A biorefinery for the conversion of glycerol to value added products

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Center for Microbial Biotechnology
Department of Systems Biology

SEVENTH FRAMEWORK PROGRAMME

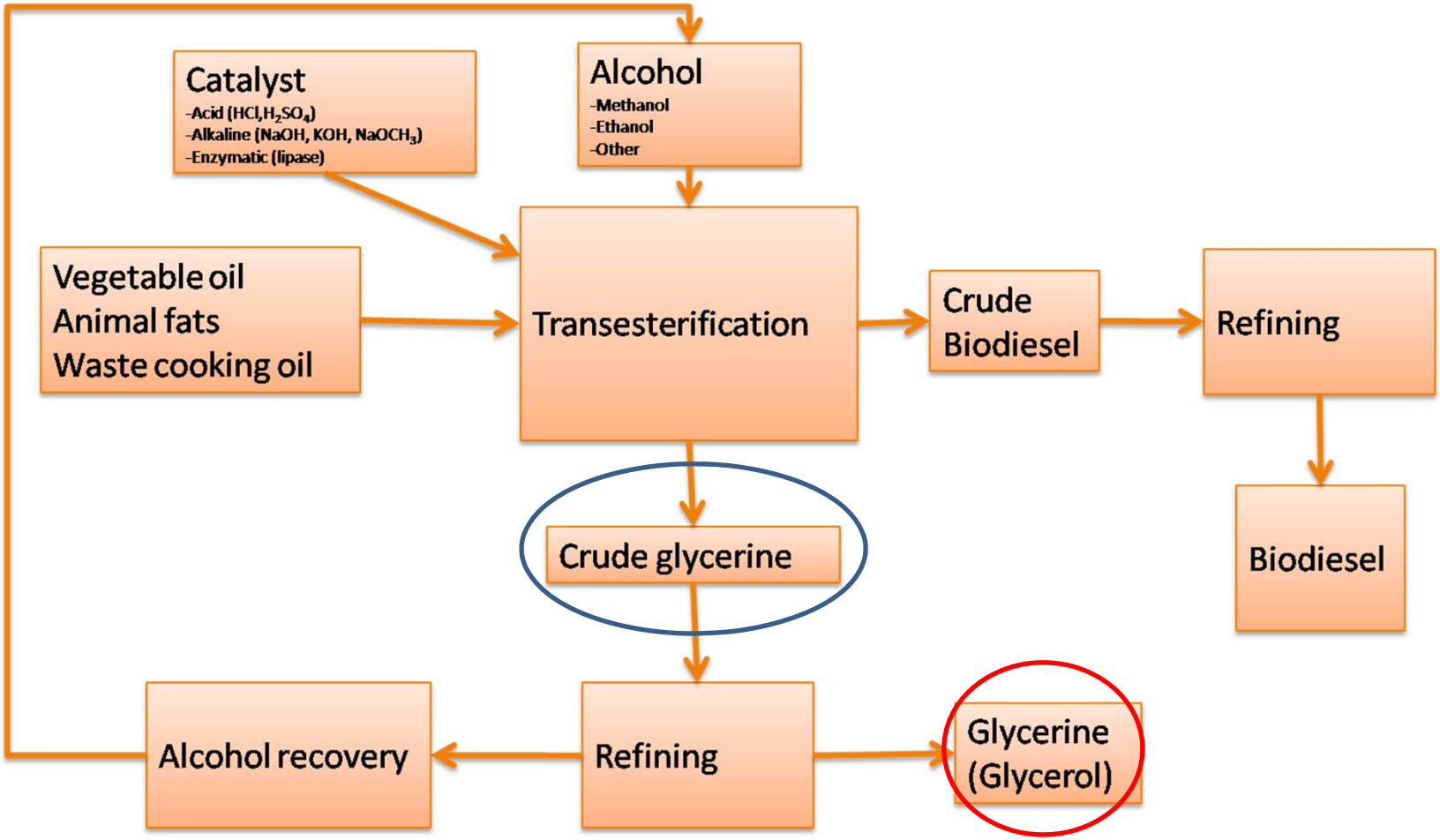
DTU

GLYFINERY partners

- Dept. Systems Biology, DTU
- BioGasol ApS, Denmark
- A&A Biotechnology, Poland
- MEROCO, Slovakia
- The Institute for Energy and Environmental Research, Germany
- ProChimia Surfaces, Poland

Project period: March 2008 – February 2012

Biodiesel production process



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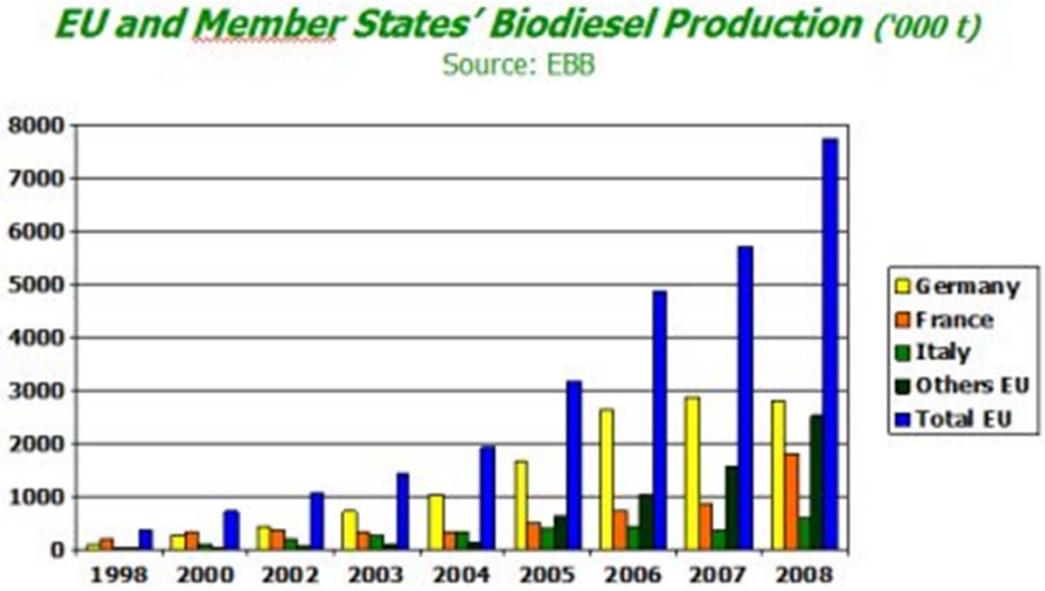
Biofuel production in Europe



Over 7.7 million tons of biodiesel were produced in the European Union in 2008, representing an increase of 35.7% over the previous year.

Biodiesel accounted for over 80 % of the total biofuels production.

