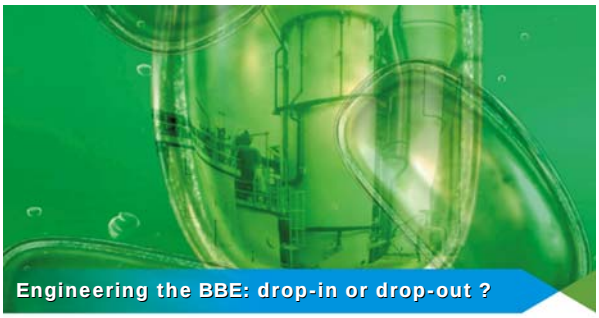

Engineering the BBE: drop-in or drop-out ?

UC Berkeley Bioeconomy | 27 march 2013

Luuk van der Wielen and Jan van Breugel

TUDelft Innovation BioBased

BE-Basic Foundation

Max the BBE opportunities ?

A. drop-in (bioethene, biosuccinate, bioPET, …) blend with existing economy (existing industry, infrastructure, capital, products, buyers, … *so 'hail shale gas'* ?), or

B. substitute (PLA, PEF, biojet fuel…) replace existing products by biorenewables (similar functionalities, reduced emission - cost, …), or

C. drop-out: (bioconcrete, biosolar, …) "New Bioeconomy" (novel products-industries, away from vested interests, full benefit of sustainable* development, rural development-jobs-income, distributed manufacturing, … *but Bio-Bubble – remember "New Economy-2001" ?)*

- Can A, B, C can all be realities ?
- What does it require ?

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* climate, economic, social

partners & affiliates

BE-Basic Foundation supports with 45 M€ or 60 M$ per *year, BBE innovation through industrial and environmental biotechnology worldwide*

Bioprocess Pilot Facility (Delft North campus)

operational since mid 2012, while being renovated (www.bpf.eu)

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1. Why ? global & regional drivers
2. How ? BBE technology portfolio
3. What ? feedstocks, products, yields
4. How – again ?
5. Why – again ?

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Global drivers for a BBE ?

- more people with more wealth
- less **nett** GHG emission (global warming) and/or climate adaptation
- politics (security of oil/gas supply)
- innovation, rural income and economic development
- increasing (*and decreasing*) prices of resources
- in time*, limited fossil reserves
- add sustainability to food chain
- add value to food chain and prevent hunger

Pick your personal selection !

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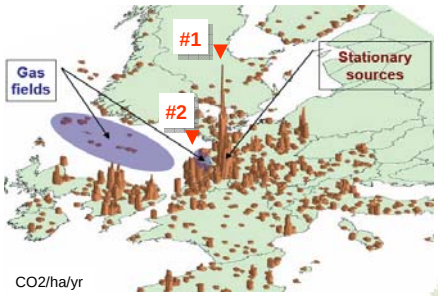
NRW and NL are #1 and # 2 in Europe



CO2/ha/yr

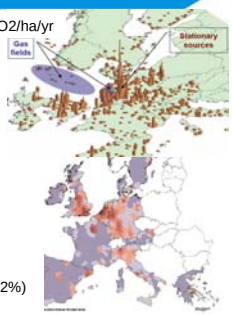
… in GHG emissions !
(so we have carbon to be recycled)

two sides of the coin in NW EU

GDP € 512 bn (#20 in 2010)
chemicals €13bn / 3% of GDP
€47bn sales / 20% export
energy €30bn sales
imports 150 MT oil/ gas / 30% EU
emissions 224 MT CO_2e/yr

