# Nordbiochemistry™

Technology presentation

Tallinn, July 2017

“The stone age did not end because we had a lack of rocks and the oil age will not end because we have a lack of oil.”

*Sheikh Zaki Yamani*

# NordBioChem Ltd.

**Private, profit oriented R&D management company:**

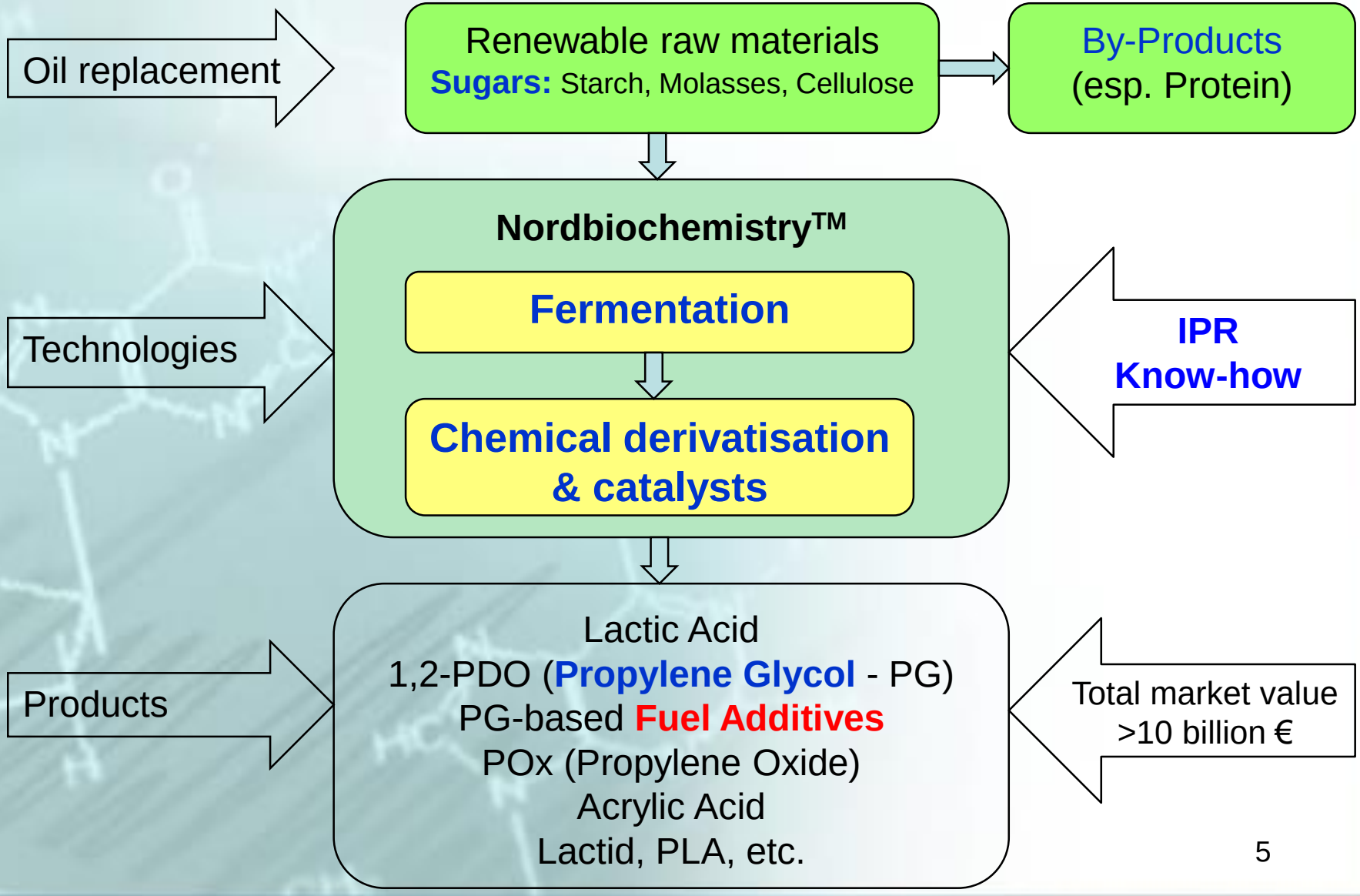
- NordBioChem has created a **unique**
- fully protected by several patents
- **technological platform for Lactic-acid-fermentation-chemistry** (we call it **Nordbiochemistry™** )
- combined with new solutions in **catalytical** mechanisms and **chemical derivatisation** technologies
- allowing competitive **high-volume**
- **replacements for petrochemicals** as standardized commodity chemicals and
- significant **reduction of $CO_2$ emission** and **toxic** reaction components.