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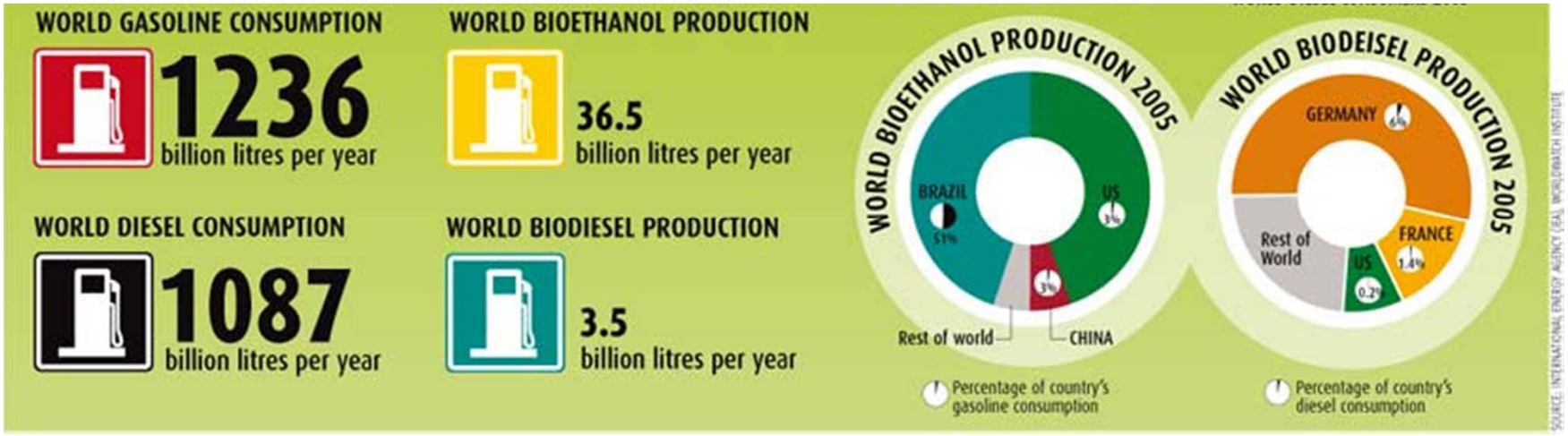
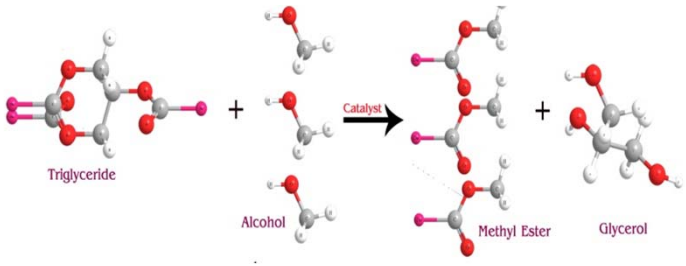
Glycerol: future technologies



Biofuels: a historical perspective



1900
Diesel engine run on peanut oil at the World's Fair in Paris

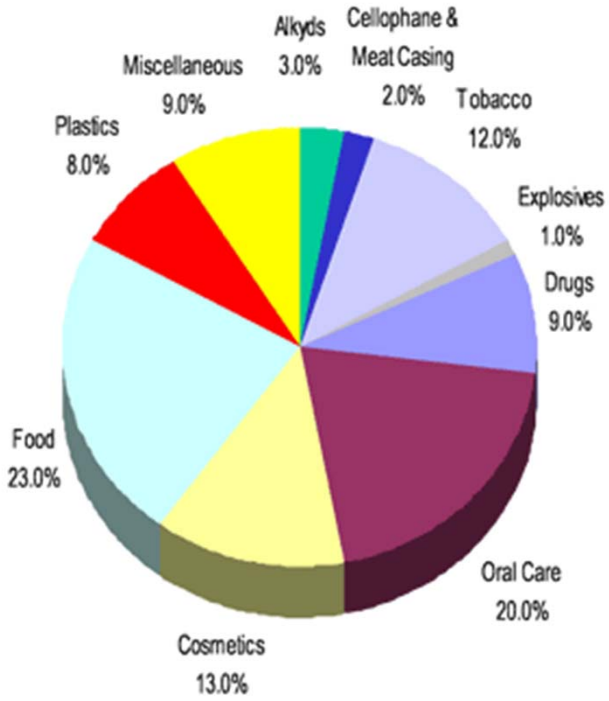
1937
Chavanne granted patent for "Procedure for the transformation of vegetable oils for their use as fuels"

Petroleum replacement fuel

1977
Brazilian scientist Expedito Parente filed patent for same process

Biofuels

Current uses of glycerol



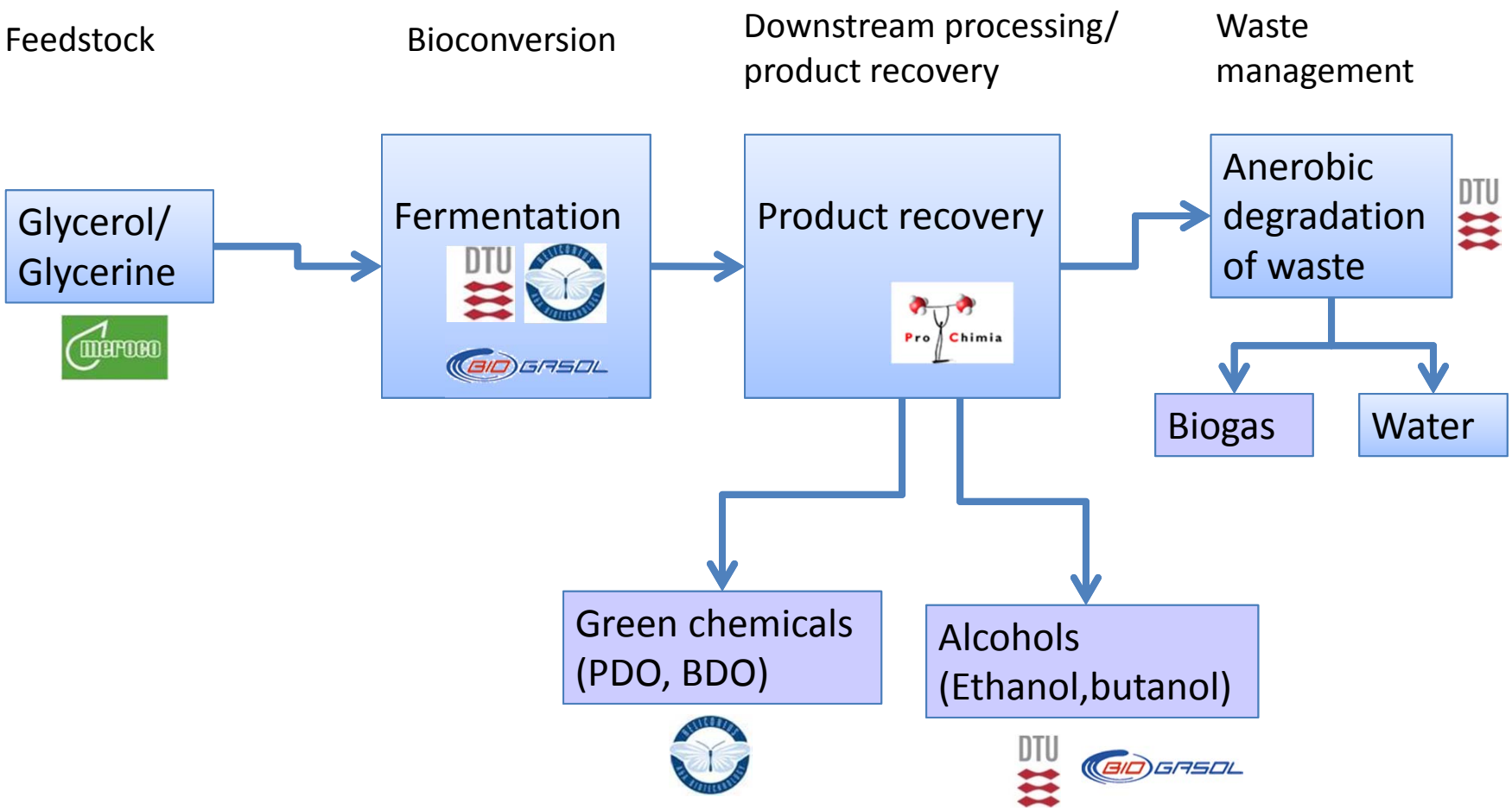
Over 2000 established uses for glycerol in the drug, food, beverage, chemicals and synthetic materials industries.