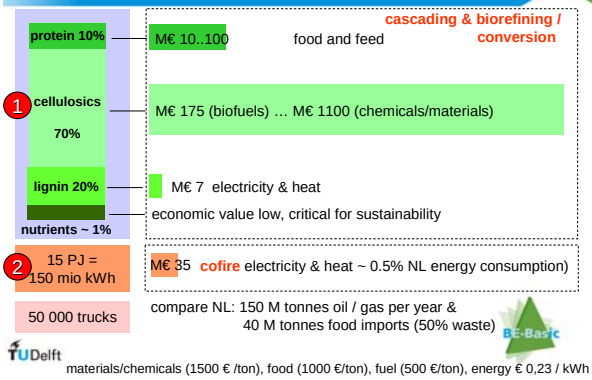
GDP € 2500 (#5) 543 bn (#19)
chemicals €46bn / 8% of NRW GDP
€145bn sales / 20% export
energy €33bn of GDP
chemical €109bn exports / €87bn imports (12%)
emissions 827 MT CO2e/yr

CO2/ha/yr



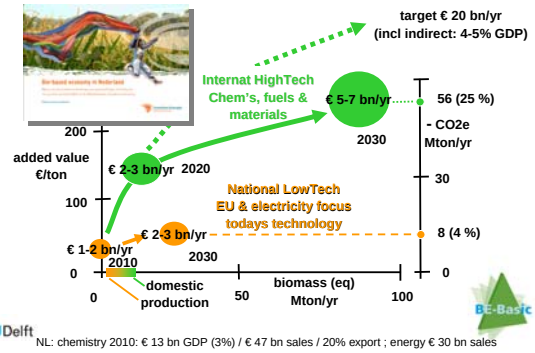
jobs/ha (red-high)
Rhine corridor

scenarios and value of biomass: 1 mio tonne



materials/chemicals (1500 € /ton), food (1000 €/ton), fuel (500 €/ton), energy € 0,23 / kWh

Technology roadmap and (direct) economic impact ('08)



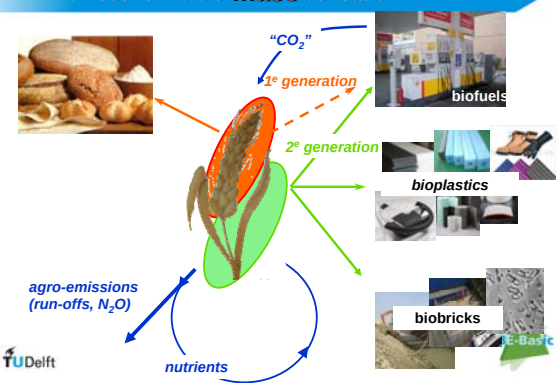
NL: chemistry 2010: € 13 bn GDP (3%) / € 47 bn sales / 20% export ; energy € 30 bn sales

contents

1. Why ? global & regional drivers
2. **How ? BBE technology portfolio**

   A drop-in, B substitute, C drop-out
3. What ? feedstocks, products, yields
4. How – again ?
5. Why – again ?

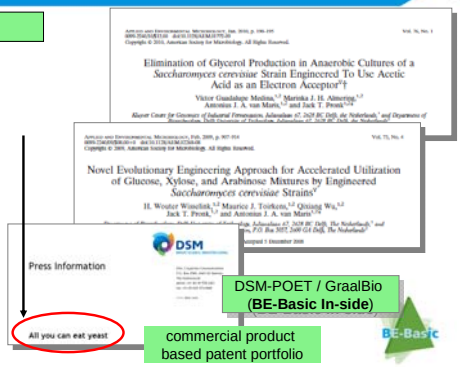
BBE : full economic bio-mass-utilisation



Synthetic Biology in the real world?

A

- glucose
- xylose
- arabinose
- acetate
- glycerol
- furanics

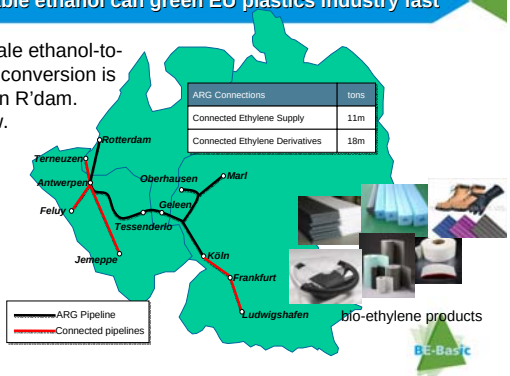


DSM-POET / GraalBio (**BE-Basic In-side**)

commercial product based patent portfolio

sustainable ethanol can green EU plastics industry fast

Large scale ethanol-to-ethylene conversion is feasible in R'dam. tomorrow.

