

Cost effective C3-fermentation chemistry

The NordBioChem's way out of Fossils

Cologne, April 7th 2016

The logo for Nordbiochem LLC features the company name in a blue sans-serif font. A green leaf icon is positioned above the letter 'i' in 'bio'. Below the name, the letters 'LLC' are centered between two horizontal green bars. The background of the slide is a blurred image of laboratory glassware, including a graduated cylinder and a beaker.

Nordbiochem
LLC

Message

NordBioChem will in following show, that

- an efficient and competitive **C3-fermentation-chemisry** is available and next to PLA
- a high variety of C3-Bio-Chemicals like propylene oxide, propylene glycol, their derivatives, acrylates as well as many other basic and new chemicals could be produced.

Introduction

C3-Chemistry is the second largest sector of chemistry but C3-Bio-Chemistry hasn't reached the same impact.

Way?

There is still **missing an effective and sustainable C3-fermentation technology**, as a base for self-sufficient (independent from subsidies) industrial high volume production.

How? (Principles, NordBioChem is following)

Principle of Siam-Twins: At the same time a

- Technology must be reliable and a
- (Bio-)Product must be competitive against replacements (petrochemistry)!

Principle of Emissions:

- Not competitive are bio-technology processes with high emissions – like the production of ethanol, where 1/2 of the raw material is converted into (CO₂) emission.
- **Lactic acid fermentation** generates no CO₂ emission and converts up to 95% of raw material into lactic acid.

NordBioChem OÜ (NBC)

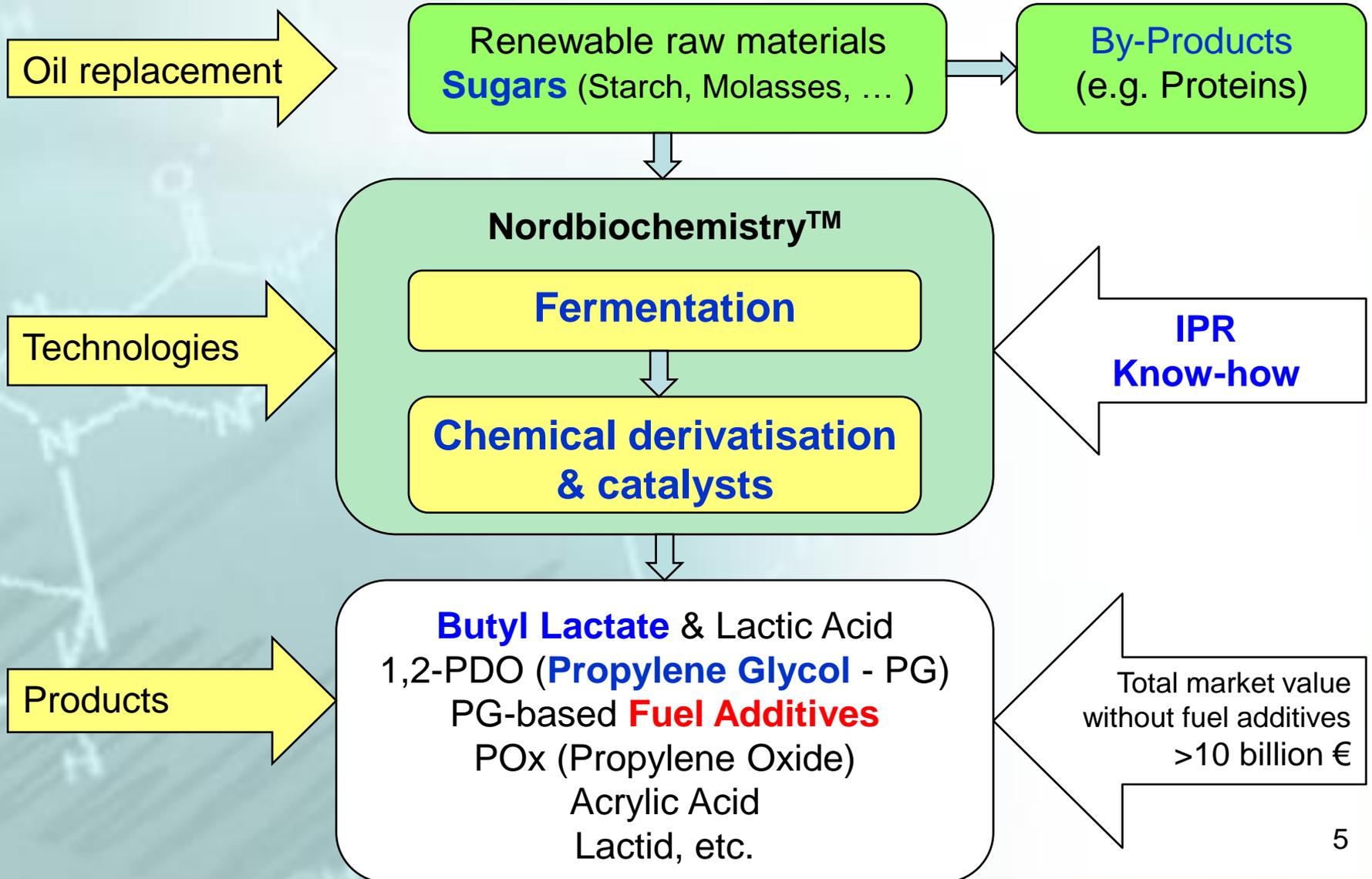
NBC is a private R&D management company.