Disposal of surplus glycerol is by incineration.

GLYFINERY project

- Targeted to development of novel technologies based on biological conversion of glycerol
- Aimed at producing new and known advanced liquid biofuels, bioenergy and biochemicals
- Integrated biorefinery concept
- Improve economics of the biodiesel biorefinery by enhancing energy conversion efficiency

Integrated GLYFINERY concept



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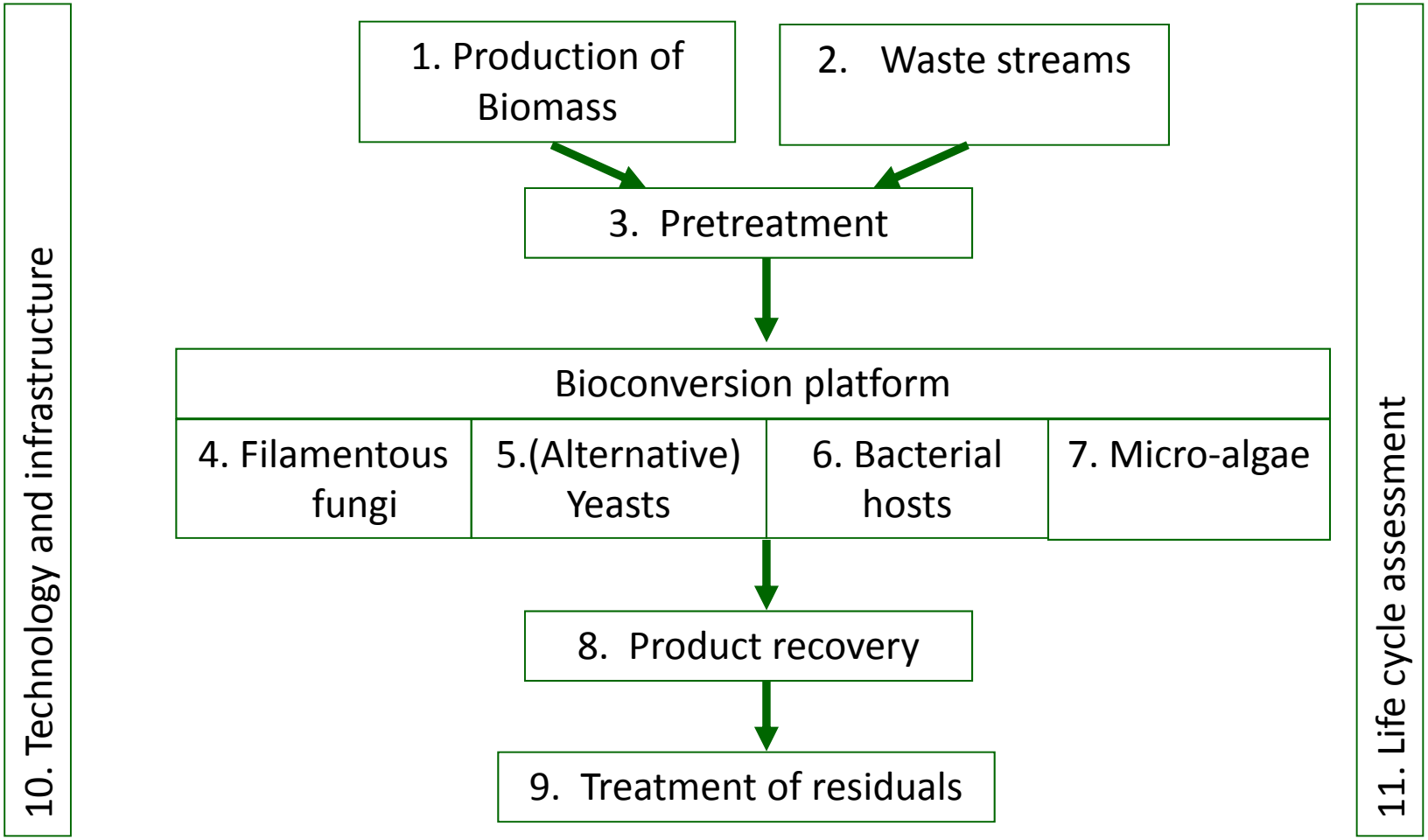
Biorefinery concept



Target products

- Green chemicals

1,3 – propanediol, produced by *Clostridia* (A&A Biotechnology, Poland)

- Alcohols

Ethanol and butanol produced by yeasts and anaerobic bacteria (BioGasol and DTU, Denmark)

