Legend:

Key slide

Question… — Key feedback asked

Data — Model input

Consultation feedback — Consultation feedback still to take into account

Global Calculator

Chemicals Workshop

Products & Manufacturing of the Global Calculator

Workshop of April 25th 2014 (version of July 17th)

Brussels

Department of Energy & Climate Change

CLIMACT

World Resources Institute

eit Climate-KIC

Climate Media Factory

北京人文创新国际能源科技中心 Energy R&D International

LSE The London School of Economics and Political Science

Imperial College London

EY Building a better working world

国家发展和改革委员会能源研究所 Energy Research Institute, National Development and Reform Commission

Preliminary information on this preread

Global Calculator

- This document
  - Supported workshop discussions of April 25th 2014
  - Addresses cement assumptions to refine the model
  - Other materials assumptions are addressed through sector specific consultations which are available through these links (steel, cement)
  - There is also a cross-sector analysis here
- The model was subsequently updated however it is still a work in progress as of July 2014. Some non processed expert feedback is noted within the document
- You are more than welcome to share feedback and we will try to include it in future version of the analysis. For this reason, this document will continuously update itself until September 1st
- All this documentation is open source

Global Calculator

Content

• **Introduction to the Global Calculator**	**9 -10h**
• Chemicals demand prospective	10-11h
• Chemicals manufacturing with lower energy intensity	11h30-13h

Introduction to the Global Calculator

Background

Expert & Literature review

Most introduction material is described in the cross sector document

- Background of the global calculator project
- Purpose of the workshop
- Team & model structure

The cross sectoral document is available here

Introduction to the Global Calculator

Background

Expert & Literature review

The following stakeholders have been provided with an opportunity to review the steel assumption

Global Calculator

Chemicals specific experts

International Council of Chemical associations
- Rachelina Baio

CEFIC (European Chemical Industry Council
- Peter Botschek
- William Garcia, Isabelle Chaput (cross sectoral)

CPCIF (China Petroleum and Chemical Industry Federation)
- Dr. Ye Jianhui

Japan PetroChemical Industry Association

Dechema
- Alexis Bazzanella, Florian Ausfelder

Steel Institute VDEh
- Marten Sprecher

BASF
- Susan Kuschel, Charlene Wall-Warren

Dow Chemicals
- Mark Weick, Keith (K) Kenebrew, Michael (MH) Mazor

All sectors (interaction planned later)

Think tanks
- WBCSD
- GIZ

Academic
- Tsinghua University
- UK Engineering and Physical Sciences Research Council (EPSRC), author of With both eyes open, Jonathan M Cullen
- LBNL (China Energy Group)

NGOs
- Greenpeace
- WWF

Legend
● Workshop presence

NOTE: (1) The stakeholders do not validate or endorse the assumptions described in this document, the assumptions are the sole choice of the Global Calculator team

Most referred to analysis has been taken into account to make this model

Global Calculator

Main sources used for this analysis

Organisation	Source
Cambridge	• With both eyes open
IEA	• Energy Technology Perspectives 2012, Pathways to a clean energy system • Chemical and Petrochemical Sector – Potential of Best Practice Technology and Other Measures for Improving Efficiency (IEA, 2009) • Summary report
ICCA	• Technology Roadmap: Energy and GHG Reductions in the Chemical Industry via Catalytic Processes (IEA, ICCA, Dechema) • The role of the chemical industry in achieving targets of IEA roadmaps on biofuel and bioenergy (2011)(ICCA and SRI International) • Building Technology Roadmap: The Chemical Industry's Contribution to Energy and GHG Savings in Residential and Commercial Construction Buildings roadmaps (2012) (ICCA)
CEFIC	• European chemistry for growth, Unlocking a competitive, low carbon and energy efficient future (2013)
Plastics Europe	• Plastics- the facts 2013
Utrecht University	• Ren, T. 2009. Petrochemicals from Oil, Natural gas, Coal and Biomass: Energy Use, Economics and Innovation. PhD
McKinsey	• McKinsey cost abatement curves v2.1 • Manufacturing the future: the next era of growth and innovation (2012)
Ecofys	• SERPECC studies
European Climate change Foundation	• Europe's low carbon transition: Understanding the challenges and opportunities for the chemical sector (2014)
Other	• Chemical Industry of the Future: New Process Chemistry Technology Roadmap, July 2001 • Catalysis - a key technology for sustainable growth"
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

Global Calculator

Content

Content	Time
Introduction to the Global Calculator	9-10h
Chemicals demand prospective	**10-11h**
Chemicals manufacturing with lower energy intensity	11h30-13h