- NBC has created a unique technological platform for the
- industrial fermentative bio-chemistry - we call it *Nordbiochemistry™*

Nordbiochemistry™ is based on a *combination* of high-effective

- **Asynchronic Continuous Flow Membrane Fermentation** and
- **synthetic zeolites** catalysed
- **chemical derivatisation** reactions.

Nordbiochemistry™ - a Technology platform



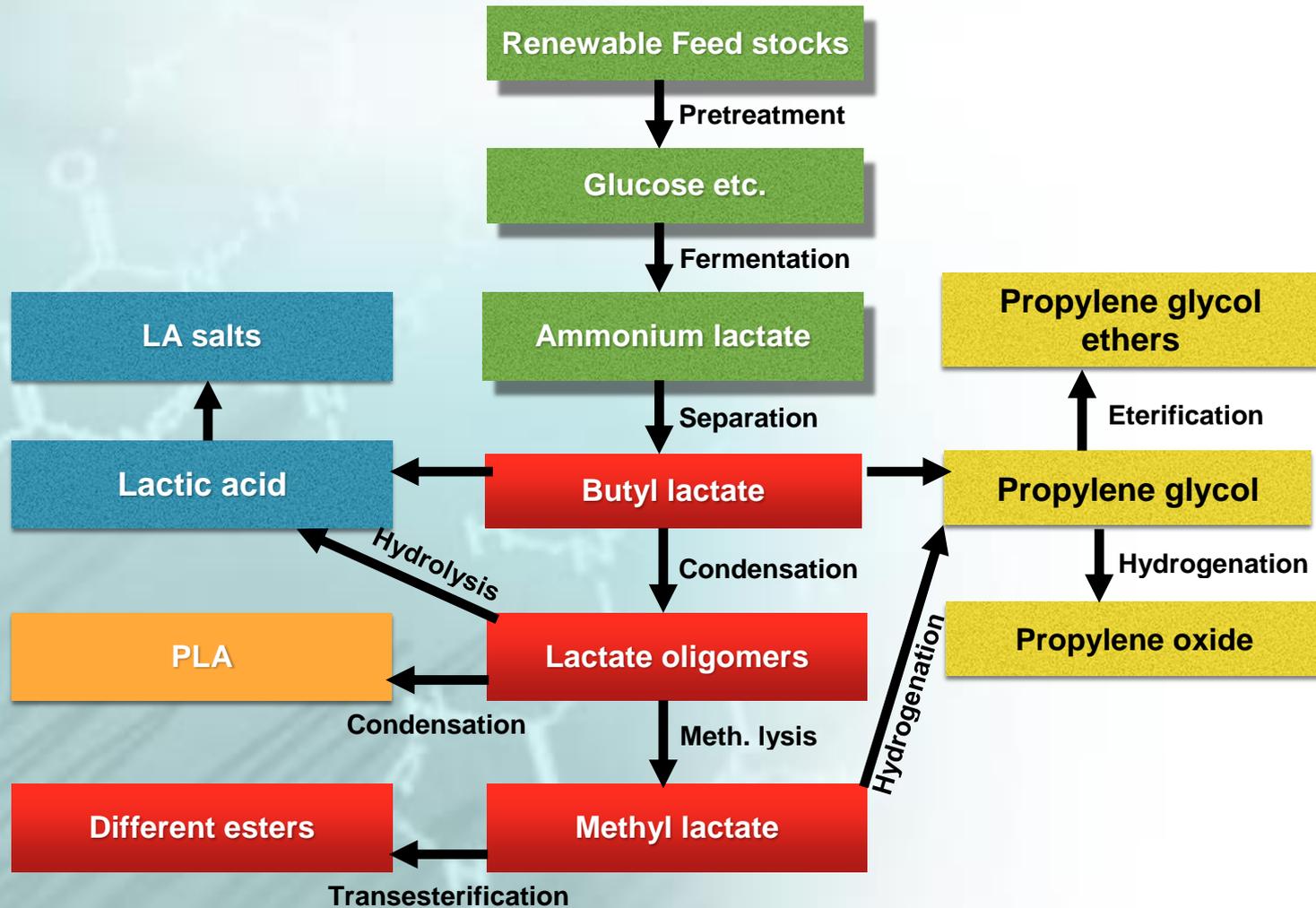
Advantages of Nordbiochemistry versus conventional C3-fermentation

