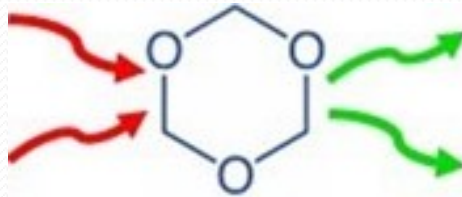


BIOLOGICAL CONVERSION OF TRIOXANE

A new approach in the production of feed, chemicals and fuels from non-food feedstocks

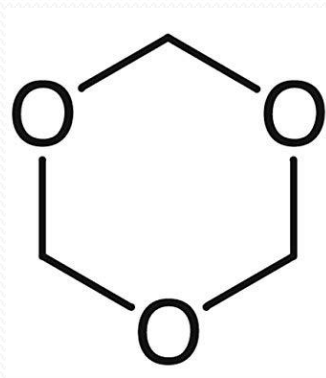


Jan de Bont

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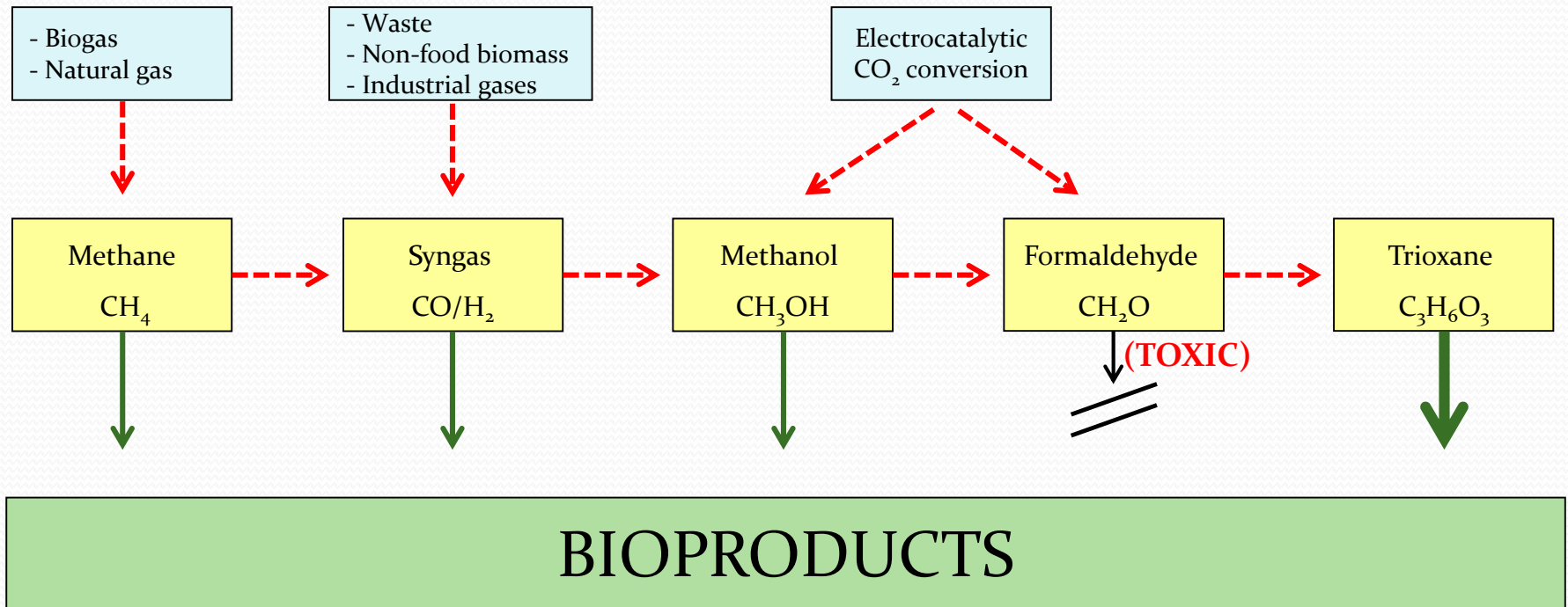
FeedstocksUnited

