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Biocommodities

Conversion routes to cellulosic alcohol

Proving second generation processes in practical demonstration

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VOGELBUSCH Biocommodities GmbH | Vienna | Austria

Contents

Biocommodities = white biotechnology

| We make biotechnology work.

- Since 1921 independent
- Located in Vienna, Austria, Hong-Kong and Huston, TX
- Bioprocess plants for the sugar, starch and food industries
- From raw material preparation to final product
- Proprietary technology
    - alcohol | bioethanol
    - vinegar
    - yeast
    - organic acids
    - starch sugars

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| Process design of alcohol plants since 1921

- Some 40 plants in the late 1970ies/early 1980ies in Brazil, first African bioethanol plant in 1983 (Kenya)
- 36 bioethanol plants since 1981 in
  North America, China, Europe with a total annual capacity of 5 million tons
- First with largest bioethanol plants on three continents
- Technology supplier to major producers, e. g.
  - Jilin Fuel Ethanol
  - Abengoa Bioenergy
  - Cargill
  - Südzucker (CropEnergies)

Second generation ethanol

| VOGELBUSCH experience

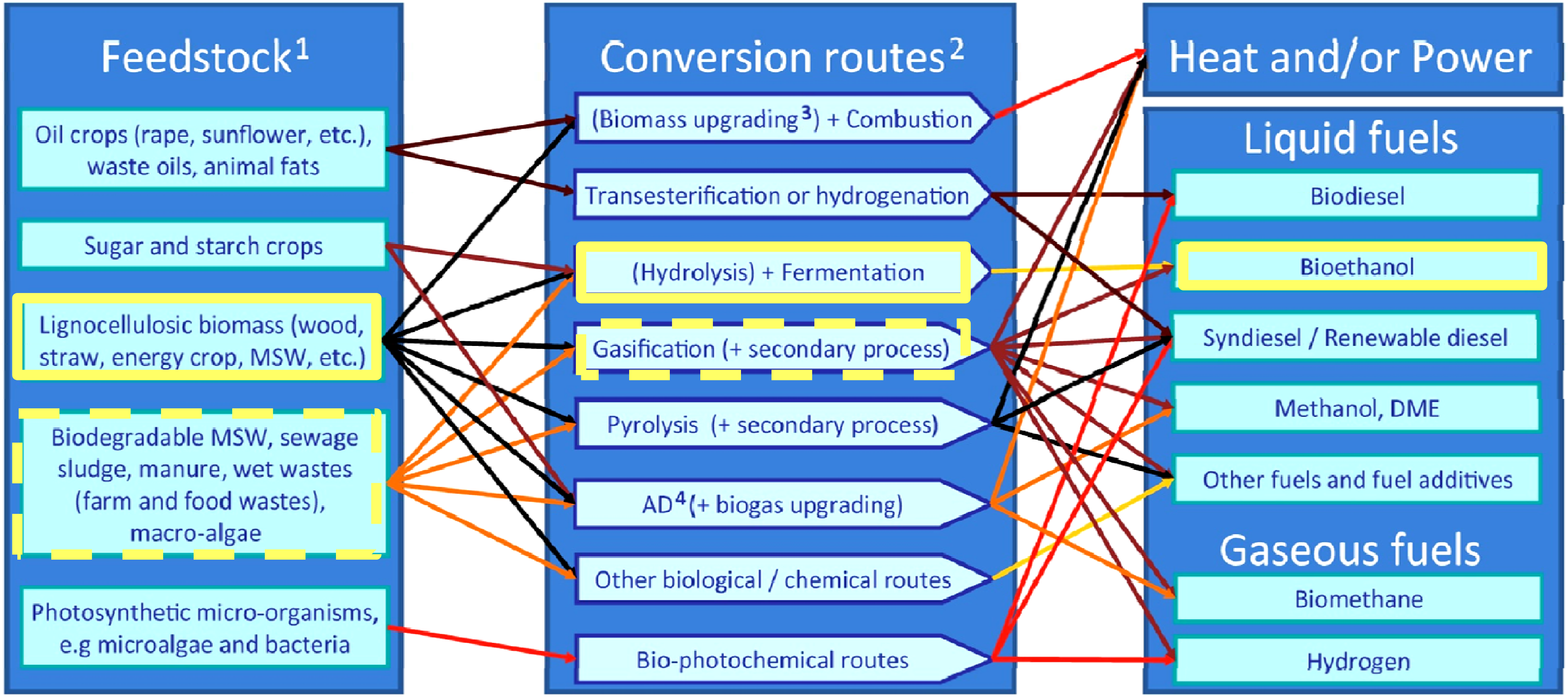
Complementing client's 2G process with proven bioethanol technology