1. Process **speed** 50-100 g/l/h versus 2-5 (max10) g/l/h (10-fold difference) at conventional.
2. Ca. 50 kg **waste** per ton of Lactic Acid versus ca.1400 kg/t (mostly CaSO_4 = gypsum) (25-fold difference)
3. „Asynchronous-Continuous-Flow“- type of **fermentation** by NBC versus conventional mostly „Batch“-type.
4. By Nordbiochemistry a 10-15 times smaller equipment produces the same amount of endproduct (LA) as by conventional LA-production – it means accordingly lower investment and maintenance **costs**.

Technology platform

- As raw materials C6-sugars like glucose, saccharose, fructose and maltose are preferred, also
- C5 could be utilized, but less effectively - because of the nature of C5-sugars and not because of the technology.
- The high process yield from C6-sugars to endproducts lies e.g. by 76% for POx and 87% for PG.
- The NBC's fermentation technology is
 - proven by a large scale (1m³) long term (60 days continuous) piloting and
 - confirmed through independent secondary tests incl. Germany's Leibniz-Institute.

Technological chart flow map



Current focus

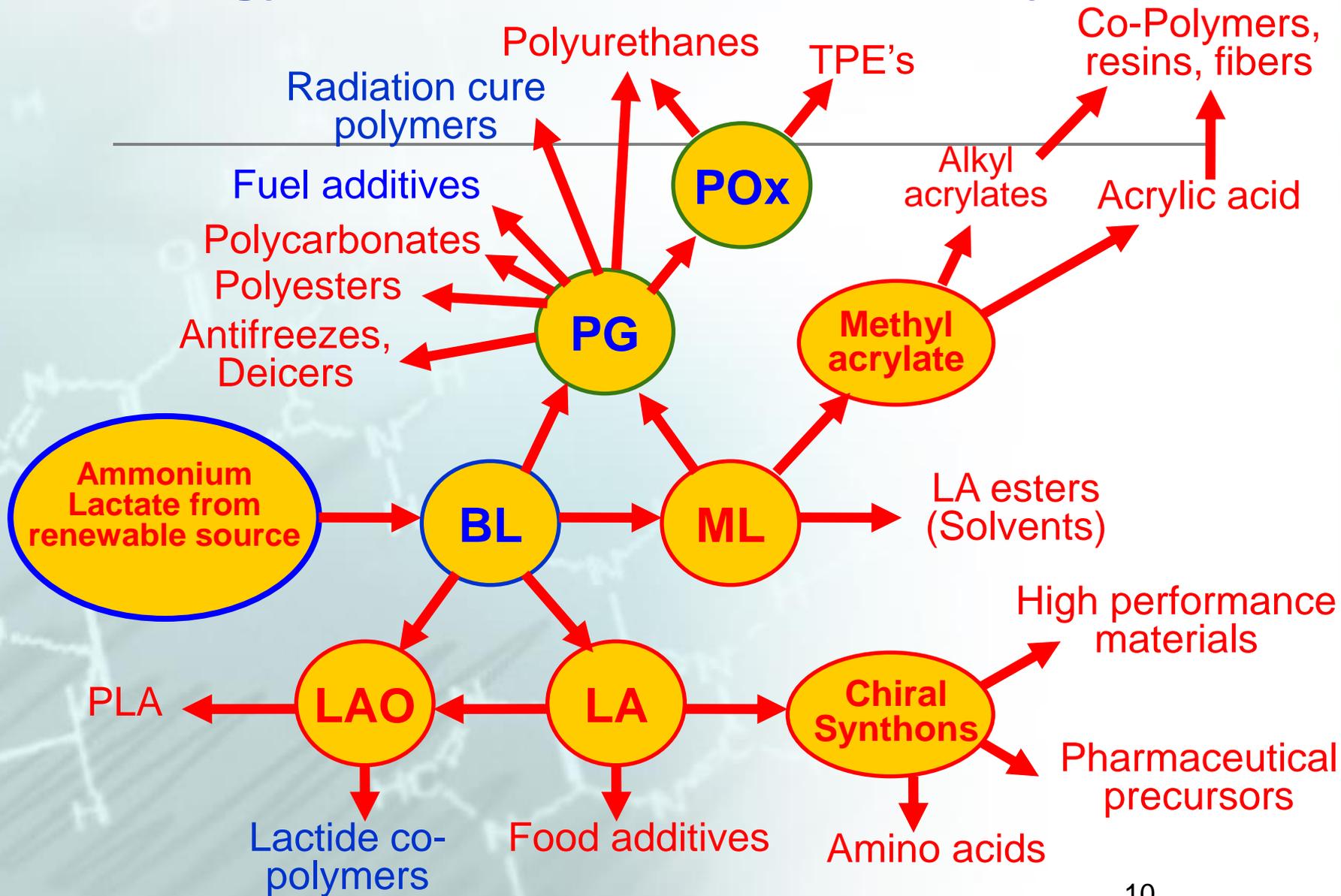
Current NBC focus lies on **C3-bio-chemicals**, especially on