# History of NordBioChem

NordBioChem and its predecessors have been since 1986 involved in the development of industrial biotechnologies and construction of several industrial laboratories and plants in

- industrial grade microbiology synthesis,
- gene and cell engineering as well as
- development and building of pharmaceutical and chemical plants

# Nordbiochemistry™



# Fermentation by Nordbiochemistry™

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

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

- allows Fermentation speed up to 100 g/l/h
- lab maximum 220 g/l/h, optimal between 50-90 g/l/h

# R&D & Intellectual Property Rights

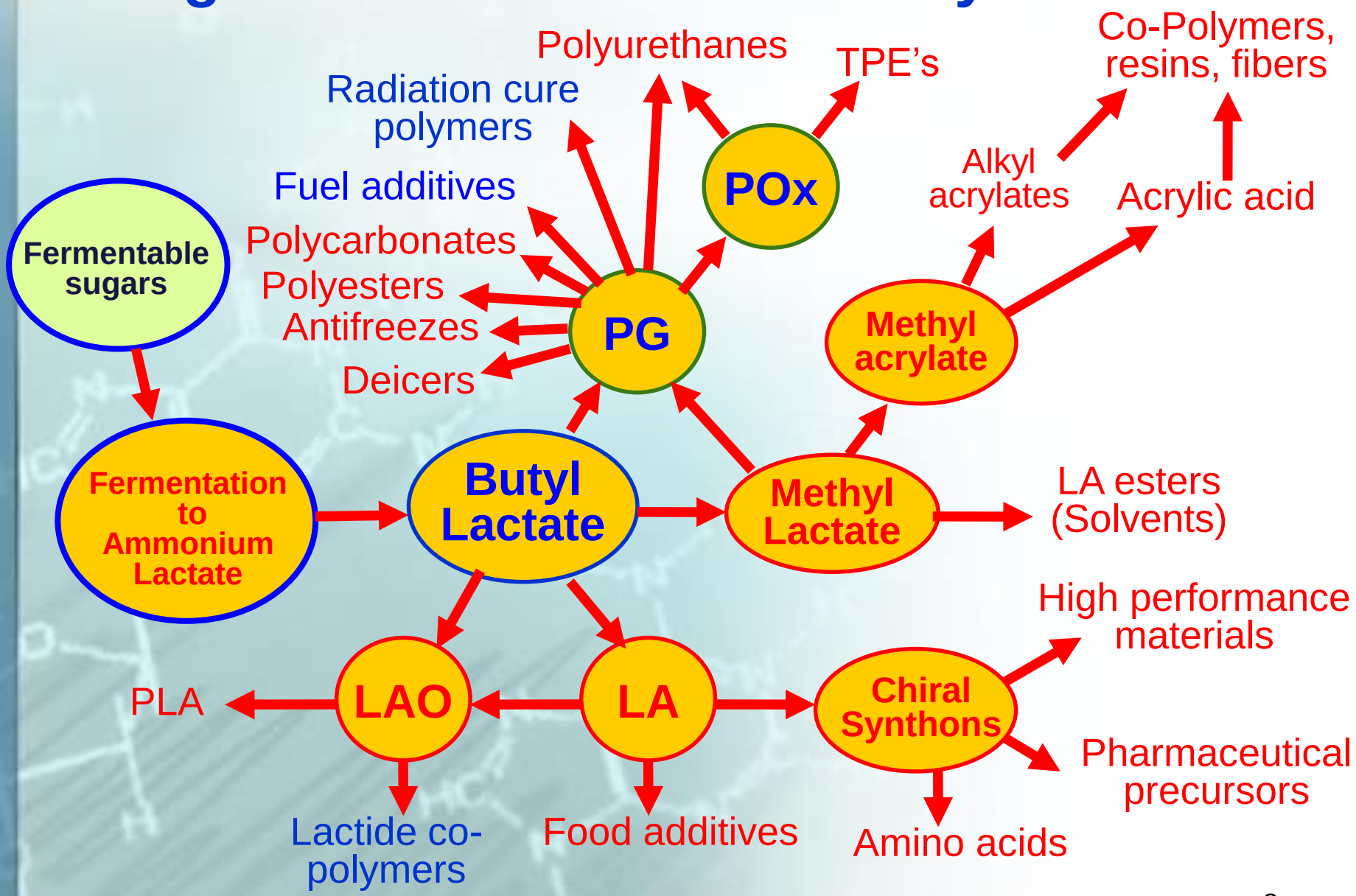
NordBioChem, established 2004, finances R&D activities and acts as applicant and owner of commercial rights.