TRIOXANE



Cyclic acetal

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



Selection of bioproducts considered on the basis of one-carbon compounds

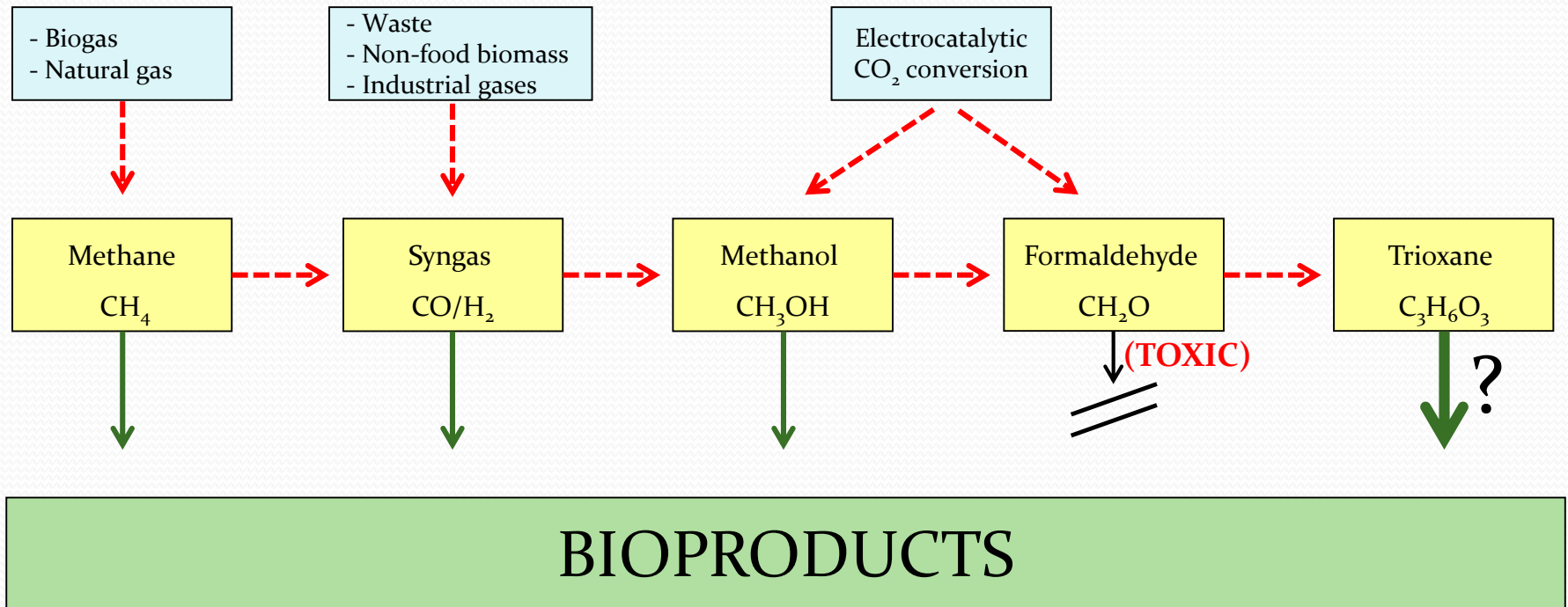
Bioproduct	C₁-substrate	Reference
Single Cell Protein (SCP)	Methane	feedkind.com; unibio.dk
Polyhydroxyalkanoates (PHA)	Methane	Strong <i>et al.</i> 2016
Isobutanol, butanediols, etc.	Methane	dna.com (Intrexon)
Lactic acid	Methane	natureworksllc.com
Ethanol and others	Syngas	lanzatech.com
Methionine and other amino acids	H ₂ and CO ₂	trelystech.com
Lysine and other amino acids	Methanol	Brautaset <i>et al.</i> 2007
Amino acids, dicarboxylic acids, etc.	Methanol	Pfeifenschneider <i>et al.</i> 2017
Single Cell Protein (Pruteen)	Methanol	Imperial Chemical Industries

Strong *et al.* 2016 *Microorganisms* 4:11

Brautaset *et al.* 2007 *Appl Microbiol Biotechnol* 74:22

Pfeifenschneider *et al.* 2017 *Biofuels, Bioprod. Bioref.* <https://doi.org/10.1002/bbb.1773>

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



Our Technology

Anaerobic metabolism of trioxane

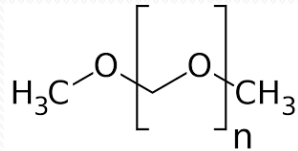
The biology behind trioxane degradation was not known until recently

FeedstocksUnited has obtained a bacterium with the ability to convert trioxane under anoxic conditions