- propylene oxide & derivatives
- propylene glycol & derivatives
- acrylic acid & esters
- lactide co-polymers

The most interesting path is **Propylene Oxide** with its derivatives: polyols (urethanes), propylene glycol & derivatives (ethers, acetates, solvents, carbonates), butanediol & derivatives (diols, esters, solvents).

There are applications in the fields of polyester resins, urethanes, automotive parts, coatings, paints, coolants, personal care & cosmetics, pharmacy, bio-fuels etc.

Technology blocks of Nordbiochemistry™



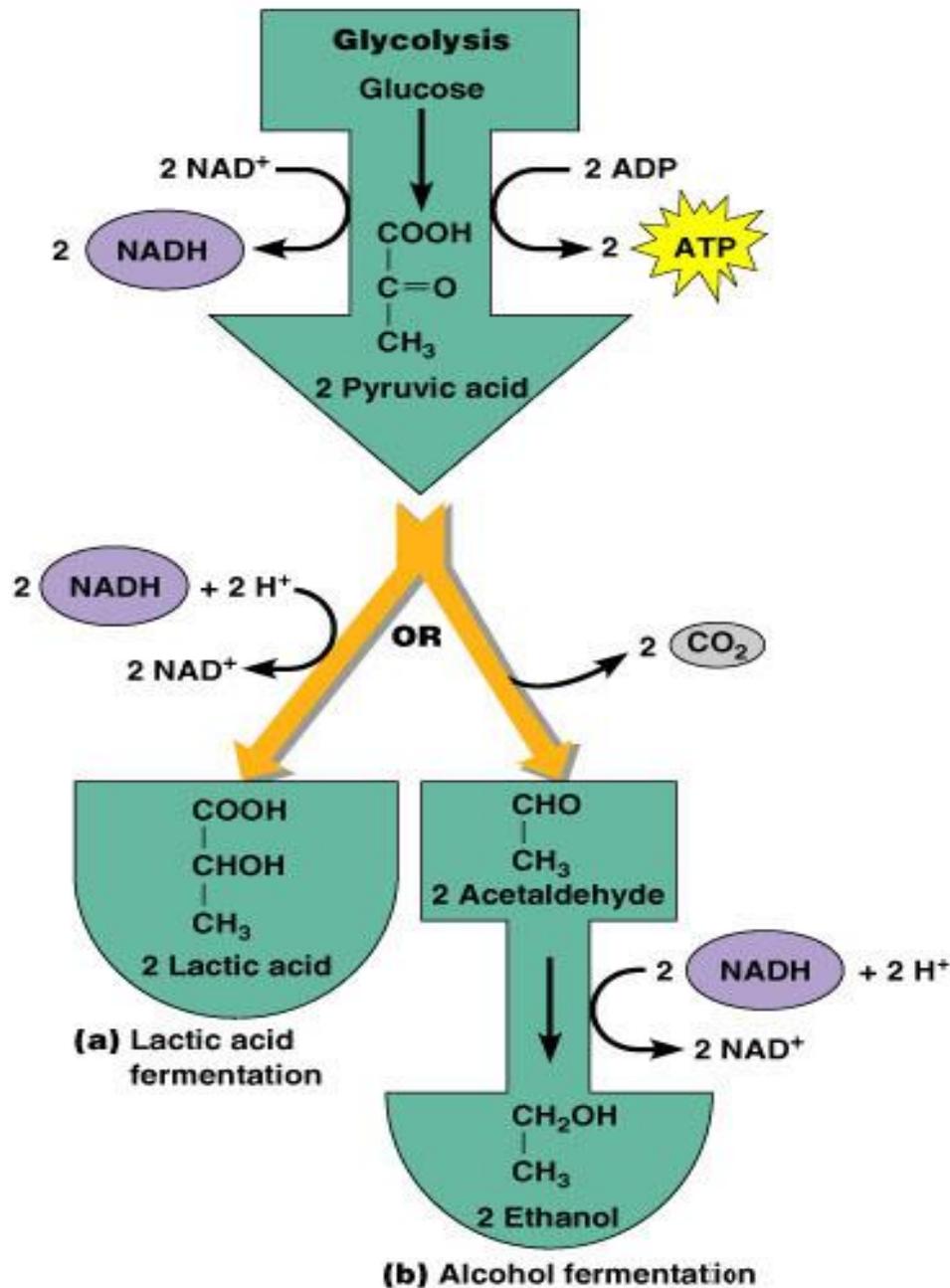
Fuel Additives based on Bio-Propylene-Glycol

Di- and tri-propylene-glycol combined ethers are well known **oxygenates**, whose widespread usage was suppressed by the high price of these petrochemical compounds.

Now NordBioChem has developed cost effective technologies for the production of **Bio-Propylene-Glycol** and **ethers** based on it:

- **Di-Propylene-Glycol**, a C6-compound, (+ methyl, ethyl etc. groups)
- **Tri-Propylene-Glycol**, a C9-compound, (+ methyl, ethyl etc. groups)

Propylene-glycol-ethers have a big **potential to replace bio-ethanol** and **bio-diesel** and free ethanol (from to be fuel additive) for that use where it is good: food and chemistry.



Microbiological differences of the C2- ja C3-fermentation

Ethanol - the most known biochemical

