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Opportunities for the fermentation-based chemical industry

An analysis of the market potential and competitiveness of North-West Europe

The full study is available on the website of Deloitte. The study was carried out by Deloitte and sponsored by Rabobank and other partners. Some selected data is used with the kind permission from LMC International

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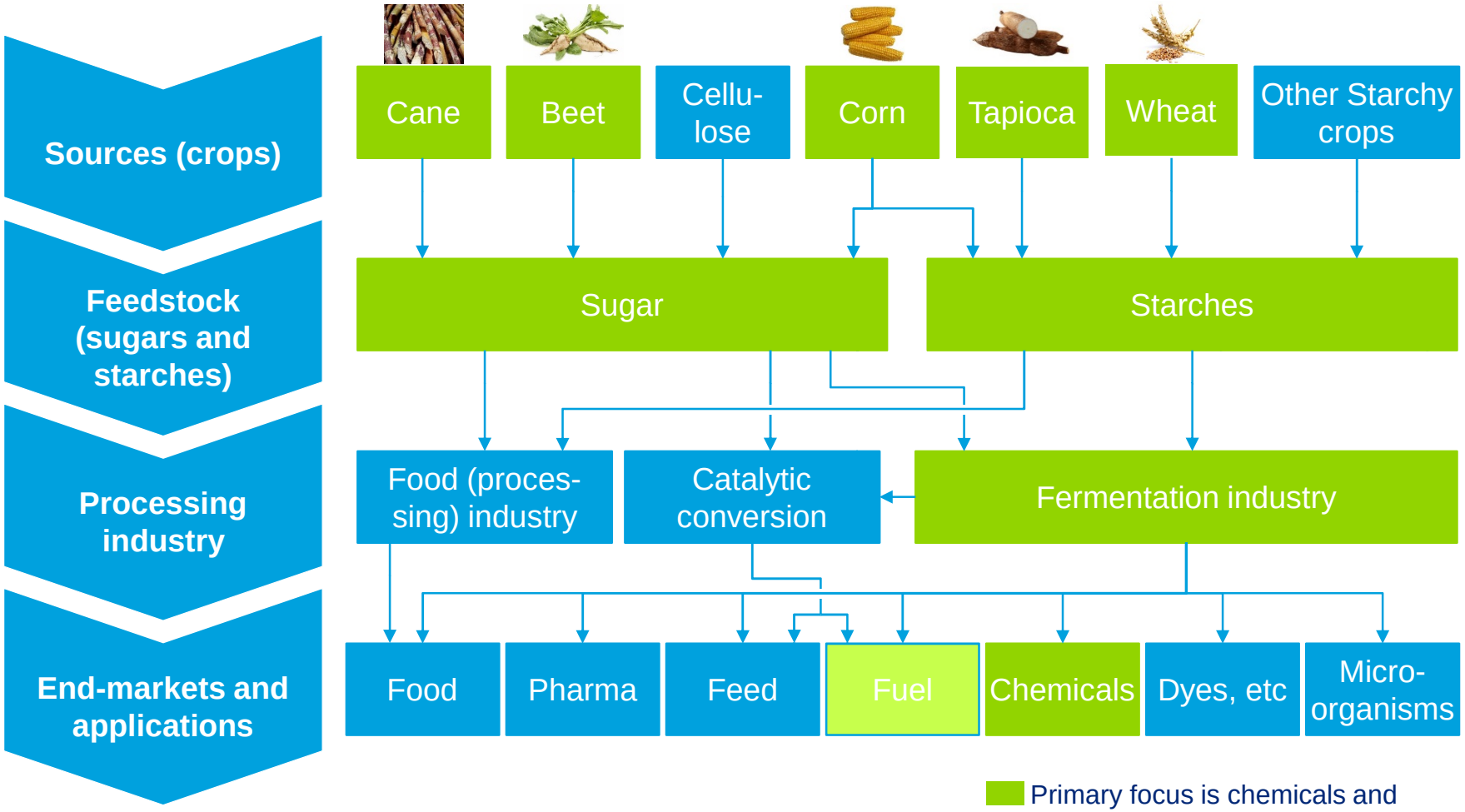
Hannover, 8th September 2016

Chemicals derived from cane, beet, corn, tapioca, and wheat through fermentation are the primary focus on this study

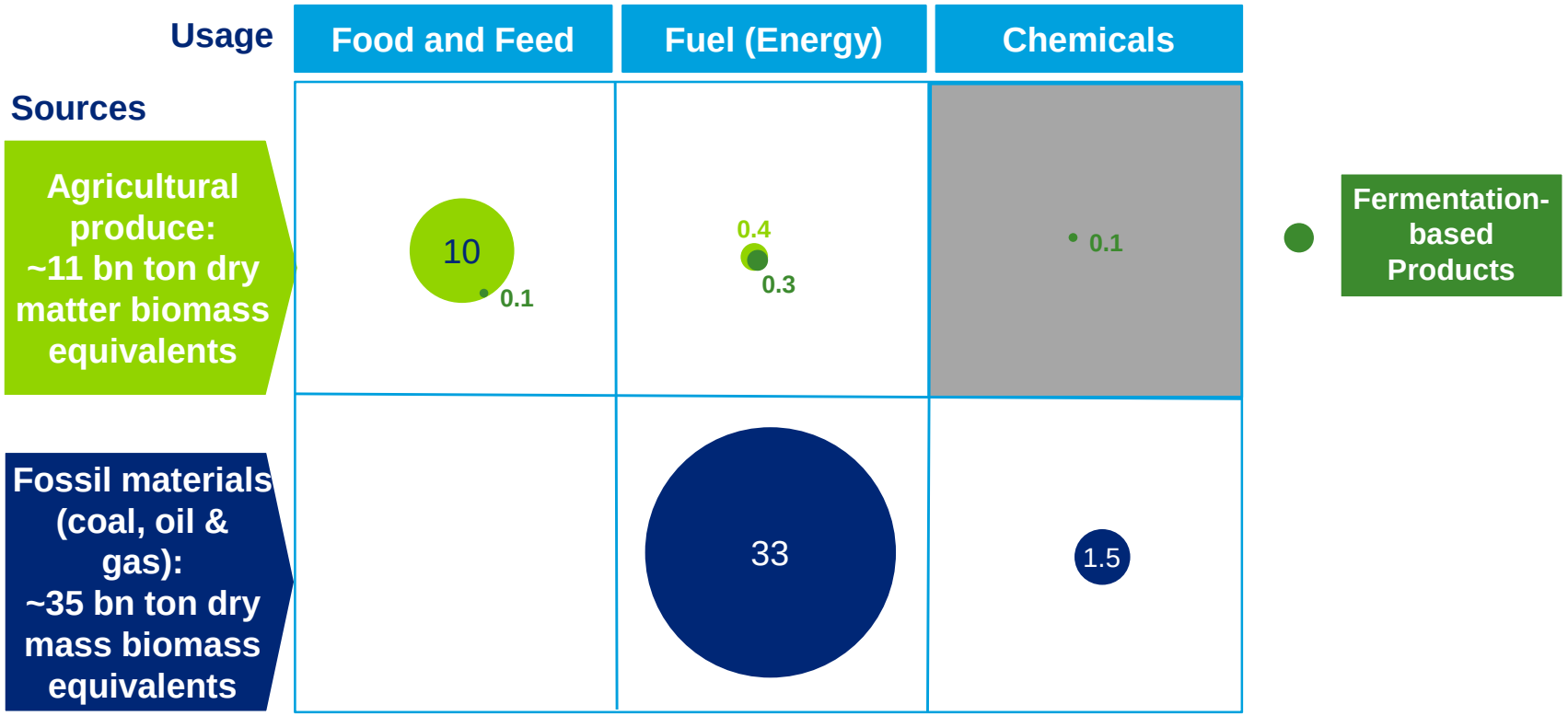
Fermentation-based chemical value chain – "Agri meets Chemicals"



Note: Excludes streams of co-products

Crops and arable land use for fermentation-based chemicals will remain insignificant compared to food, feed and fuel while the added value is high

Global fossil and biomass inputs and outputs (2013, in biomass equivalents)



