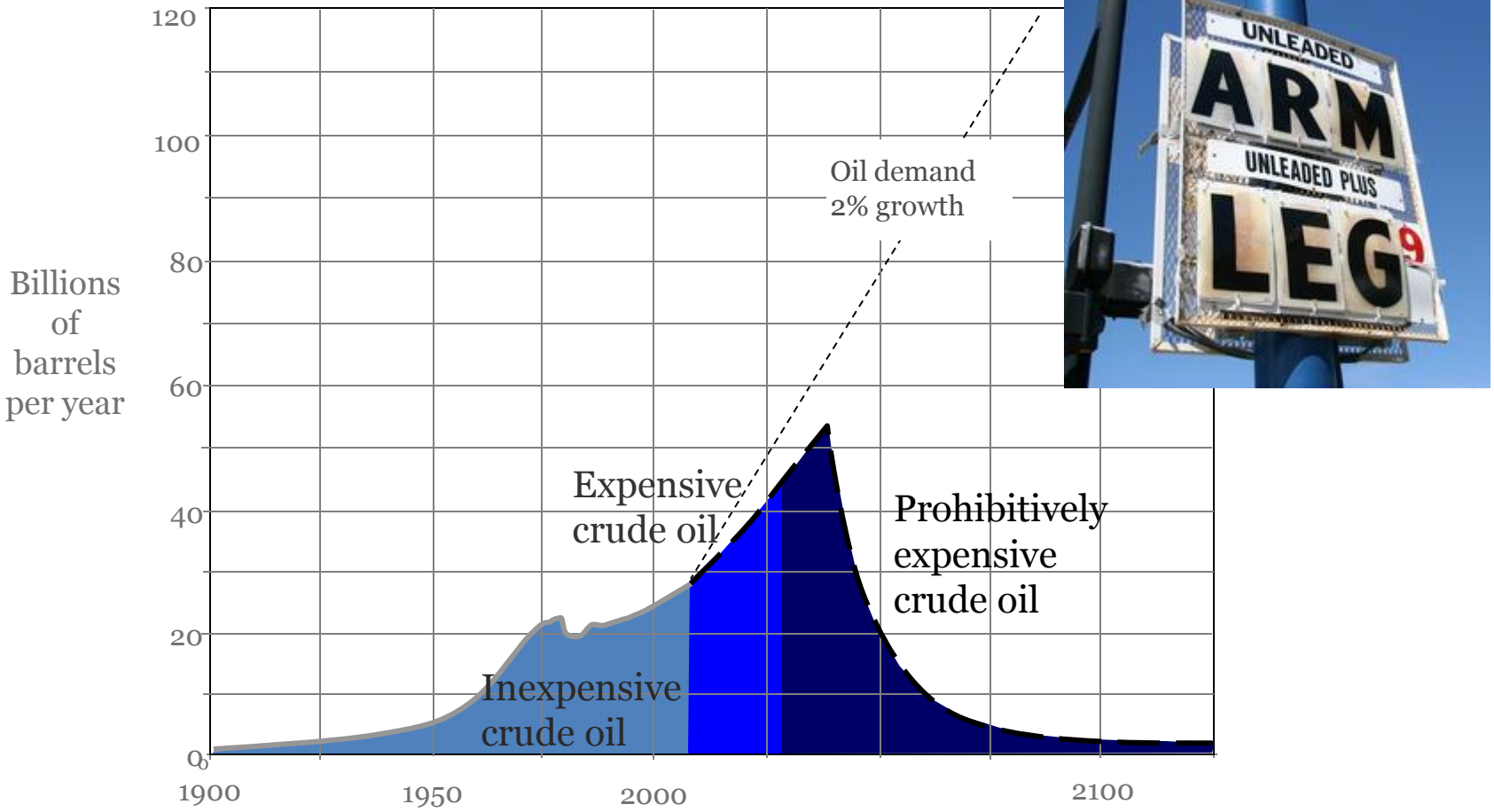
OECD Biotechnology Statistics Database, December 2012.

Current R&D expenditures *versus* future markets for biotechnology by application

	Share of total OECD business expenditures on biotech R&D, 2003	Est. potential share of total biotech GVA in the OECD area, 2030
Health	87%	25%
Primary production	4%	36%
Industry	**2%**	**39%**
Other	7%	-
	100%	100%

OECD (2009). The Bioeconomy to 2030. Designing a policy agenda. OECD Publishing, Paris.

Energy security



Bioeconomy jobs through Industrial Biotechnology

- Bio-based chemicals and plastics support more jobs and value-added than biofuels and bioenergy[1,2]
- US: for every job created in chemistry, up to 7.6 jobs are created in other sectors[3]
- Agricultural efficiencies have drastically reduced rural jobs
- Shifting 20% of current plastics production into bioplastics could create a net 104,000 jobs in the US economy[4]
- Triple policy goals: rural regeneration, high quality jobs, competitive chemicals industry

Sub-sector[5]	Number of jobs in Europe (2011)	Turnover (2011)
Biofuels	~150,000	EUR 6 billion
Bio-based chemicals	~150,000	**EUR 50 billion**

[1] Carus et al. (2011). Nova- Institute Publication 2011-04-18
[2] Sormann (2012). Departement Economie, Wetenschap en Innovatie (EWI), October 2012
[3] http://www.americanchemistry.com/Jobs
[4] Heintz & Pollin (2011). Political Economy Research Institute, Amherst, MA
[5] BRIDGE 2020 (2012). BRIDGE presentation

Importance of chemicals in Europe

- The EU chemical industry is the world leader
- Major contributor to the EU economy (24% of the world turnover of EUR 2.4 trillion in 2010)

BUT

- Competitiveness is at risk due to relatively high cost of production, low market growth
- Petrochemicals sector is growing in the Middle East and China

USD 5 billion capital expenditure project *expansion* of the Petro Rabigh petrochemicals complex.

