

WP7 Integrated Assessment

Mid-term report meeting, June 15

Brussels

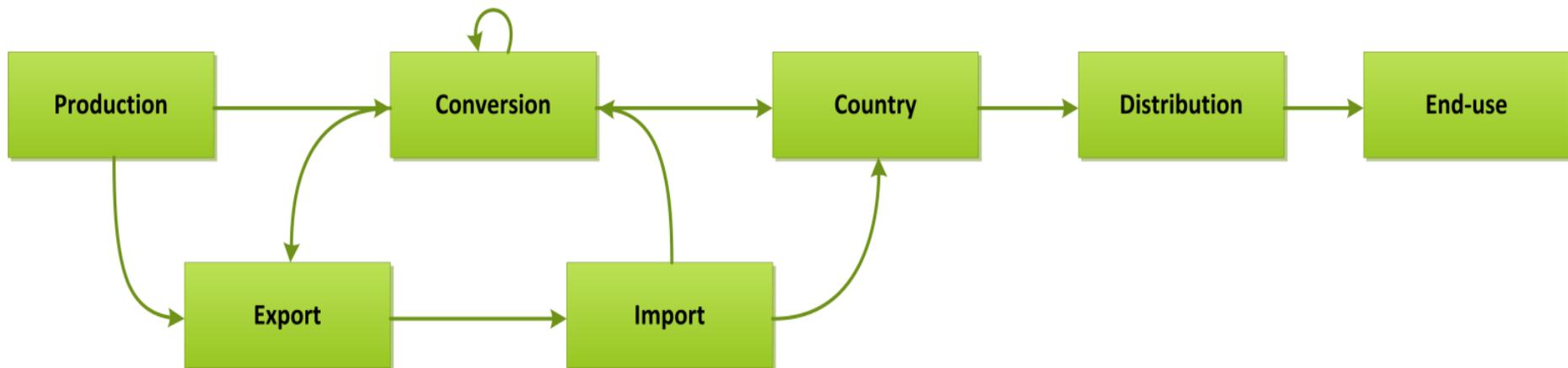
ECN, Imperial,
Alterra, VITO, IINAS,
Clever Consult,
BTG, JRC

Introduction and objectives for today



- Will Europe have sufficient biomass to:
 - Meet its renewable energy objectives *and*
 - Provide a sufficient resource based for a biobased chemistry and materials sector?
- Essential subquestion:
 - How much biomass demand will there be?

- Key tool: RESolve-Biomass
 - Full biomass chains
 - Biomass to:
 - Heat
 - Power
 - Biofuels
 - *Novel chemicals and materials*



- Focus on product-market combinations (PMCs)
 - Innovativeness versus data availability
 - Sufficient coverage but not too many PMCs
 - Data needs:
 - Current and future market size
 - Prospects for bio-based options
 - Related biomass demand
- Status: Three final draft reports available:
 - On heat and electricity
 - On PMCs based on C5, C6 and lignin
 - On six other PMCs

Proposed product-market combinations (PMCs)

	Product	Market	Current	2020	2030
1	Heat	District heating	x	x	x
2	Electricity	Power market	x	x	x
3	BTX	Petrochemical industry		x	x
4	Adv. Biofuels ¹	Transport fuel		x	x
5	Bio-methane	Grid, transport	x	x	x
6	Methanol	Transport, chemical industry	x	x	x
7	Hydrogen	Transport, (petro)chem. ind.		x	x
8	Ethylene	(petro)chemical industry			x
9	Mixed alcohols	(petro)chemical industry			x
10	Ethanol	Transport	x	x	x
11	C6 sugars	C6 chemistry			x
12	C5 sugars	C5 chemistry			x
13	Lignin	Lignin chemistry			x

¹: Advanced biofuels from FT processes and pyrolysis oil upgrading

- Heat and power markets well understood
- Advanced biofuels and bioethanol: NREAP basis
- PMCs 3-10: some quantitative information available
- PMCs 11-13: hardly any quantitative market outlooks available
 - Not for future biomass demand
 - Not at all for biomass purchasing power
- Solutions:
 - Future biomass demand: indicative 'what if' values to be chosen
 - Biomass purchasing power: show the impact of additional biomass demand on marginal biomass costs

14.15: Draft results for PMCs 4-9

- Current market size
- Estimates of future bio-based markets
- Related biomass demand

15.00: Discussion and feedback on the results and our assumptions

15.30: Draft results for PMCs 11-13

- Future products

15.50: Discussion on:

- Most promising biobased options
- The order of magnitude of market size we should expect
- Indicative biomass demands

16.20: Concluding remarks, closure

- **Presentation**
- **After each PMC we check for the amount of questions**
- **Questions and discussion after the entire presentation**
 - So that we can prioritise the PMCs that raise the most questions

Market review of BTX, biomethane, methanol, hydrogen, ethylene, mixed alcohols

Hamid Mozaffarian (ECN)

Marc Londo (ECN)