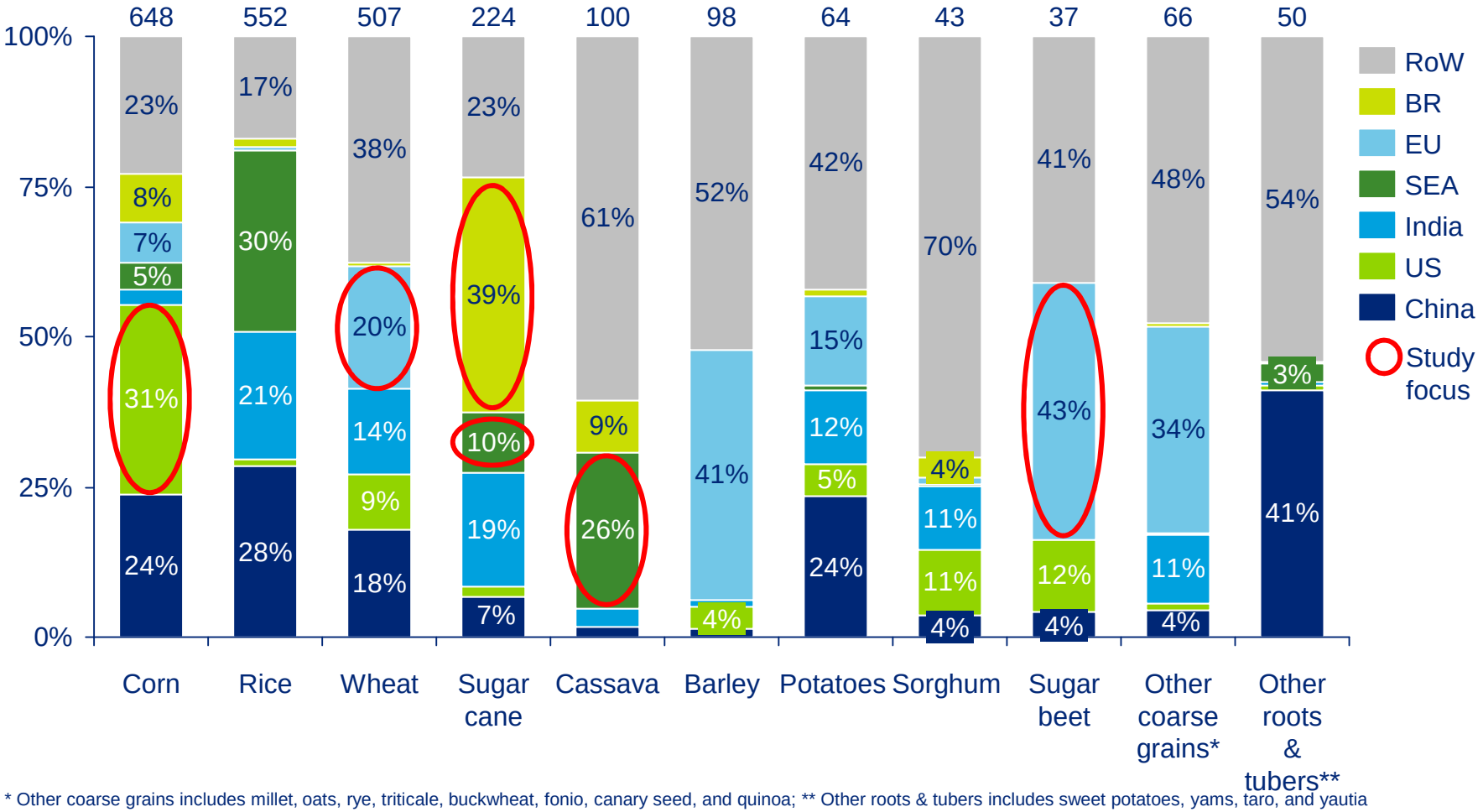
Note: All figures are indicative; Biofuel excludes wood; See separate table with detailed figures covering added value, arable land use
Sources: FAO, IEA, EIA, Sanders & Bos (2013), Deloitte Analysis

- The fermentation-based chemical industry, while growing, is still small compared to petrochemicals
- Oil and gas are mainly used for energy and only a small part for chemicals – ca. 3% and another 3% for the energy required to make the chemicals
- All figures are indicative; See separate table with detailed figures covering added value, arable land use

The study focuses on the regions with the highest concentration of carbohydrates of interest to the fermentation industry

Global production of carbohydrate feedstocks per region (mln ton CHEQ, 2012)

Total: 2,388 mln ton CHEQ

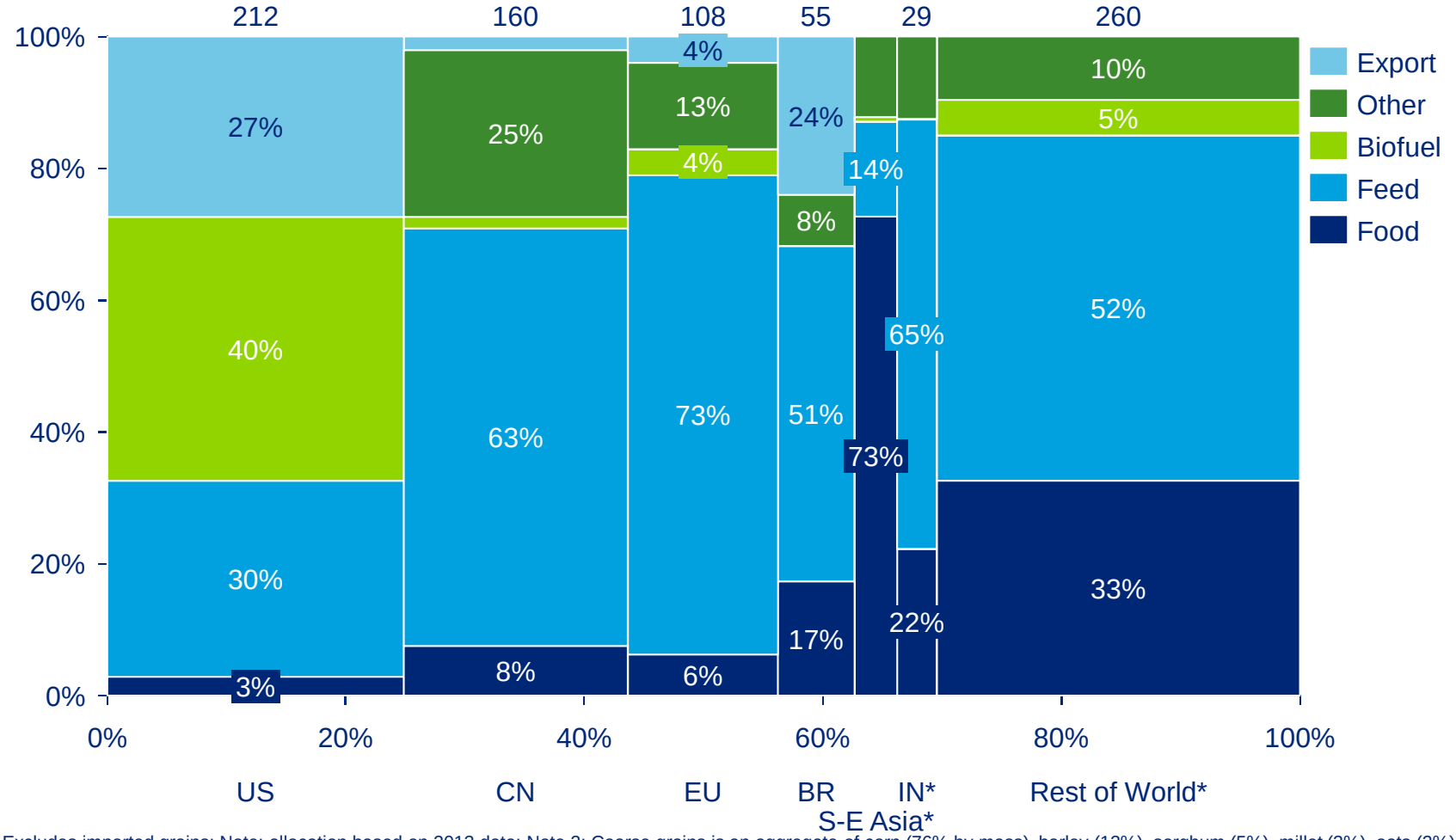


* Other coarse grains includes millet, oats, rye, triticale, buckwheat, fonio, canary seed, and quinoa; ** Other roots & tubers includes sweet potatoes, yams, taro, and yautia

Source: OECD-FAO Agricultural Outlook 2013, USDA nutrient database, Deloitte Analysis

Only in the US, corn and other coarse grains are predominantly used for biofuel, while in the rest of the world the majority goes to food and feed