Global Calculator

Chemicals demand perspectives

Current situation

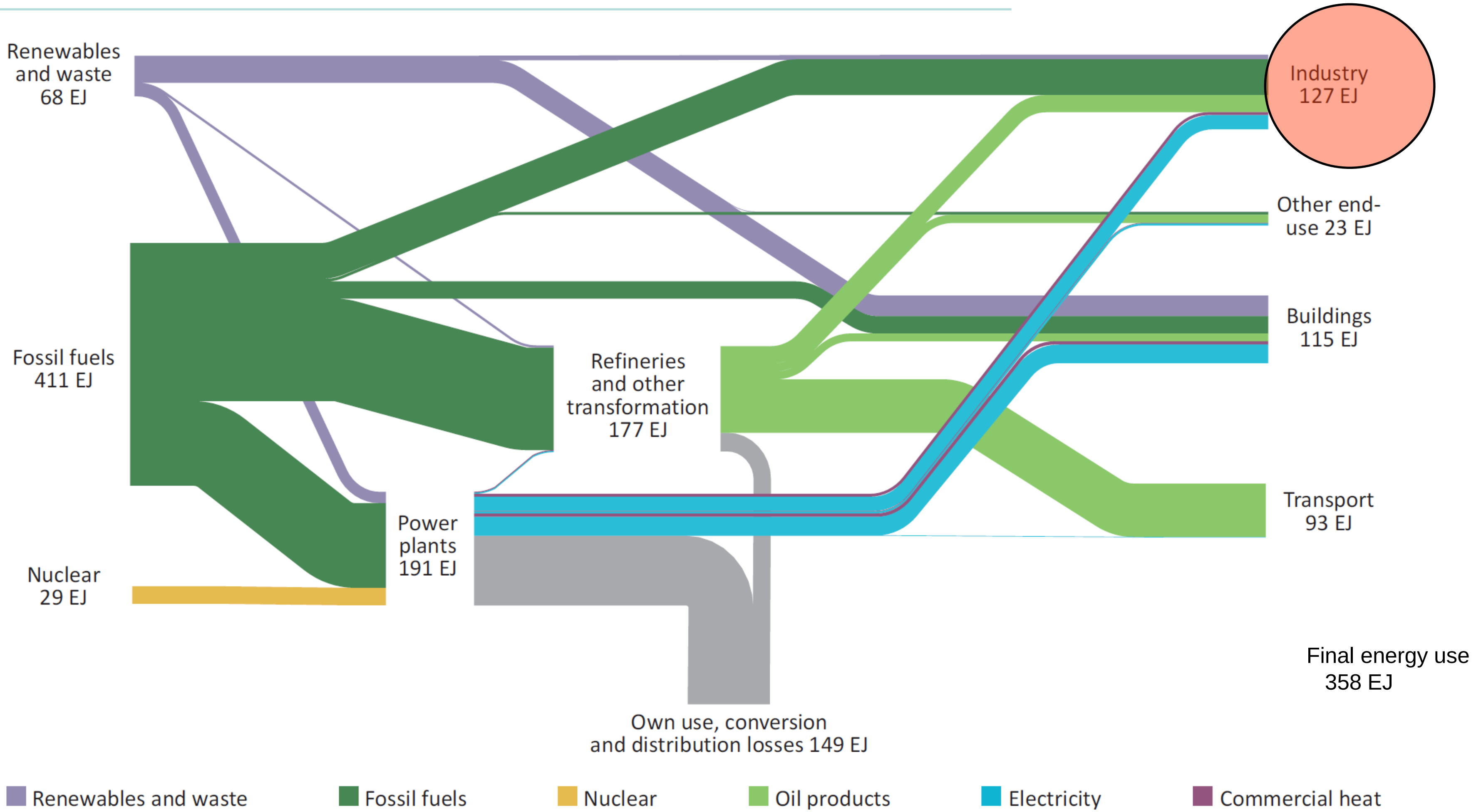
Chemicals demand drivers

Resulting chemicals demand at constant technology

Industry is ~35% of final energy use, it mainly relies on fossil fuels

Global Calculator

Energy Sankey in 2009, (EJ)



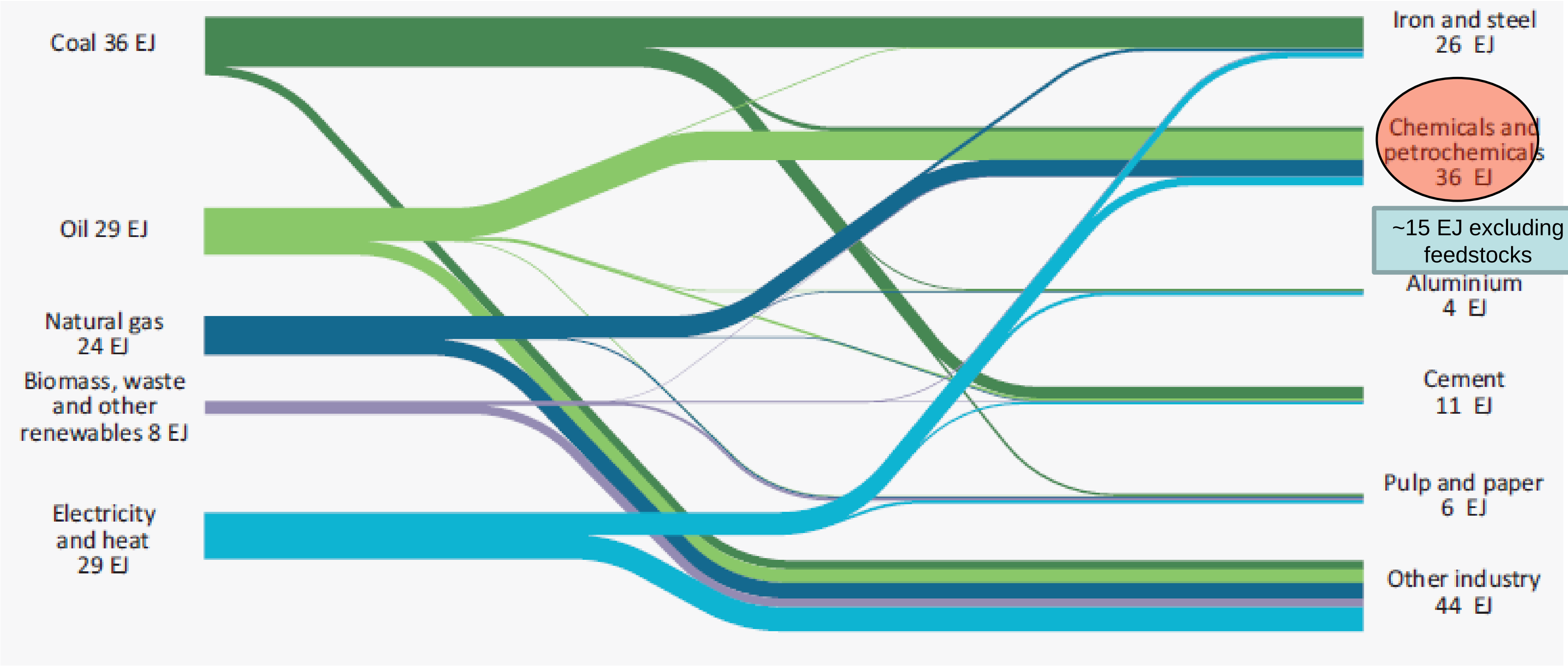
SOURCE: ETP 2012, IEA

NOTES: (1) Worldsteel recently raised the steel specific energy consumptions, this is not yet reflected by this picture
(2) Energy consumption is dominated by fossil fuels in all sectors