- Process design for pilot and demonstration plants
- Assist in developing fermentation and separation strategies
- Equipment supply for separation, distillation and dehydration

Examples:

- demo plant of INBICON | DK
- demo plant of IOGEN | CD
- pilot plant ABENGOA BIOENERGY | US
- pilot plant of MITSUI/SIME DARBY | MY
- commercial plant INEOS Bio | US

Biorefineries



[1] Parts of each feedstock, e.g. crop residues, could also be used in other routes

[2] Each route also gives co-products

[3] Biomass upgrading includes any one of the densification processes (pelletisation, pyrolysis, torrefaction, etc.)

[4] AD = Anaerobic Digestion

Source: Executive Summary Bioenergy – a Sustainable and Reliable Energy Source, IEA, 2009

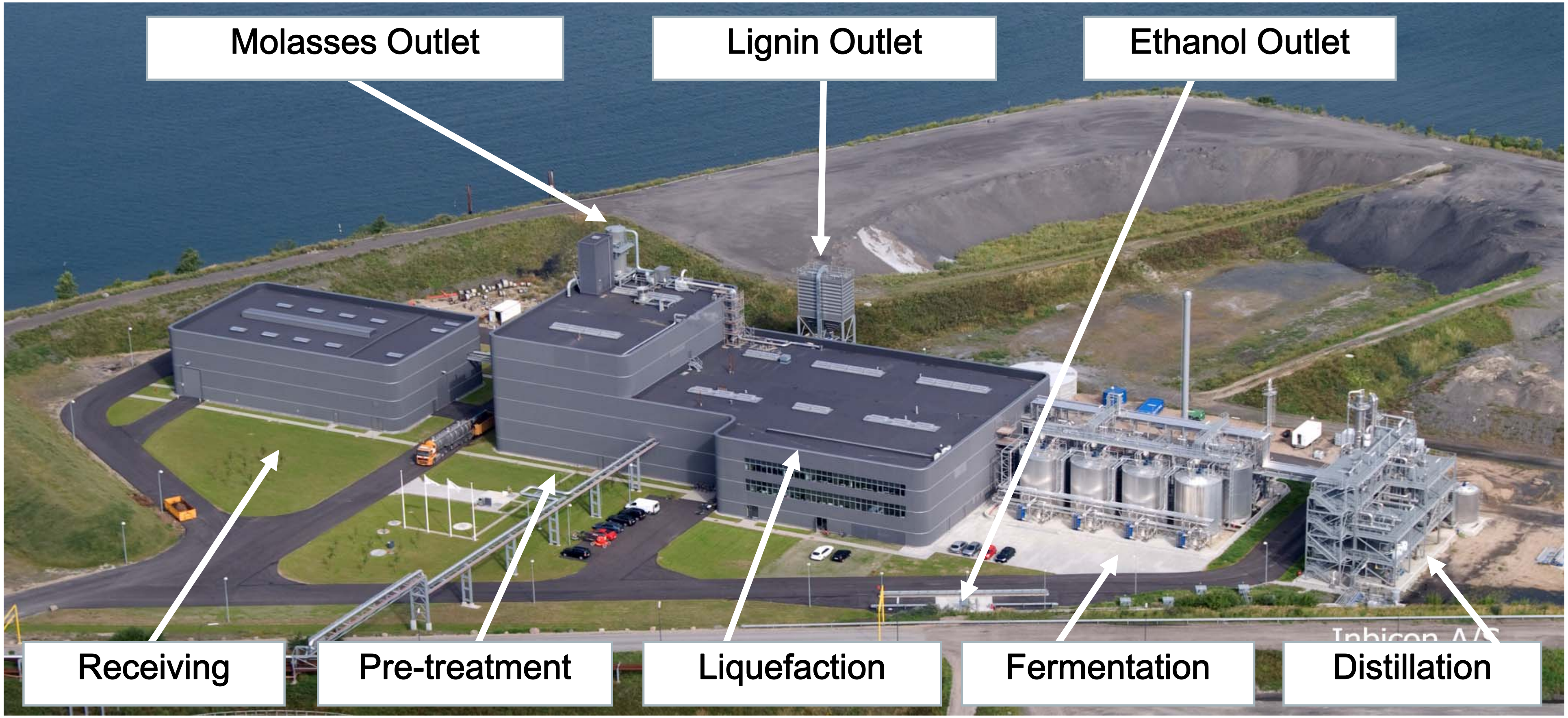
SHOWCASE PROJECT: INBICON | Kalundborg | Denmark