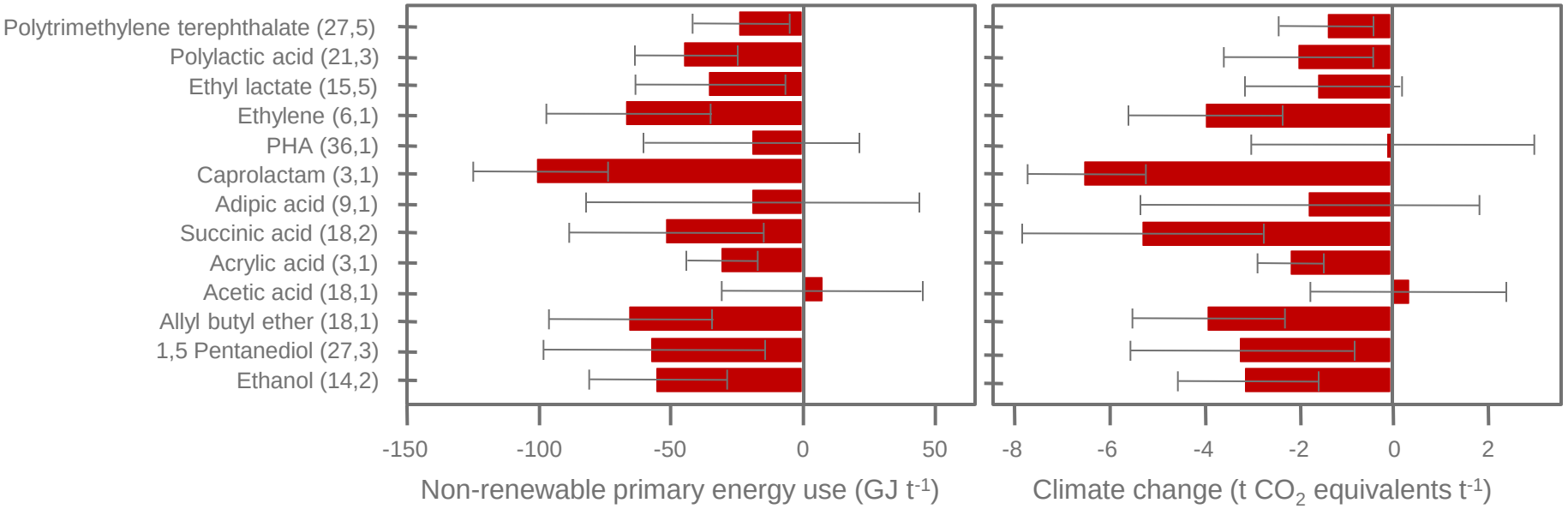
"Scientists call for action to tackle CO_2 levels" BBC News, May 11/2013

Scientists are calling on world leaders to take action on climate change after carbon dioxide levels in the atmosphere broke through a symbolic threshold. Daily CO_2 readings at a US government agency lab on Hawaii have topped 400 parts per million for the first time. Sir Brian Hoskins, the head of climate change at the UK-based Royal Society, said the figure should "*jolt governments into action*"[1].

- To date 167 countries have signed up to the Copenhagen Accord in trying to limit the temperature rise, compared to pre-industrial levels, to 2°C.
- Given known 2000–06 CO2 emissions, *less than half* the proven recoverable oil, gas and coal reserves can still be emitted up to 2050 to achieve such a goal
- If GHG emissions are halved by 2050, there is a 12–45% chance of > 2°C
- **Given a 20% CO2 emissions rise between 2000-06, policies are needed urgently to stay below the 2°C target[2]**
- **Update: global energy-related CO2 emissions increased by 1.4% to reach 31.6 Gt in 2012, a historic high[3]**

1 http://www.bbc.co.uk/news/science-environment-22491491
2 Meinshausen et al. (2009). *Nature* 458, 1158-1163
3 IEA (2013). Redrawing the energy-climate map. World Energy Outlook special report.

Environmental impacts of bio-based products



Weiss et al. (2012) found that biobased materials save, on average, 55 +/- 34 MJ non-renewable energy and 3 +/- 1 kg CO_2 per kg material

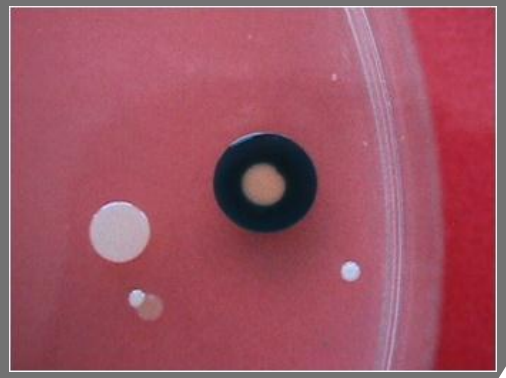
Weiss et al. (2012). *Journal of Industrial Ecology* 16, Supplement S1, S169–S181

WHAT CAN INDUSTRIAL BIOTECHNOLOGY OFFER ?