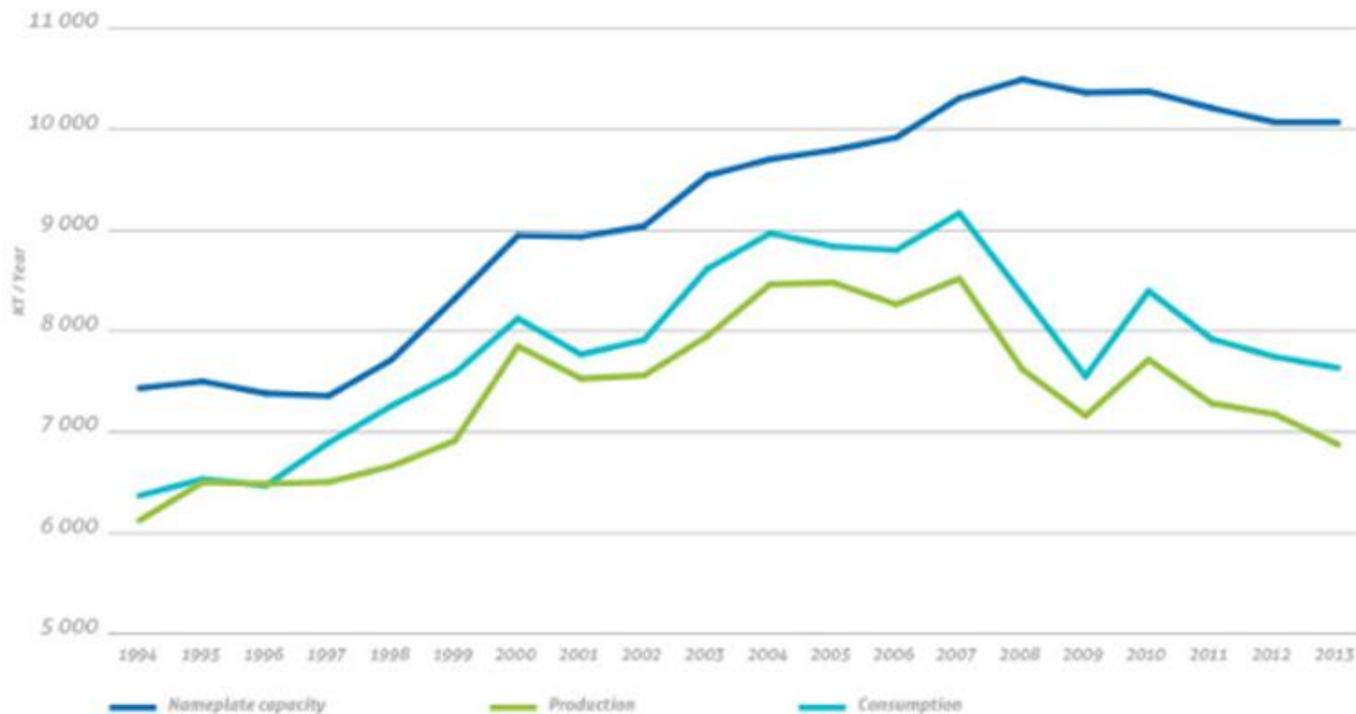
Considered product-market combinations (PMCs)

	Product	Market	Current	2020	2030
1	Heat	District heating	x	x	x
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3	BTX	Petrochemical industry		x	x
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6	Methanol	Transport, chemical industry		x	x
7	Hydrogen	Transport, (petro)chem. ind.		x	x
8	Ethylene	(petro)chemical industry			x
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11	C6 sugars	C6 chemistry			x
12	C5 sugars	C5 chemistry			x
13	Lignin	Lignin chemistry			x

BTX (aromatics)

Interm. Product	Interm. market	Final product	Final market
BTX	Petrochemical industry	Polystyrene	Chemical industry
BTX	Petrochemical industry	PET	Chemical industry
BTX	Petrochemical industry	Fuel additives (Toluene)	Transport sector

- **Global market aromatics: 5-10% growth per year**
- **US demand BTX (2010): 21 Mt**
- **Western Europe: benzene cap., prod., cons.**



- **Reforming of lignocellulosic biomass to fuels, with BTX as a byproduct**
- **Fermentation of carbohydrate-rich streams into isobutanol, followed by conversion to BTX**
- **Production of BTX from lignin**

- **Main product: bio-SNG**
- **Byproduct: BTX**
- **Optimized BTX production**
 - **efficiency product gas: 65%LHV**
 - **efficiency BTX: 15%LHV**
- **Optimized bio-SNG**
 - **efficiency bio-SNG: 70%LHV**
 - **efficiency BTX: 5%LHV**

Current and expected bio-based production Europe

	Unit	Value
Current production	kt	0
Expectation 2020 (2% of benzene production in Western Europe in 2013)	kt	130
Expectation 2030 (6% of benzene production in Western Europe in 2013)	kt	400

Biomethane

Interm. Product	Interm. market	Final product	Final market
		Biomethane	Grid
		Biomethane	Transport fuel

- **Anaerobic digestion of biodegradable MSW, sewage sludge, manure, wet wastes (farm and food wastes), and micro-algae, followed by a biogas upgrading step**
- **(indirect) gasification of biomass to a product gas, followed by product gas upgrading to biomethane (bio-SNG)**

Dutch biomethane ambition

	Unit	Value
Dutch ambition biomethane 2020	Billion m3	1
Dutch ambition biomethane 2030	Billion m3	3
Contribution gasification 2020	Billion m3	0.62
	PJ	22.33
Contribution gasification 2030	Billion m3	1.83
	PJ	65.86

