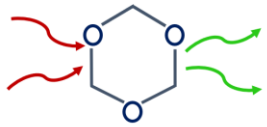
BIOLOGICAL CONVERSION OF TRIOXANE INTO BIOPRODUCTS

FeedstocksUnited



Jan Wery

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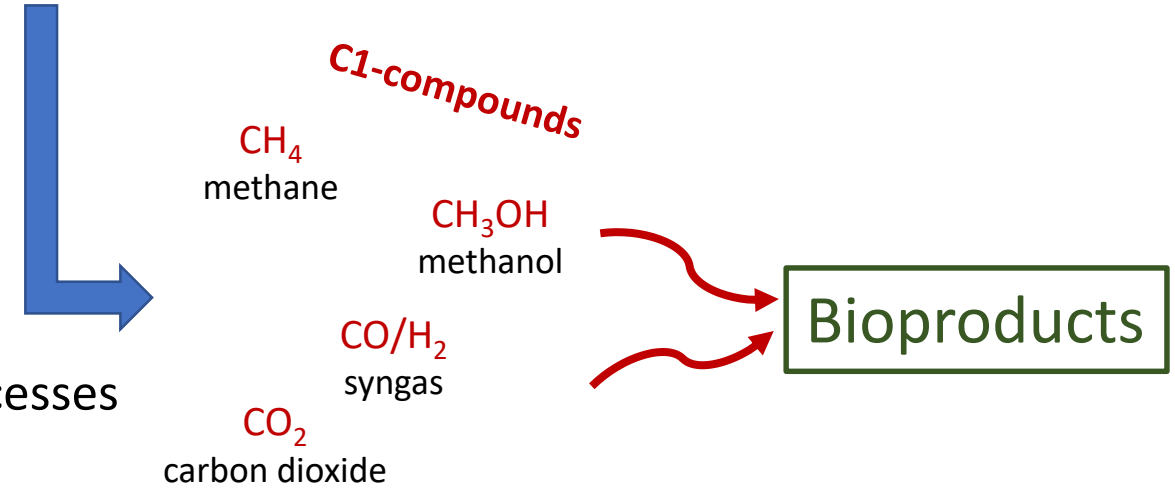
The MB6.0 Fall meeting of the
Microbial Biotechnology section of the KNVM
November 4th, 2019

Why one-carbon compounds as feedstock for bioproduction?

- In many cases cheaper than sugar **natural gas, off-gases, biogas, biomass, wastes**
- Abundantly available
- Decoupling production from agriculture, no land-use
- Possibility to integrate with renewable electrification processes
- Great CO_2-reduction potential