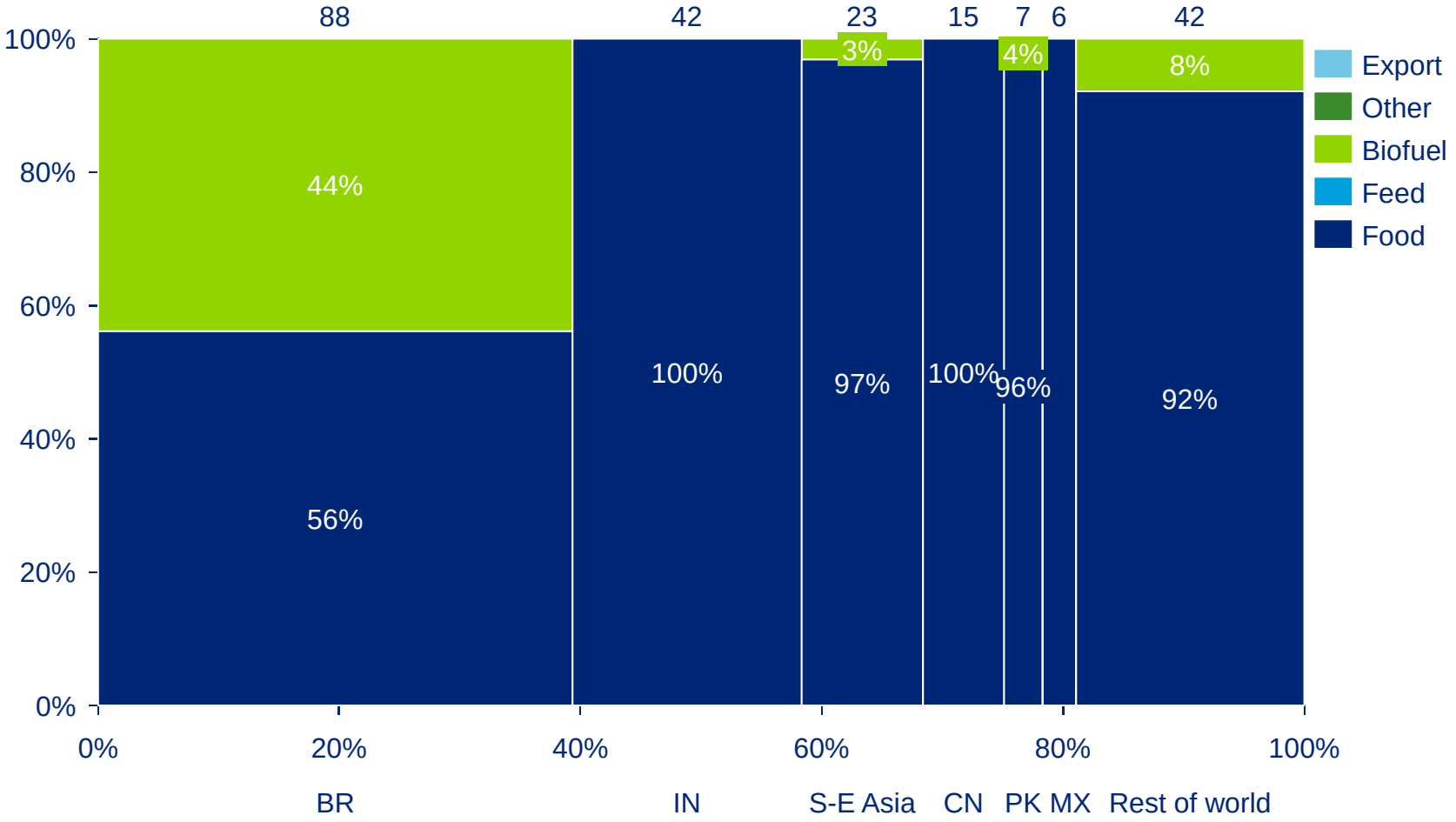
Global production and use of corn and other coarse grains (mln ton CHEQ, 2012)



* Excludes imported grains; Note: allocation based on 2013 data; Note 2: Coarse grains is an aggregate of corn (76% by mass), barley (12%), sorghum (5%), millet (3%), oats (2%), rye, triticale, buckwheat, fonio, canary seed, and qinoa; Source: FAO, OECD-FAO Agricultural Outlook 2013, USDA nutrient database, Deloitte Analysis

Production of sugar cane is dominated by Brazil, also the most extensive user of cane for biofuel; other countries mainly use cane for food purposes

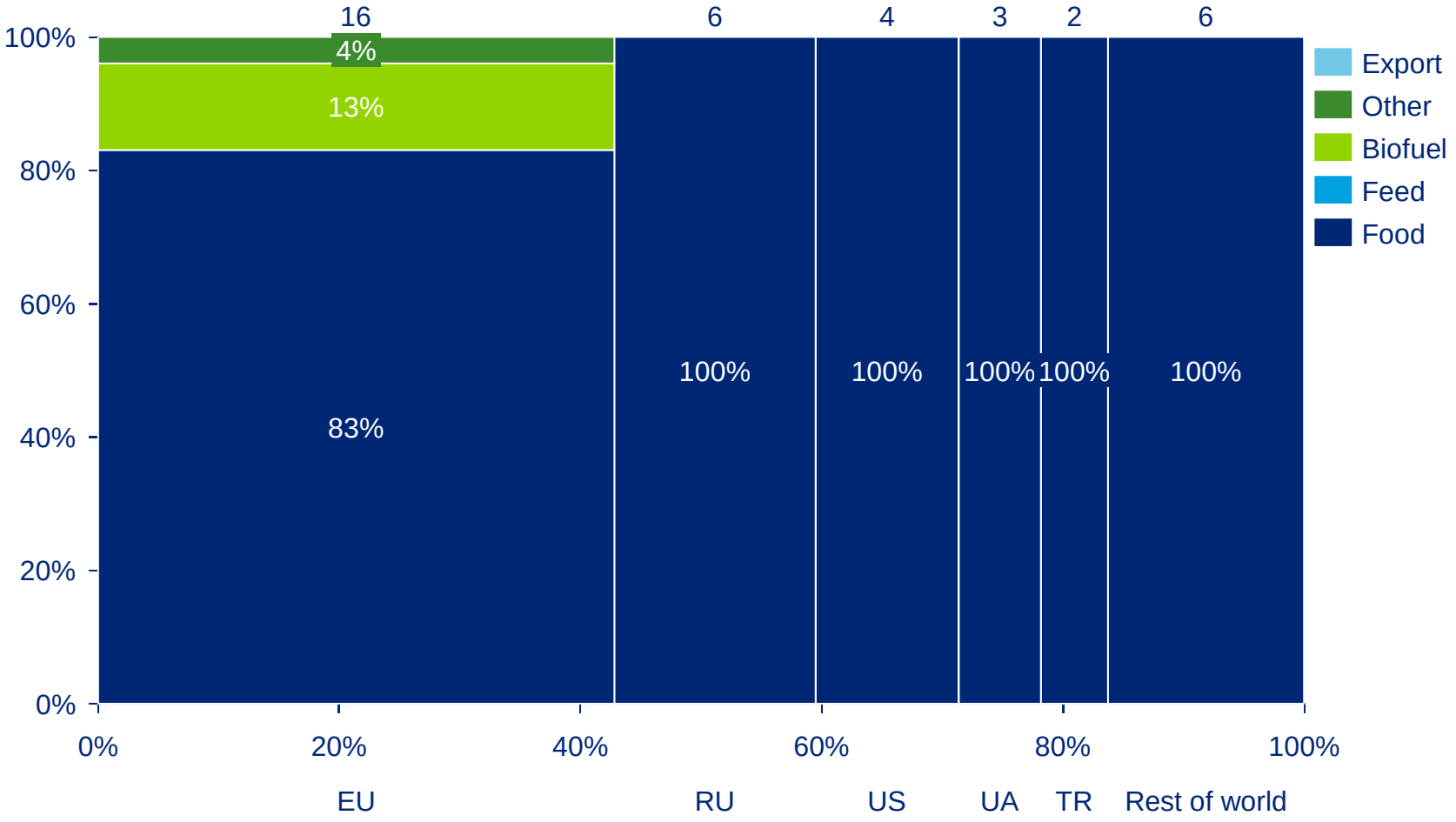
Global production and use of sugar cane (mln ton CHEQ, 2012)



Note: allocation based on 2013 data, use of food is calculated as total production minus use for biofuel since main use is production of sugar
Source: FAO, OECD-FAO Agricultural Outlook 2013, USDA nutrient database, Deloitte Analysis

The EU is the main producer of sugar beets and the only region where beets are directly used to produce biofuel

Global production and use of sugar beet (mln ton CHEQ, 2012)



Note: allocation based on 2013 data, use of food is calculated as total production minus use for biofuel and “other” since main use is production of sugar
Source: FAO, OECD-FAO Agricultural Outlook 2013, USDA nutrient database, Suiker Unie, Deloitte Analysis

Corn, wheat, cane, cassava, and beet require different processes to produce sugar or starch

Carbohydrate production processes

Corn*

- Cleaning
- Steeping
- Germ separation
- Grinding
- Starch separation
- Syrup conversion
- Syrup refining

HFCS, Starch

Wheat

- Cleaning
- Dry grinding
- Wetting
- Starch separation
- Starch refining
- Drying

Starch

Sugar cane

- Washing
- Cutting**
- Crushing
- Juice purification
- Evaporation
- Crystallisation
- Centrifuging

Raw sugar

Cassava

- Cleaning
- Peeling & cutting roots
- Rasping
- Filtering
- Centrifuging
- Settling & Drying
- Grinding