Chemical s & petrochemicals represents ~30% of the industry energy use, it also mainly relies on oil

Global Calculator

Energy Sankey in 2009 for the industry , (EJ)



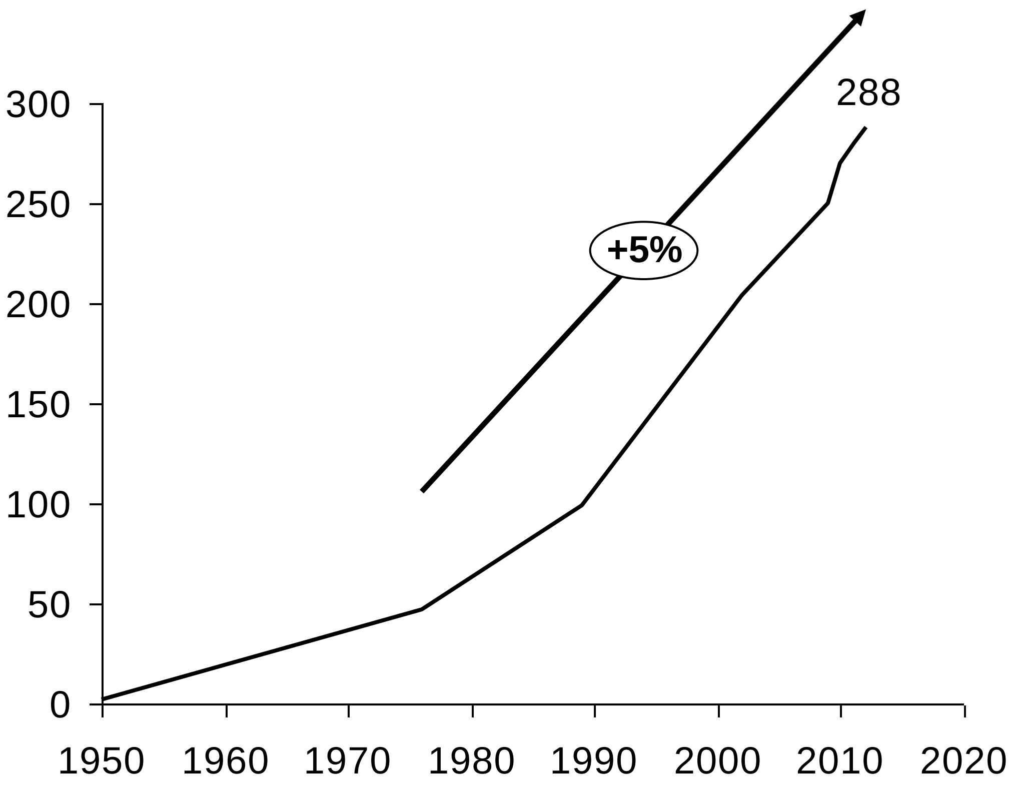
SOURCE: ETP 2012, IEA

NOTES: (1) Worldsteel recently raised the steel specific energy consumptions, this is not yet reflected by this picture
(2) Energy consumption is dominated by fossil fuels in all sectors

Chemicals demand has experienced a strong growth (5% CAGR) since the 1980s

Global Calculator

World Plastics production [3]
(M tons)



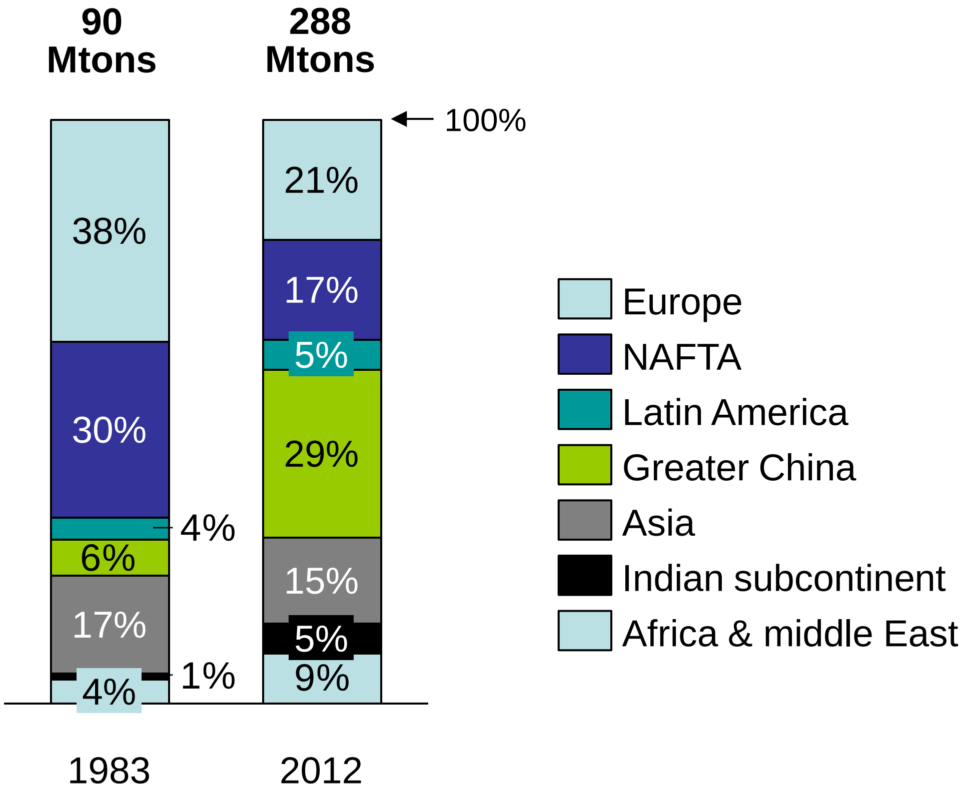
- More than 95% of all manufactured products rely on chemistry [2]
- While growth has levelled off in some industrialised counties, production in China and other emerging economies continues to increase rapidly [1]