Expected production of biomethane via gasification in Europe



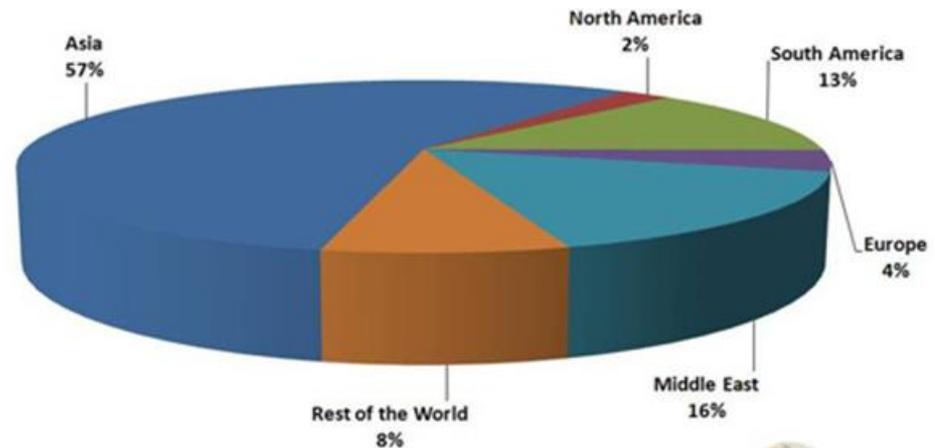
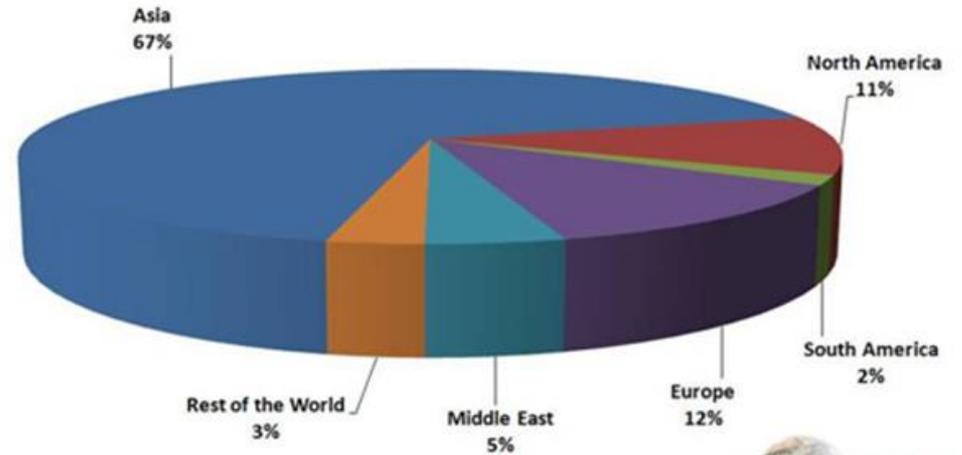
- Dutch biomethane ambition: upper limit for NL
- Currently limited MS active in bio-SNG production (NL, SE, AT)
- Expected production in Europe assumed to be equal to contribution to Dutch biomethane ambition via gasification

Methanol

Interm. Product	Interm. market	Final product	Final market
Methanol	Chemical industry	Methanol	Transport sector
Methanol	Chemical industry	MTBE	Transport sector
Methanol	Chemical industry	DME	Transport sector
Methanol	Chemical industry	FAME	Transport sector
Methanol	Chemical industry	Formaldehyde	Chemical industry
Methanol	Chemical industry	Acetic acid	Chemical industry

Methanol demand & supply

- Global demand/supply: 64,575 kt (2013E)



- **Syngas production via pressurized CFB gasification, followed by methanol synthesis**
- **Conversion efficiency methanol: 60%LHV**
- **Conversion efficiency usable heat: 15%LHV**

Current and expected consumption in Europe

	Unit	Value
Current global production (2013E)	kt	64575
EU consumption (2013E)	%global	12%
	kt	7749
EU expectation 2020 (reference scenario)	kt	7749
EU expectation 2030 (reference scenario)	kt	7749

Current and expected bio-based production in Europe

	Unit	Value
Current production	kt	0
Replacement fossil-based methanol in 2020	%	2%
Replacement fossil-based methanol in 2030	%	10%
Expectation 2020 (reference scenario 2020)	kt	155
Expectation 2030 (reference scenario 2030)	kt	775

Hydrogen

Interm. Product	Interm. market	Final product	Final market
Hydrogen	(Petro)chemical industry	Hydrogen	Transport sector
Hydrogen	(Petro)chemical industry	Hydrogenates	Transport sector
Hydrogen	(Petro)chemical industry	Ammonia	Chemical industry
Hydrogen	(Petro)chemical industry	Hydrochloric acid	Chemical industry

Current and expected production Europe

	Unit	Value
Current global production	BNm ³ /a	700
	PJ	7560
Current (2007) EU production	BNm ³ /a	0.9
	PJ	972
EU expectation 2020 (reference scenario)	PJ	1070*
EU expectation 2030 (reference scenario)	PJ	1170**

* 10% more due to increased hydrotreating at refineries and as fuel in the transport sector

** 20% more due to increased hydrotreating, as fuel in the transport sector, but also as fuel in fuel cells for stationary application

- **Biological routes**
 - fermentation of biomass to hydrogen
 - anaerobic digestion with methane reforming
- **Biomass gasification (HT, LT)**
- **Bio-photochemical conversion of photosynthetic micro-organisms, like microalgae**

Selected route

- **Biomass gasification (assumed conversion efficiency: 60%LHV)**

Current and expected bio-based production in Europe

	Unit	Value
Current production	PJ	0
Replacement fossil-based hydrogen in 2020	%	0.5%
Replacement fossil-based hydrogen in 2030	%	5%
Expectation 2020 (reference scenario 2020)	PJ	5.4*
Expectation 2030 (reference scenario 2030)	PJ	58**