1. Mass balances show anoxic bacterial consumption of trioxane
2. Leads obtained from RNA-seq analyses point to specific enzymes involved in trioxane degradation

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

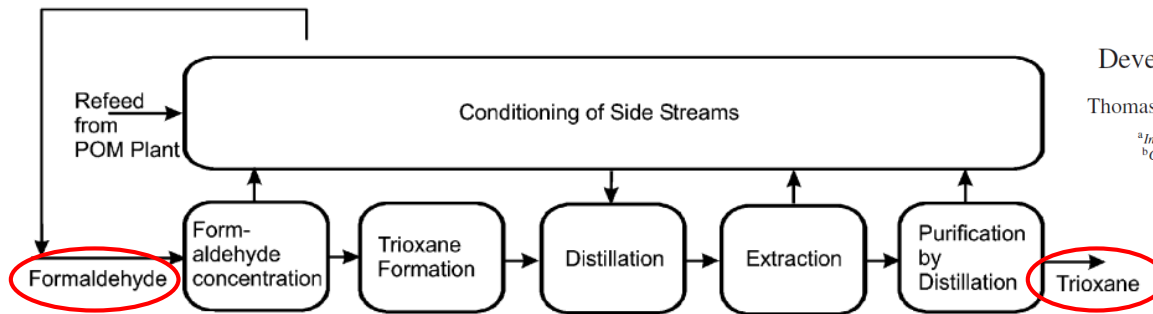


Fig. 1. Simplified flow sheet of the state-of-the-art process for trioxane production.

Development of a new industrial process for trioxane production

Thomas Grützner^a, Hans Hasse^a, Neven Lang^b, Markus Siegert^b, Eckhard Ströfer^b

^aInstitute of Thermodynamics and Thermal Process Engineering, University of Stuttgart, D-70567 Stuttgart, Germany

^bChemicals Research and Engineering – Process Development GCE/C, BASF AG D-67056 Ludwigshafen, Germany

Chemical Engineering Science 62 (2007) 5613–5620

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

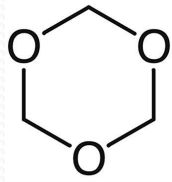
Trioxane production for fermentation purposes

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 from formaldehyde will be substantially lower when it is used as feedstock for fermentations rather than for POM production

Trioxane as feedstock



Physical properties:

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

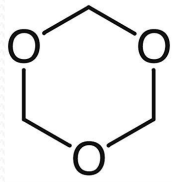
Bioprocess issues:

- 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

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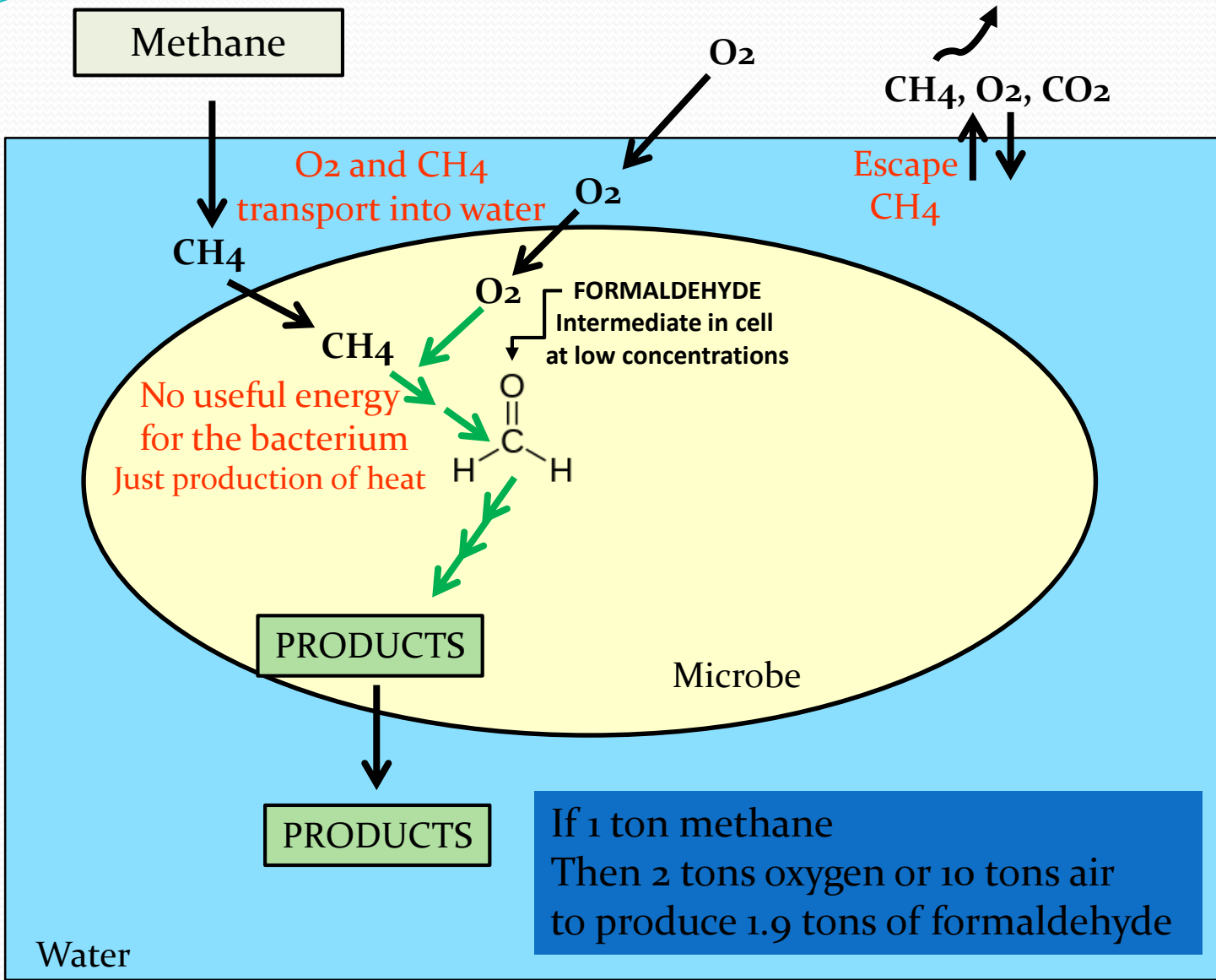