SOURCE : (1) IEA ETP 2012 (2) ICCA, 2010), (3) PlasticsEurope (PEMRG) / Consultic via Plastics Europe Association of Plastics manufacturers

Plastics demand is moving east

Global Calculator

Evolution of demand per region
(M tons)



- Consumption of plastics isn't averaged uniformly around the world:
  - Europe, Japan & the US consume ~120kg/ person/year
- In the UK 11kg for plastics packaging

NOTE: This regional segmentation will differ from production estimations (e.g. Europe is an exporter)
SOURCE: Applied Market Information Ltd., Bristol, England

Chemicals demand perspectives

Current situation

Chemicals demand drivers

Resulting chemicals demand at constant technology

1

The analysis starts from the demand for products and derives material production and resource use

Global Calculator

Value chain | **Illustrations**

Resources

Materials analysis: Rare materials · Iron ore · Sand

Energy analysis: Uranium · Fossil hydro-carbons · Biomass

Materials

Steel · Cement · Aluminium · Chemicals · Pulp & paper

Products

- Taking advantage of the global scope, the materials analysis can include embedded emissions and resources impact
- Part of the product demand is a model input, another is generated by the requirements of other sectors

1 Output from the chemical industry covers three wide ranges of products

Global Calculator

Base chemicals

- Acrilates
- Adipic acid
- Amines
- Ammonia
- Aniline
- Benzene
- Butadiene
- Caprolactam
- Ethylene
- Ethylene oxide
- Formaldehyde
- Hydrogen
- Mono vinyl chloride
- Nitric acid
- Propylene
- Styrene
- Sulfuric acid
- Toluene
- …

Specialty chemicals

- Adhesives
- Agrichemicals
- cleaning materials
- cosmetic additives
- construction chemicals
- Elastomers
- Flavours
- food additives
- Fragrances
- Industrial gases
- Lubricants
- Polymers
- Surfactants
- Textile auxiliaries
- …

Consumer chemicals

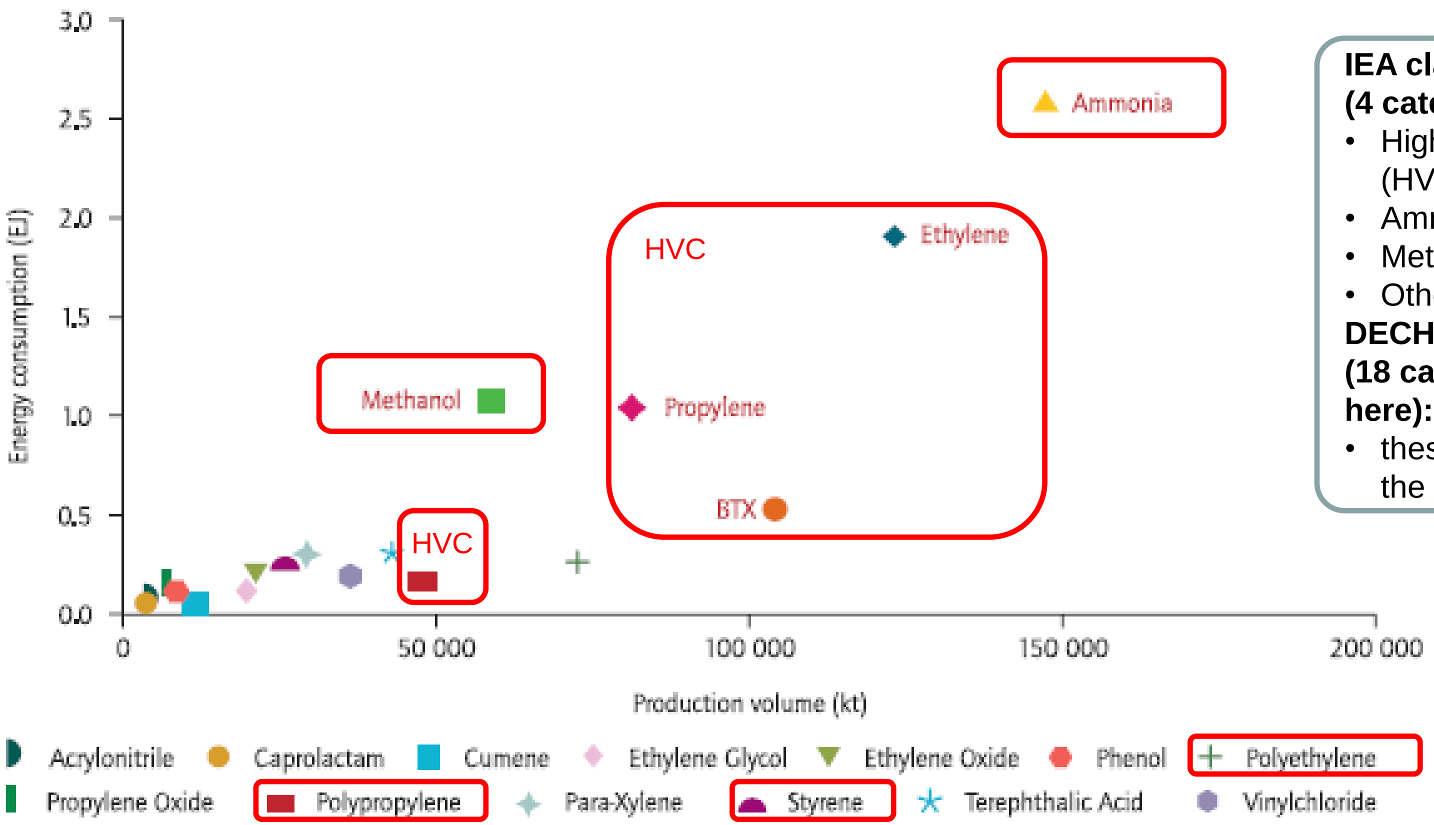
- Automobiles
- Cleaning materials (e.g. detergents)
- Cosmetics (e.g. Soaps)
- Electronic gadgets
- Materials used to construct home
- Paints & coatings
- Plastics
- …