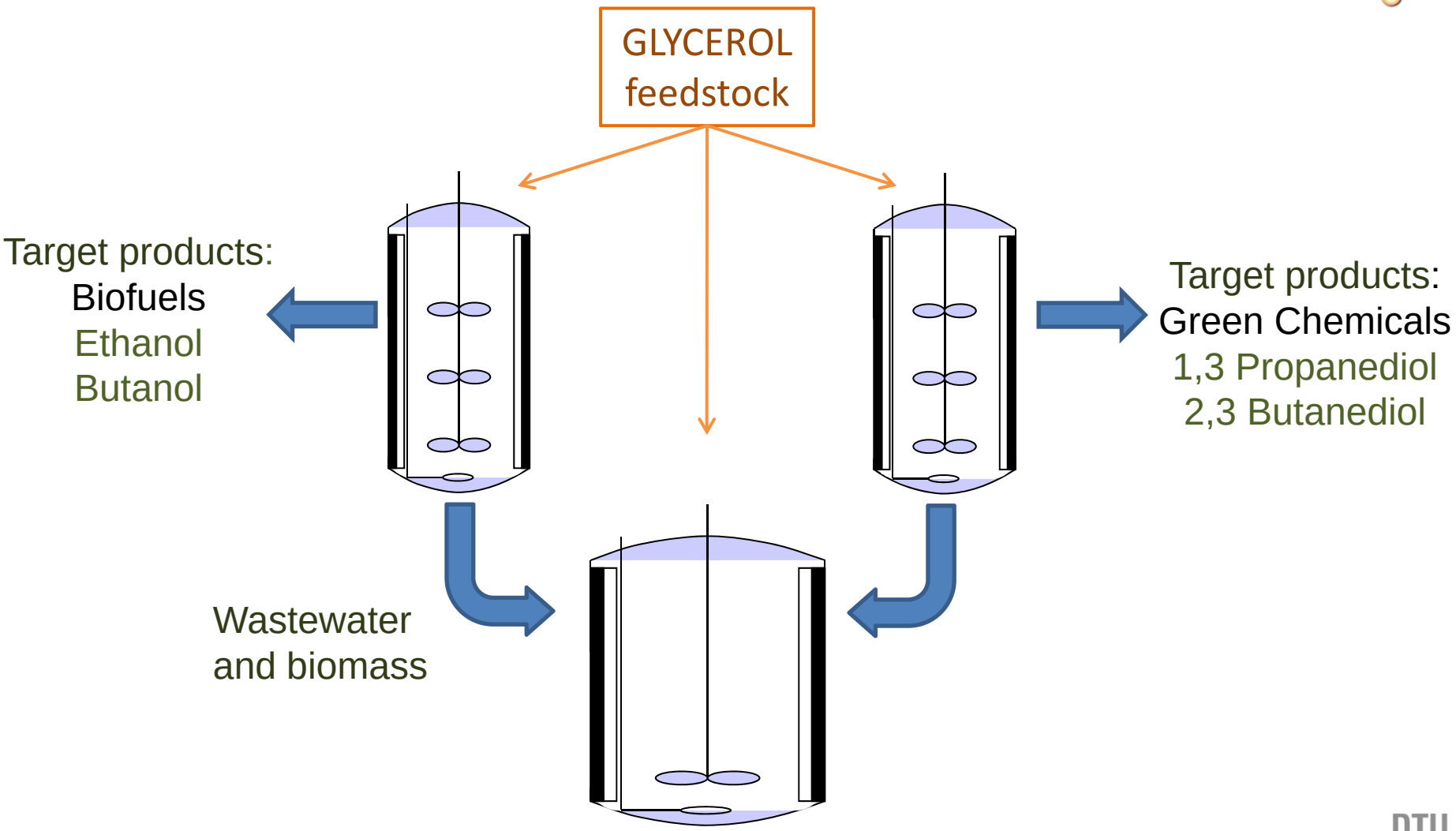
- Biogas

Biomethane (DTU/SLU)

Process choice and design guided by Life Cycle Assessment (economic, environmental and technical (IFEU, Germany)

Product recovery solutions (ProChimia Surfaces, Poland)

Target products



Production of biofuels

- Ethanol production in the non-conventional yeast Pachysolen tannophilus (DTU)

- Butanol production by Clostridia (BioGasol)

The Company

- **Developes technologies for cellulosic ethanol production**
  - – High performance continuous pretreatment process & equipment
  - – C5-sugar fermentation with high efficiency
  - – Integrated process concept

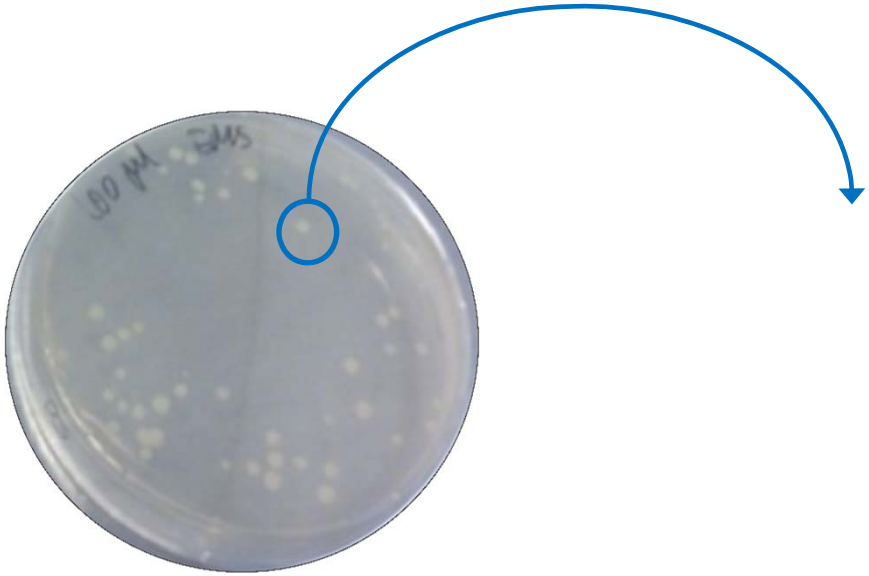
- **Unique combination of skills: combined biotechnology & engineering**
  - – 30 employes
  - – 10 patent families

Comparison of biofuels

Name	Chemical formula	Chemical weight [g/mol]	Boiling point [°C]	Air-fuel ratio [kg/kg]	Energy density [MJ/l]	Specific energy [MJ/kg air]	Enthalpy of vaporization	Solubility % w/w at 20°C	RON (octane number)
Methanol	CH_3OH	32.04	65	6.5	16	3.1	1.2	Completely	104
Ethanol	$CH_3CH_2(OH)$	46.1	78	9.0	19.6	3.0	0.92	Completely	129
Butanol	$C_2H_5CH_2CH_2(OH)$	74.12	117	11.2	29.2	3.2	0.43	8	96
Gasoline				14.6	32	2.9	0.36	insoluble	91-99

(Lide 2005; Varde et al. 2007).

Development of a mutant strain



Mutant strain having increased tolerance towards the crude glycerol.

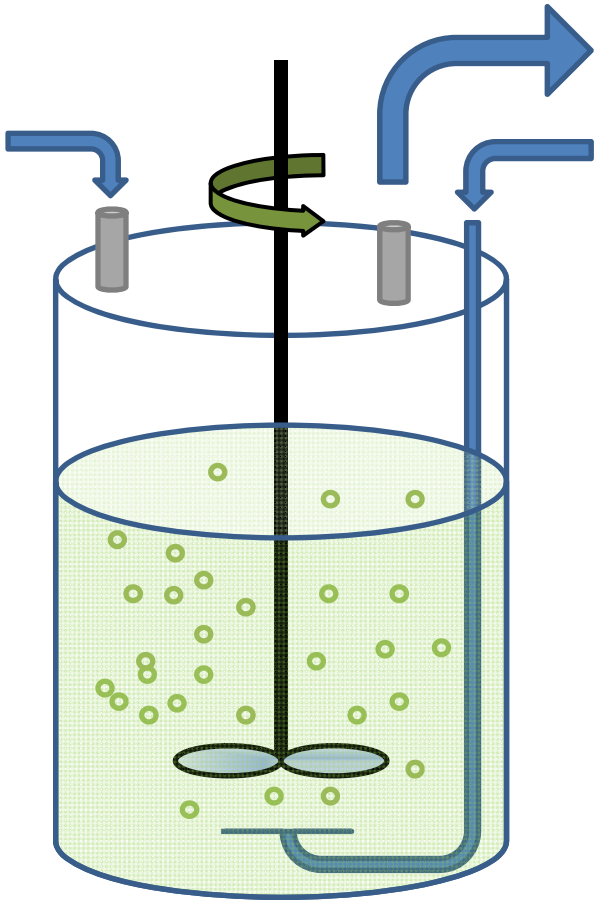
Producing almost equal amounts of 1,3-propanediol and butanol