- More than 100 contract scientists & developers
- Nordbiochemistry™ is protected by several patents

**NordBioChem's patents:**

| | |
|---|---|
| • Published Patents | 11 |
| • Filed patent applications | 10 |
| • Applications in preparation | 15 |

# Range of C3-Nordbiochemistry™



# Replacement Market for biobased C3-Chemicals

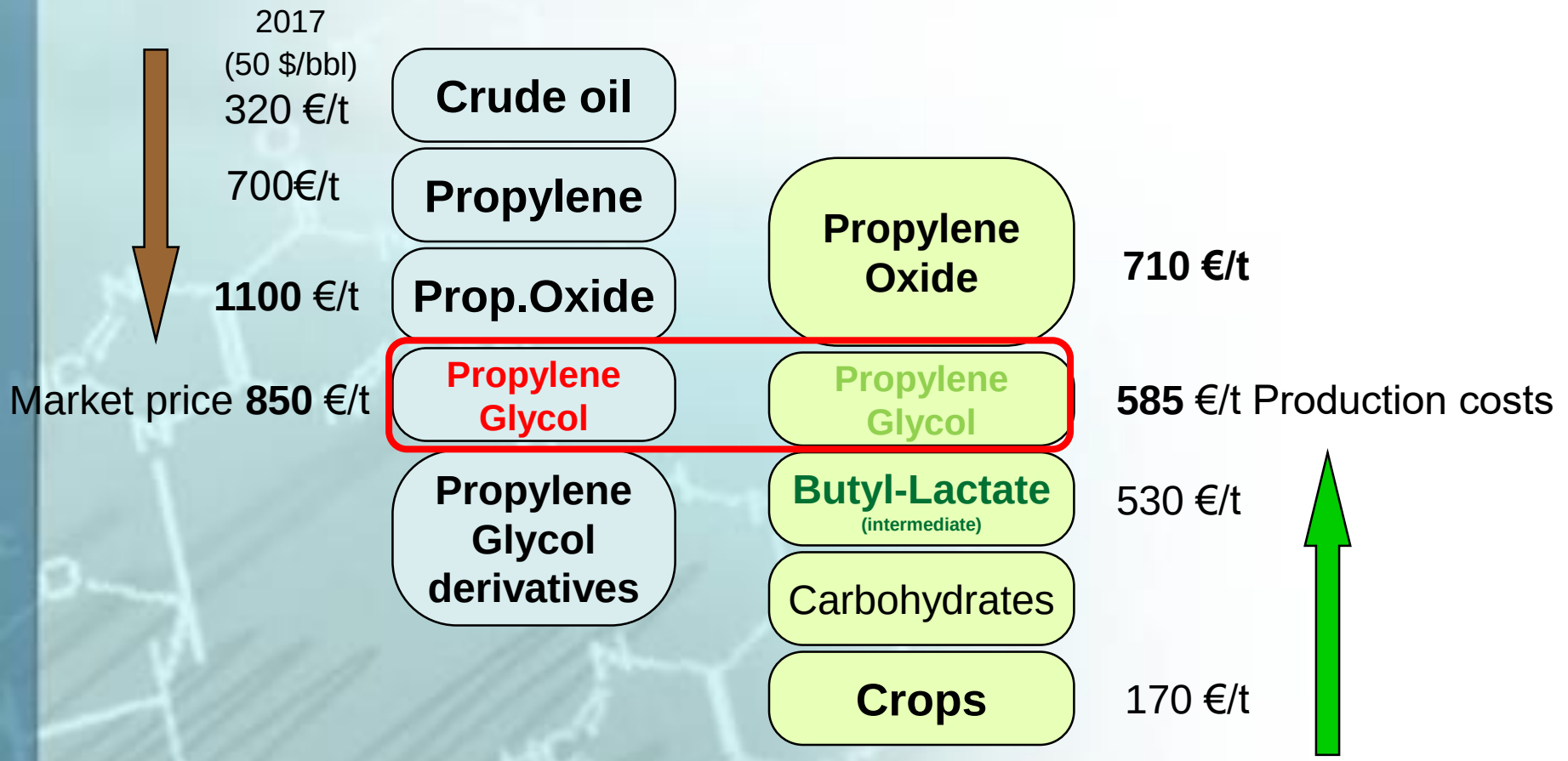
- **Chemical Industry**: solvents, foams, adhesives, paints, polymers (i.a. radiation cure polymers for 3D-printing) etc.
- **Cosmetics and Pharmacy**: polymers, moistures, binders
- **Fuel Additives**: as replacement for ethanol and bio-diesel
- **Food and Feed Industry**: moistures, fillers, fragrances, preservatives, food additives, etc.
- **Agriculture**: preservatives, feed additives, etc.