SOURCE: Climact analysis

1 3 categories (used by the IEA) cover most of the chemical production & energy consumption

Global Calculator

Energy consumption and volume production of chemical products
(EJ, Kt)



IEA classification (4 categories):

- High Value Chemicals (HVC)
- Ammonia
- Methanol
- Other chemicals

DECHEMA classification (18 categories (illustrated here):

- these represents 75% of the sector GHG emissions

Covered by 3 IEA categories

NOTE: Energy consumption for olefins in this figure represents that of the steam cracking process
SOURCE DECHEMA

HVC drivers

HVC demand is modelled through plastics demand[1]

Plastics materials characteristics (including various alloys and treatments)

Diversity	Plastics encompass a broad range of materials with diverse composition and treatments. This leads to a very diverse set of properties
Mouldability	One common characteristic of plastics is the ability to be moulded [2]
Recycling	Some of the plastics can be recycled but not all (to simplify the thermoplastics can be reprocessed while the thermosets get their properties once and for all) Some are biodegradable and this is not directly correlated to the fact they are made of bioplastics The diversity of their composition makes recycling complex
Strength	Some plastics can be stronger than most other materials available. They can be resistant to traction (e.g. fibres) and compression (e.g. blocks). Hybrid mixes combine the advantages of both
Light	Some plastics can be lighter than most other materials
Durability	Some plastics can keep their properties for a very long time and be resistant to chemical reactions

It is this possibility to reach a wide range of characteristics which explains the strong demand for plastics

NOTE: (1) Aromatix (BTX) are HVC but are not plastics
(2) The word plastics comes from πλαστικος which means « can be moulded

SOURCE: with both eyes open

1

HVC drivers
A large variety of plastics compositions are available;
& for each, properties can then be modified by treatments

Global Calculator

Plastics types (non-exhaustive)

Plastic type		Market share(3)	Properties	Applications
HDPE	High density polyethilene	12%	Stronger , stiffer , chemical resistance	Containers, caps, toys, pipes
LDPE (LLDPE)	Low density polyethilene	17,5%	Flexible, can be transparent, chemical resistance	packaging (bags & films), bottles; wire cables
PP	Polypropylene	18,8%	Tough & flexible, chemical resistance	Textiles, stationary, automotive components (e.g. car bumper), packaging
PS	Polystyrene	7,4%	Light	Protective packaging, glass frames, yoghurt pots
PVC	Polyvinylchloride	10,7%	Cheap & versatile, chemical resistance (e.g. corrosion)	Boots, window frames, pipes, fittings, canoes, garden hoses
ABS	Acrylonitrile butadiene styrene		Tough & easy to mould, glossy, shiny finish	Helmets, machinery casing, children toys (lego)
PMMA	Polymethylmethac rylate)		Tough transparent plastic	Windows & safety spectacles
PA	Polyamide		Tough	Nylon, car tires, ropes, tubing
PET	Polyethylene terephthalate	6,5%	Resistant	Beverage bottles
PUR	Polyurethane	7,3%	Strength	Sponges, Lycra, spandex, gears, bearings & wheels
PLA	Polylactic acid		Bioplastic	Wide, also medical implants
Other		19,8%		

Properties can also be modified through the use of additives, fillers, heat treatment processes and mechanical deformation

NOTE: (3) Of European demand
SOURCE: With both eyes open, (3) PlasticsEurope (PEMRG) / Consultic via Plastics Europe Association of Plastics manufacturers