Two products are produced simultaneously

Butanol is removed *in situ*

1,3-Propanediol is accumulated in the fermentation broth

Fresh media with crude glycerol

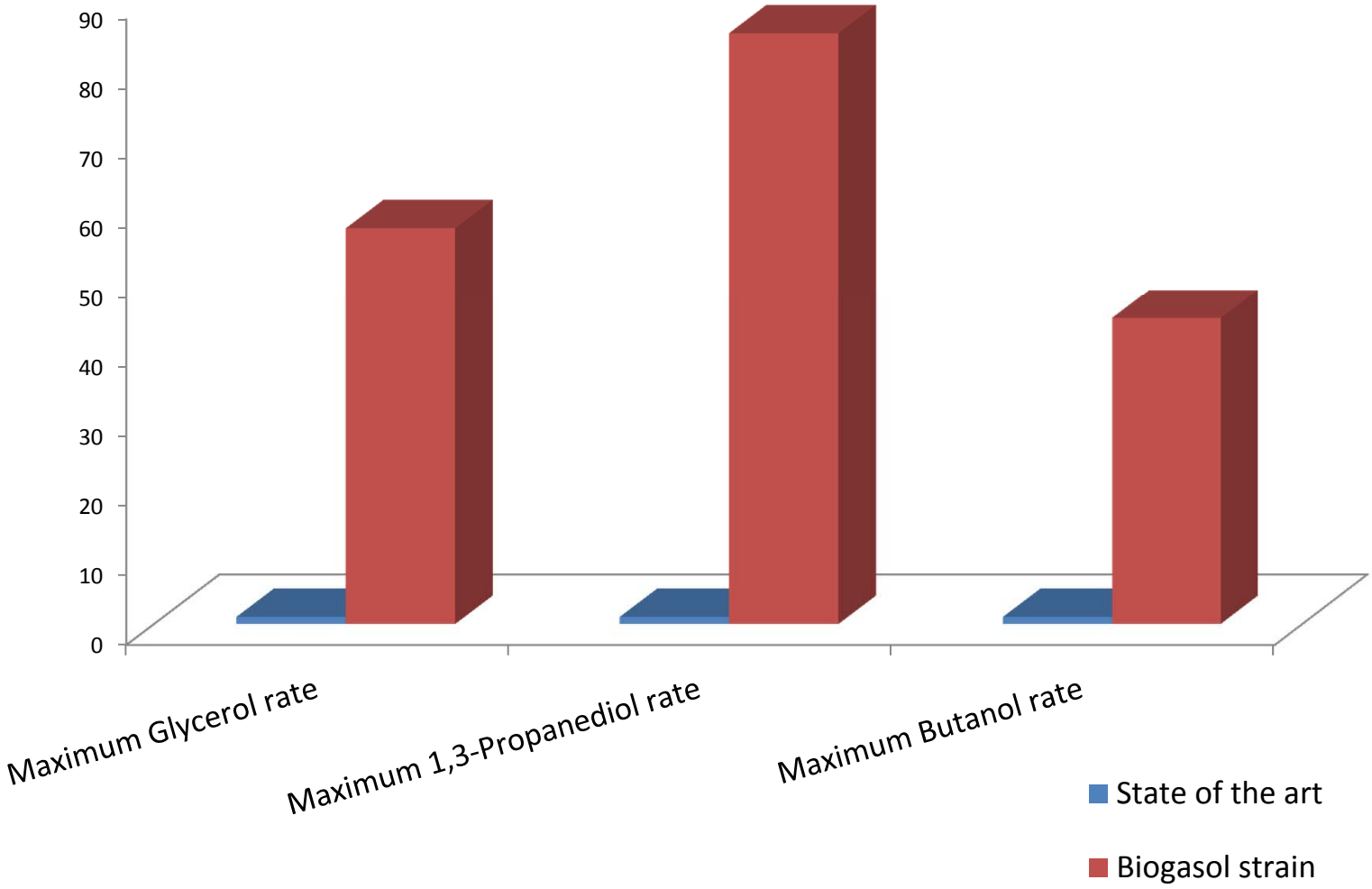


Butanol$^{(gas)}$

Gas-flow

The less toxic 1,3-propanediol is accumulated

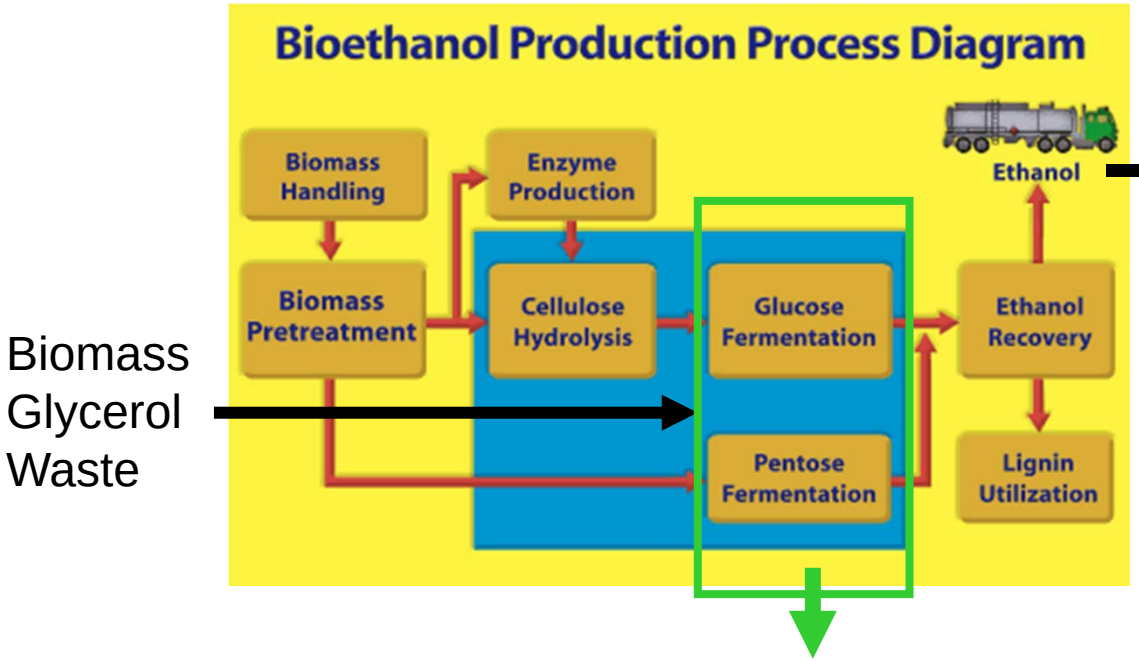
Relative increase in rates



Production of ethanol - DTU

- Screening of potential cell factories for conversion of glycerol
- Quantitative microbial physiology
- Fermentation optimisation

Systems Biotechnology in Biorefineries Research



Biofuels and biochemicals

Biomass
Glycerol
Waste

Development of microbial production platforms by:

- Strain evolution, selection and screening
- Optimise stress resistance
- Metabolic engineering and synthetic biology
- Modelling and Systems Biology
- Fermentation optimisation

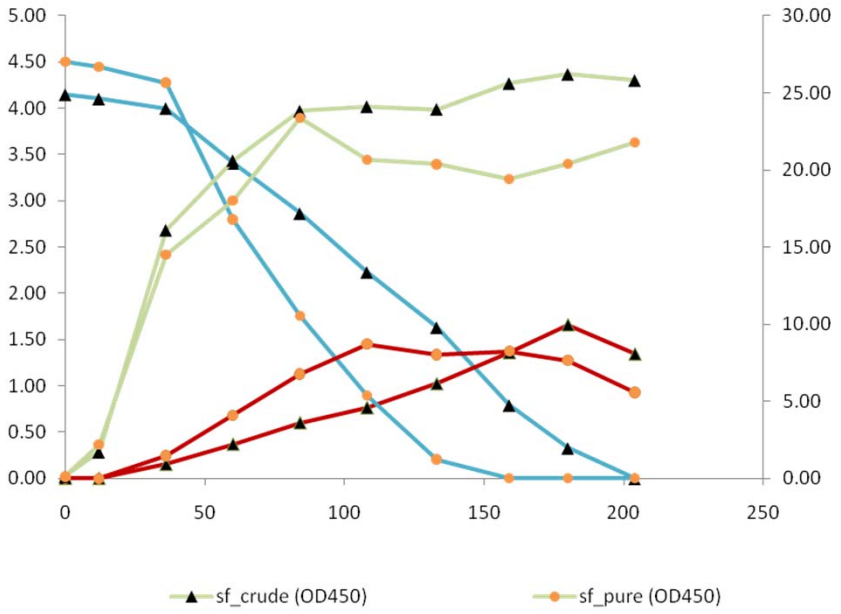
DTU

Screening of non-conventional yeasts

Pacchysolen tannophilus

- Known producer of ethanol from D-xylose
- Previously shown to ferment glycerol (Maleszka, 1982)
- No growth anaerobically

Supply of glycerol



- Biodiesel industry typically uses variety of oil blends
- Meroco rape seed oil biodiesel
- Blends with used cooking oil
- *P . tannophilus* not affected by variations in glycerol batches from Meroco

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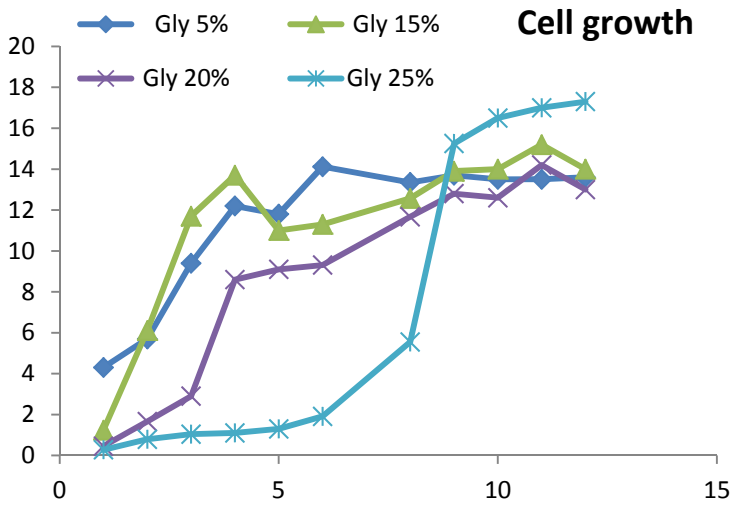
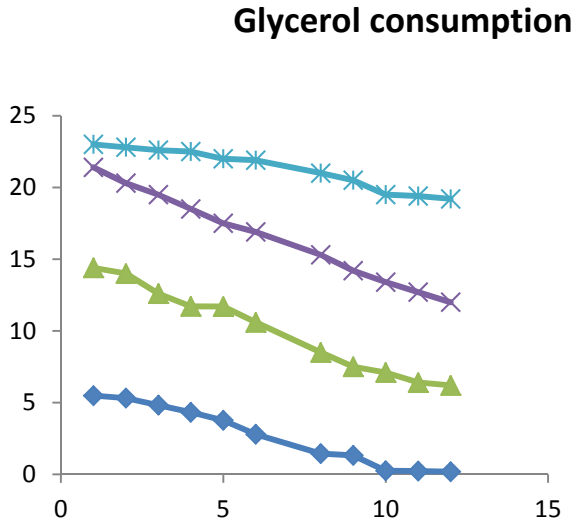
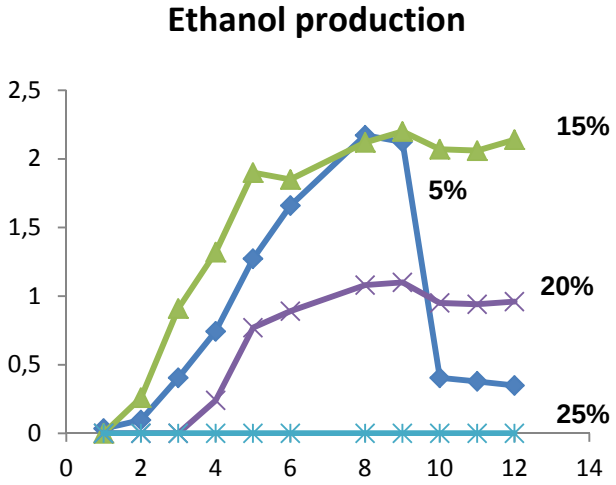
P. tannophilus growth on glycerol