Selection of bioproducts considered on the basis of C1-compounds

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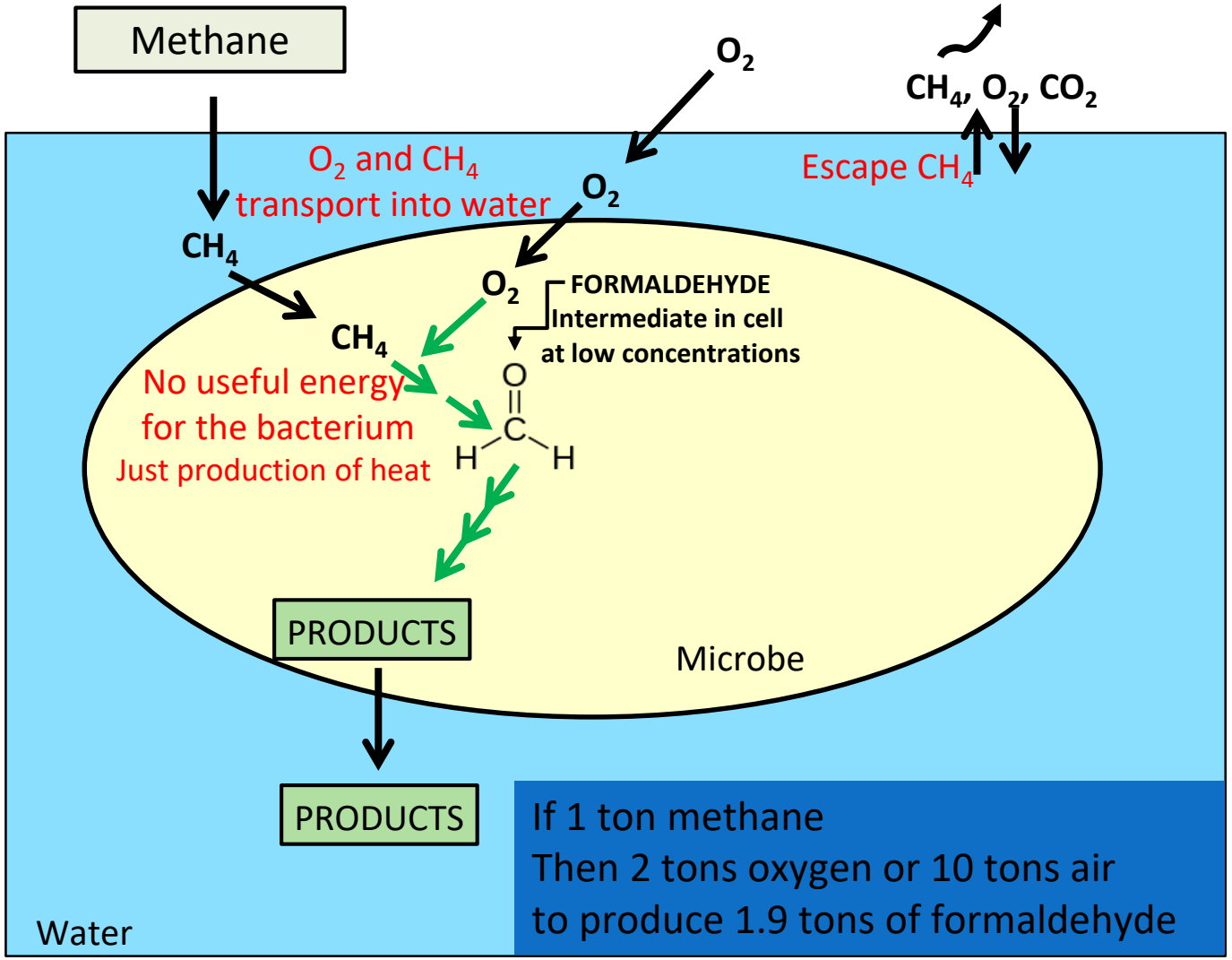
Bioproduct	C1-substrate	Reference
Single Cell Protein (SCP)	Methane	Feedkind.com (Calysta/BP/Cargill), Unibio.dk
Lactic acid/PLA	Methane	Calysta/Natureworksllc.com
Butanediols, Isobutanol, etc.	Methane	MBP Titan (Formerly Intrexon)
Ethanol and others	Syngas	lanzatech.com
Polyhydroxyalkanoates (PHA)	Methane	Strong *et al.* 2016
Methionine and other amino acids	H2 and CO2	trelystech.com
Lysine and other amino acids	Methanol	Brautaset *et al.* 2007
Amino acids, dicarboxylic acids, etc.	Methanol	Pfeifenschneider *et al.* 2017
Single Cell Protein (Pruteen)	Methanol	Imperial Chemical Industries

Direct fermentation of C1-compounds is challenging!