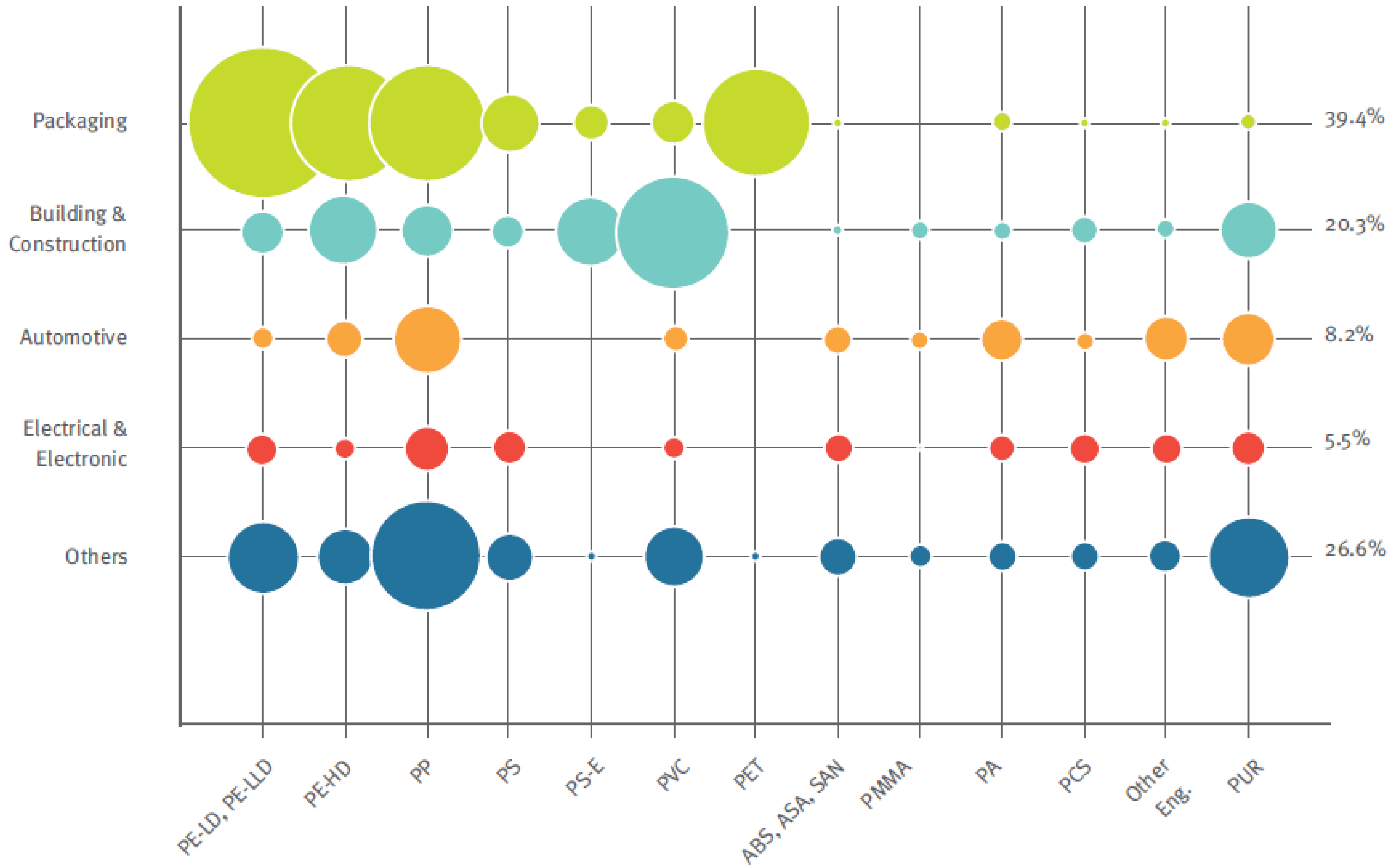
1

HVC drivers

There is no simple correlation between plastic types and applications

Global Calculator

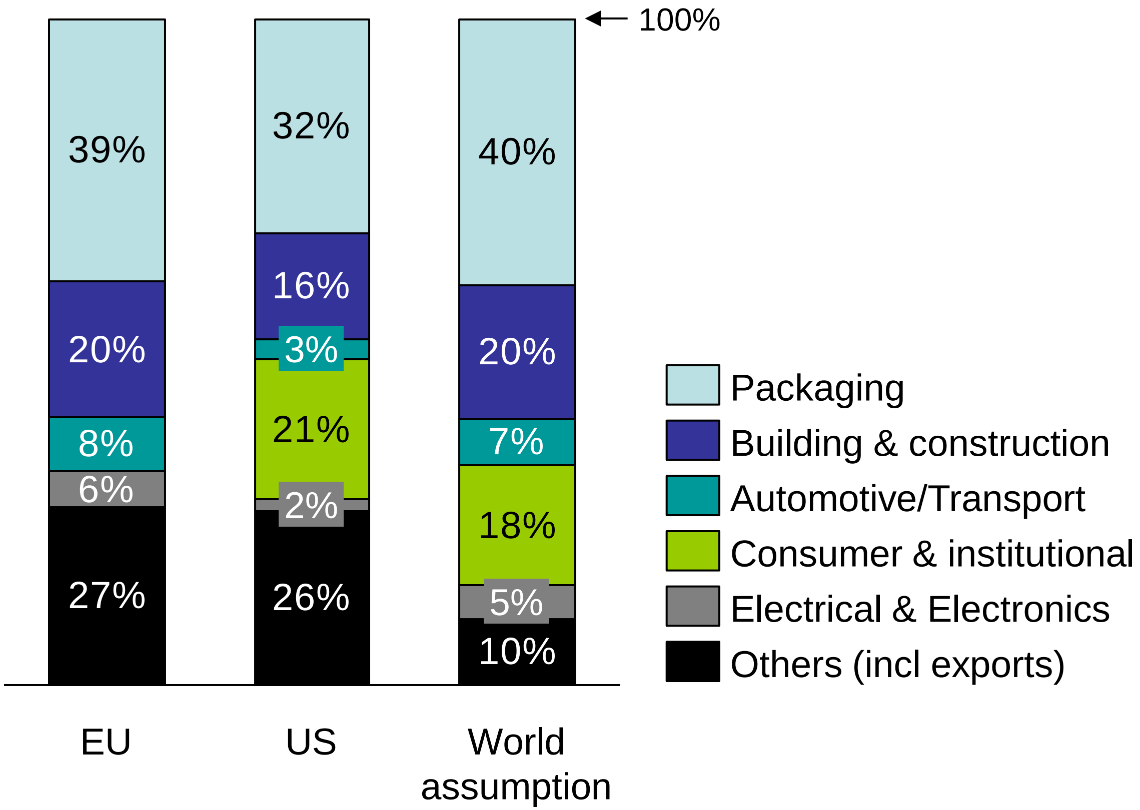
Plastics demand by segment and resin type
(2012, European market EU 27+CH,%)