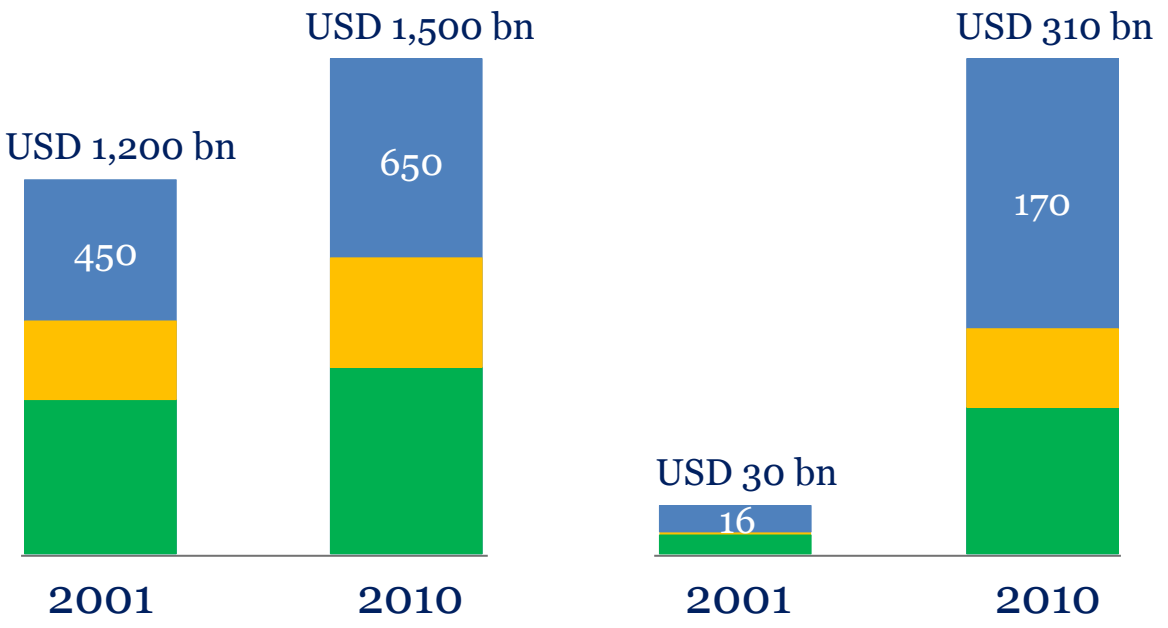
BIOFUELS

BIOPLASTICS

BIOCHEMICALS



Global market share of fine and specialty chemistry in Industrial Biotechnology



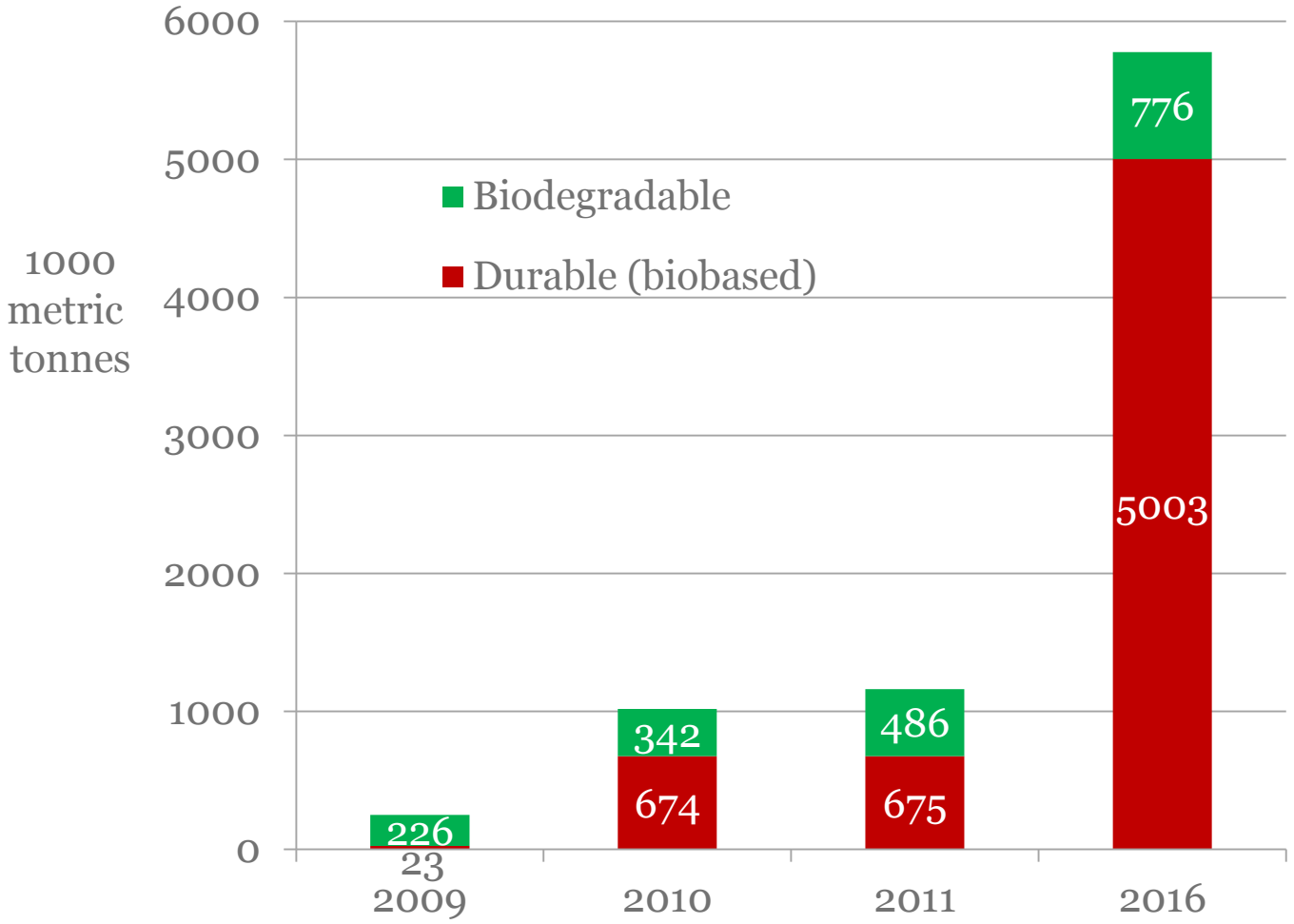
http://www.cib-frankfurt.de/mm/CIB-Image-RZe-online.pdf

US market projections (in USD billions)

	2005		2010		2025	
Sector	Total	Biobased	Total	Biobased	Total	Biobased
Commodity	475	0.9	550	5-11	857	50-86
Specialty	375	5	435	87-110	679	300-340
Fine	100	15	125	25-32	195	88-98
Polymer	250	0.3	290	15-30	452	45-90
Total	1,200	21.2	1,400	132-183	2,183	483-614

US Biobased Products Market Potential and Projections Through 2025
USDA, OCE-2008-01, February 2008
www.usda.gov/oce/reports/energy/BiobasedReport2008.pdf

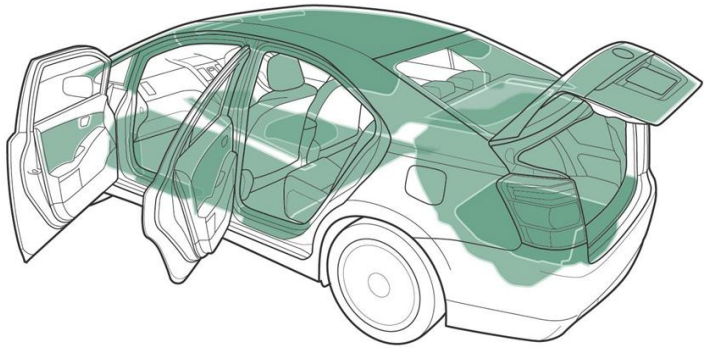
Market changes for bioplastics



Recent updates by European Bioplastics and nova-Institüt

Bioplastics: a new revolution in plastics

October 11, 2011:
Toyota plans to replace a total of 20% of oil-based plastics across the range by 2015, equal to 360,000 tons.



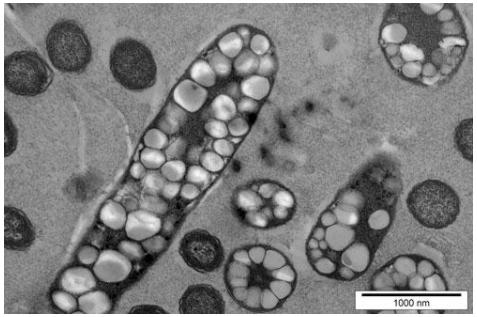
Total Ecological Plastic coverage
approx. 80% of interior surface

December 15, 2011:
Coca-Cola has entered into 3 SME partnerships in order to reach their target of 100% biobottles, equal to several million tons of PET.

plantbottle
100% reciclable, elaborada hasta con un 30% a base de plantas.

México Coca-Cola
Viviendo Positivamente

EU bioplastics issues: Full scale production



Bioplastics R&D

Doing fine…

- Diverse projects and strategies under FP7, CIP etc.
- Budget increase planned in "*Horizon 2020*"

Demonstration

On the way…

- Support growing, importance recognised
- First biorefinery prototypes completed