Second generation demonstration plant

Input: 30 000 t/y wheat straw

Output: 5.4 million liters ethanol
13,100 t lignin pellets
11,250 t C5-molasses

SHOWCASE PROJECT: INBICON | Kalundborg | Denmark



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Inbicon

SHOWCASE PROJECT: INBICON | Kalundborg | Denmark

Combination of technology

Straw Handling	Hydro-thermal Pretreatment	Liquefaction	Fermentation	Destillation
				

DONG 20 years experience	INBICON core technology	VOGELBUSCH downstream technology

SHOWCASE PROJECT: INBICON | Kalundborg | Denmark

Status Quo

- Proven technology for integral process on industrial scale – design capacity reached
- Steam explosion pretreatment – no chemicals required
- 2G Bioethanol produced at spec
- Distribution of BIO95 2G fuel in Denmark by STATOIL
- Highly pure lignin pellets delivered to power plant
- C5 molasses delivered to biogas plant
- Design available for industrial scale plants

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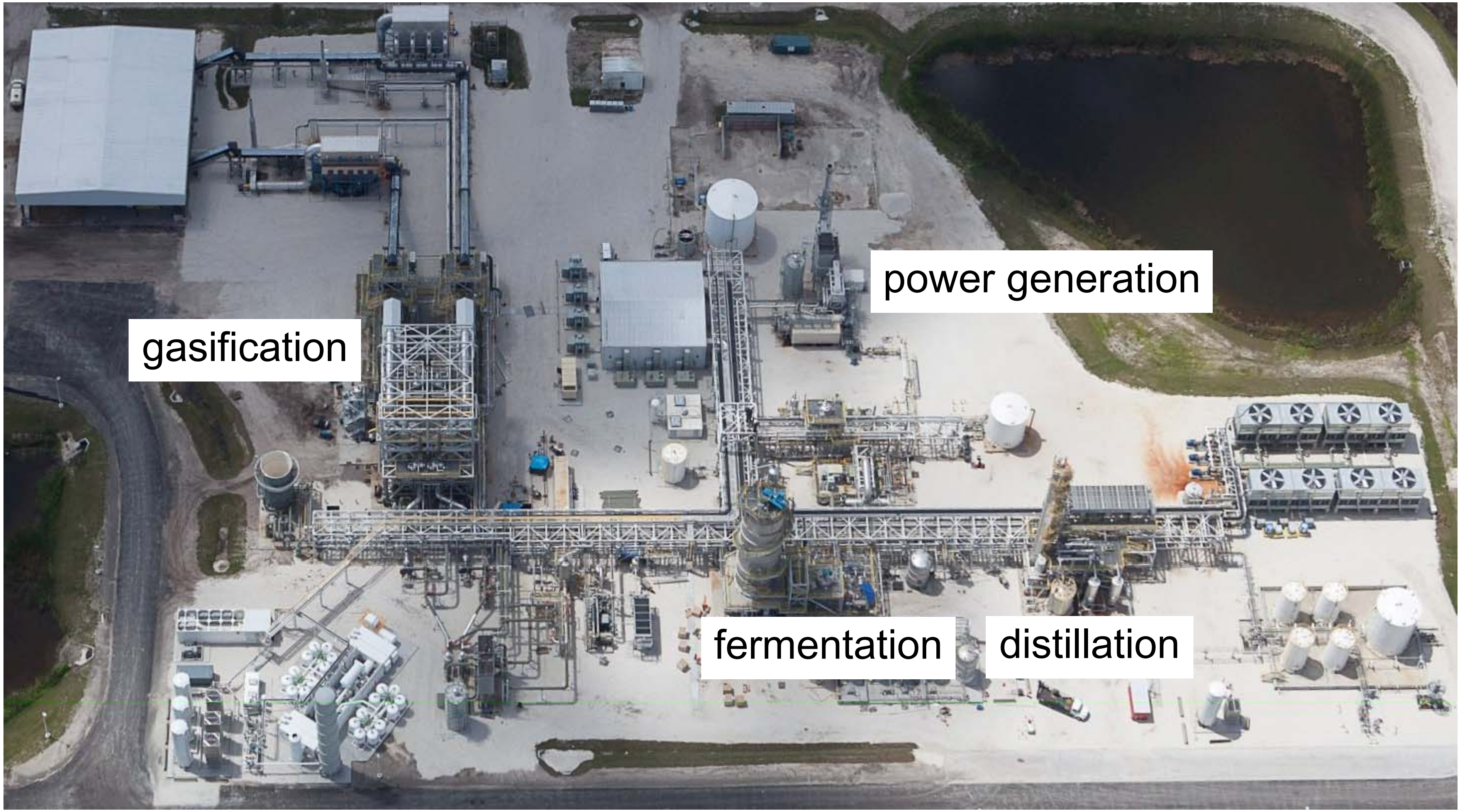
Inbicon