SOURCE: PlasticsEurope (PEMRG) / Consultic / ECEBD

HVC drivers
Plastics demand drivers are being identified

Plastics demand drivers
(%)



In the Global calculator, it can be linked to:

- Packaging (40%)
- Appliances (35%)
- Transport (5%)
- Buildings (20%)

NOTE: World segmentation is a Climact estimate based on the EU and US data

SOURCE: With both eyes open, PlasticsEurope (PEMRG) / Consultic / ECEBD for 2012

1

Ammonia drivers

Global Calculator

Rationale for ammonia demand

- Ammonia contributes to the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers. About 50% of the world's food production relies on ammonia-based fertilisers [(1)]
- Ammonia is used for the synthesis of many pharmaceuticals
- Ammonia is used in many commercial cleaning products
- Emissions caused by the application of fertilizers are assessed in the Land/Food/Biomass section of the global calculator

- Fertilizer consumption evolution is linked to the evolution of yield in the agriculture sector as follows:
- % change in fertilizer =
  - 30%[(2)]
  - *% change in yield
  - *% change in food production
- This way the fertilizer production is even linked to the consumer food habits (which drive food production demand)

NOTE: (2) Factor reflects yield growth can evolve for a number of factors (genotype + environment), e.g., irrigation, better farm management and crop varieties.

SOURCE: (1) Erismann, 2008, Global Calculator workshops

Global Calculator

Methanol drivers

Rationale for methanol demand

Making other chemicals	• The largest use of methanol by far • ~40% of methanol is converted to formaldehyde, and from there into products as diverse as plastics, plywood, paints, explosives, and permanent press textiles
Fuel	• Methanol is used on a limited basis to fuel internal combustion engines
Other uses	• Solvent • antifreeze in pipelines and windshield washer fluid

In the Global calculator, it can be linked to the HCV evolution (and therefore to the same drivers)

SOURCE: Global Calculator analysis

In a later model version, Plastics Europe could be contacted to validate this allocation as well as the total production of other chemicals

1

Today, this is the model generated demand, it w evolve based on Product demand defined by the other sectors

| Calculator

Products		Amounts (units, 2011)	Intensity (tons/product/year)				Chemicals (M tons, 2011)[(2)]			
			HVC	Ammonia	Methanol	Others	HVC	Ammonia	Methanol	Others
Transport	Cars & light trucks	113 (M Vehicles)	0,12	-	0,02	0,07	14	-	3	8
	Trucks	5,7 (M Vehicles)	0,4		0,07	0,24	2		0,4	1
	Ships	1 (k units)	-	-	-	-	-	-	-	-
	Batteries (not modelled in v1)	-	-	-	-	-	-	-	-	-
Buildings	Buildings residential	3930 (km² [(4)])	0,014	-	0,002	0,009	54	-	10	35
	Buildings Others	830 (km² [(4)])	0,012	-	0,002	0,008	10	-	2	6,5
	Appliances	250 (Mt)	0,438	-	0,08	0,29	111	-	20	73
Consumer goods	Packaging	530 (Mt)	0,24	-	0,04	0,16	128	-	23	84
	3D Printing (not modelled in v1)	-	-	-	-	-	-	-	-	-
	Population (Fertilizers)	7,0 Bln people	-	23 kg/person	-	-	-	164	-	-
Energy	Windmill (blades in carbon fibre)	17,600 2MW turbines	30 tons	-	-	-	0,5	-	-	-
	PV panels	160 M m²	5kg /m²	-	-	-	0,7	-	-	-
Total	**Total**	**/**	**/**	**/**	**/**	**/**	**320**	**164**	**58**	**208**

Model demand drivers

Legend

Representative Products

Niche product (for the analysis)

NOTES: (1) High Value chemicals typically include Ethylene, Propylene, BTX aromatics(benzene, toluene and mixed xylenes)

(2) Linking product to material demand for a same year is a modelling simplification; in reality, the material production can happen several years before the product delivery