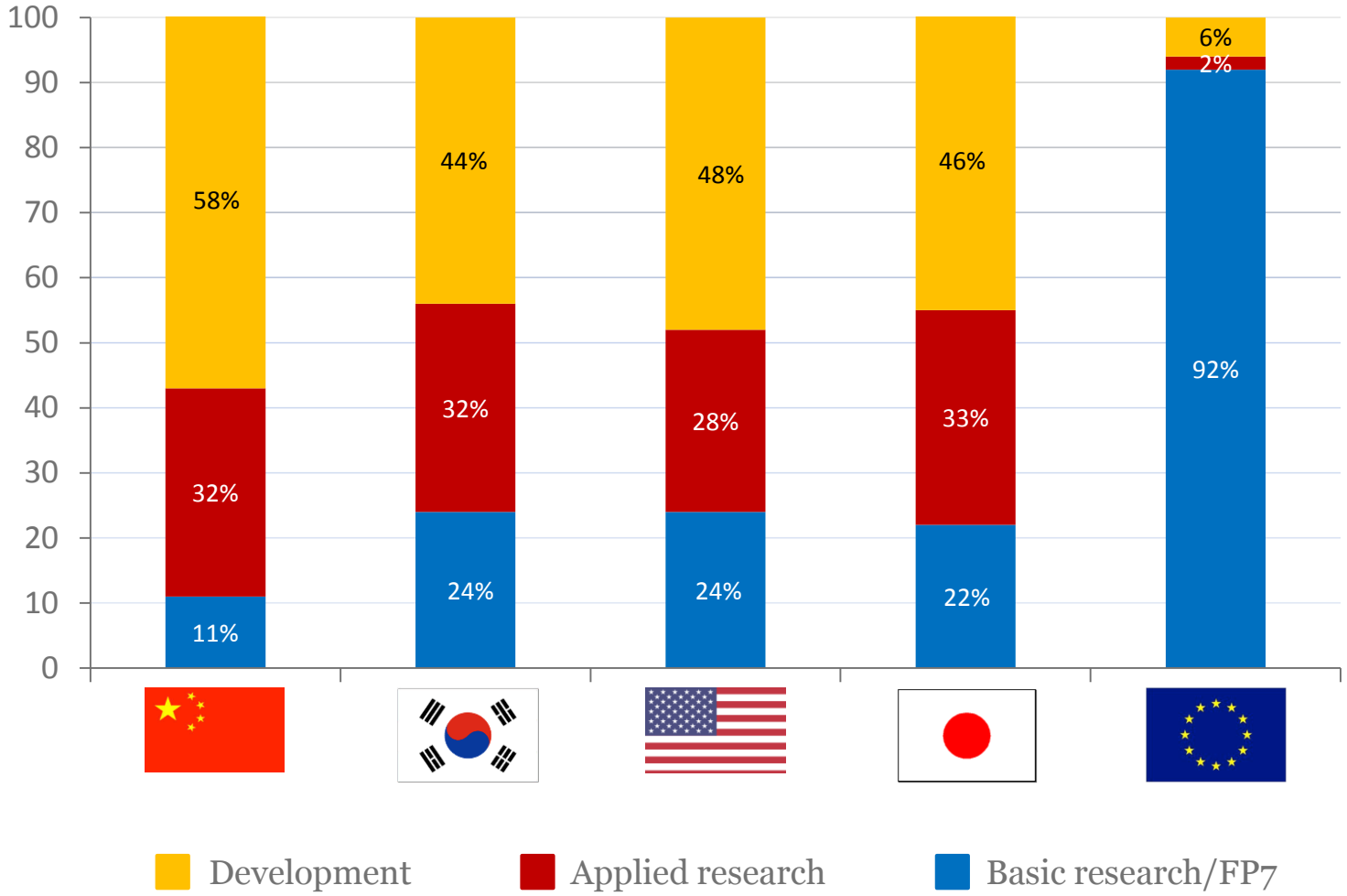
Implementation

…Missing !

- No supportive framework in place
- Lack of visible strategy

- ***Result**: Scale-up may not happen in the EU*
- *Capacity building is occurring in Asia and Brazil*

International benchmark on the share of basic, applied and development activities



http://ec.europa.eu/dgs/jrc/downloads/events/20130425-ket-sme/20130425-ket-sme-crean.pdf

Demonstrator plants

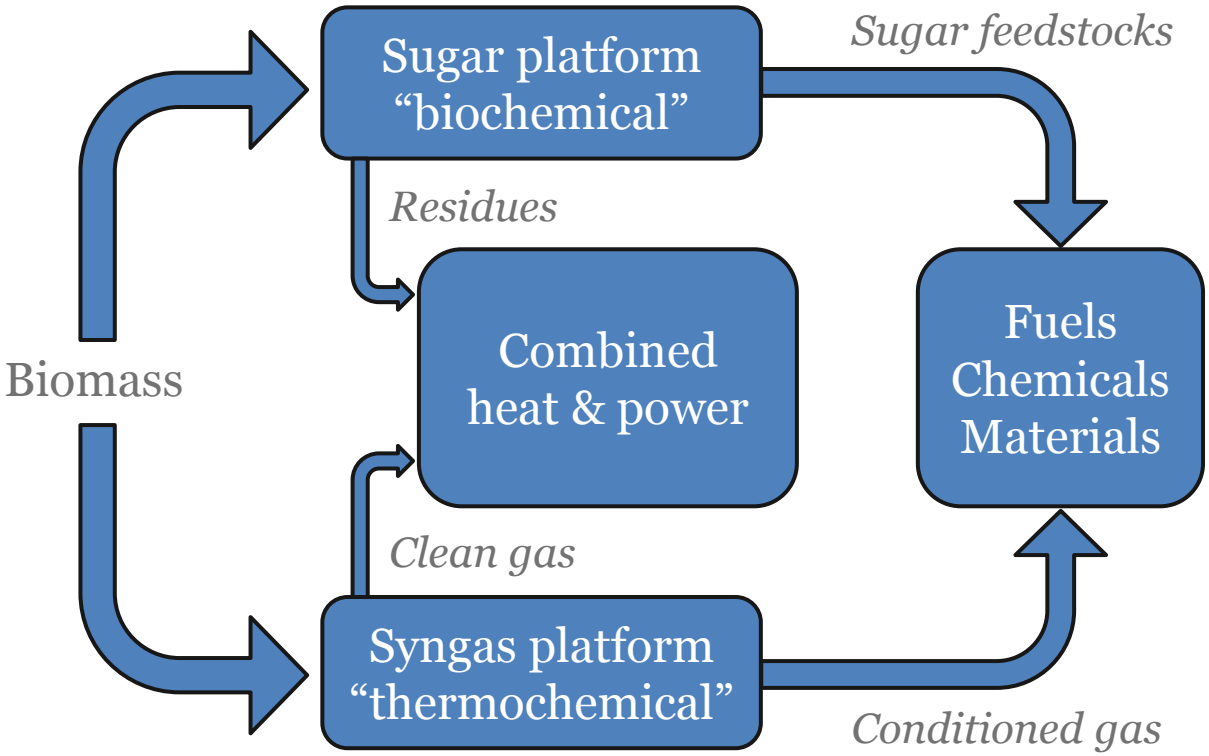
Oregon: Woody biomass to acetic acid and ethyl acetate

Chempolis Biorefining Park, Oulu, Finland

Kalundborg, Denmark: wheat straw to ethanol

Louisiana: cellulosic ethanol demonstrator

The integrated biorefinery concept



Redrawn from www.nrel.gov/biomass/biorefinery.html

Refining margins: likely to get worse

"The oil refining sector both in the UK and across the EU, continues to face difficult conditions through a combination of factors, including poor refining margins, weak demand, the legislative climate in the EU and the UK, and competition from non-EU refineries."
www.ukpia.com, June 2012

"What is probably needed to restore balance is another round of refinery closures. Uncompetitive plants in Europe ought to be the first to close. But many of these zombie refineries are kept in business due to political pressure on oil companies from governments struggling with Europe's economic crisis…Refineries in Britain, Canada and the United States are all at risk."
Reuters, April 15, 2013