SHOWCASE PROJECT: INEOS Bio | Vero Beach, FL | USA

Second generation commercial plant

Input:	vegetative waste yard waste municipal solid waste
Output:	30 million liters ethanol per year 6 MW gross electric power generation

SHOWCASE PROJECT: INEOS Bio | Vero Beach, FL | USA



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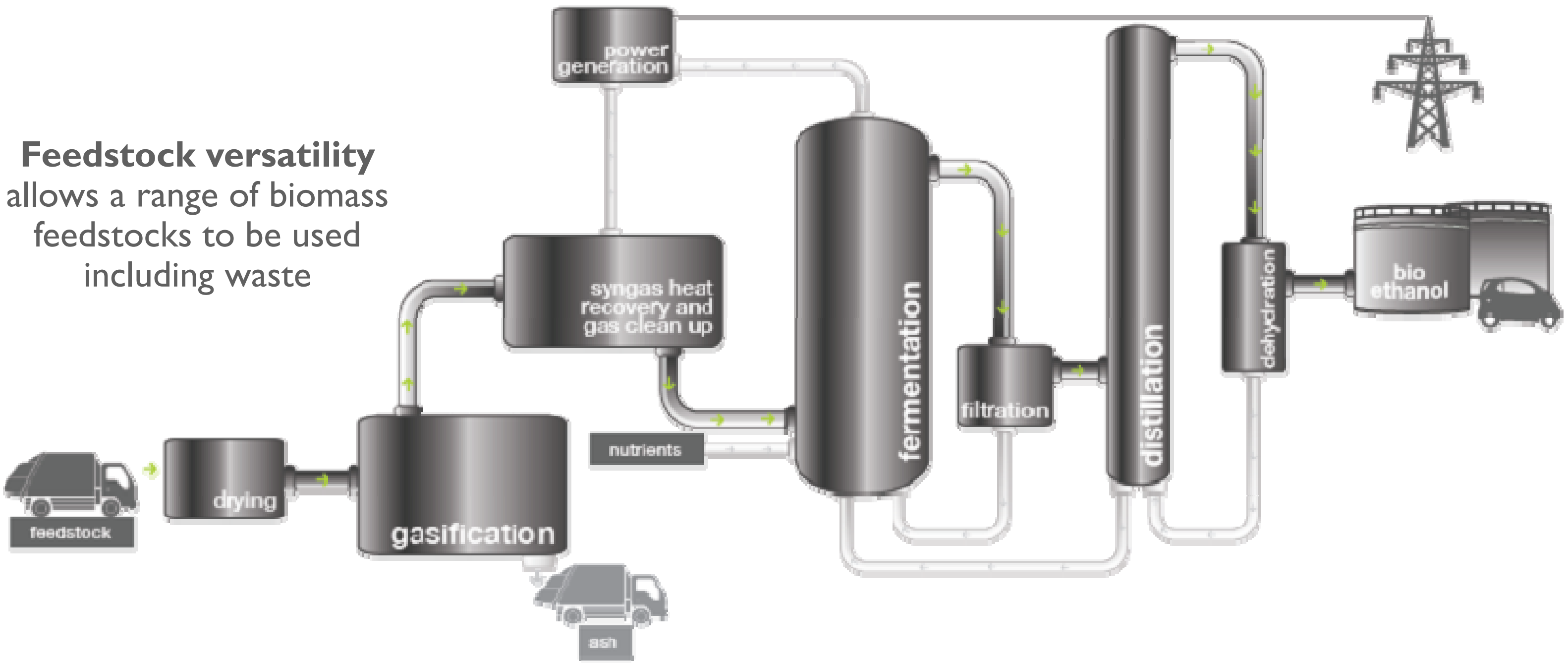
INEOS Bio