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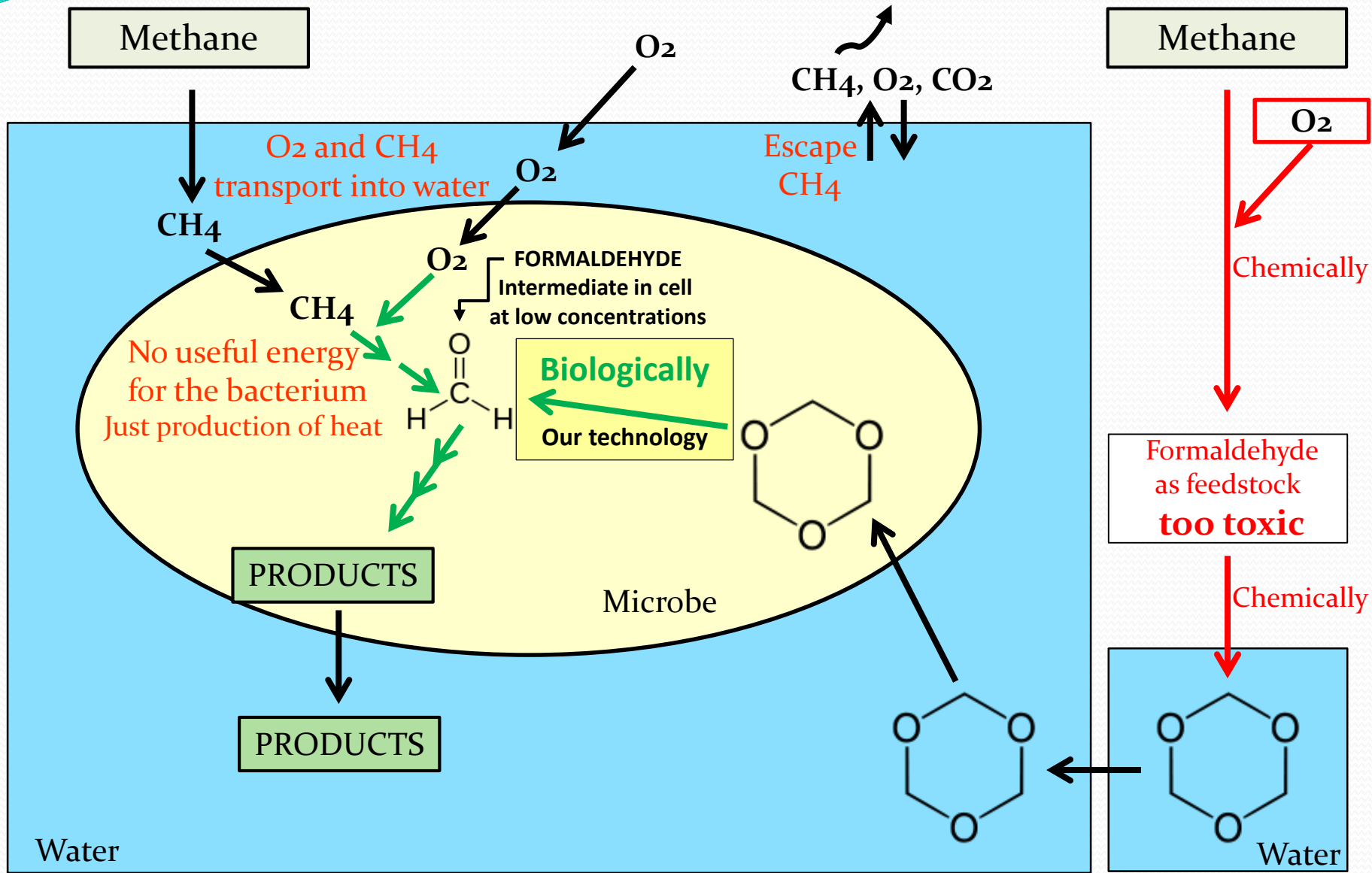
Trioxane is just a sugar in disguise