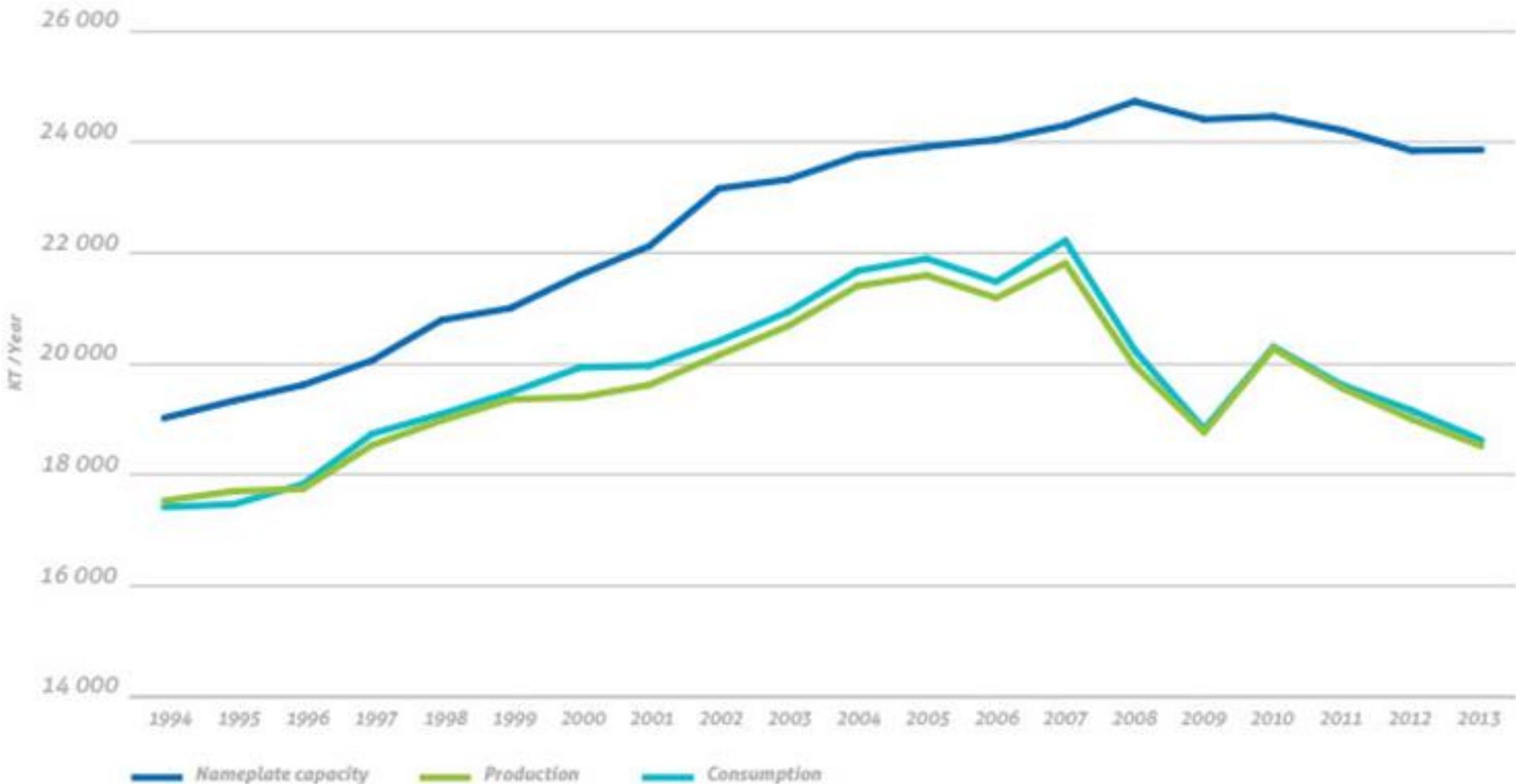
* Sufficient fuel for 400,000 hydrogen vehicles