# Technology valuation by NordBioChem

NordBioChem is offering licensing & know-how based services:

- IPR licensing
- Know-How
- General Engineering
- Piloting and upscaling services for up to 2.5 $m^3$ fermentor
- Education & Training
- Process monitoring
- Technical support and updating

# Economy of C3-Bio-Cemistry: Petro- versus Nordbiochemistry™




PG Price-difference: 850-585=265 €/t = -30%

# Lactic acid based Bio-Polymers

The best known **Lactic Acid based Bio-Polymer is PLA**
PLA has some advantages, but also some serious disadvantages:

- mechanical properties are poor,
- requirements to the purity of lactide and complexity of purification technology are very high and it causes
- PLA to be expensive compared to classical fossil polymers (like PE or PP)

A new very promising group of Bio-Polymers are lactic acid based **Bio-Co-Polymers**. They have a

- simple process of monomer purification,
- wide possibilities of polymer properties regulation,
- new consumer properties of new polymer materials and
- low capital-output ratio.

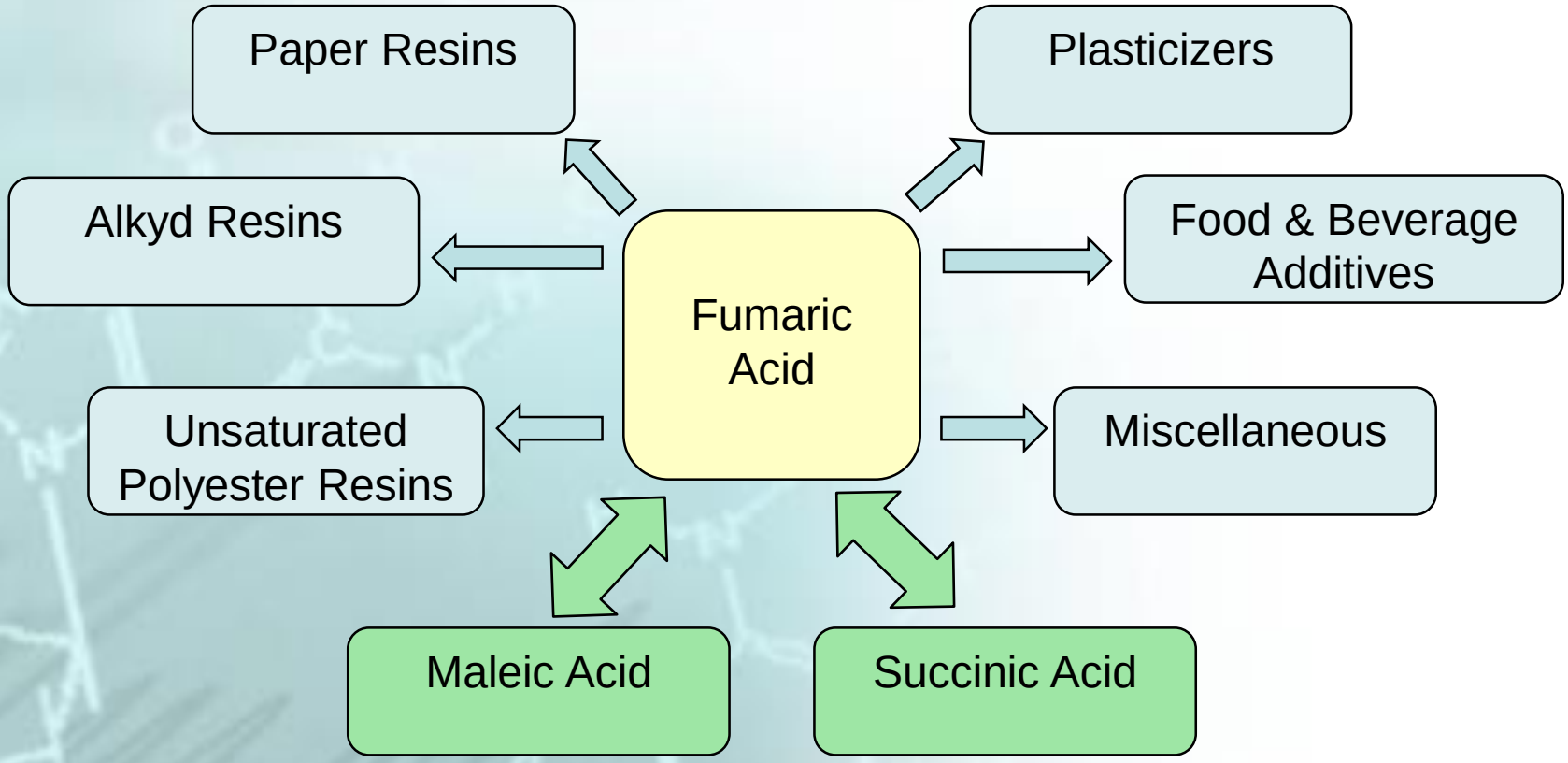
# C4-compounds - Perspectives (1)