Starch

Sugar beet

- Washing
- Slicing
- Juice extraction
- Juice purification
- Evaporation
- Crystallisation
- Centrifuging

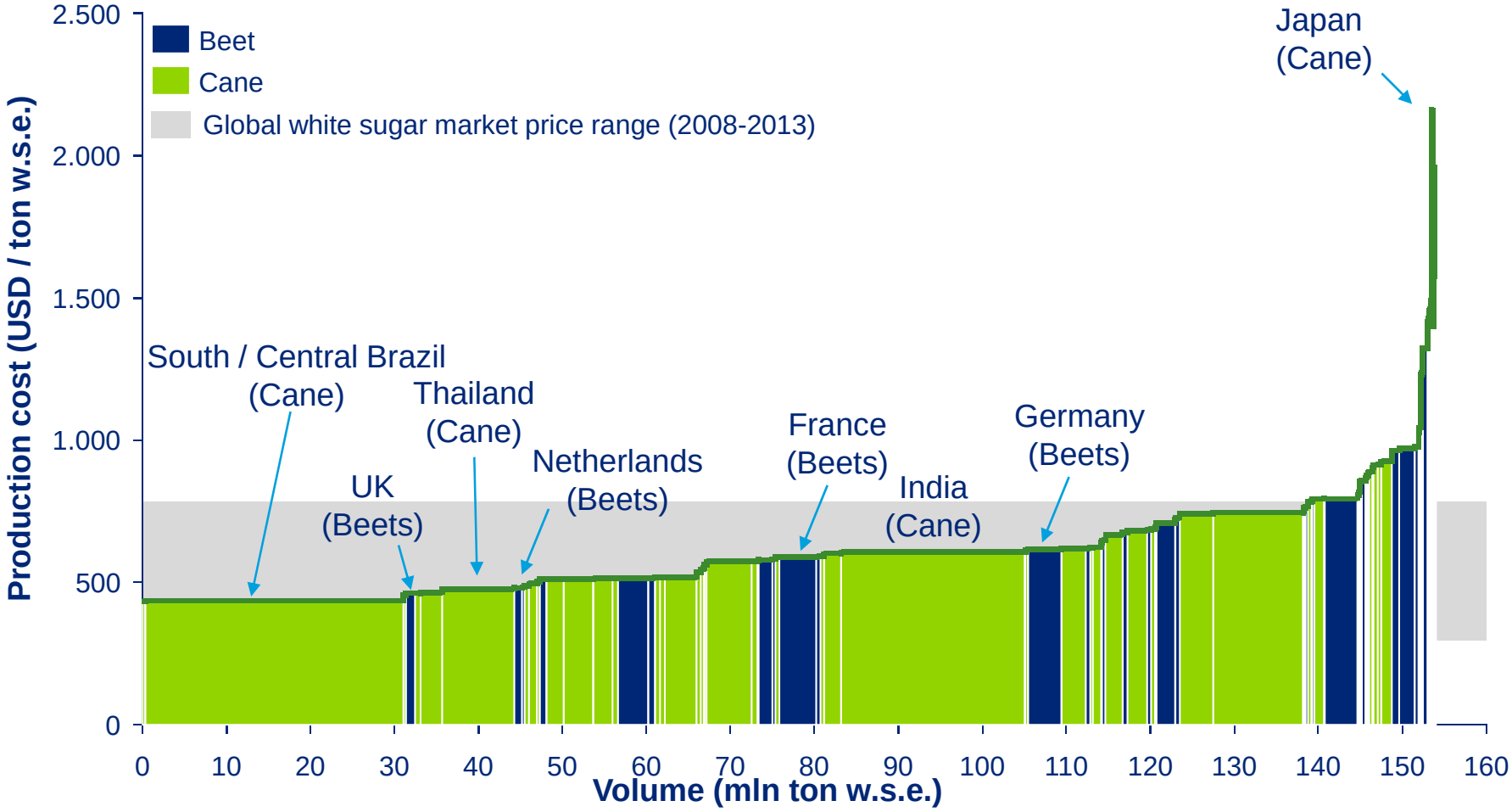
White sugar

* Wet milling process ** Required for manually harvested cane only since a harvester machine cuts the cane during harvesting
Source: Unica, Suiker Unie, Corn Refiners Association, Thai Tapioca Association, Overleggroep Producenten Natte Veevoeders

Average production costs over the past 5* years vary with strong positions for the US, Brazil, Thailand and the Netherlands

Global supply curve of sugar (average *2008/09 – 2012/13)

With kind permission from LMC International



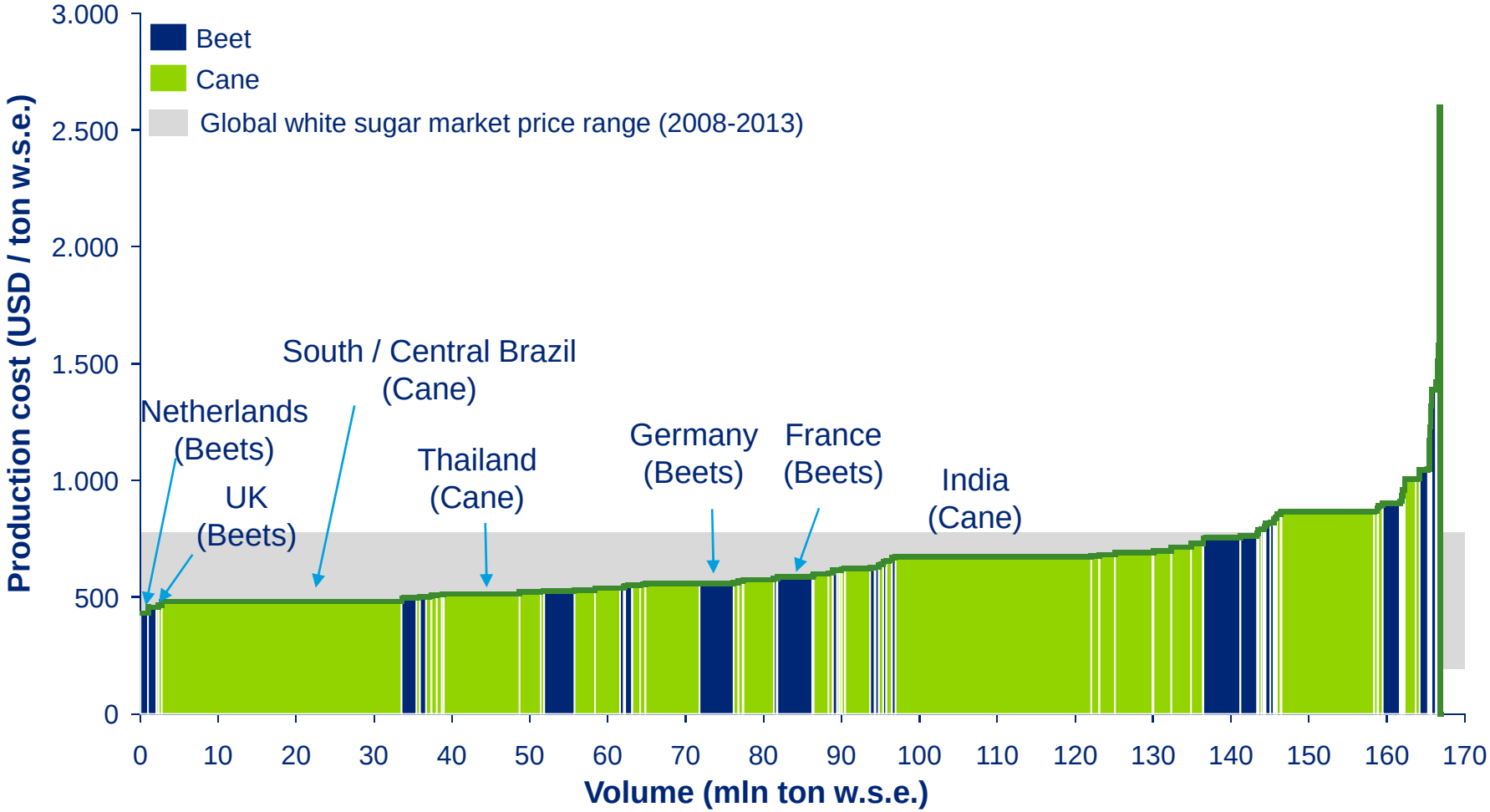
Note: Production costs of raw sugar converted to w.s.e. multiplying by 1.087 (polarisation constant) and adding refining costs of $65 / ton, raw sugar volume converted to w.s.e. by dividing volume by 1.087; Note 2: Production costs for beet and cane include for both land and factory costs for labour, capital (incl. a.o. land rent and depreciation), input (incl. a.o. seeds, fertilizer, chemicals, and energy), and factory by-product revenue

Source: LMC International Sugar & HFS report 2014, UNICA Harvest Reports 09/10 – 12/13, Deloitte Analysis