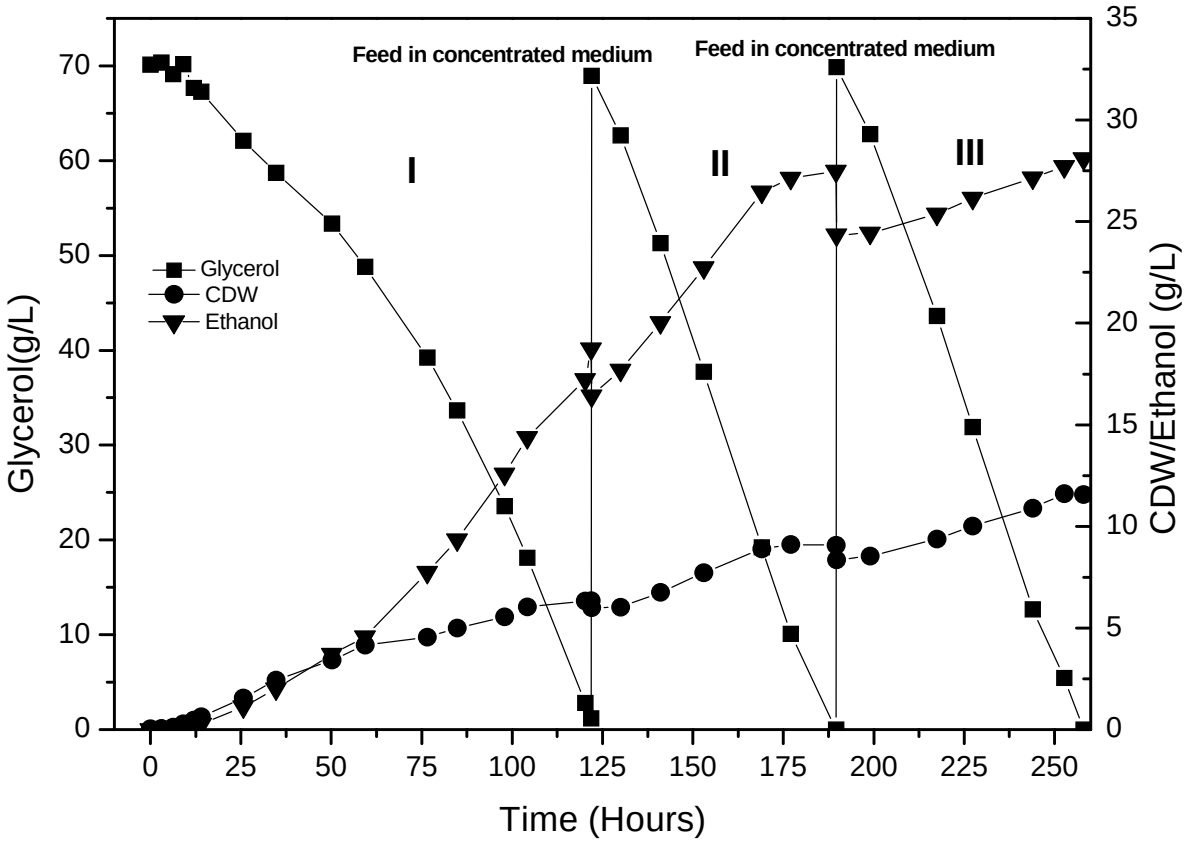




- *P. tannophilus* is capable of growing on 25% glycerol in shake flasks but no ethanol produced at this concentration.

Liu, Jensen and Workman (2011) Bioresource Technology. In press

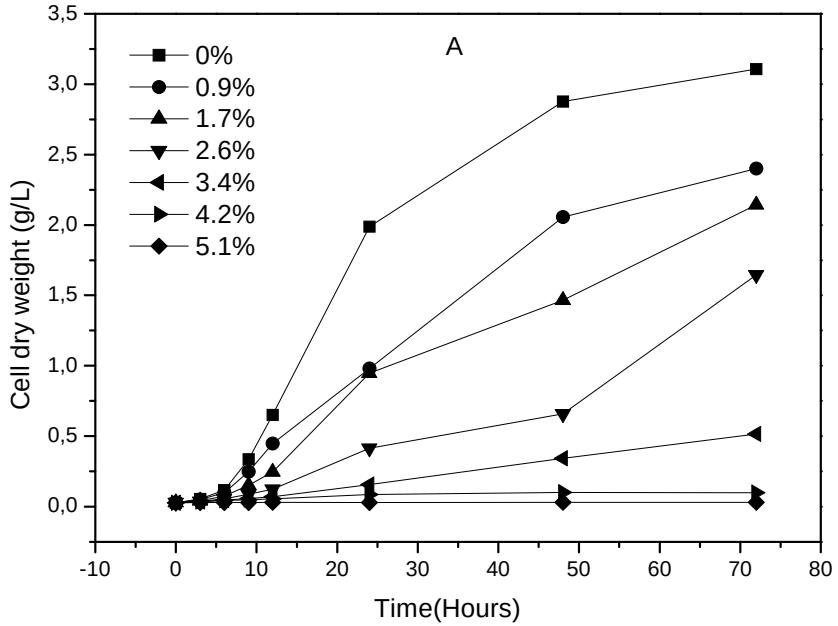
Staged Batch Process



Highest ethanol production obtained for a yeast species growing on glycerol

Liu, Jensen and Workman (2011) Bioresource Technology. In press

Ethanol tolerance

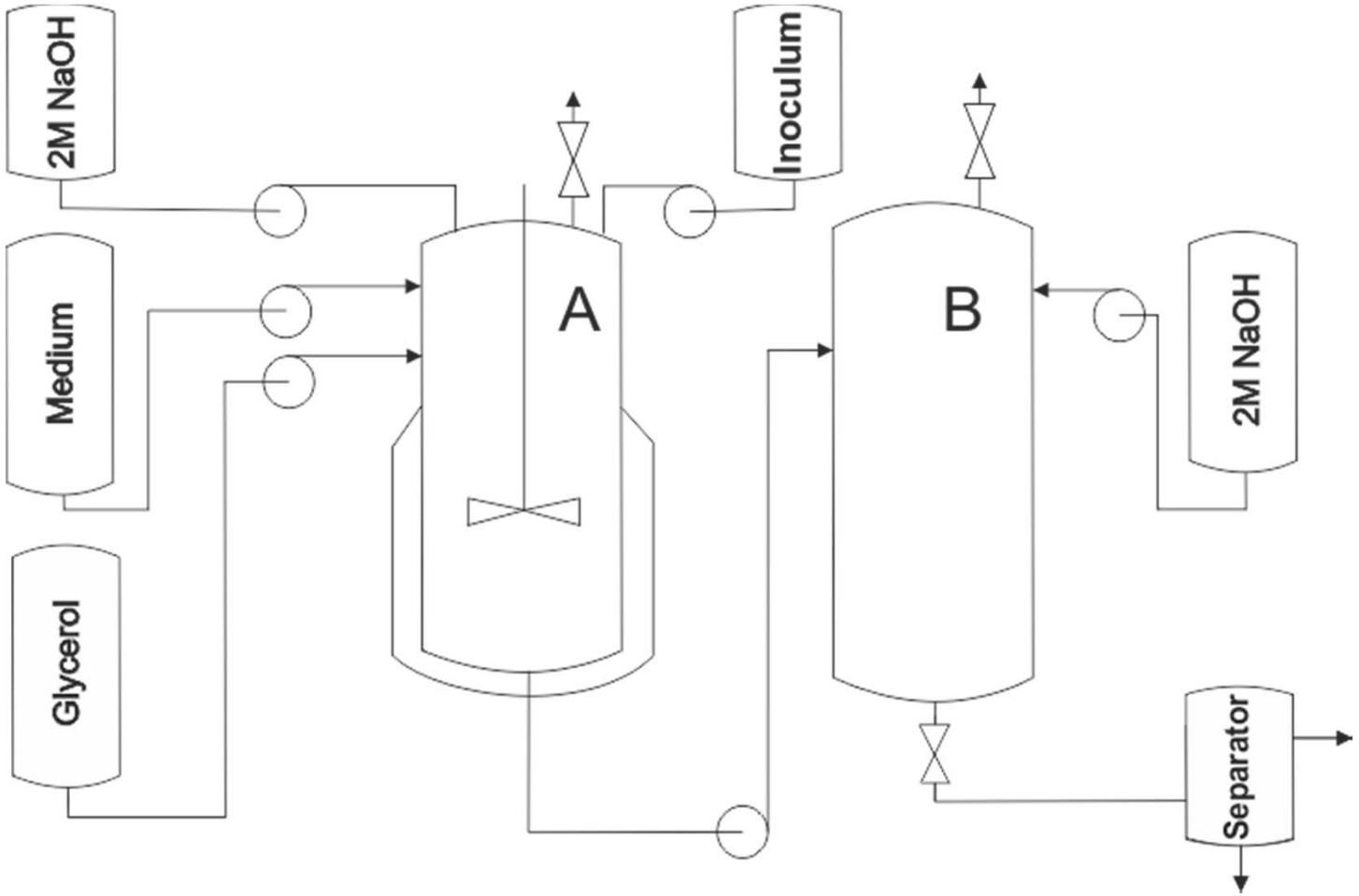


Further steps to increase ethanol tolerance by adaptive evolution

Liu, Jensen and Workman (2011) Bioresource Technology. In press

Production of green chemicals

Proposed model of fermentation of crude glycerol and production of butanol and 1,3-PDO