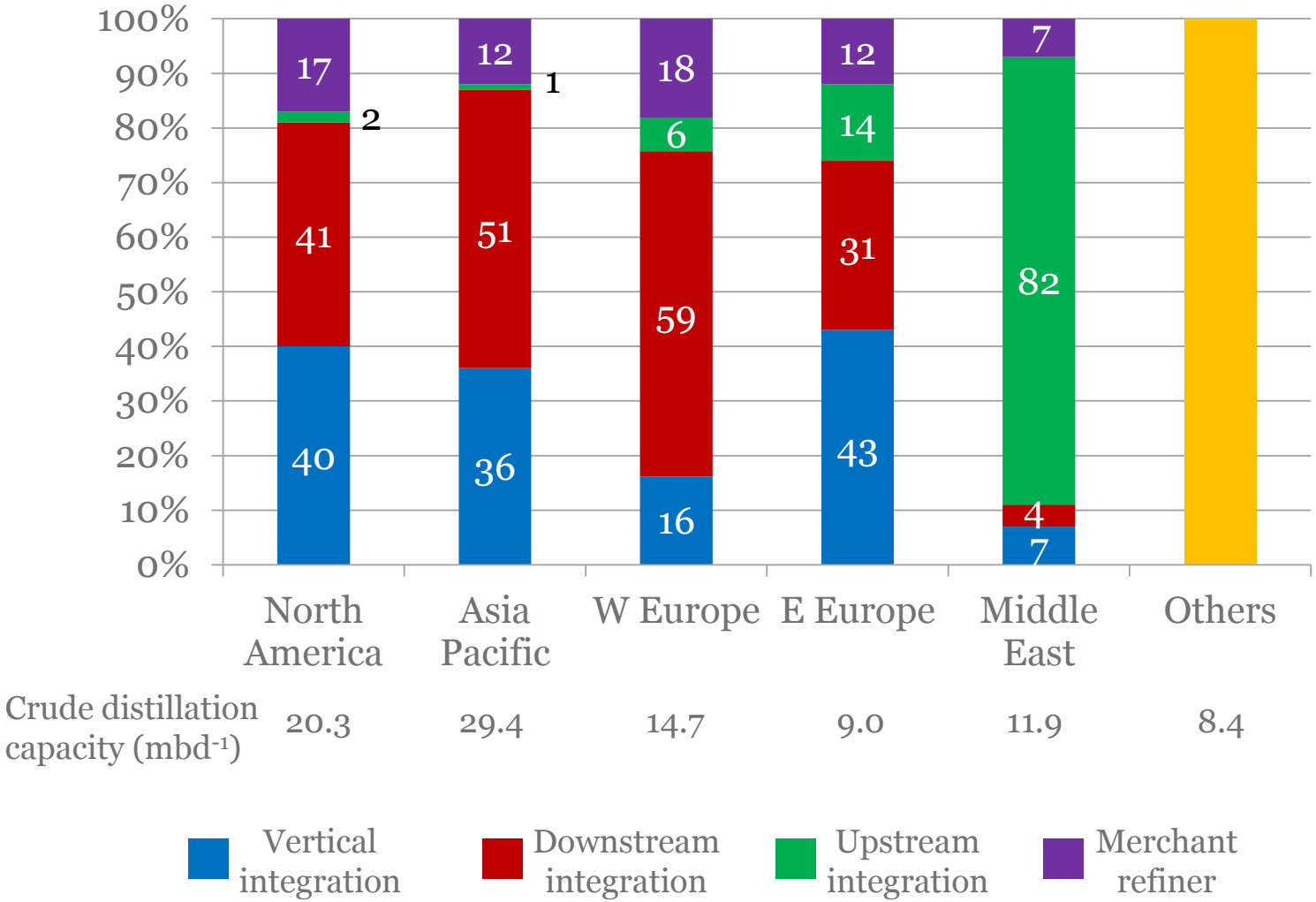
"The last wave of refining capacity rationalization has largely run its course in the developed world. The United States, Britain, Germany, Canada, Japan and Australia have all seen multiple refineries close."
Reuters, April 15, 2013

"With one in five oil refineries expected to cease operations over the next five years, choosing the right operating model and level of integration will be crucial for survival and sustained profitability."
ATKeaerney (2012). Refining 2021: Who Will Be in the Game?, May 2012

Sinopec, Asia's largest oil refiner, posted a 24% increase in profits for the period January to June 2013. http://www.bbc.co.uk/news/business-23838922

Refining capacity by region, 2011

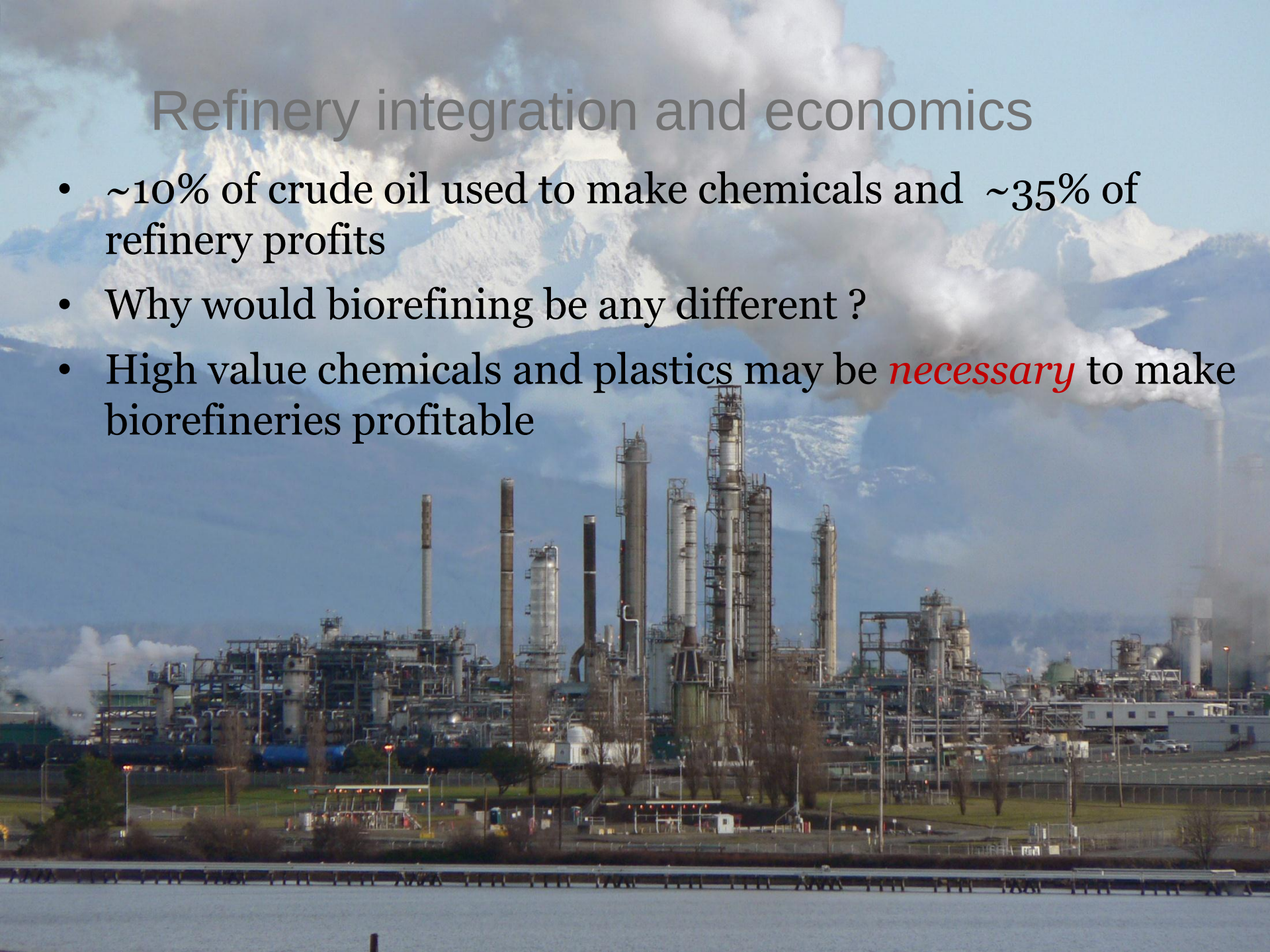
"Refineries that are prime candidates for closure are merchant facilities with few competitive advantages."
Reuters, April 15, 2013