- is a perfect & **useful chemical** for producing materials
- useful, but „dangerous“ **foodstuff**
- **wrong energy carrier**
 - for to produce 1 liter ethanol more than 1 liter oil is in the total cycle needed
- By producing (fermentation) of **1 molecule ethanol**
 - **1 molecule CO₂** will additionally generated (> 100 million tons yearly worldwide)
 - **½ of raw material is wasted** ⇒ low efficiency
- **Alternately Lactic Acid fermentation converts 95%** of raw material ⇒ the only efficient fermentation technology today

Effectiveness of Di- and Tri-propylene glycol type of fuel additives:

Engine-test of diesel oil, blended with 10% of PG-additives reduces

- specific fuel consumption up to 8%
- emissions
 - Sulfur content up to 9%
 - SO_x emission up to 26%
 - NO_x emission up to 27%
 - CO emission up to 58%

These characteristics are the main differences and advantages compared to bio-ethanol & bio-diesel based fuel additives.

Motorentest für Bio-Kraftstoffzusätze

Auszug aus dem Messprotokoll

Tallinn, 31.01.2014

Tests

1. Test 1 96,5% (v/v) Dieseldieselkraftstoff + 3,5% (v/v) Thiophen (um einen schwefelreichen Treibstoff zu simulieren)
2. Test 2 Test 1 + 5 % (v/v) Dipropylenglykol
3. Test 3 Test 1 + 10 % (v/v) Dipropylenglykol

Testmotor: 1-Zylinder Diesel-Motor „Ricardo Hydra“ mit ungeteiltem Brennraum
Drehzahl der Kurbelwelle $n = 2000 \text{ min}^{-1}$.