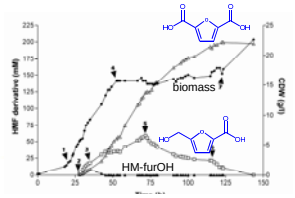


bio-ethylene products

The other 70% : FDCA for "Bio*PEF*"

B

- Top-12 value-added chemicals from biomass
- Platform chemical - market size 4-12 bn $/yr
- Replace terephthalate in 15 mio ton polymers
- Concept in B-Basic (TUD/TNO - '09) – FDCA direct production from lignocellulosic HMF
- indust biocat (BIRD Eng /TUD-'09) – bioprocess (BIRD –'10) – invest round - piloting (BE-Basic-'11)
- 2013 - acquisition of BIRD Eng / FDCA by Purac

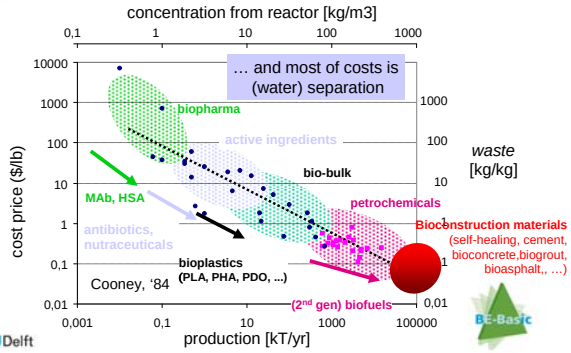


purac

plantbottle

Cost price due to feedstock, waste and separation costs

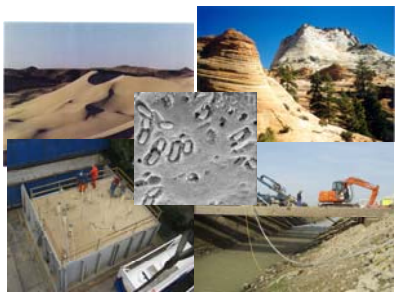
C



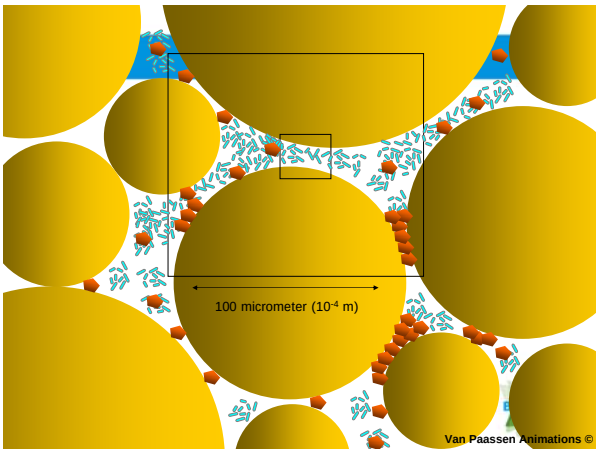
Life in a Delta is …

Biogrout & bioconcrete: from soft soil to rock solid

C



In-situ concrete by carbonate fixation



C. drop-in & out

Soft soils engineering

- Mechanical properties – long and short term → civil engineering/ construction sector
- Permeability → agri-engineering
- Molecular and biological composition → biodiversity/nature engineering

CO_2: from 4 €/tonne 'problem' to 40 ... 400 €/tonne fertiliser/bioconstruction solutions