In the last* season, volumes have been higher than average and the Netherlands has taken the lead in low cost sugar production

Global supply curve of sugar (*2012/13)

With kind permission from LMC International



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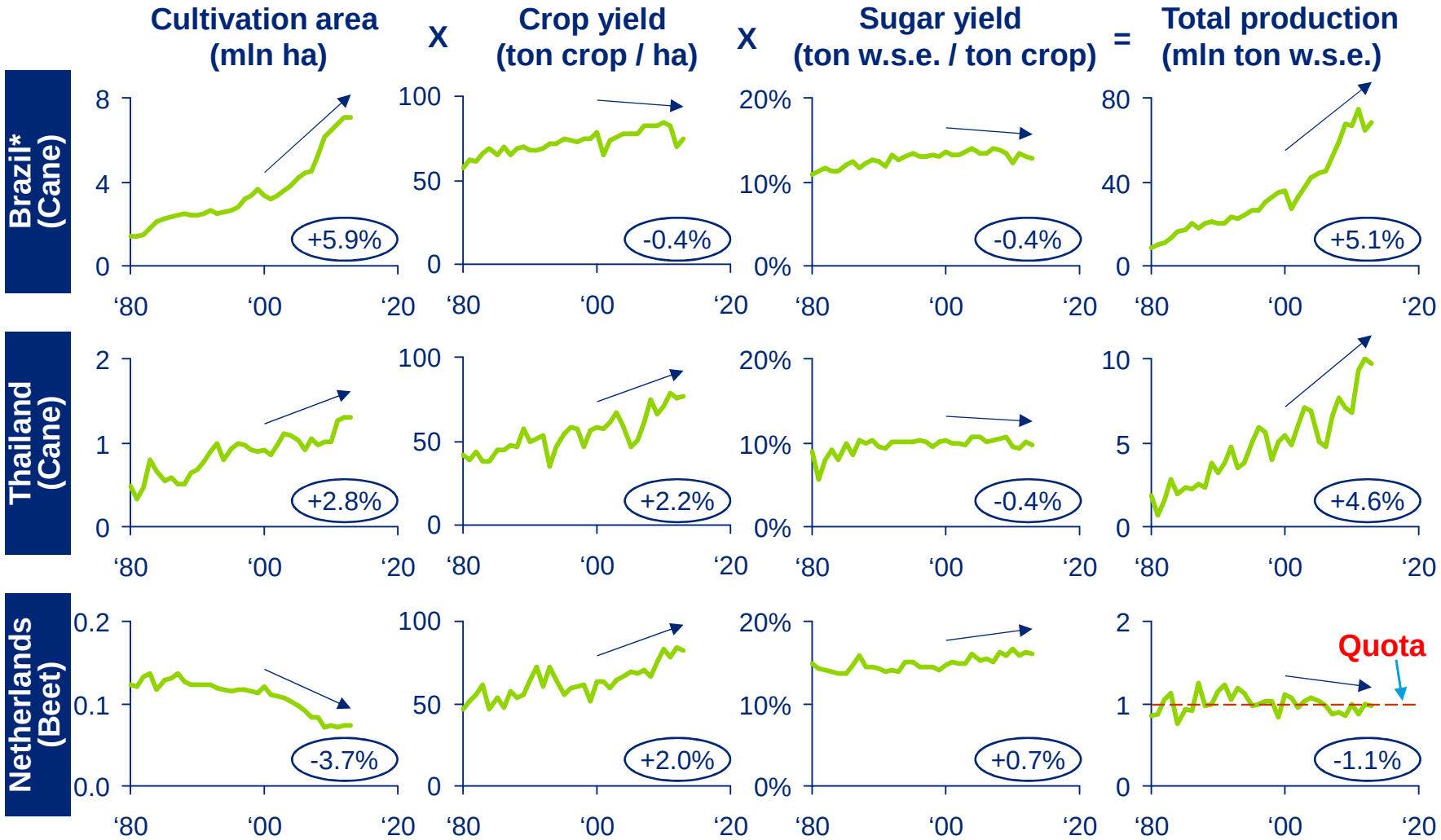
Source: LMC International Sugar & HFS report 2014, UNICA Harvest Reports 09/10 – 12/13, Deloitte Analysis

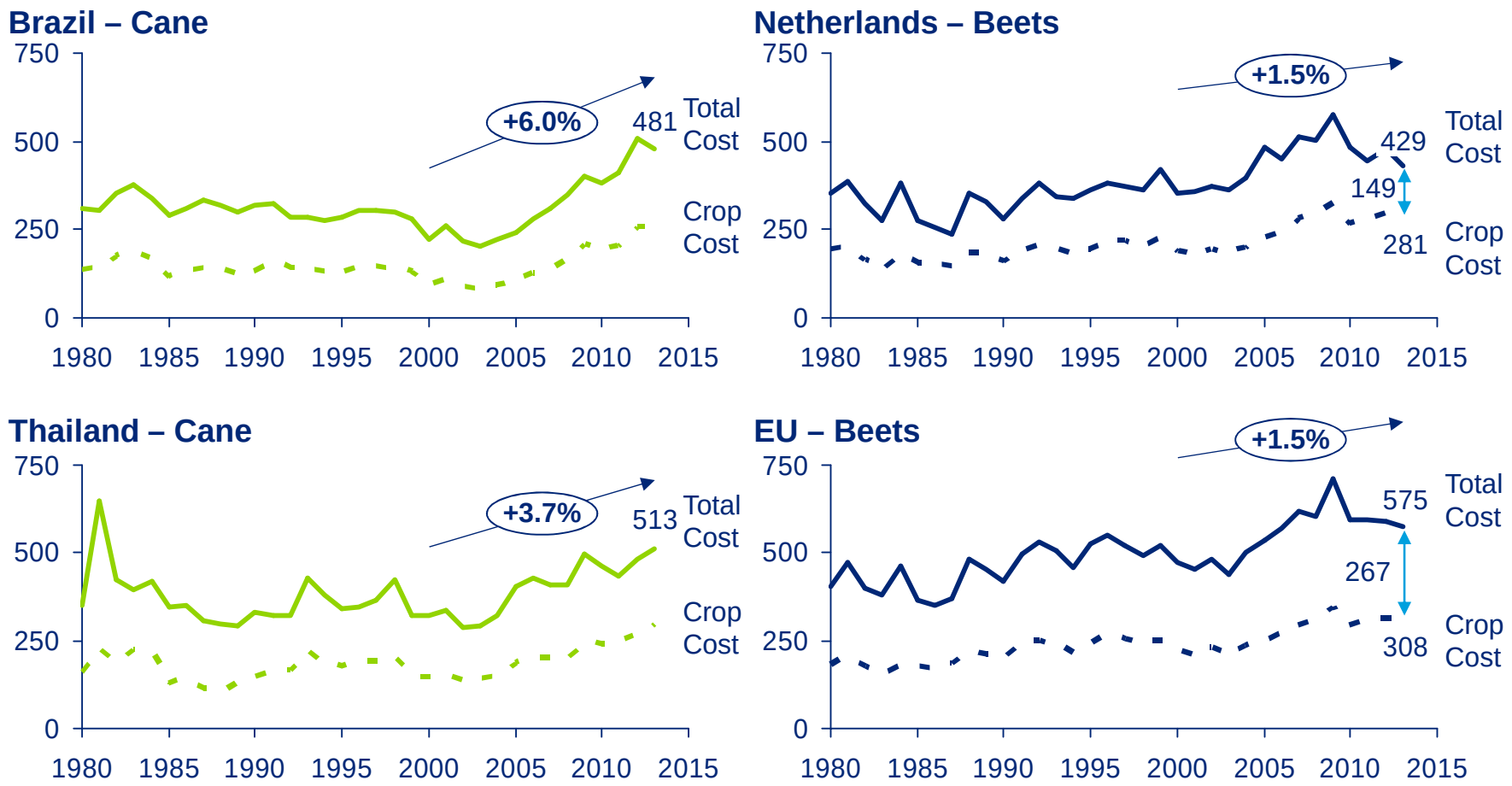
Brazil and Thailand increased production mostly by increasing acreage and/or crop yield, whereas production in the Netherlands is under quotum



* Figures include all cane and sugar produced, no adjustment for ethanol production has been made
Source: LMC International Sugar & HFS report 2014, Deloitte Analysis

Since 2000 the production costs in Brazil have increased significantly more than in the Netherlands, resulting in a higher price level

Production costs (USD / ton w.s.e., 1980-2013)



Note: cost levels same as previously defined
Source: LMC International Sugar & HFS report 2014, Deloitte Analysis

(%) = CAGR 2000-2013

Currently eight key categories of molecules or compounds are produced commercially and ample opportunities for future developments exist