** Sufficient fuel for 4.5 million hydrogen vehicles

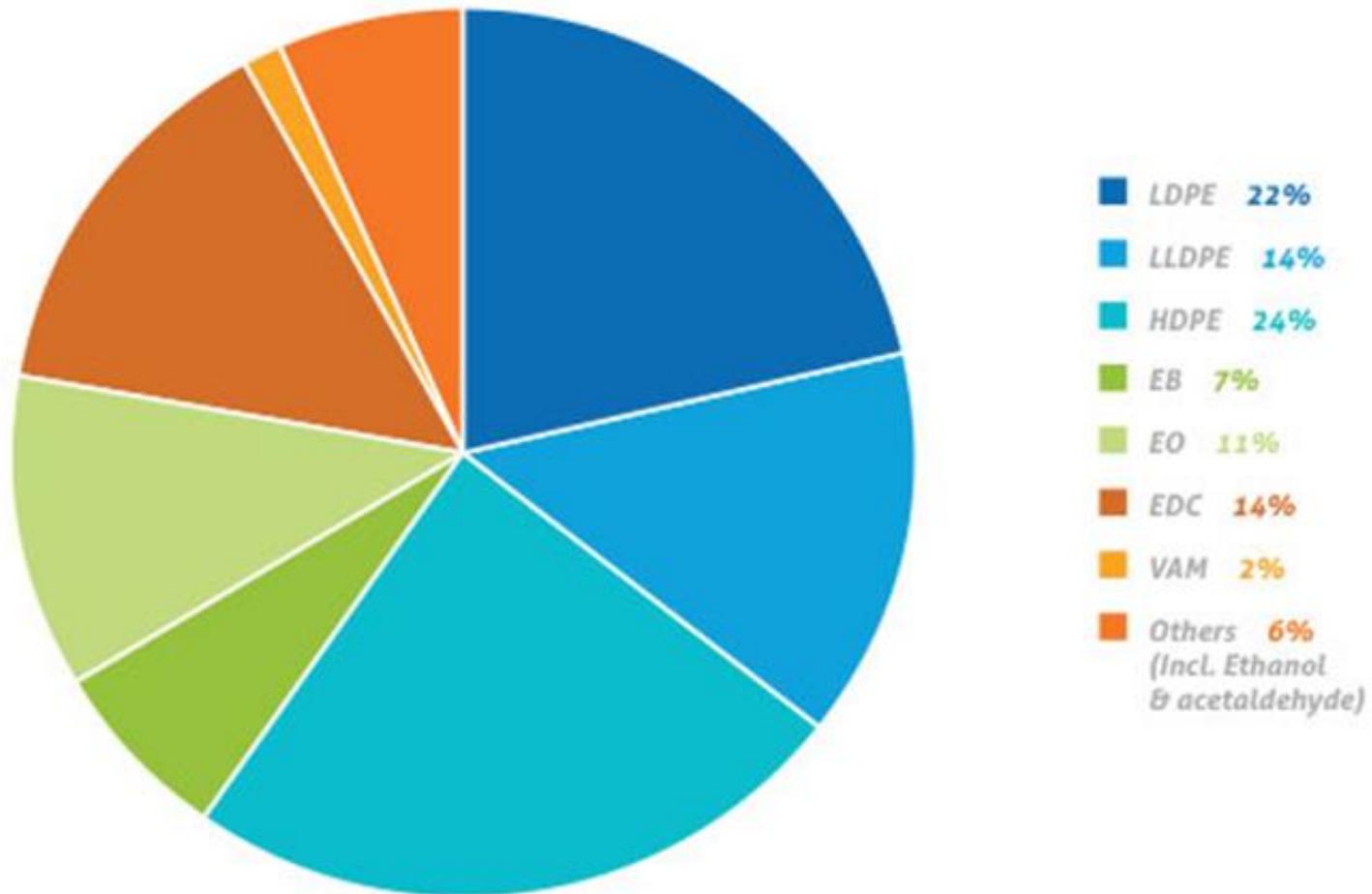
Ethylene

Interm. Product	Interm. market	Final product	Final market
Ethylene	(Petro)chemical industry	Polyethylene	Chemical industry
Ethylene	(Petro)chemical industry	Ethylbenzene	Chemical industry
Ethylene	(Petro)chemical industry	Ethylene oxide	Chemical industry
Ethylene	(Petro)chemical industry	Ethylene dichloride	Chemical industry

Market Western Europe



West European ethylene consumption by derivative 2013



- Dehydration of bioethanol (global prod. 420 kt/a)
- In Brazil based on sugarcane
 - bio-ethylene production already economically competitive
 - A plant producing 200 kt/a in operation
- In U.S.A. based on corn
- In Europe based on lignocellulosic biomass such as wood or straw
 - conversion eff. straw-to-ethanol: 36.5%LHV
 - Electrical eff. straw-to-ethanol: 6.6%LHV
- 1 t bio-ethylene requires 1.74 t bioethanol

Current and expected production in Western Europe

	Unit	Value
Current global production (2013E)	Kt/a	140,000
Current production Western Europe (2013)	Kt/a	18521
EU expectation 2020 (reference scenario)	Kt/a	18521
EU expectation 2030 (reference scenario)	Kt/a	18521

Current and expected bio-based production in Europe

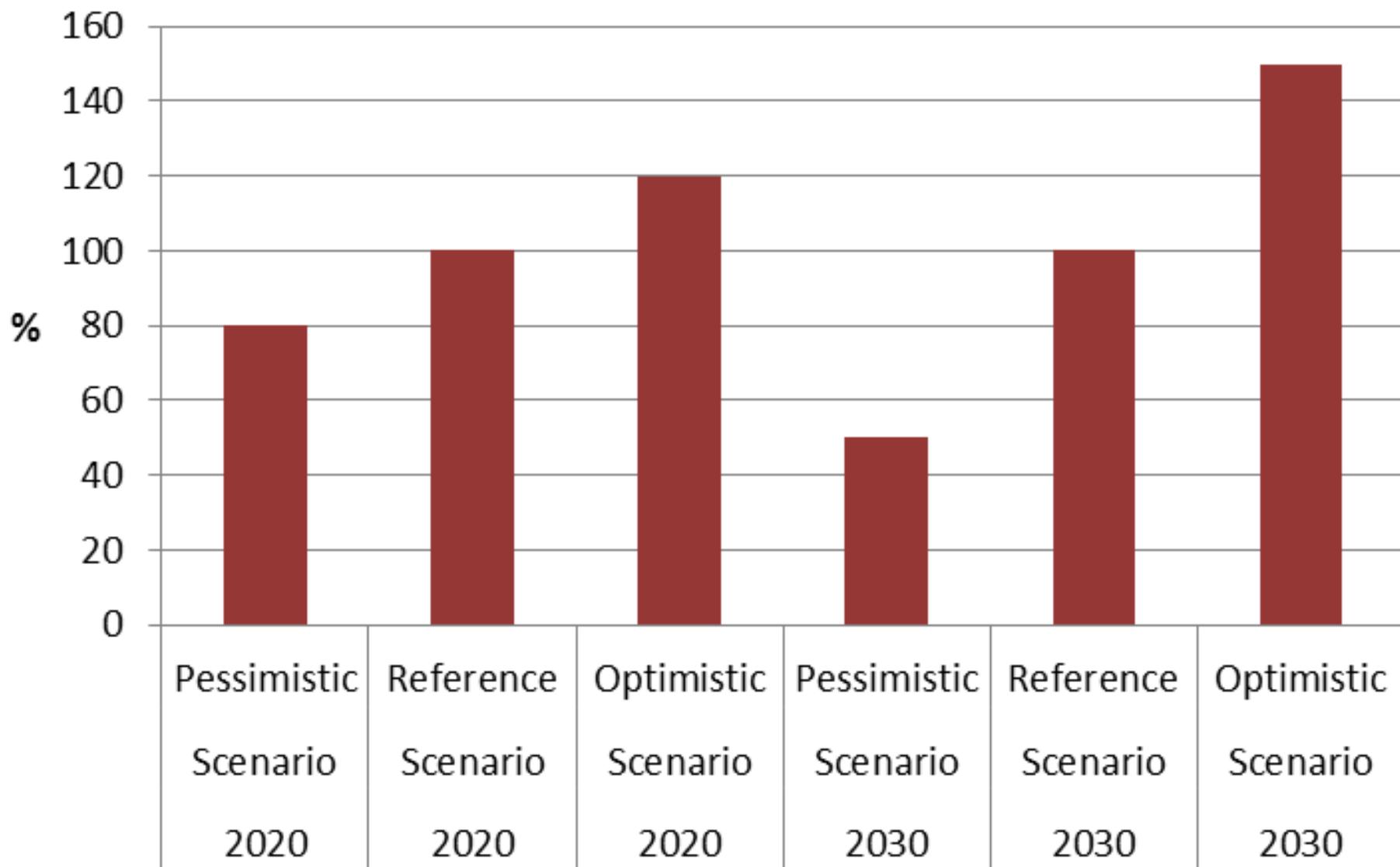
	Unit	Value
Current production	kt/a	0
Replacement fossil-based hydrogen in 2020	%	0%
Replacement fossil-based hydrogen in 2030	%	10%
Expectation 2020 (reference scenario 2020)	kt/a	0
Expectation 2030 (reference scenario 2030)	kt/a	1852