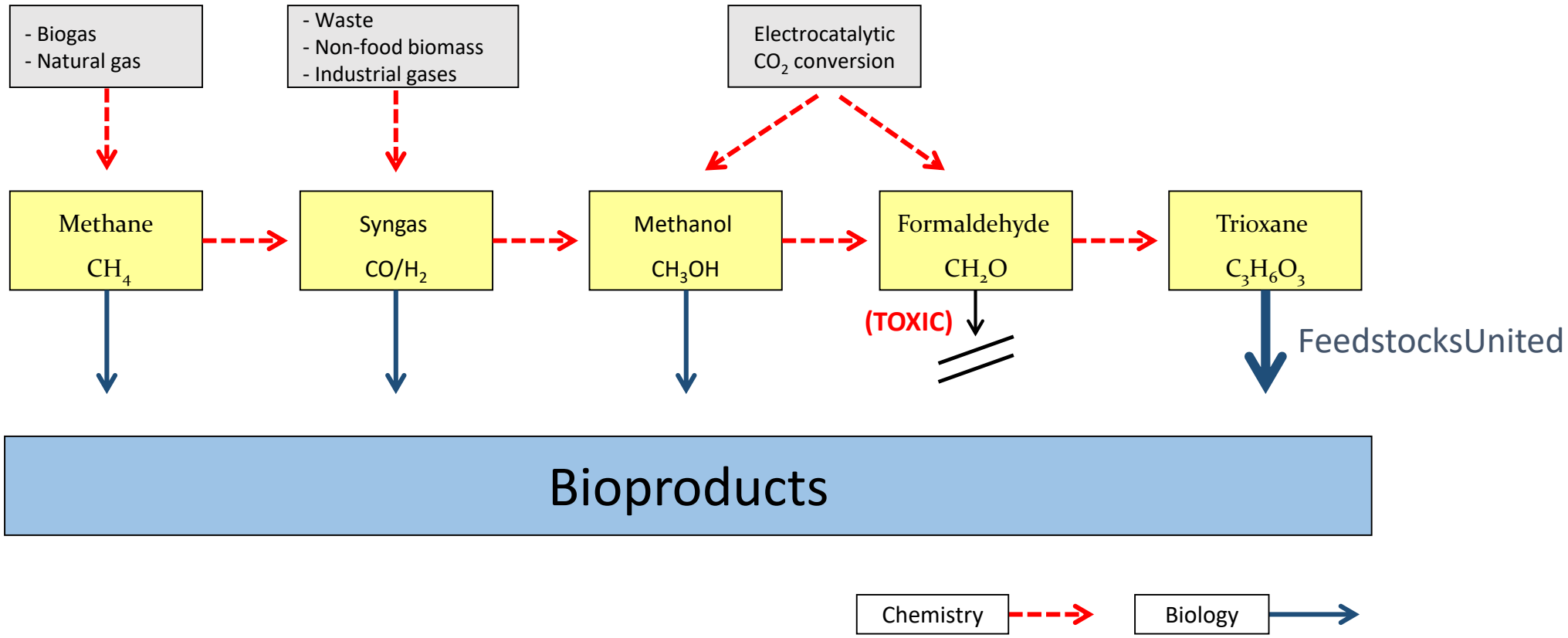


Key issues

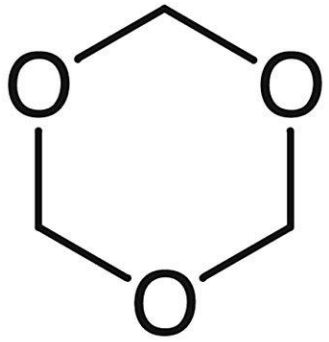
- Oxygen supply and cooling
- Limited volumetric productivity due to limitations in substrate and oxygen transfer
- Excess unwanted biomass and by-product formation
- Safety (explosion limits, handling)

➡ No commercial large scale process implemented after 40 years of work on the topic