SHOWCASE PROJECT: INEOS Bio | Vero Beach, FL | USA

Process Overview: Bioethanol from waste combined with CHP

Waste heat and offgas recovery for renewable power generation for use in the bioethanol process and for export

Feedstock versatility allows a range of biomass feedstocks to be used including waste



Two stage gasification to produce syngas without significant by-products

Syngas converted into bioethanol via fermentation using proprietary biocatalyst then distillation

SHOWCASE PROJECT: INEOS Bio | Vero Beach, FL | USA

Status quo

- Strong US government partnership
  - DOE grant & USDA loan guarantee
- EPC awarded to AMEC in November 2010
- Ground broken in February 2011
- Currently under commissioning

Syngas fermentation

General facts

- Fermentation of syngas into ethanol based on the following reactions:
  - $6CO + 3H_20 \rightarrow C_2H_5OH + 4CO_2$
  - $2CO_2 + 6H_2 \rightarrow C_2H_5OH + 3H_20$
- Also other side reactions e.g. into acetic acid
- Microorganisms:
  - High productivity of ethanol
  - Low by-product formation
  - High tolerance against inhibiting substances in the syngas
  - e.g. Clostridium ljungdahlii

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Syngas fermentation

General facts

- Feedstock for gas fermentation can be derived from a broad range of sources:
  - Syngas of biomass (e.g. vegetative waste, yard waste)
  - Syngas of municipial wastes
  - Industrial waste gases (e.g. steel production)
  - Combination of several sources
- Waste streams converted directly on site into thermal or electric power

Comparison of different technologies

	Starch based	Cellulosic based	Syngas fermentation
Raw material	wheat / corn	wheat straw	biomass
Yield l alcohol / t raw material	390	180 (C6) 250 (C6 + C5)	200 - 260
Fermentation time hours	60 – 70	120 – 150	< 1
Alcohol content %vol in mash	11 – 16	5.0 – 10.0	3.0 – 5.0
Viscosity cP	30 – 50	200 - 400	5 – 10
Steam consumption t /1000 l alc			
Upstream (Hydrolysis)	0.3 – 0.4	2.0 – 4.0	-
Distillation / Dehydration	1.2 – 2.0	1.7 – 2.5	3.0 – 5.0
Evaporation / Drying	1.8 – 2.0	2.5 – 4.0	???
By products	DDGS	Lignin C5 fraction	Thermal / electrical power

Cellulosic ethanol – Status quo

Achieved

- *Stable, proven processes*
- *Plant in industrial design available*
- *Industrial product quality requirements*

Unresolved

- *Insufficient legal framework to support cellulosic ethanol*
- *High investment costs compared to G1 plants*
- *Still higher production costs compared to G1 product*
- *Raw material availablity and costs*
- *„First of its kind“ Issues*

Special downstream processing solutions

| For first and second generation bioethanol

GIVEN CONTEXT

Cutting process energy consumption improves the plant feasibility.