Kennzahlen	Test-methode	Maß-einheit	Messwerte				
			Test 1	Test 2		Test 3	
			Wert	Wert	Änderung %	Wert	Änderung %
Treibstoff							
Schwefelgehalt	EVS-EN ISO 20846	Masse-%	1,65	1,59	-3,6	1,50	-9,1
Abgasemission							
CO ₂		Masse-%	2,23	1,59	-28,7	1,49	-33,2
CO		ppm	43	21	-51,2	18	-58,1
NO		ppm	189	154	-18,5	137	-27,5
NO _x		ppm	199	162	-18,6	144	-27,6
SO ₂		ppm	134	123	-8,2	99	-26,1
H ₂ S		ppm	42,5	34,3	-19,3	23,3	-45,2
Motoren-Kennzahlen							
Effektivleistung des Motors		kW	3,4	3,6	5,9	3,8	11,8
Spezifisches Treibstoff-Verbrauch	GOST 18509	g/(kW h)	387,2	380,0	-1,9	356,4	-8,0

New interesting pathways

Very special bio-products are **radiation cure polymers**, produced from biobased di- and tri-propylene-glycol.

These radiation sensible bio-polyethers could significantly speed up 3D-printing and lower its raw materials cost.

Utilisation of methane using microbiological methods is a new and challenging target for the chemical industry, especially because of a very quickly expanding production of shale-gas.

Being the universal method of fermentation, Nordbiochemistry allows economically viable solutions for the production of lactic-acid and its derivatives by using methanotrophic microorganisms e.g.

Lactobacillus Helveticus.

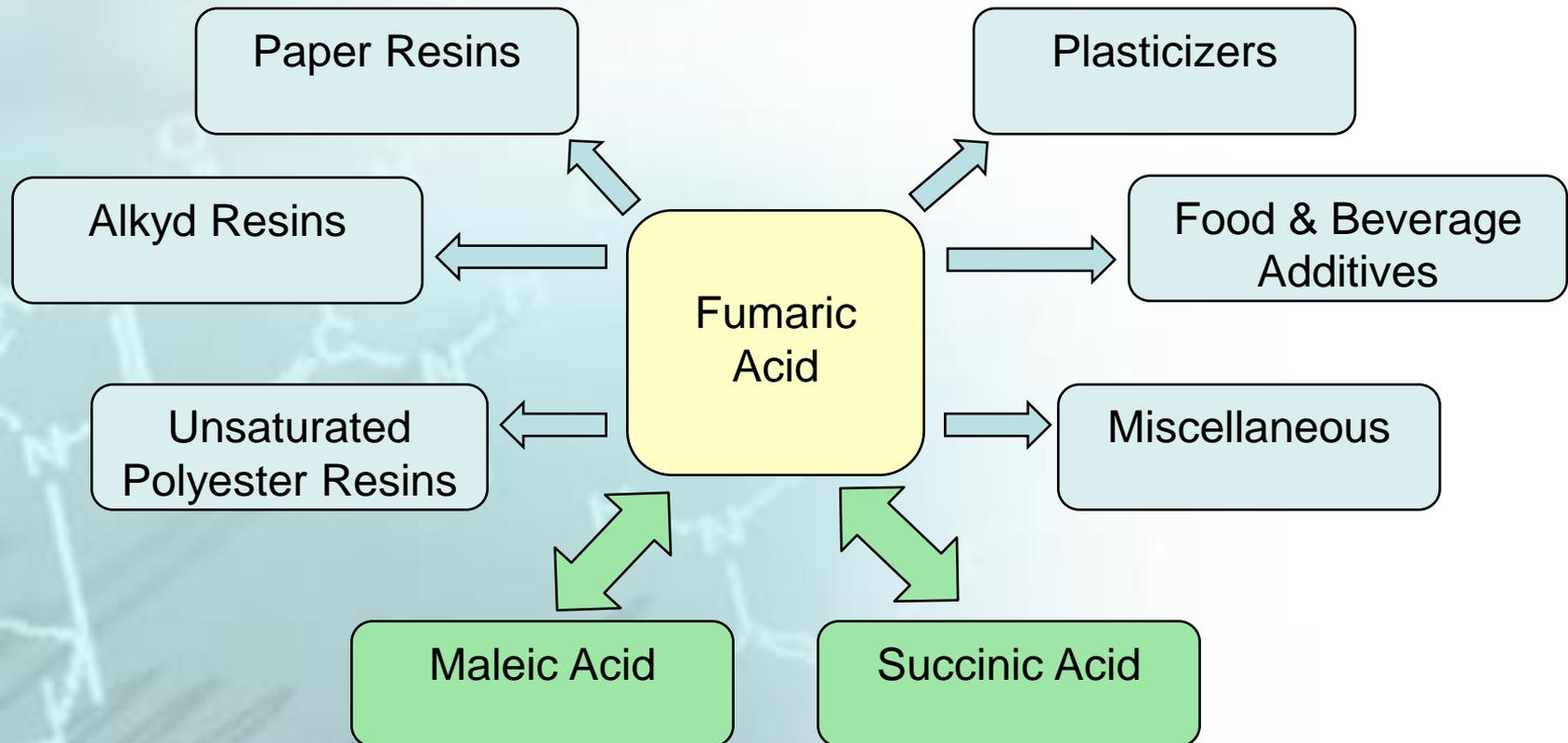
C4-compounds - Perspectives (1)