Fermentation molecules and a selection of representative compounds

Currently commercial fermentation processes

Alcohols & Ketones	• Ethanol • Butanol • BDO • Acetone	Organic acids	• Citric • Lactic • Succinic	Polymers	• Xanthan • PHA	Anti-biotics	• Beta-lactam • Tetracycline • Clavulic acid
Amino acids	• MSG • Lysine • Threonine • Tryptophan	Biogas	• Methane	Vitamins	• Vitamin C • Vitamin B2 • Vitamin B12	Industrial enzymes	• Amylase • Cellulase • Lipase • Protease

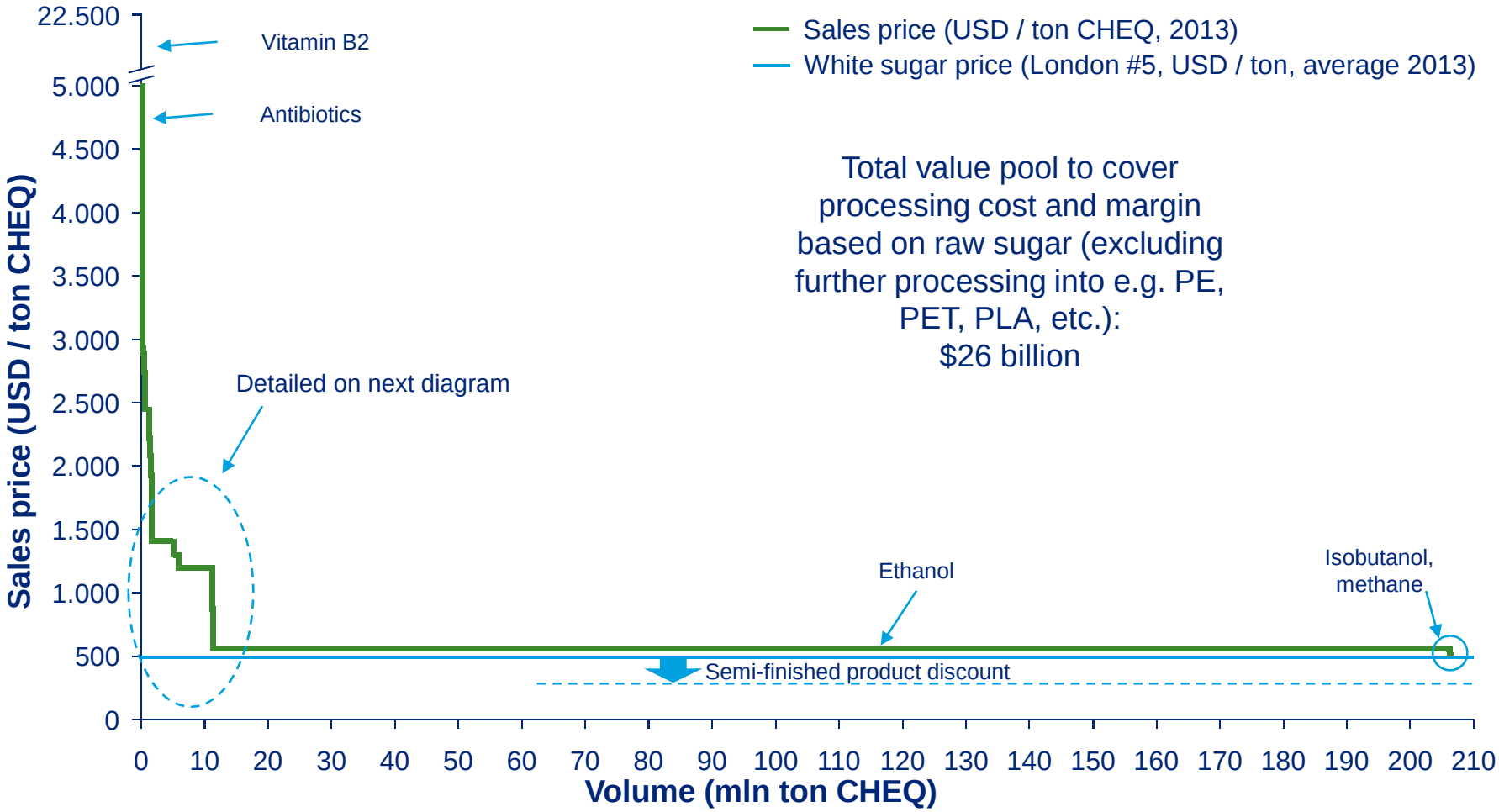
Selection of future developments based on current research (ranging from theoretical research to testing plant phase)*

Alkanes	• Nonane • Tetra-decane	Olefins	• Butadiene • Isoprene • Propene • Farnesene	Amines	• Histamine • Tyramine	Esters	• Malonyl-ACP
Dyes	• Various dyes (e.g. Indigo)	Microbial oils	• Biodiesel				

*Selection based on interviews and in-depth research that showed these products are currently produced on a very small scale, e.g. farnasene is produced on laboratory scale of appr. 0.04 million tons per year
Note: Yeasts and other microorganisms excluded from the scope of this study
Source: BCC Research, FO Licht Renewable Chemicals Database, Deloitte Analysis

The sales price curve shows a potential profitable market of about 11m ton CHEQ of fermentation products from sugar with a margin of >$500 / ton

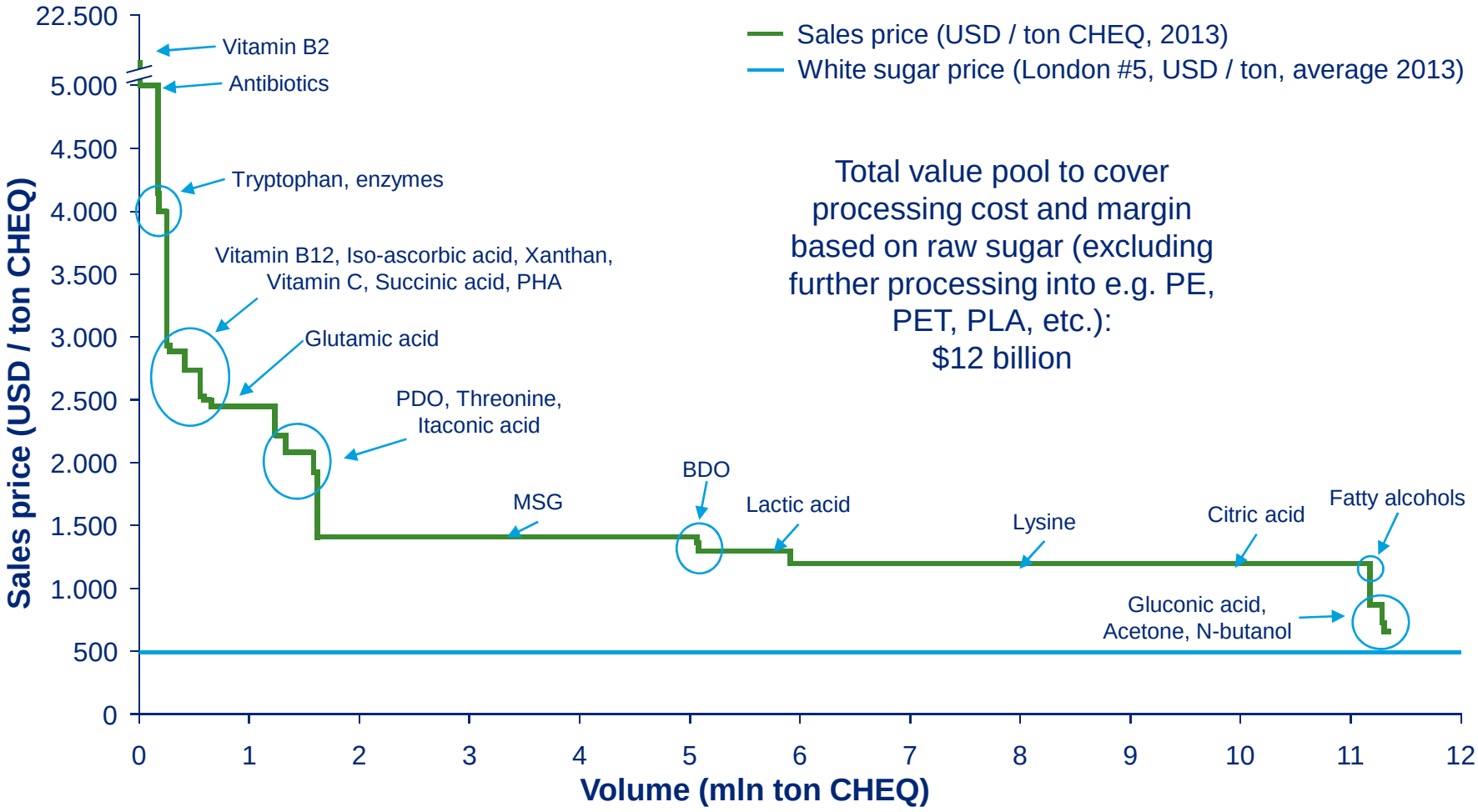
Fermentation products global average market price at industrial grade (2013)