AT Kearney (2012). Refining 2021: Who Will Be in the Game?

Refinery integration and economics

- ~10% of crude oil used to make chemicals and ~35% of refinery profits
- Why would biorefining be any different ?
- High value chemicals and plastics may be *necessary* to make biorefineries profitable



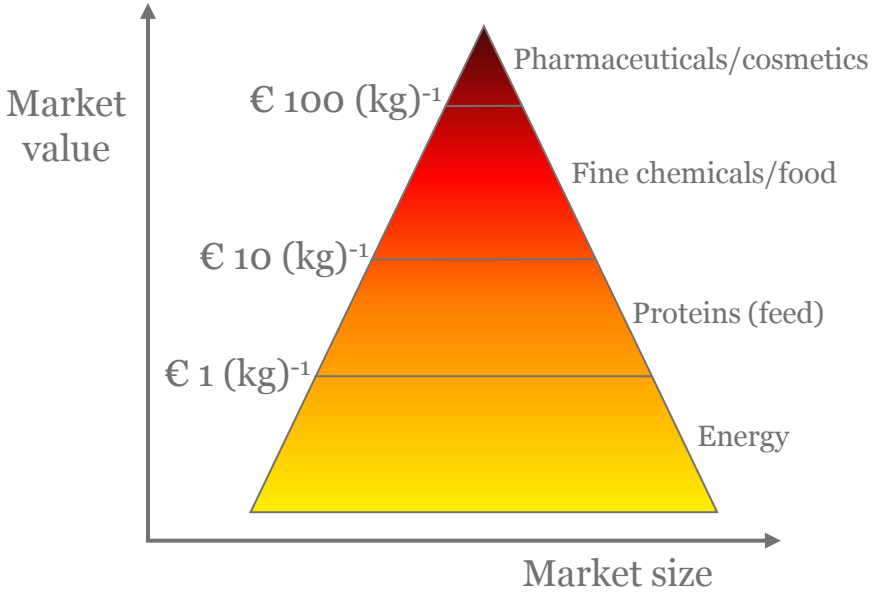
Value-added - Cascading use of biomass

Molecule	Photons required	USD per photon	Market size (per annum)
Octane	100	1	7.5 B barrels (US)
Lysine	92	5.9	700,000 tonnes (WW)
Phenylalanine	96	32	11,000 tonnes (WW)

Adapted from Ducat et al. (2011). *Trends in Biotechnology* 29, 95-103.

Algae: disruptive technology ?

Crop	Oil yield [gallons (acre)$^{-1}$]
Corn	18
Cotton	35
Soybean	48
Mustard seed	61
Sunflower	102
Rapeseed	127
Jatropha	202
Oil palm	635
Algae	**10,000**



Why synthetic biology ?

WORLD ECONOMIC FORUM

COMMITTED TO IMPROVING THE STATE OF THE WORLD

At the Summit on the Global Agenda 2011 in Abu Dhabi, United Arab Emirates, the World Economic Forum's Global Agenda Council on Emerging Technologies asked some of the world's leading minds within the entire GAC Network which technology trends would have the greatest impact on the state of the world in the near future. *SYNTHETIC BIOLOGY CAME SECOND*

2. Synthetic biology and metabolic engineering

The natural world is a testament to the vast potential inherent in the genetic code at the core of all living organisms. Rapid advances in synthetic biology and metabolic engineering are allowing biologists and engineers to tap into this potential in unprecedented ways, enabling the development of new biological processes and organisms that are designed to serve specific purposes – whether **converting biomass to chemicals**, **fuels and materials**, producing new therapeutic drugs or protecting the body against harm.

www.synbio.org.uk/synthetic-biology-index/2423-top-10-emerging-technologies.html

Jay Keasling named as the recipient of the 2013 George Washington Carver Award for innovation in industrial biotechnology

"I truly believe that through synthetic biology all petroleum-based products can be produced from sugar-based microbes resulting in cleaner processes and slowing global warming."

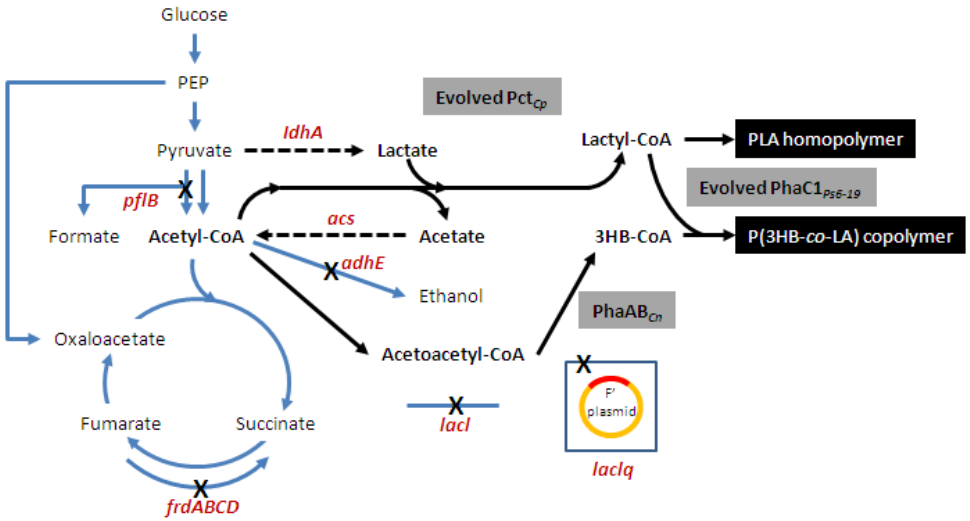
The Biotechnology Industry Organization, April 18, 2013, Washington, D.C.