Mixed alcohols (via gasification)

		Selectivity (CO ₂ -free)
Temperature (°C)	300	
Pressure (bar)	140	
H ₂ /CO ratio	1.2	
mol% CO conversion (per pass) to:		
CO ₂	13.0%	-
CH ₄	4.5%	18%
C ₂ H ₆	0.5%	2%
Methanol	4.1%	16.4%
Ethanol	11.4%	45.6%
Propanol	3%	12%
Butanol	1.0%	4%
Pentanol & higher	0.5%	2%
Total	38%	100%

- **No data found on conversion efficiency of the process;**
- **The process is mostly developed in the USA (NREL), where the major focus lies on renewable alternatives for fossil-based gasoline;**
- **In Europe this process will compete with FT-diesel production via gasification of lignocellulosic biomass. The latter process is an important option for Europe w.r.t. production of 2nd generation biodiesel;**
- **Alternative process for EU: ethanol production via biochemical conversion of lignocellulosic biomass;**
- **Based on the above-mentioned remarks, it is not likely that the mixed alcohols process would be a promising process for Europe.**

Scenarios 2020 / 2030



Thank you for your attention !

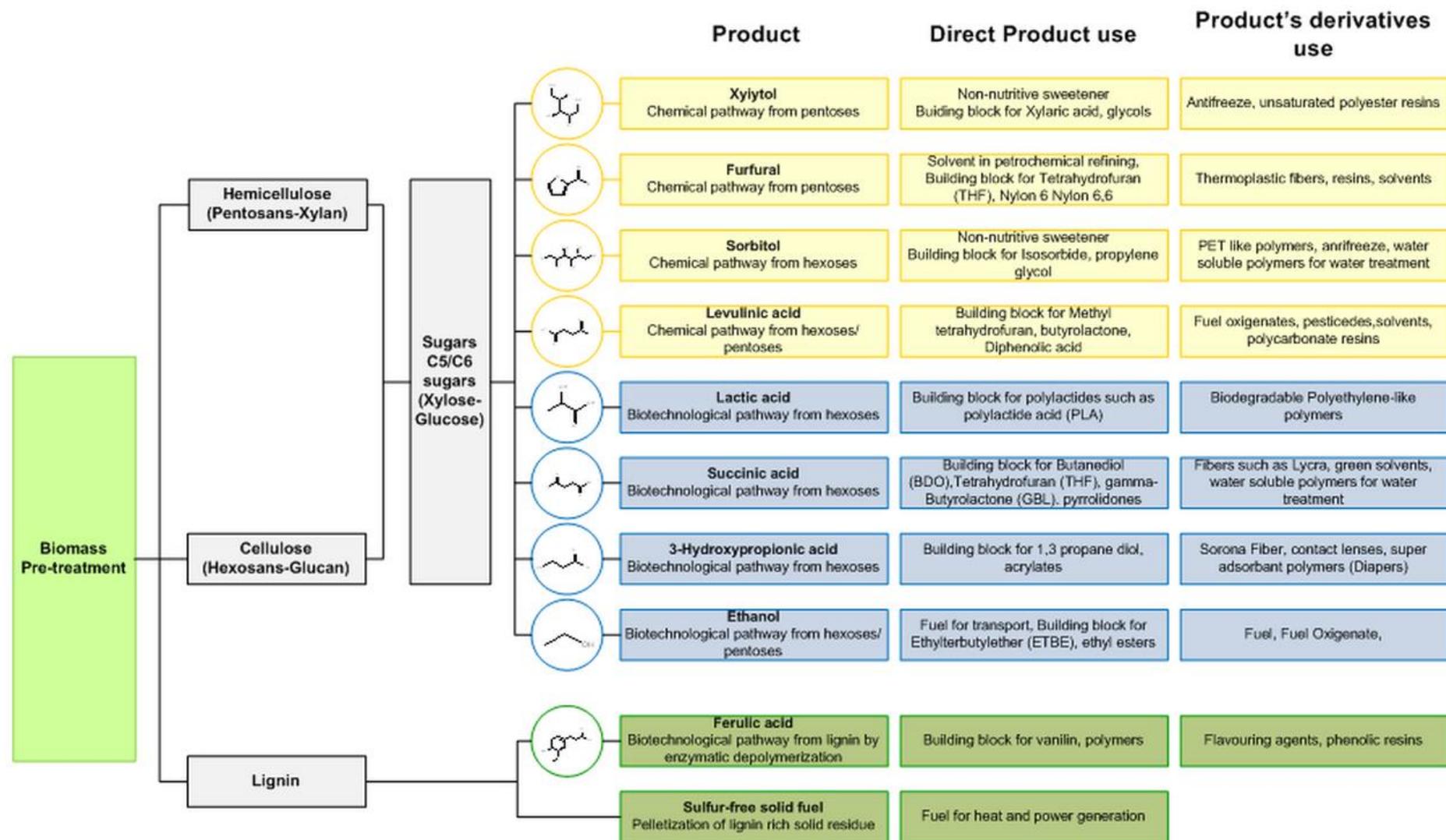


Market review of sugar-lignin platforms

Marco Pantaleo (IC)
Marc Londo (ECN)