FeedstocksUnited proposes to use trioxane rather than other one-carbon compounds



TRIOXANE

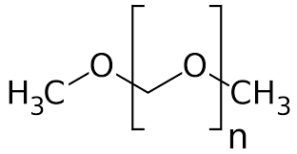


$C_3H_6O_3$

Cyclic acetal

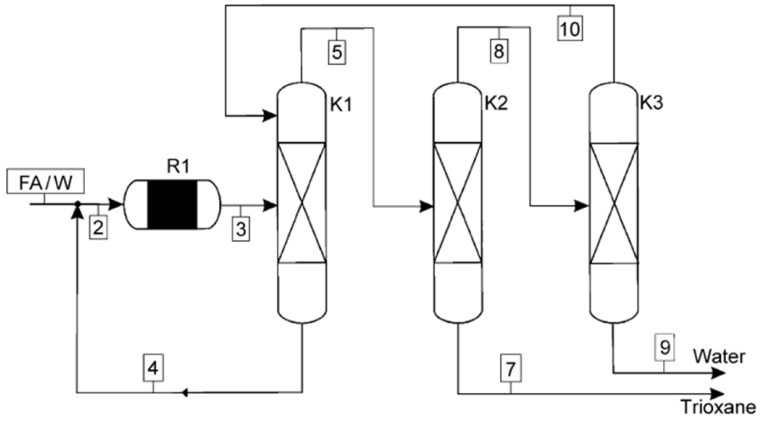
Trioxane production from formaldehyde

Trioxane is produced as a monomeric compound in the manufacture of polyoxymethylene (POM)



Production of POM is ~500,000 tons/year

T. Grützner et al. / Chemical Engineering Science 62 (2007) 5613–5620



Development of a new industrial process for trioxane production

Thomas Grützner[a,1], Hans Hasse[a,*], Neven Lang[b], Markus Siegert[b], Eckhard Ströfer[b]

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Prof. Hans Hasse, now the director of the Laboratory of Engineering Thermodynamics, Technical University of Kaiserslautern, Germany

Trioxane production for fermentation purposes

Trioxane for POM production has to be ultra-pure and free of water

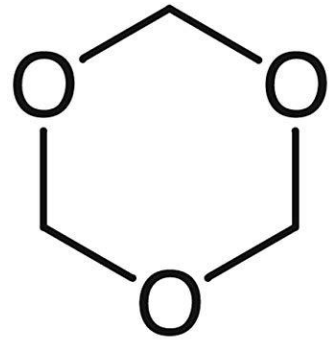
Trioxane for fermentations can be less pure, and water obviously is no issue

Hence, the cost price of trioxane production at fermentation specs will be substantially lower (target = sugar price range)

Trioxane as a fermentation feedstock

Physical properties:

- Good solubility in water of up to 800 g/l (depending on temperature)
- Stable in water
- Volatility no issue



$C_3H_6O_3$

Cyclic acetal

Bioprocess advantages:

- Not toxic to microbes
- Limited problems in combatting contaminations
- Clean stream which is very beneficial in downstream processing of bioproducts

Biological aspects:

- Oxygen-independent enzymatic degradation **(our technology)**
- The oxidation/reduction levels of trioxane and sugars are the same