Source: BCC Research, FO Licht Renewable Chemicals Database, NOVA Institut, Deloitte Analysis

The majority of the volume of this potential market (89%) is currently in five products, namely, lysine, MSG, citric acid, lactic acid, and glutamic acid

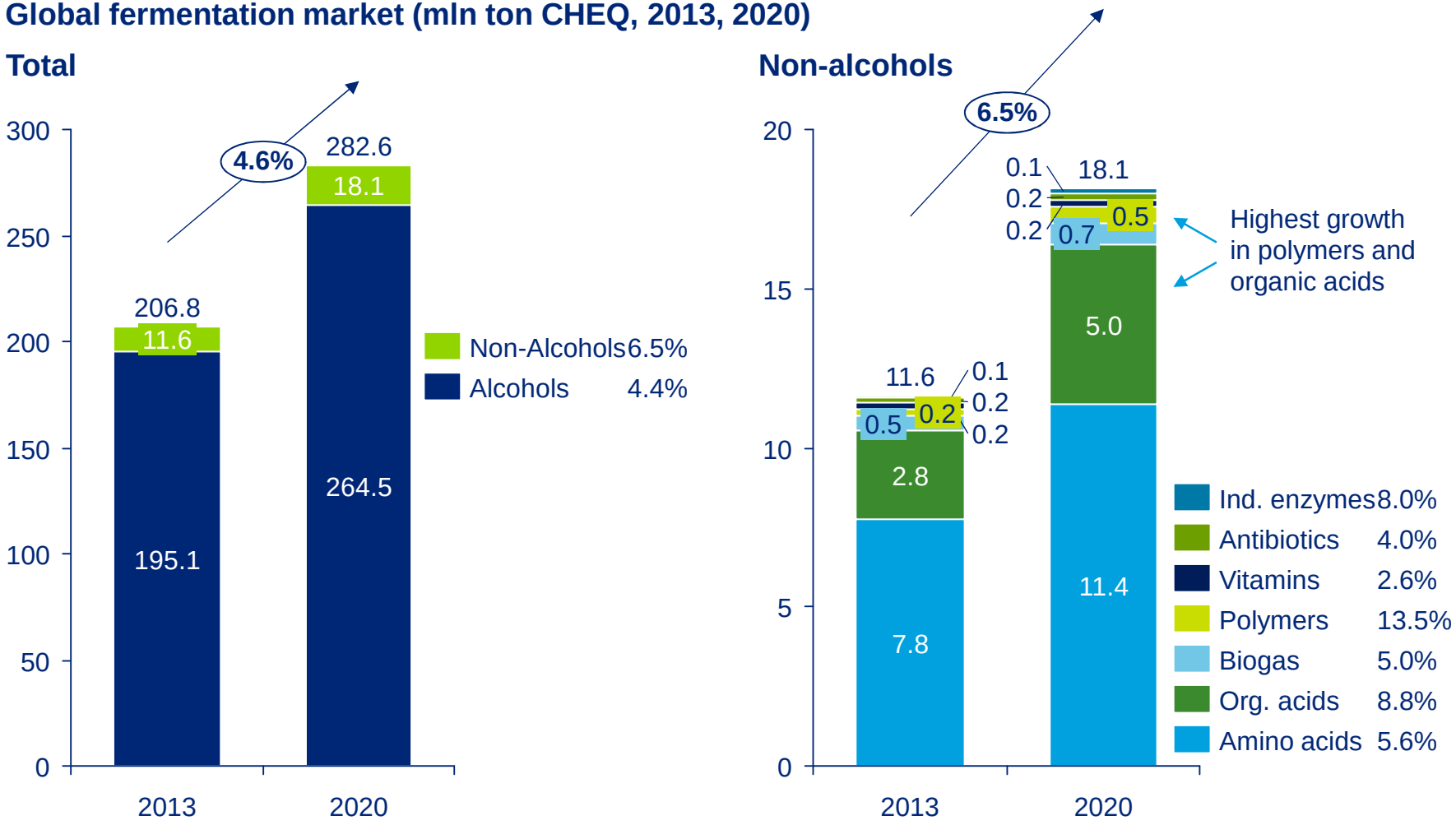
Fermentation products global average market price at industrial grade (2013)



Source: BCC Research, FO Licht Renewable Chemicals Database, NOVA Institut, Deloitte Analysis

Market studies show a projected base case growth of 5% CAGR with alcohols staying the key segment and polymers showing the highest growth

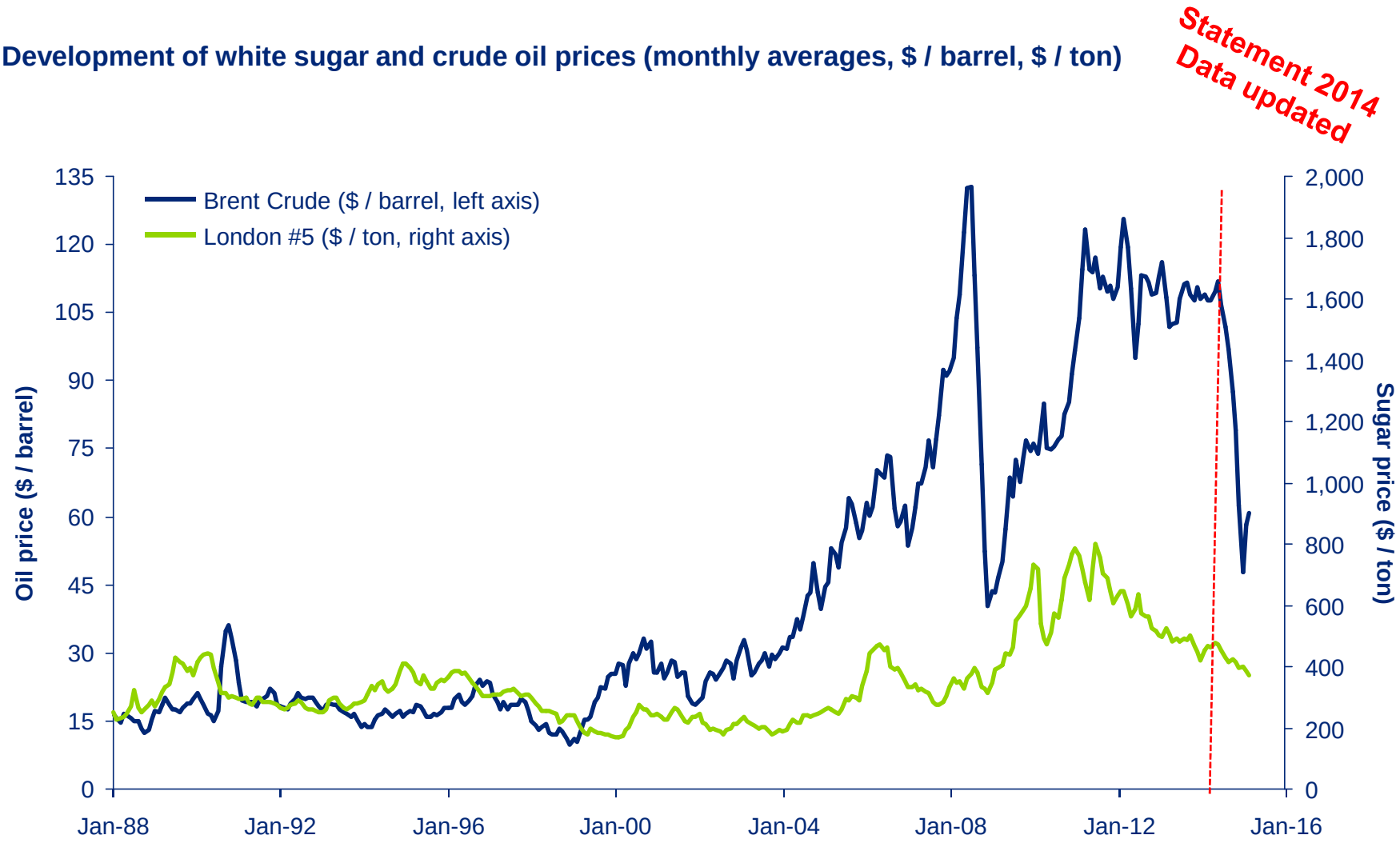
Global fermentation market (mln ton CHEQ, 2013, 2020)



Note: 2020 outlook is based on available predictions where possible and extrapolation in case no explicit predictions are available
Source: BCC Research, FO Licht Renewable Chemicals Database, NOVA Institut, OECD-FAO Agricultural Outlook 2013, Novozyme 2013 Annual report, DSM Factbook 2014, Deloitte Analysis