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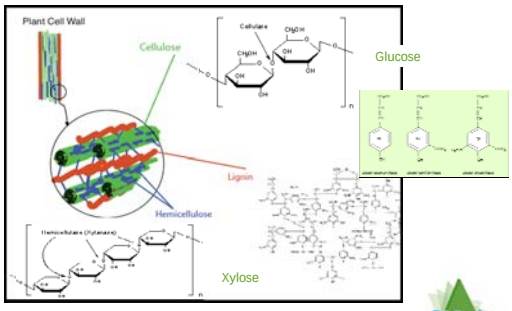
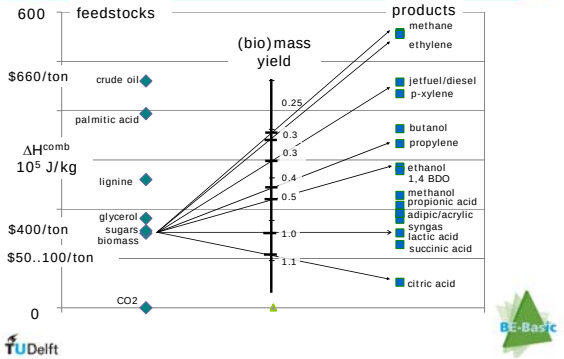
Fermentable sugars

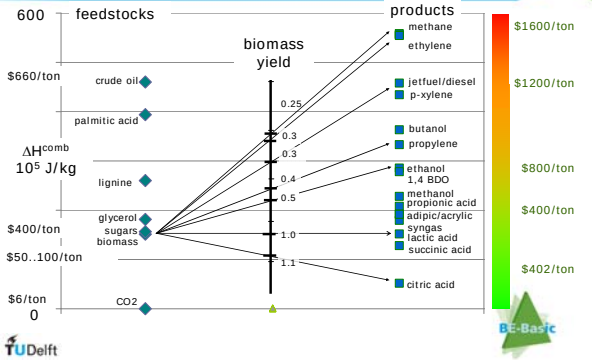


Plantation image from: biofuel.webgarden.com

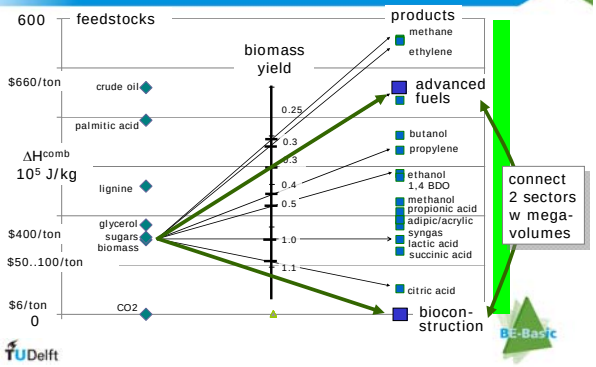
feedstocks, products and yields



Cost contribution of feedstocks



drop-in & out scenario ?



ASEAN - Scenarios mill-integrated biomass processing

A1 (*n*=1) mill based

plantation + mill based B1

A2

B2

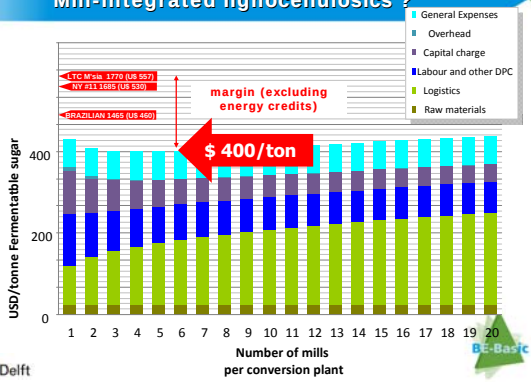
A5

B5 (*n*=5)

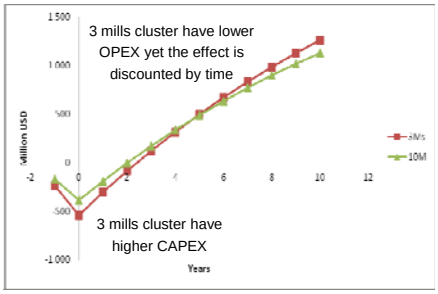
n regular mills per

1 central biomass processing plant

Mill-integrated lignocellulosics ?