Trioxane could be used like a sugar in fermentations

The FeedstocksUnited concept connects industrial chemistry and biology

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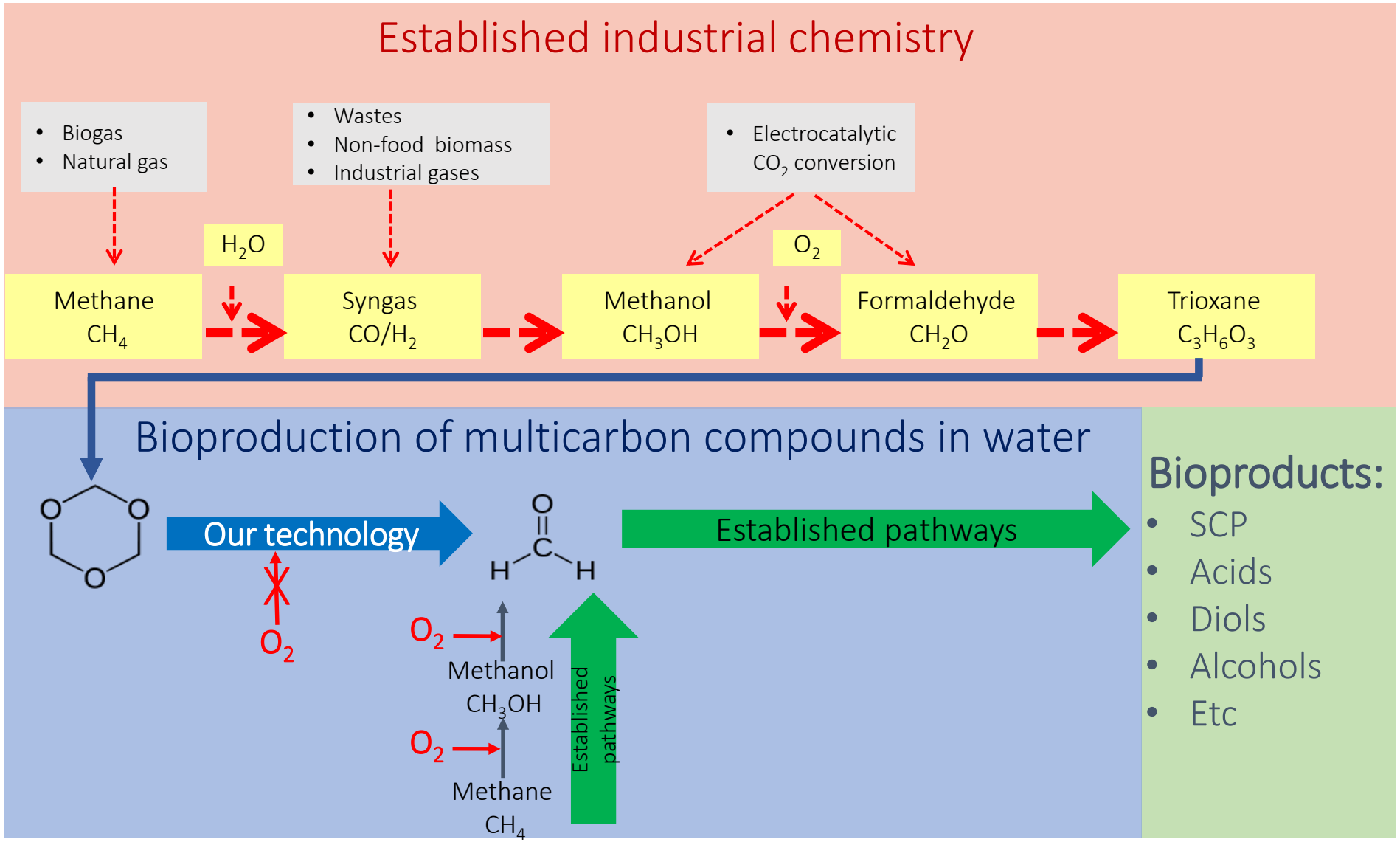