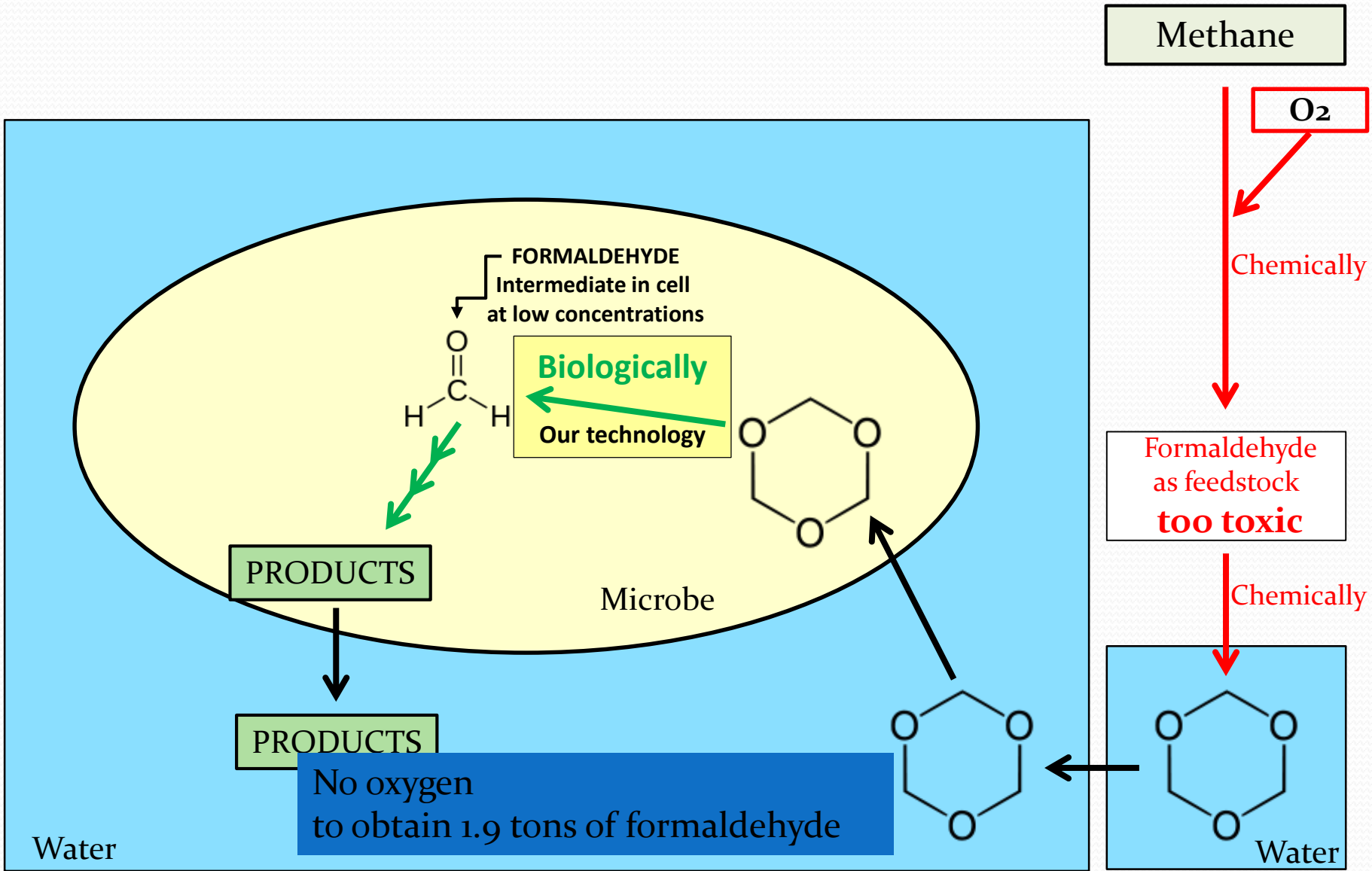
Key issue

Oxygen budget in water

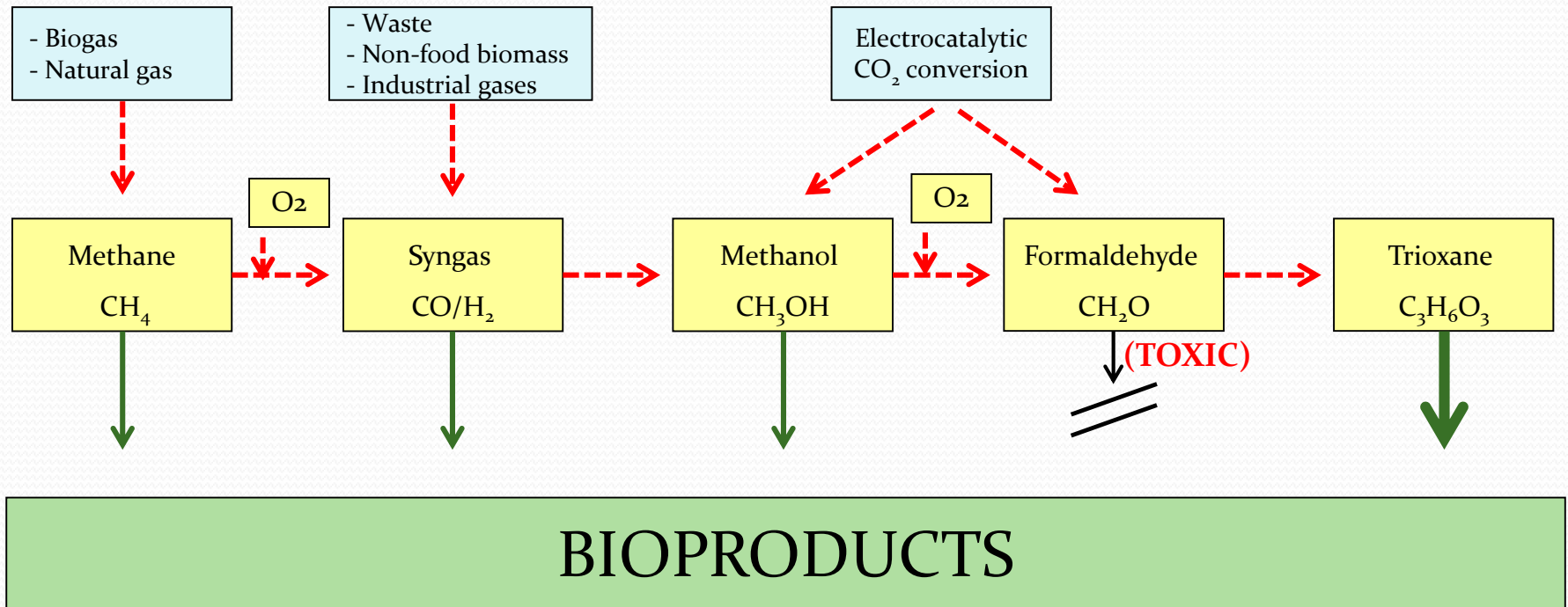


If 1 ton methane
Then 2 tons oxygen or 10 tons air
to produce 1.9 tons of formaldehyde