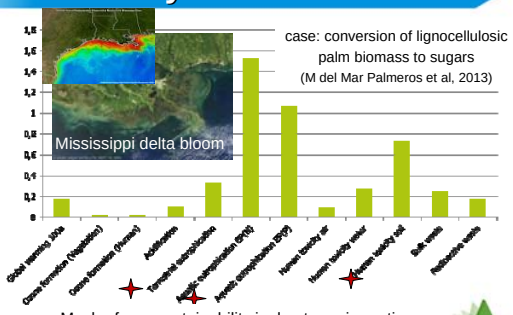
NPV / DCCF / PBT for 3* and 10 mill clusters



* productivity of 3 mill cluster is scaled (x 3.3) to that of 10 mill cluster

M del Mar Palmeros et al (2013); final report of MICCI project

Life Cycle Assessment



case: conversion of lignocellulosic palm biomass to sugars
(M del Mar Palmeros et al, 2013)

Much of non-sustainability is due to agri-practices
integral process design including nutrient recycles
connect to 2C 'soil engineering / bioconstruction'

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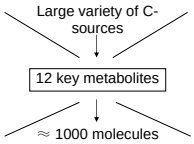
Structuring principles in metabolism– key platforms



Carbon-"Bowtie"
J J Heijnen TUD'10

Un-structured in single organism:

100 feedstock molecules x 1000 metabolic products = 100 000 pathways

Structured via platforms

(100 feed mol + 1000 products) x 12 key metabolites = 13 000 pathways

order of magnitude less "CAPEX" (enzymes, etc)

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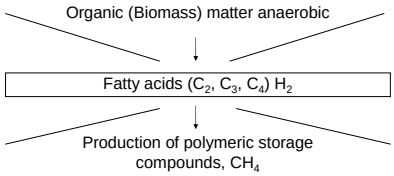
Structuring principles in ecology – similar platforms

Ecology of (micro)organisms digests complex organic feedstocks into few platform molecules and from there, in range of (storage) products.

Costs: 10-40% of feedstock (gibbs) energy to drive multistep synthesis

= low OPEX



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Same structuring principle in petro-industry ecology

- **complex crudes** (oil, coal) are 'cracked' into few high quality **platforms** (lower alkenes, low alcohols, aromatics, H2, syngas) to build complete **product families**
- requires an **Ecology of Industries** for efficient use (success of Port Industry Cluster in Rotterdam, S'pore, Houston, etc)
- petro-industry is carbon-constrainted (mass utilisation), because of abundent energy (heat, H2) – needs rethinking

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Implications for biorefineries / BBE

- It will not develop as a refining complex of all sorts of products from all sort of feedstocks **(so no dedicated-product crops !)**
- **platforms** preferrably (but not necessarily) **compatible with existing infrastructure** (drop-in: lower alkenes, low alcohols, aromatics, H2, syngas) to build complete **product families** ?
- requires an **ecology of industries** for efficient use ('symbiosys')
- carbon-constrainted (full mass utilisation) as well as energy constrainted (energy integration) – needs rethinking

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- add value to food chain and prevent hunger

Pick your personal selection !

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Global biobased network

'Drop-in' in 'Old World' while 'Rest of the World' will see Substitute or Drop-out scenario's ?

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Max the BBE opportunities !

- **(A) drop-in, (B) substitute and (C) drop-out** can all be realities and require:
- **further integration** of industrial sectors – fuel & construction, fuel & agro, waste & feed, … to enable full (bio)mass utilisation (mass, energy, economy, climate)
- **regional diversification** to benefit fully from brown field (EU, USA) and green field (LA, Africa, Asia) situations
- **rethink scale & regulations** – hi-tech distributed manufacturing, process technology, infrastructure, agri-models, finance models, regulations (especially around recycling)

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