Impact of synthetic biology

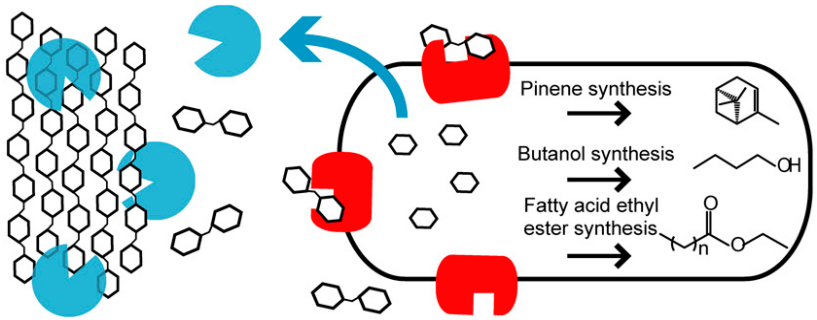
- Synthetic biology offers huge potential e.g. Consolidated Bioprocessing (CBP)
- Many countries are gearing up research in synthetic biology

BUT

- There will be resistance in various parts of the world



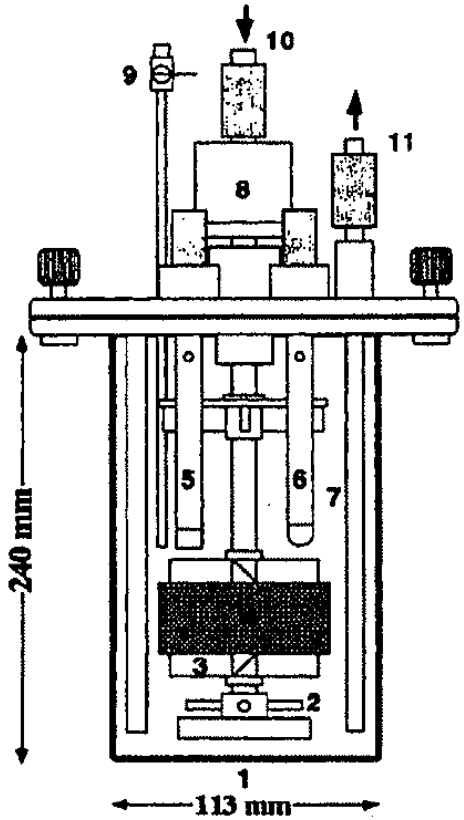
Jung & Lee (2011). *Journal of Biotechnology*



Bokinsky et al. (2011). *PNAS*.
www.pnas.org/cgi/doi/10.1073/pnas.1106958108

Fermentation of waste gases

Tanaka et al. (1995)[1]

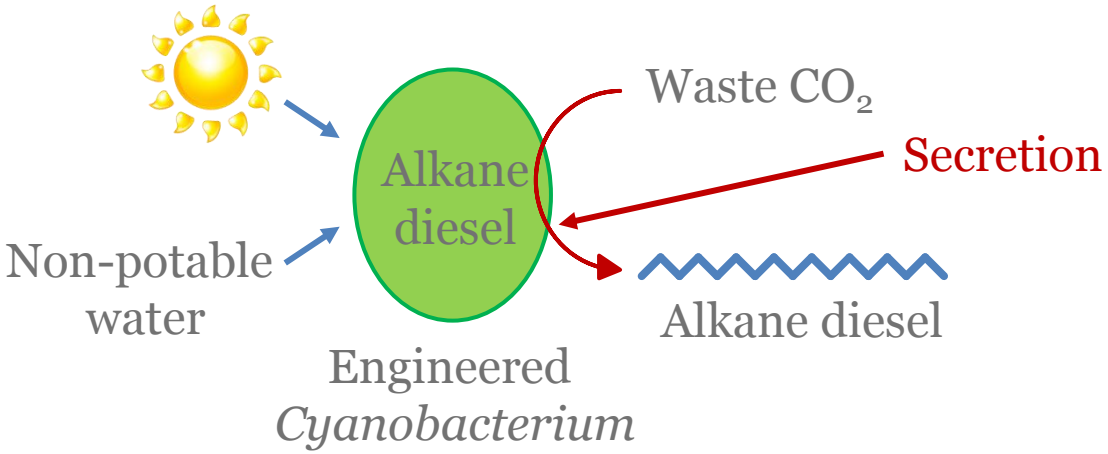


LanzaTech, 2012[2]

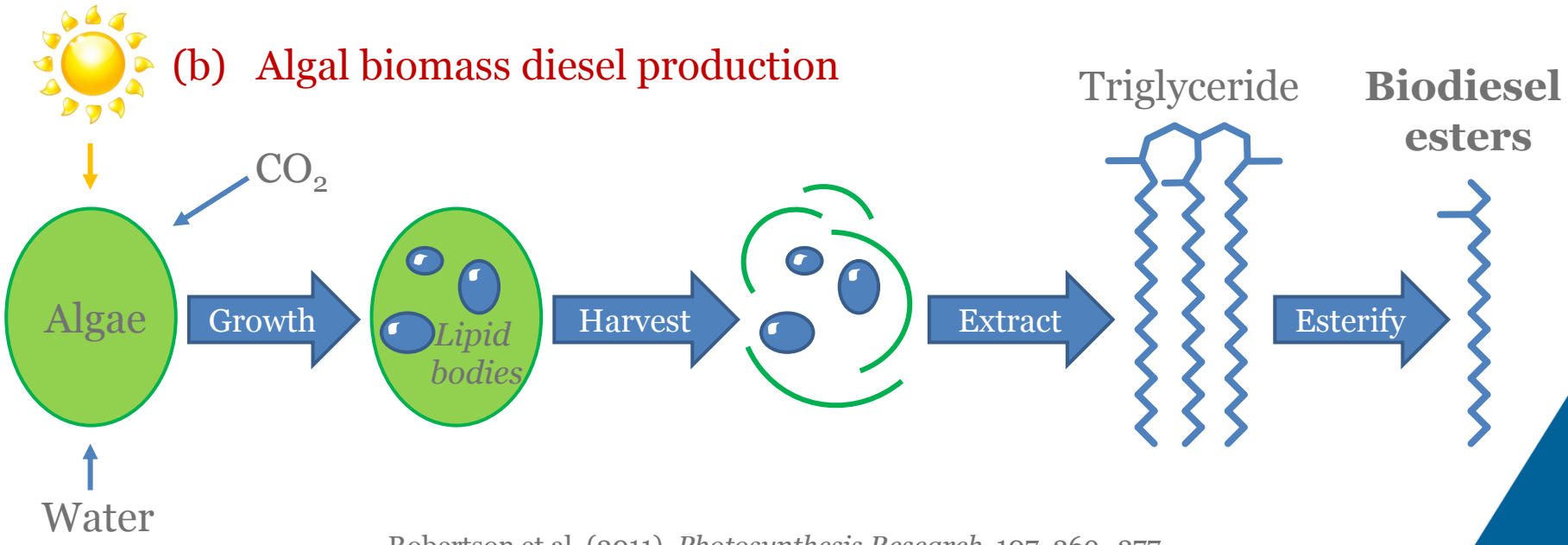
[1] Tanaka et al. (1995). *Biotechnology and Bioengineering* 45, 268-275.
[2] Courtesy of LanzaTech, New Zealand, www.lanzatech.com

The industrialisation of photosynthesis

(a) Direct, continuous process for renewable diesel production



(b) Algal biomass diesel production

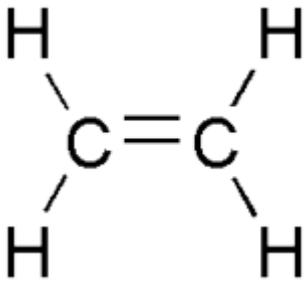


Robertson et al. (2011). *Photosynthesis Research* 107, 269–277.