- Fumaric acid is a naturally occurring organic acid. It was first isolated from the plant *Fumaria Officinalis*, from which it derives its name. Many microorganisms produce fumaric acid in small amounts, as it is a key intermediate in the citrate cycle.
- Fumaric acid is currently produced by isomerization of maleic acid, which is produced from maleic anhydride. Maleic anhydride, in turn, is industrially produced by catalytic oxidation in the gas phase of hydrocarbons: benzene predominantly, but *n*-butane or *n*-butane–*n*-butene mixtures has become more important in recent years.
- By our calculations, the fermentation of fumarate in a speed of 25 g/l/h (which is a moderate speed for Nordbiochemistry) is in terms of costs comparable to petrochemical production.

C4-compounds - Perspectives (2)

- Based on fumaric acid, several intermediates and directly used products like succinic and maleic acids, 1,4-butanediol, polymers, solvents etc. can be synthesized.
- They can substitute a number of traditionally produced solvents and polymers like: tetrahydrofuran, polyurethanes, polyterephthalats, polyvinyls etc.
- The demand for fumaric acid today is about 2,5 million of metric tons annually.
- The market size of the fumaric acid and it's derivates is more than 6 billion EUR

Fumaric Acid based C4-compounds



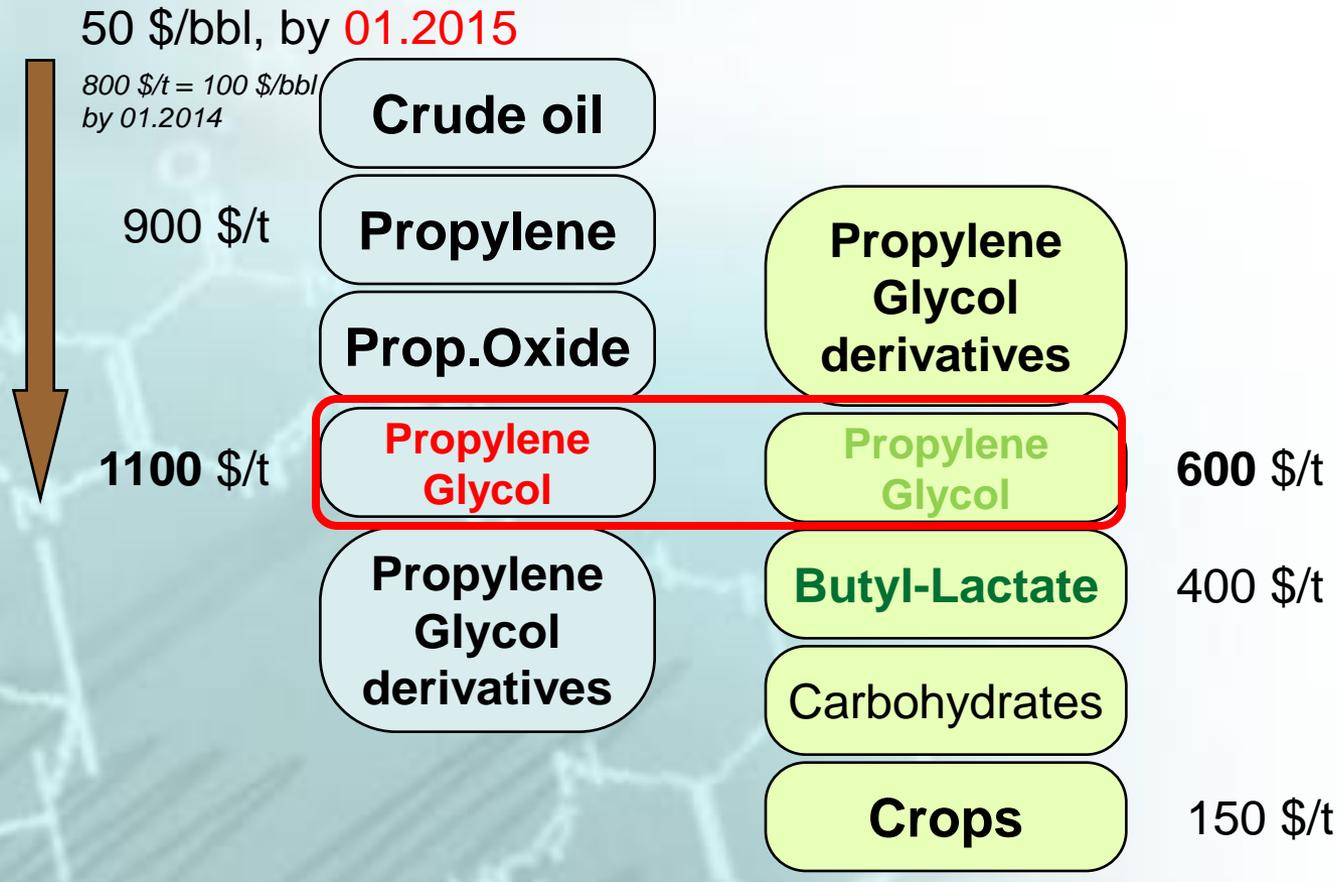
Business opportunities

Nordbiochemistry™ opens the door for very productive and **competitive fermentative C3-bio-chemistry**.

Its implementation **decreases the CAPEX** considerably because of high productivity and lower investments, thus **decreasing the production costs** for relevant chemicals up to 30%.

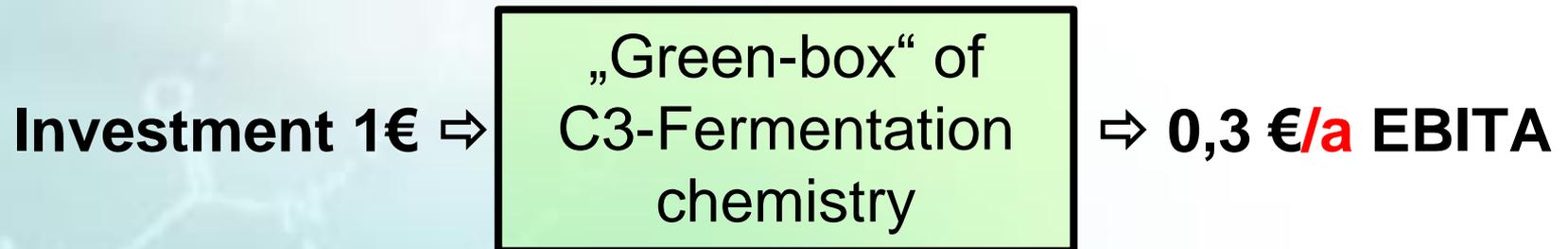
NordBioChem is **offering licenses** for developed technologies and is **looking for partners for industrial implementation**.

C3: Petro- versus Nordbiochemistry™



Price-difference: $1100 - 600 = 500$ \$/t = 45%

Technology valuation for investors



Business for NBC

licensing & know-how based services:

- IPR
- Know-How
- General Engineering
- Education & Training
- Process monitoring
- Technical support and updating

Conclusions

- A cost-effective C3-fermentation is possible and available!
- High variety of competitive C3-Chemicals like Propylene Oxide, Propylene Glycol and their derivatives as well as many different basic and new chemicals could be produced already.

Nordbiochemistry™ offers a platform for very productive and competitive fermentative C3-chemistry.

We would be happy to share it with you.

With compliments

Armand Andres Pajuste

Member of supervisory board

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