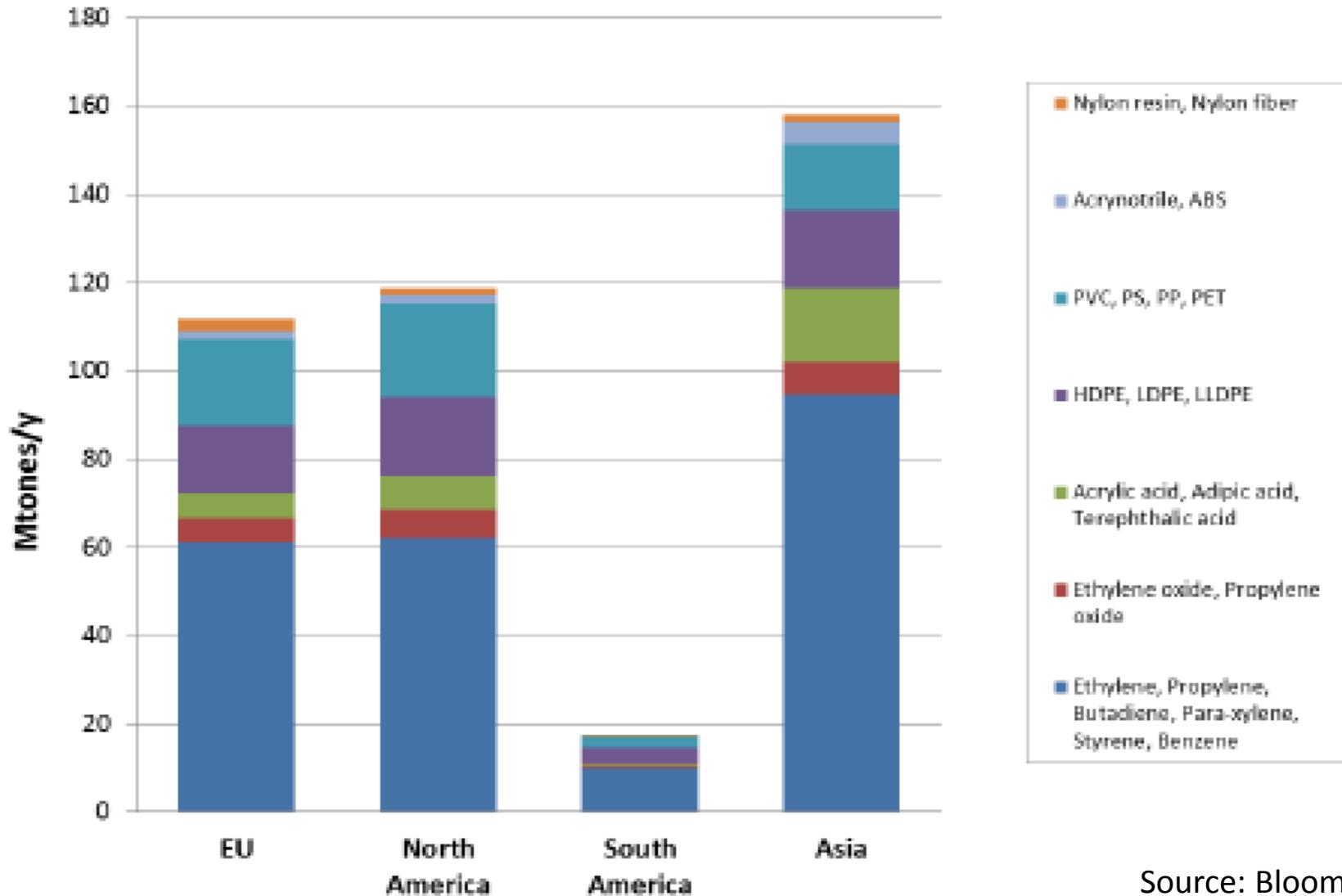
Sugar-lignin platform potential for value-added chemical production under the biorefinery concept



Key routes for bio-based chemicals

Interm. product	Interm. market	Final product	Final Market	Current	2020	2030
C6 sugars	Chemical industry	PLA (via lactic acid)	Food, chemicals			x
C4 sugars	Chemical industry	Butanediol and THF via succinic acid	Fibres, solvents, pharmaceutical			x
C5 sugars	Chemical industry	Nylon and furfural		x	x	x
C6 sugars	Chemical industry	Propane diol	Bio-plastics, textile fibres, paint industry			
C5 sugars	Chemical industry	Glycol or ethylene glycol (via xylitol)				