Oil prices were stable up to 2000 after which it increased dramatically; white sugar prices have been volatile but increased more gradually

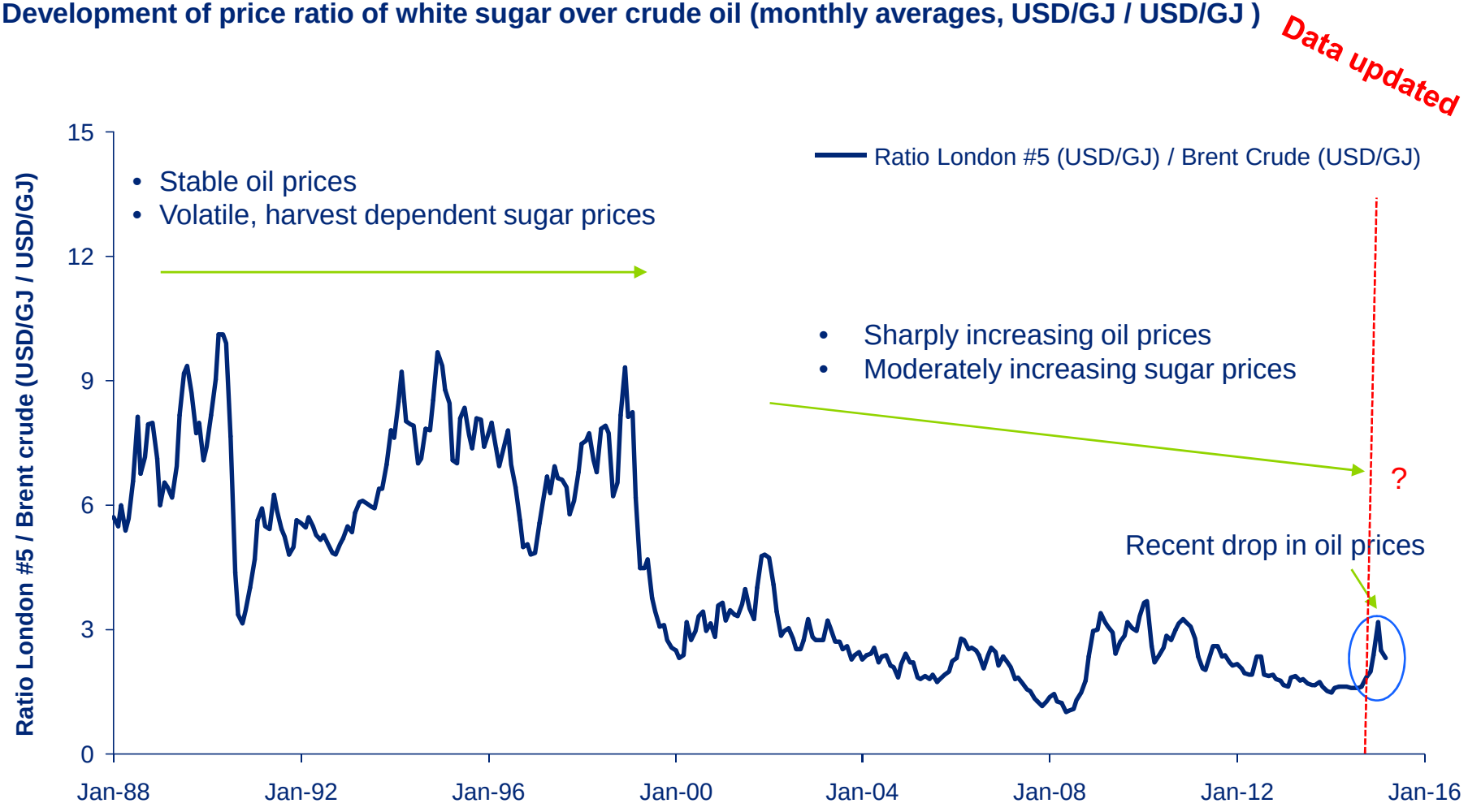
Development of white sugar and crude oil prices (monthly averages, $ / barrel, $ / ton)



Source: FO Licht, EIA, Deloitte Analysis

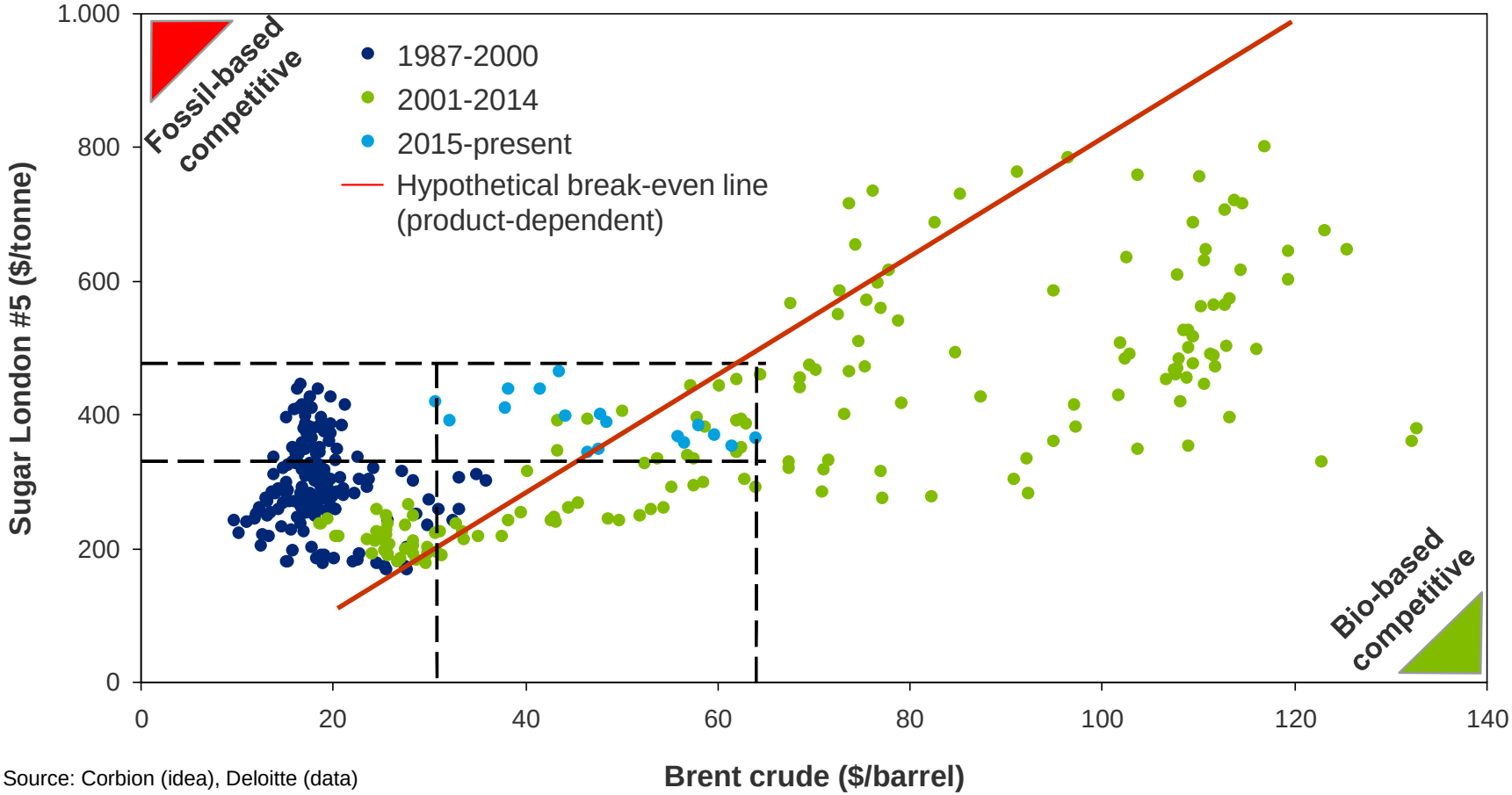
As a result, in the past fifteen years the sugar price decreased relative to crude oil, creating an opportunity for sugar in the biobased economy

Development of price ratio of white sugar over crude oil (monthly averages, USD/GJ / USD/GJ)



Source: FO Licht, EIA, Deloitte Analysis

The competitiveness of bio-based products is dependent on sugar versus brent crude oil prices (2/2)



Source: Corbion (idea), Deloitte (data)

In a nutshell
… a positive picture for NW-EU

1. **NW-EU** and sugar beets have **surprisingly strong competitive position**
2. Due to de-regulation **additional volumes** will come on the market in 2017
3. The current market for biobased chemicals is still relatively small, but expected to **grow with 6.5% CAGR** until 2020
4. Biobased chemicals are an **attractive market** with **high economic value-add ($12 billion / annum)** in 2013
5. Each product needs it own **business case**
6. Land use for functional molecules will remain insignificant
7. Sugar has become cheaper compared to oil … until 2014

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