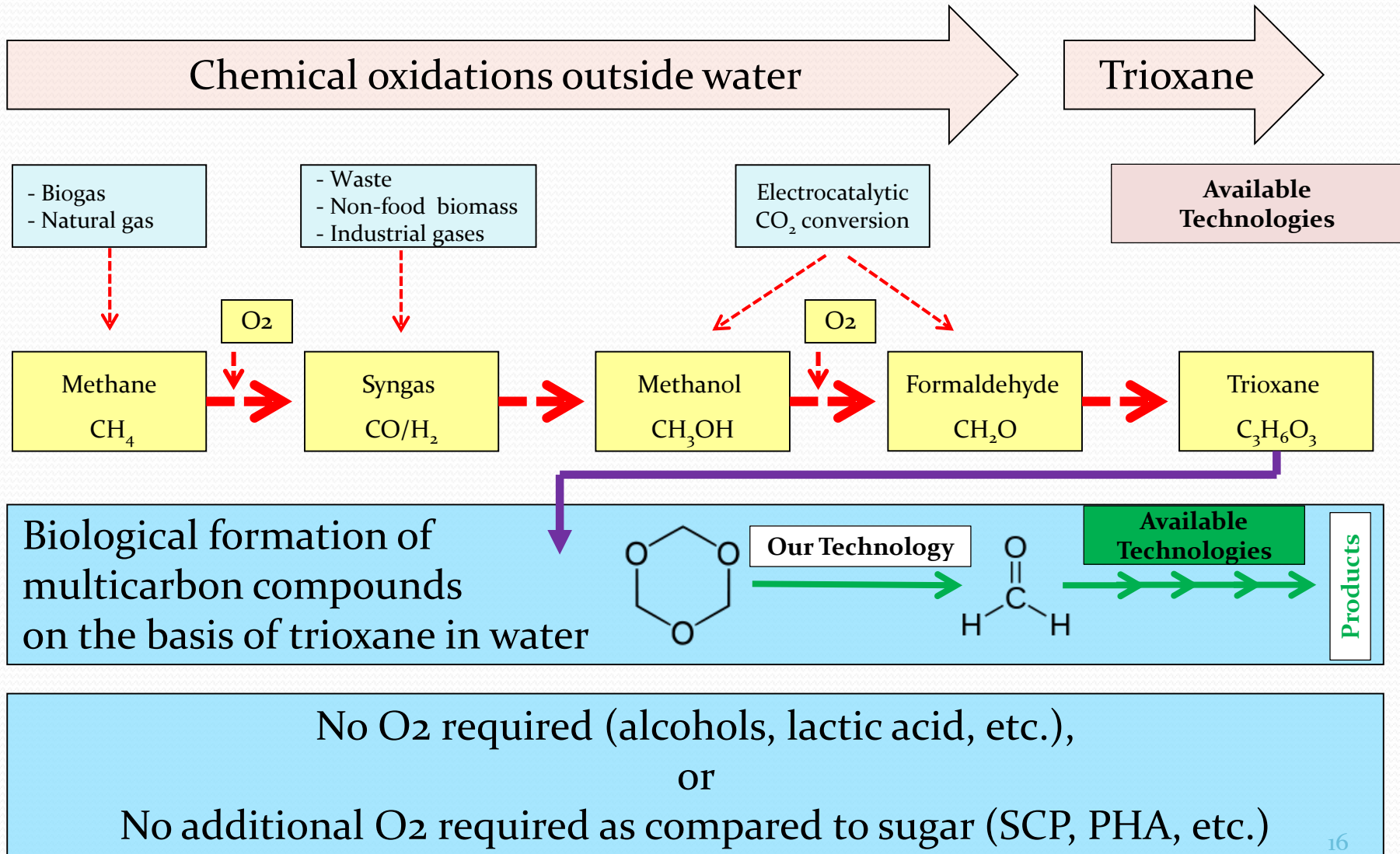




FeedstocksUnited proposes to use trioxane rather than other one-carbon compounds



The trioxane concept



Patent application

Patent application filed

“Trioxane as unifying fermentation feedstock”

Claims concerning genes, organisms and processes

FeedstocksUnited

Start-up company

Three co-founders:

- Jan de Bont (Managing Director)
- Jan Wery (R&D Director)
- Bart Swinkels (IP Director)

Two advisors:

- Ger Bemer (Business)
- Hans Hasse (Trioxane production)

The company is interested in partnering