- Fumaric acid is a naturally occurring organic acid. It was first isolated from the plant *Fumaria Officinalis*, from which it derives its name. Many micro-organisms 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 in recent years *n*-butane or *n*-butane–*n*-butene mixtures have become more important.
- By NBC's calculations, the fermentation of fumarate with 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. could 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



# Biobased
# Fuels, Fuel Additives & Oxygenates

# EU directive 2009/28/EU & Estonia

## 10% biobased fuel additives since 2020

- Accordingly to the EU directive 2009/28/EU Estonia introduced the regulation to implement **Y2020 10% biofuels**.

- Currently Estonia is not producing biofuels by itself.
- Estonia consumed 2014 730,000 ton of transport fuels.
- To fulfill 10% obligations 73,000 ton imports are needed.
- By current prices (500€/t ethanol) yearly **imports 35 mio. €**

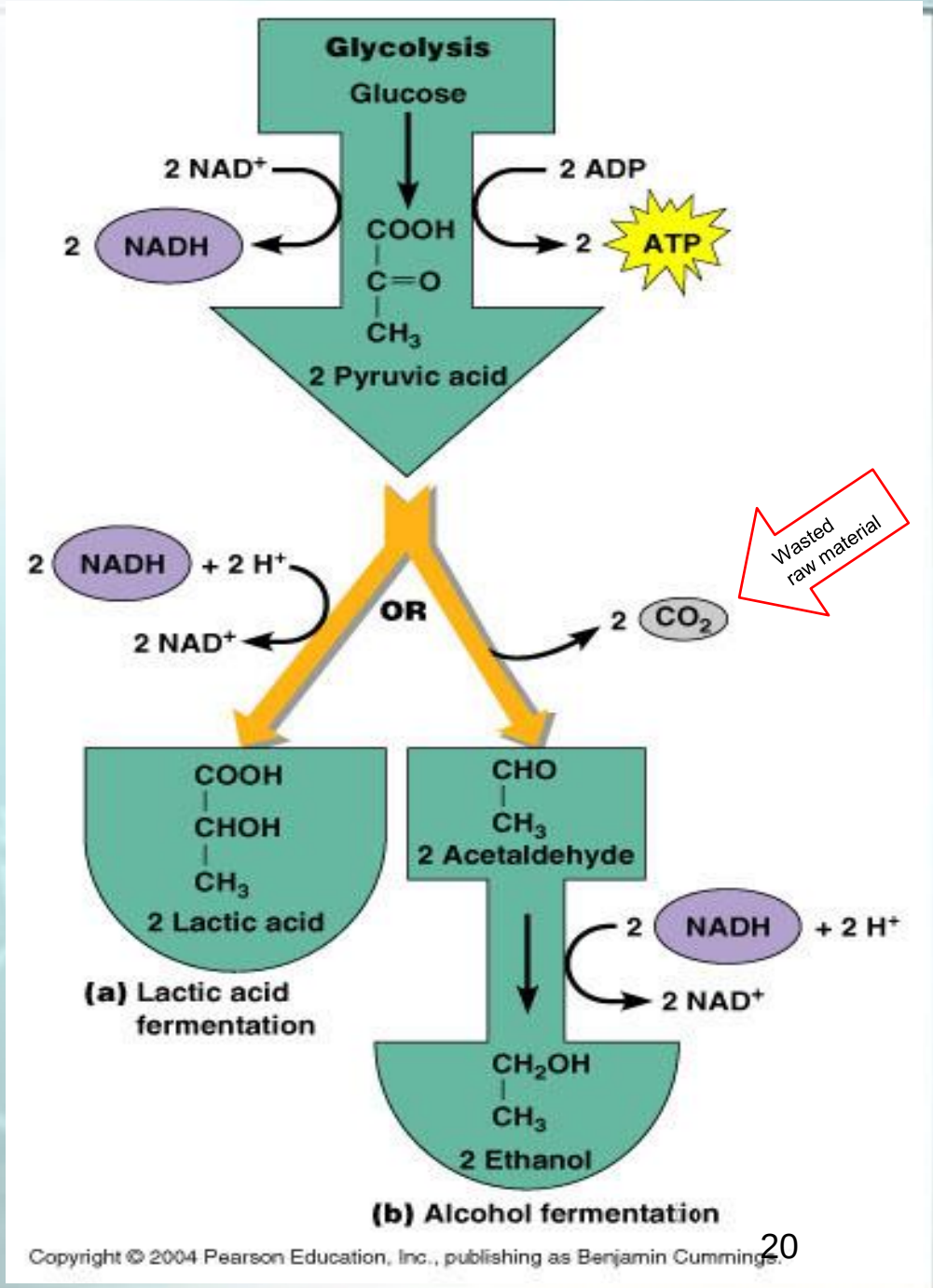
# Biofuels

- Worldwide over 100 mio. ton of ethanol is yearly produced
- The nature of Ethanol fermentation is that at the same time 100 mio. ton of $CO_2$ will be yearly generated
- EU countries used Y2014 270 mio. ton of fossil transport fuels. 1/3 gasoline and 2/3 diesel
- EU is importing remarkable part of needed biofuels
- The EU's sugar policy is changing and the sugar market will be open for worldwide imports as of 30 September 2017