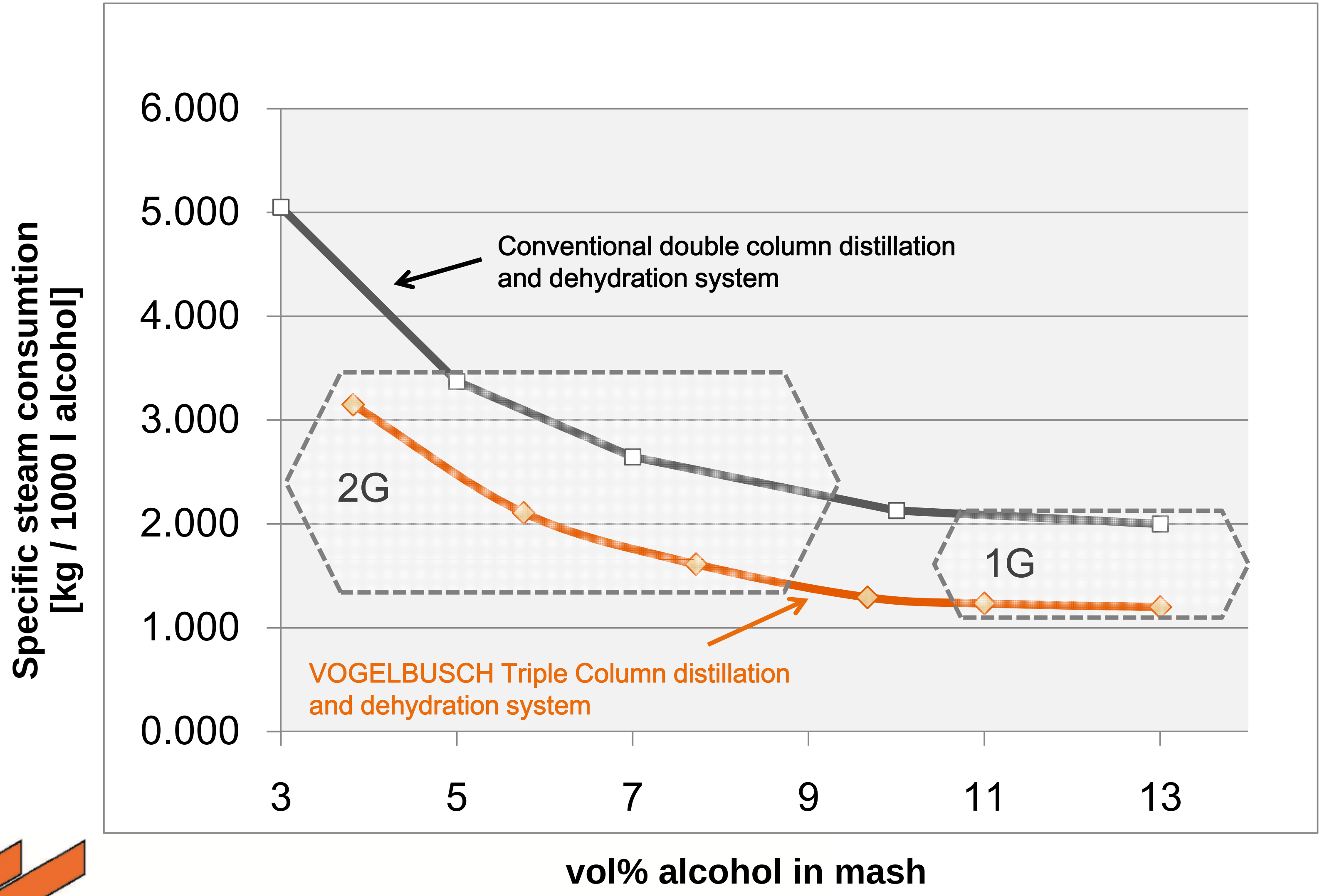
Technological measures to improve energy efficiency of cellulosic ethanol plant:

1. VB Multipressure distillation
   ➔ minimizing energy demand for distillation
2. VB Zero steam evaporator heated by dryer's vapor
   ➔ minimizing energy demand for stillage treatment

Saving energy = Saving costs!