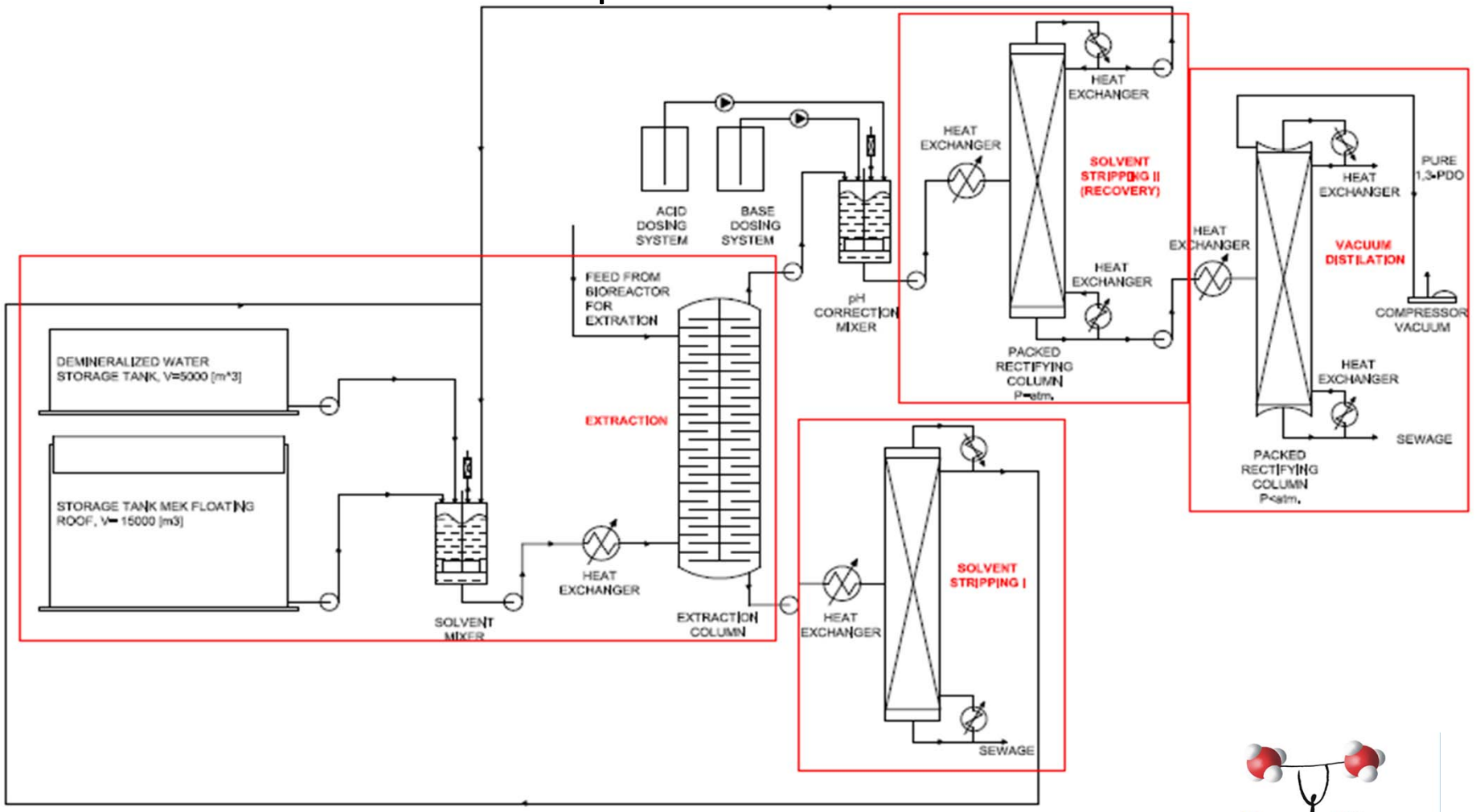


Results

- The best 1,3-PDO productivity is maintaned at 15g/l of glycerol
- Application of 2-stage fermenter system allows for complete removal of glycerol, which is anecessary parameter for 1,3-PDO extraction procedure (Prochimia)
- The highest obtained concentration of 1,3-PDO was 30,2 g/l
- The total 1,3-PDO production efficiency was 0.56 g PDO/1g glycerol
- The glycerol feeding was 1,31 g/h/l

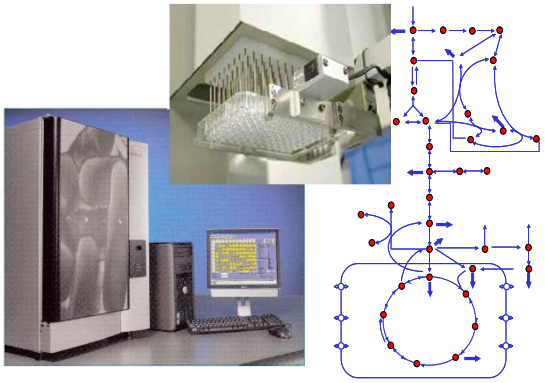
Technological scheme of 1,3-PDO recovery system

The equipment collection and set-up of 1,3-PDO extraction process



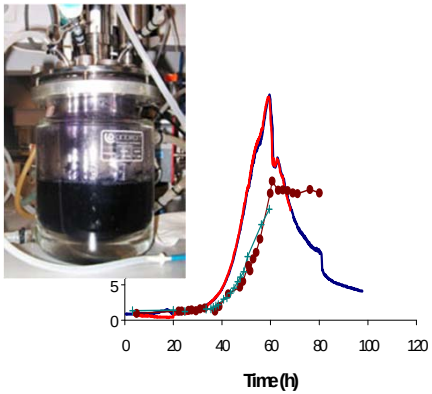
Pro Chimia

Timeline to pilot scale GLYFINERY



Isolation, screening and improvement

March 2008



Process development
Product recovery

March 2010

Process integration: pilot plant

March 2012

Acknowledgements

- Xiaoying Liu (PhD student)
- Philippe Holt (PhD student)

SEVENTH FRAMEWORK PROGRAMME

Interreg IV A
ÖRESUND – KATTEGAT – SKAGERRAK

DTU

EUROPEAN UNION
European Regional Development Fund

bio RAFFINADERI ØRESUND

Further information

Follow our progress at

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