- This will cause changes in EU sugar production and correspondingly in ethanol production
- Opening the sugar market will inevitably cause the end of cereals market protection too – causing vulnerability in next agriculture sector

# Current biofuels are handicapped

- Presently great majority of biofuels for blending of fossil fuels are ethanol for gasoline and biodiesel for diesel
- **Ethanol**:
  - Causes huge $CO_2$ generation during the fermentation process and thus loss of ½ of raw material
  - Has only ca. 60% of energy content of gasoline
  - Contains water which in winter freezes
  - For older generation of cars ethanol causes different damages
- **Biodiesel**
  - Has lower energy content compared to fossil diesel
  - Needs refurbishing of engins
  - In the wintertime has ignition difficulties

# Microbiological differences of the C2- ja C3-fermentation



# Bio-Propylene-Glycol based Fuel Additives / Oxygenates

# Fuel Additives based on Bio-Propylene-Glycol

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

Now NordBioChem has developed cost effective technologies for the production of Bio-Propylene-Glycol and its ethers :

- Di-Propylene-Glycol,
  a 6 carbon compound, (+ methyl, ethyl etc. groups)
- Tri-Propylene-Glycol,
  a 9 carbon 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.

# 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%
  - SOx emission up to 26%
  - NOx emission up to 27%
  - CO emission up to 58%
  - etc.