Vogelbusch Multipressure distillation I

| Influence of alcohol content in mash on steam demand



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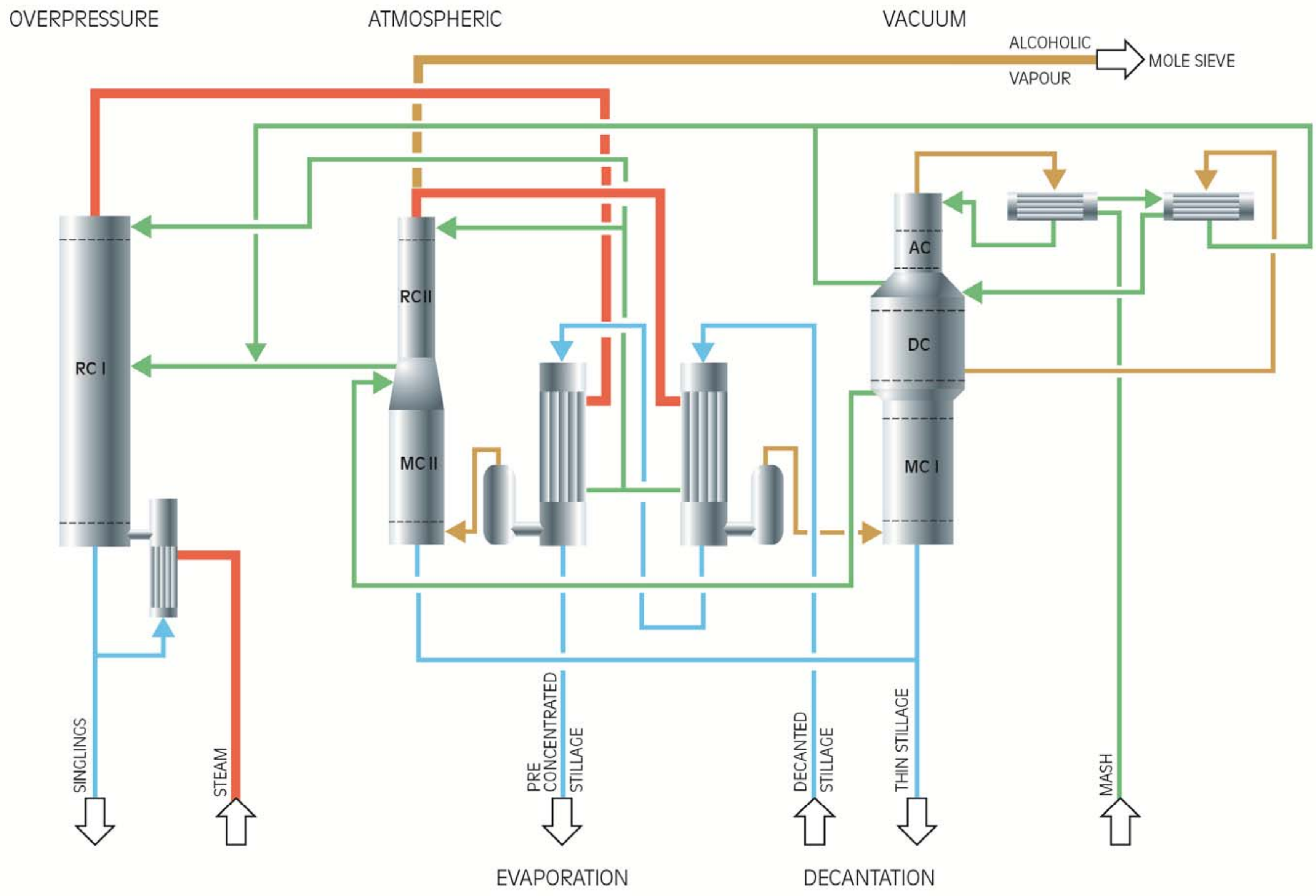
Vogelbusch Multi-pressure distillation II

| For first and second generation bioethanol

3 pressure stages for threefold usage of life steam	‣ vacuum ‣ atmospheric ‣ overpressure
Distillation in split mash columns	‣ vacuum ‣ atmospheric
Rectification in split rectifiers	‣ atmospheric ‣ overpressure
Hydrous alcohol vapors fed directly to molecular sieve unit	
Split mash columns can be used for separate feed streams (hybrid plants)	

Vogelbusch Multi-pressure distillation III



Vogelbusch zero steam evaporator

| For first and second generation bioethanol

- Evaporators are used for concentration of decanted residues from distillation
- Dryers are used for
  - DDGS in first generation plants
  - Lignin in second generation plants
- Dryer's vents are a valuable heating source for evaporation
- State-of-the art indirect heated dryers produce vapors with a wet bulb temperature of 90 – 98 °C
- Depending on wet bulb temperature 50 – 80 % of total dryer's vapors can be utilized as heating source in evaporators
- 1G Plants: multi-effect evaporators are heated completely by dryer's vapors without any additional live steam
- 2G Plants: considerable reduction of life steam for evaporation of effluents

Conclusions

Energy efficiency

- Thermal integration by special downstream solutions can save up to 40% of live steam

Additonal income

- It‘s not enough to be thermally selfsufficient!!
- Additional income by selling (more) surplus energy

CO_2 reduction

- Considerable reduction of carbon footprint of the plant

ROI

- ROI for thermal integration in downstream typically within 2 – 3 years

Thank you for your attention.

For questions please contact
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