Technology: status and next steps

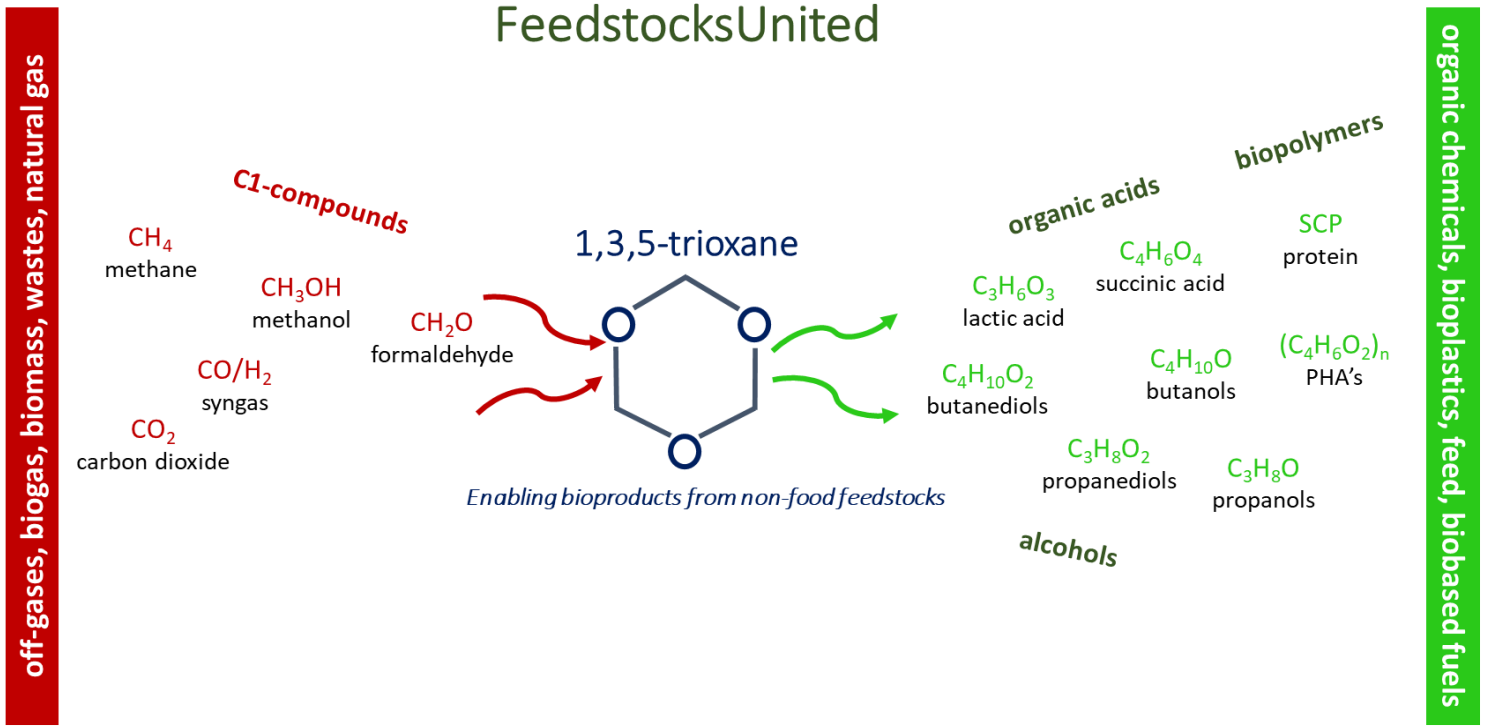
Status

- Bacterial anoxic and oxic degradation of trioxane at very low growth rates demonstrated
- The genome of one strain has been sequenced.
- Genes encoding putative trioxane degrading activity have been identified
- A patent application has been filed with claims covering genes, organisms and processes.

Next steps

- Generate a proof-of-concept: produce desired product from trioxane by expression in a suitable host
- Strengthen patent position
- Demonstrate potential of the technology
- Assess the economic and sustainability potential in detail

Opportunities for the FeedstocksUnited concept



- **Shorter term:** cheap natural gas funneled into trioxane via established bulk chemistry
- **Longer term:** waste streams (e.g. CO_2 and biomass) funneled into trioxane via biomass gasification and electrocatalytic CO_2-conversion

In conclusion

The FeedstockUnited concept enables utilization of cheap methane and derived C1-molecules by:

- Funneling these C1-molecules into trioxane via established chemical routes
- Rendering suitable microbial production hosts proprietary enzymatic activities that enable them to use trioxane “like sugar”

Advantages of trioxane over other C1-compounds in fermentations

- ✓Less oxygen demand during fermentation
- ✓Less heat generation and thus less cooling requirements
- ✓Higher volumetric productivity
- ✓Lower risk of microbial contaminations
- ✓Lower toxicity and less safety issues
- ✓Higher density, more efficient handling

Management FeedstocksUnited

FeedstocksUnited

Founders:

Jan de Bont
Managing Director

Jan Wery
R&D Director

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IP Director

Advisors:

Ger Bemer
Business

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