Synthetic biology routes to light olefins

Today :
Fossil resources

Petrochemistry



Olefins: a group of 6 molecules that are the main building blocks in chemistry

Synthetic biology

Tomorrow :
Renewable resources

1. **Ethylene**

2. **Propylene**

3. **N-Butenes**

4. **Butadiene**

5. **Isoprene**

6. **Isobutene**

Courtesy of Global Bioenergies, Evry, France

THE TIMES
TIMESONLINE
www.timesonline.co.uk

Europe must drop ban on GM crops or get left behind, Willetts warns

Oliver Moody

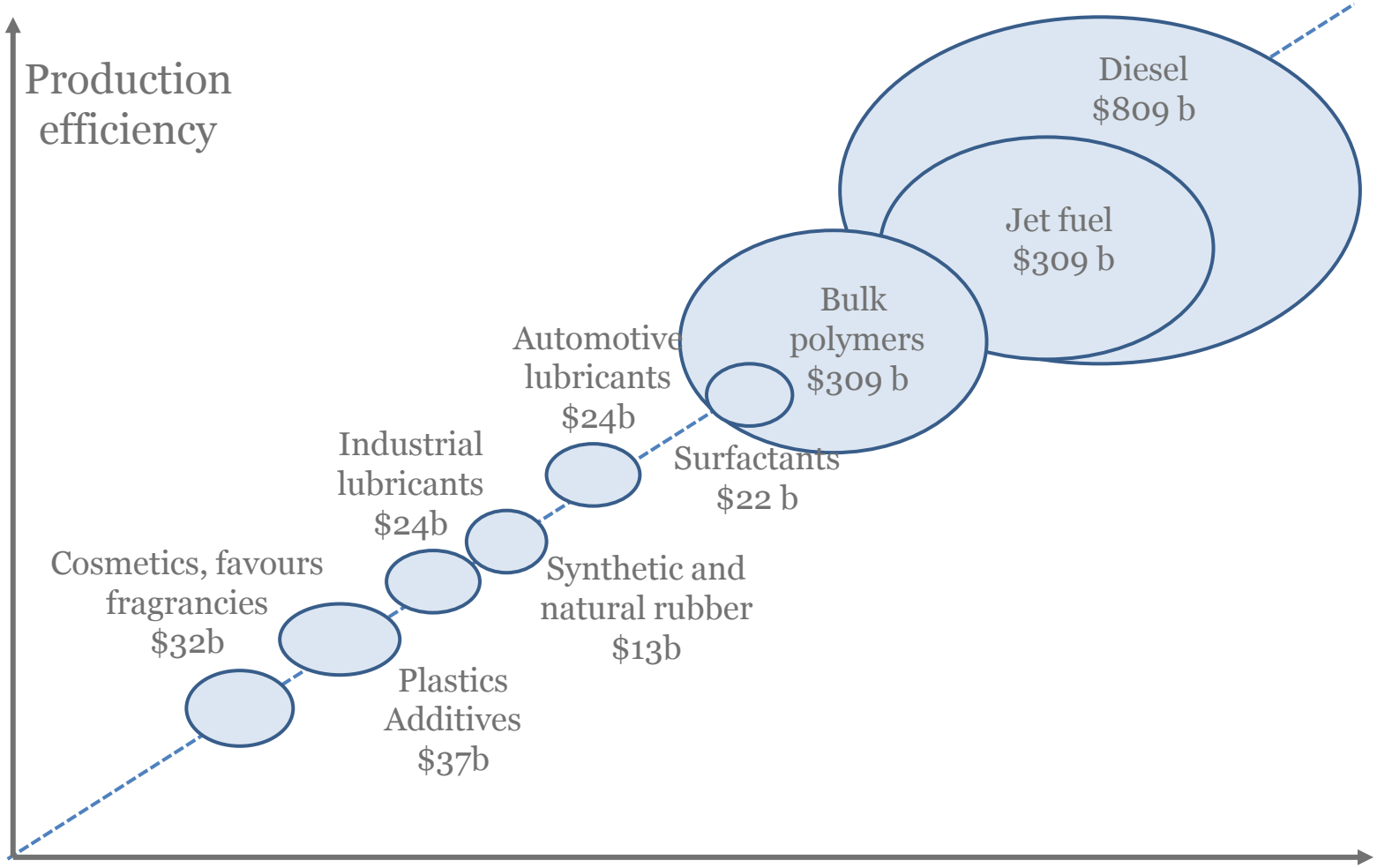
Britain is urging the European Union to ease restrictions on genetically modified crops and other cutting-edge branches of science before the continent becomes a "museum of 20th century technology", the Science Minister has said.

David Willetts said that EU rules were holding back work in fields as being very slow to adopt ... one productive way forward is to have this discussion as part of a wider need for Europe to remain innovative rather than a museum of 20th century technology." His comments came the day after Chris Grayling, the Justice Secretary, criticised EU data protection reforms that could cost British businesses hundreds of millions of pounds as "mad" and uncompetitive.

Biobased chemicals and policy

- A “level playing field” with fossil fuels, petro-chemicals and plastics
- Many bio-based chemicals are indispensible as they have no fossil equivalent
- Should production volume be a factor for policy support ?
- Are platform chemicals more “important” ?
- Production volumes much lower than biofuels
  - Do they merit their own policy regime ?
  - What about policy in relation to bio-based plastics ?

Addressable markets



Redrawn from Amyris presentation

Main European policy instruments on non-food/feed biomass use

Instrument	Biofuels	Biogas for electricity	Wood pellets for electricity	Biobased products (non-fuel)
Tax reduction	Yes	(Yes)	Yes	No
Quota (Biofuel, Renewable Directive)	Yes	Yes	Yes	No
Green feed-in tariff for electricity	Yes	Yes	Yes	N/A
Emissions Trading System (ETS)	Yes	Yes	Yes	No
Market introduction programmes	Yes	Yes	Yes	A few
Other (e.g. rural development schemes)	Yes	Yes	Yes	No
Research and development	Yes	Yes	Yes	Yes

Carus (2013). Bio-based Economy: volume, hurdles and new instruments. Dublin.

Global issue: the Level Playing Field

Aspects

- Competition with Fossil-based materials: mature products with life cycles optimised over decades, and with fully amortised plants

BUT:

- Fossil plastics in future will compete for crude oil with fuels
- Competition with Biofuels: highly supportive policies compared to biobased plastics and chemicals
- Competition for Raw materials: Biomass use for bioenergy purposes

Site storage for up to 350,000 tonnes of biomass pellets in four 63m diameter x 52.25m tall domes at Drax, the largest coal-fired power station in the UK

Summary of global challenges

- Sustainability of biomass supply
- Driving down costs
- Lignocellulose processing
- Demo plants and biorefinery integration
- Level playing field for biomaterials with biofuels and bioenergy
- A bioeconomy-ready workforce to educate
- Synthetic biology to the market place
- Public acceptance

Some relevant OECD publications

Thank you for your time