Production volumes (2013) of leading chemicals



Source: Bloomberg

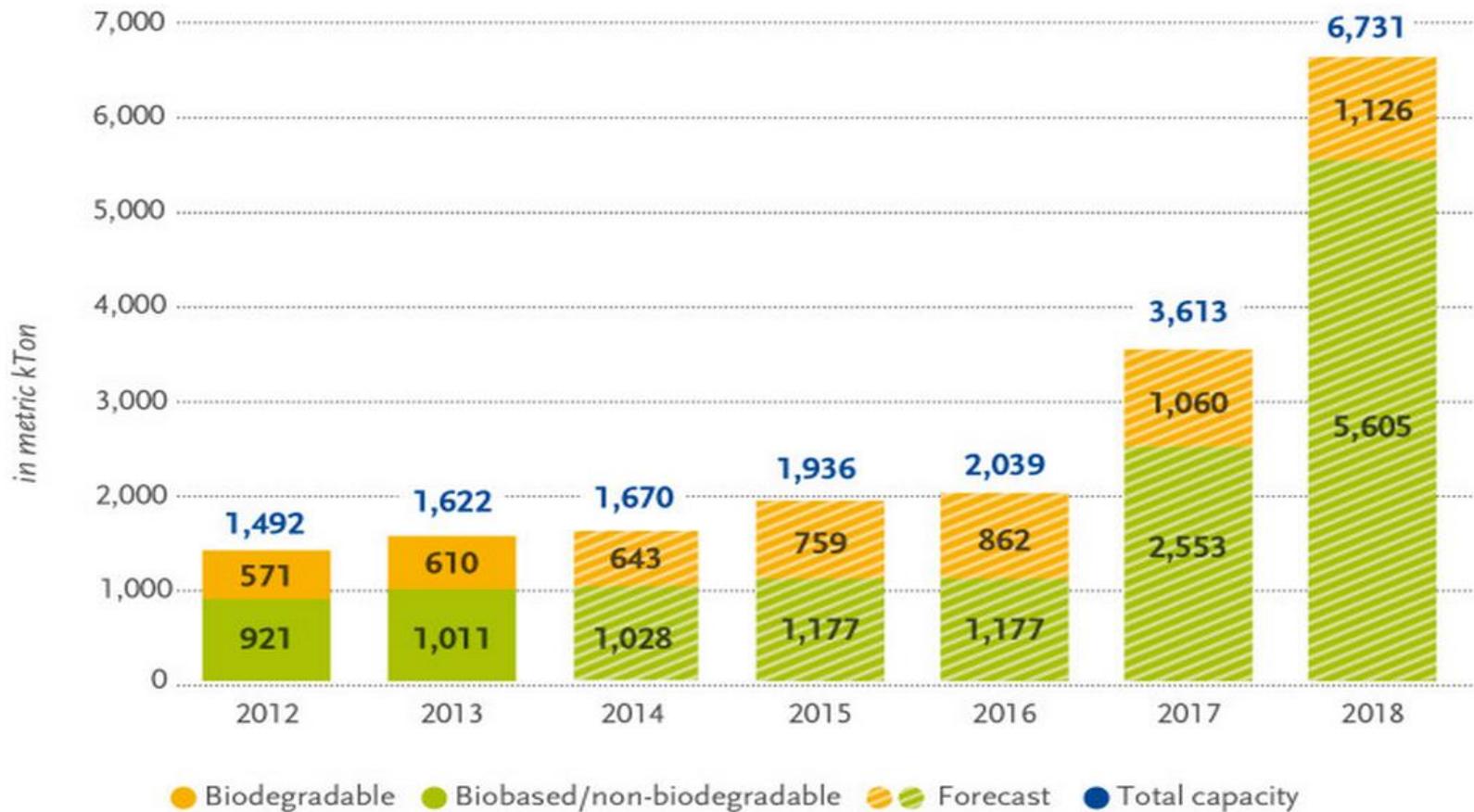
World wide market penetration from biobased products

Chemical Industry Sector	2010	2025
Commodity Chemicals	1-2%	6-10%
Specialty Chemicals	20-25%	45-50%
Fine Chemicals	20-25%	45-50%
Polymers	5-10%	10-20%

Source: USDA, U.S. Biobased Products Market Potential and Projections Through 2025

Global production capacity of bioplastics

Global production capacities of bioplastics

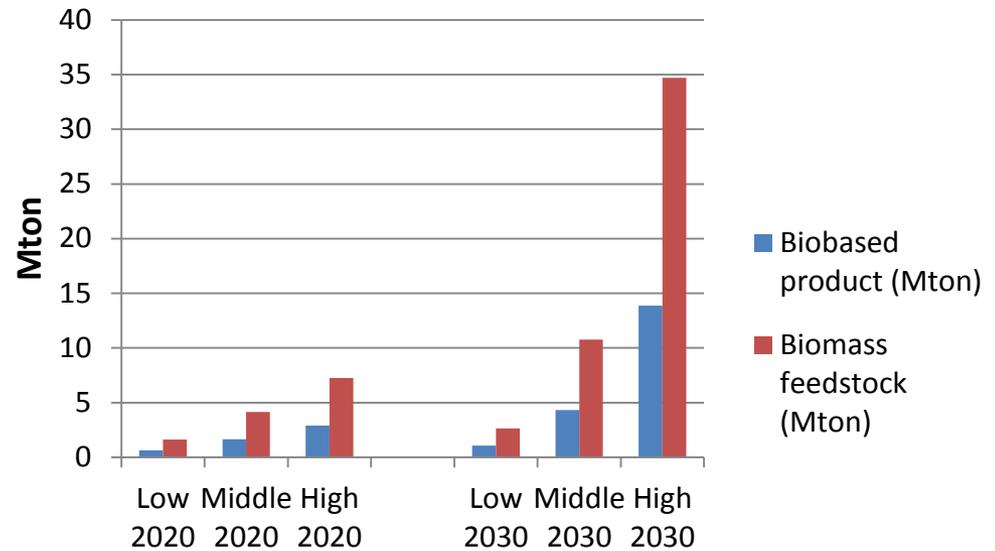


Source: European Bioplastics, Institute for Bioplastics and Biocomposites, nova-Institute (2014)
More information: www.bio-based.eu/markets and www.downloads.ifbb-hannover.de

- **2020: Wide range in indications:**
 - Global: 1.500-6.700 kton of product
 - Assume constant share of EU production
- **2030: no information**
 - Low: 10% growth 2008-2030
 - Middle: mean 2020, 10% growth 2020-2030
 - High: constant 24% growth 2014-2020-2030

Estimate of EU production and feedstock demand

- Large ranges:
 - ~factor 4 for 2020
 - ~ factor 10 for 2030
- This illustrates the major uncertainties in the prospects of this sector
- But it's a decent basis for an exploration of the impact of biomass demand.



	Biobased product (Mton)	Biomass feedstock (Mton)
Low 2020	0,7	1,6
Middle 2020	1,7	4
High 2020	3	7
Low 2030	1,1	3
Middle 2030	4	11
High 2030	14	35

For comparison

1 Mton of biomass, containing:

- **40% Cellulose**
- **30% Hemicellulose**
- **30% Lignin**

Can be converted into:

- **~220 kton (260 M l) ethanol (from C6/C5)**
 - Largest current plant ~50 M l
- **~400 kton succinic acid (from C6)**
 - Global market outlook bio-based succinics acid 2020: ~500 kton
- **~400 kton PLA (from C6)**
 - Global market outlook bio-based lactic acid 2020: ~500 kton

- Initial vote. Which scenario do you consider most plausible? Four options:
 - High scenario
 - Middle scenario
 - Low scenario
 - Other (motivate)
- Plenary discussion on data and motivation
- Final vote on same question.

Thank you for your attention !