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

# Engine tests
# with propylene glycol based fuel additive

Nordbiochem LLC

**Tests:**

**Test 1** 96,5% (volume) low-sulfur Diesel fuel + 3,5% (volume) Thiophen (to simulate high sulfur content diesel fuel, as used in marine engines)

**Test 2** Test 1 with **5 %** (v/v) **Di-Propylene-Glycol** content

**Test 3** Test 1 with **10 %** (v/v) **Di-Propylene-Glycol** content

**Test engine:** One-cylinder diesel engine „Ricardo Hydra" with undivided combustion chamber
Engine speed n = 2000 $min^{-1}$

| Parameters | Test-method | Units | Measured results | | | | |
|---|---|---|---|---|---|---|---|
| | | | Test 1 | Test 2 (5% DPG) | | Test 3 (10% DPG) | |
| | | | Value | Value | Difference in % | Value | Difference in % |
| Sulphur content | EVS-EN ISO 20846 | Mass-% | 1,65 | 1,59 | -3,6 | 1,50 | **-9,1** |
| **Exhaust gas emission** | | | | | | | |
| $CO_2$ | | Mass-% | 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** |
| $H_2S$ | | ppm | 42,5 | 34,3 | -19,3 | 23,3 | **-45,2** |
| **Engine key figures** | | | | | | | |
| **Effective power** | | kW | 3,4 | 3,6 | 5,9 | 3,8 | **11,8** |
| **Specific fuel consumption** | GOST 18509 | g/(kW h) | 387,2 | 380,0 | -1,9 | 356,4 | **-8,0** |

# Estonian C3-Biofuels Plant concept

# Development of new type of Biofuels production in Estonia

- Estonia has two choices: to import or to produce biofuels.
- Imports will mean at least 35 mio. €/a turnover
- Suggestion is to build a 40,000 t/a plant for new type of Biofuels - the C3-based biofuels (Di- and Tri-Propylene Glycol)
  - utilizing the Estonian origin technologies of NordBioChem OÜ and
  - using Estonian own raw materials (cereals). If to convert all exported cereals into C3-biofuels about 200,000 t/a biofuels will be produced from which 130,000 would by export by price 500€/t instead of 150 €/t by cereals.

# Estonian C3-Biofuels Plant

- Suggestion is to build a 40,000 t/a plant for C3-based biofuels (Di- and Tri-Propylene Glycol) utilizing the Estonian origin technologies of NordBioChem OÜ
- It will be a new type of Biofuels, which lowers the fuel consumption at least 8% and reduces significantly exhaust emissions (10-50%)
- The Nordbiochemistry™ C3-fermentation technology is tested in large scale long time piloting and is now industrial implementation ready.
- Estimated cost for a 40,000 t/a C3-based biofuels plant will be about 50-60 mio. EUR.

# Business project

- Current **project is in an initiation status**
- Estimated cost for a 40,000 t/a C3-based biofuels plant will be about 50-70 mio. EUR
- **Steps of project**:
  - Feasibility study – 3-6 month, 0,3 mio.€
    (preferably financed by government supported institution)
  - Involving stakeholders and launching of a company
  - Pilot & demonstration facility 3-6 month, 6-18 mio.€ (could also be used for educational purposes)
  - Building of the industrial 40,000 t/a plant – 18-24 month, 50-65 mio.€
- **Capital structure**
  - 25-30% Equity
  - 15-20% Grant
  - 50-60% Debt

# Estonian Agriculture (1)

- 2015 Estonia produced 1,5  mio. ton cereals, from which
- 0,7 mio ton were exported (without adding extra value).

- How can Estonian plant growing survive in next future?
- Only, if the added value will  grow!

- NordBioChem suggests to introduce technologies to the complex processing of cereals by separating them into components and processing the components differently.

# Estonian Agriculture (2)

- NordBioChem suggests to introduce technologies to the complex processing of cereals by separating them into components and processing the components differently.
  - Proteins will be divided into their components and valued as a food and feed additives
  - Starch will be used for production of amino acids and for lactic acid fermentation (there is no $CO_2$ emission here) into C3 basic chemicals, incl. fuel additives.
- C3-fermentation, compared to ethanol, produces from the same amount of raw materials 2 times more endproduct by generating no $CO_2$ emission!