(4) Of ground surface

Global Calculator

Chemicals demand perspectives

Current situation

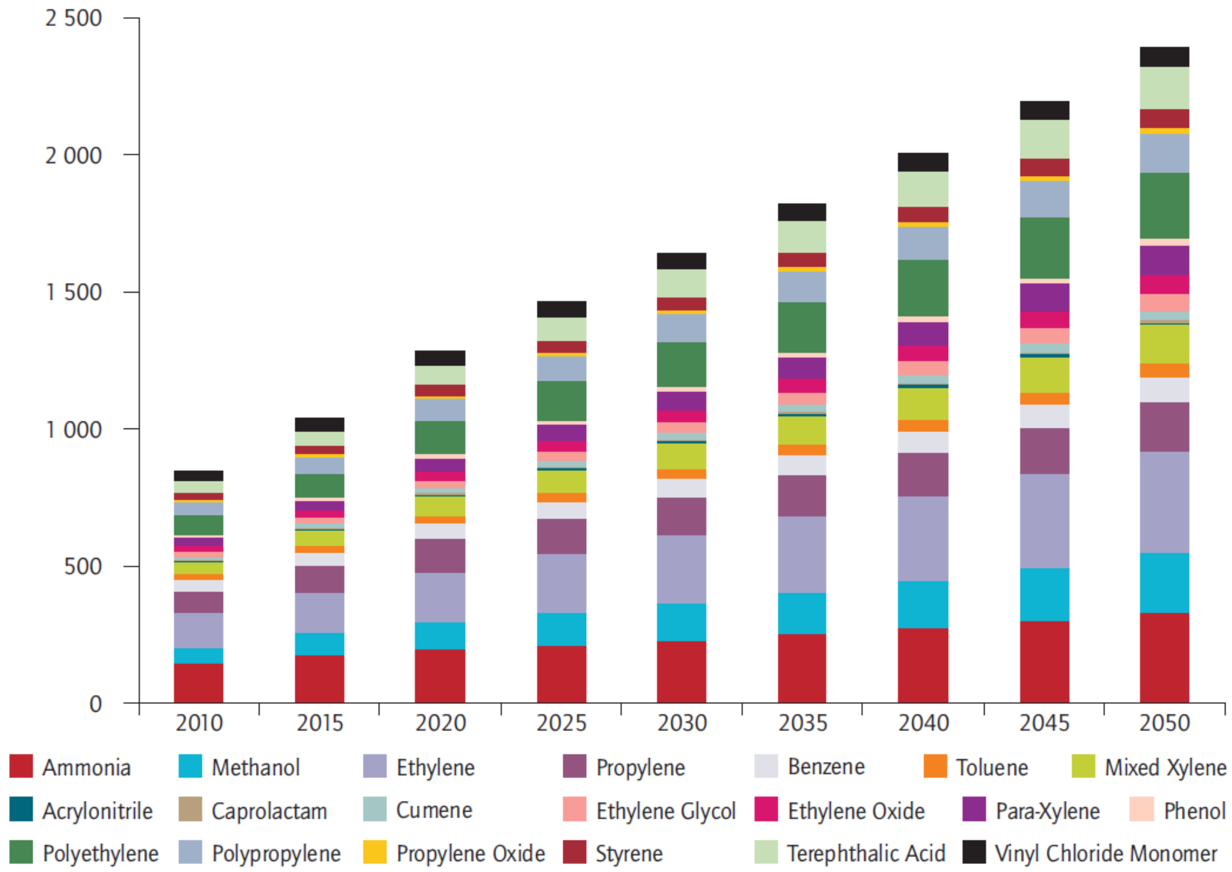
Chemicals demand drivers

Resulting chemicals demand at constant technology

1

Significant growth is expected in production volume of the chemical and petrochemical sector

Chemical production volumes forecasts
(Mt)



SOURCE: ICCA Catalytic roadmap (data from SRI consulting (IHS)

1

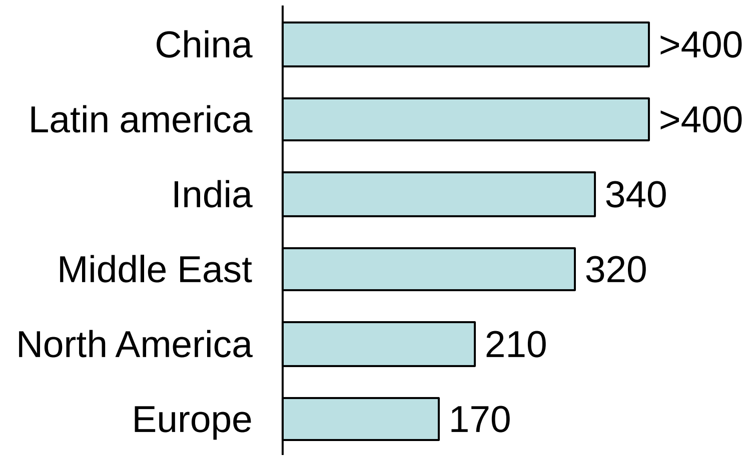
Strong variances are expected between regions (1/2)

Global Calculator

Regional variability

- The largest growth in HVC demand is expected to occur in Africa and Middle East. China already biggest chemical producer worldwide
- Demand for chemical products increases sharply in fast-developing countries
- Likely strongest increase in bulk-chemical production outside Europe
- This regional outlook could be positively impacted by shale gas in some locations (e.g. United States Gulf Coast) [2]

Growths per region to 2050
(%)[2]



SOURCE: (1) IEA ETP 2012 (2) ICCA catalytic roadmap

1 Strong variances are expected between regions (2/2)

This is because the competitiveness levels strongly differ

Global Calculator

Level of competitiveness: High / Medium / Low

	Conventional economics		Other crucial factors		
Region	Cost position	Local demand growth[1]	Access to skilled labor, skilled labor[2]/ education[3]	Business climate, ease of doing business[4]/ corruption[5]	Integration/ resilience
EU27	25-50% disadvantage compared to other regions	1-3%	17 / 14	21 / 12	Overall, highly integrated and mature industry
US	10-40% advantage vs. Europe	2-4%	6 / 25	4 / 19	Highly integrated and mature industry, new investments ongoing
China	Higher cost than EU for some products, up to 50% lower cost for others	>10%	44 / 54	96 / 80	Less mature industry, not yet fully optimized
Saudi Arabia	Cost advantage (up to >50%) for bulk chemicals	~8%	31 / 39	26 / 63	Less mature industry, more narrow range of chemicals produced

- Investments are required to improve energy efficiency and processes
- Investments will be harder to obtain in regions with a lower competitiveness level

NOTE: Europe represented by Germany in rankings;
1 Calculated as production minus net exports between 2011-2016 using data from IHS Economics;
2 Rank in “Availability of scientists and engineers”, World Economic Forum (WEF);
3 Rank in “Quality of the Education System”, WEF;
4 Rank in the World Bank’s ease of doing business index 2013;
5 Rank in Transparency International’s corruption perception index 2013
SOURCE: World Bank Doing Business 2014; HIS Economics; WEF Global Competitiveness Report 2013-2014; Transparency International

1

Rationale for expected 2050 chemicals demand

Global Calculator

Rationale for assessing future steel production

Population evolution	7 billion people in 2010[3] 8-10 billion people in 2050 [3]
Demand per capita evolution	• HVC: from 44 kg/capita in 2010 to 87-105 kg/capita in 2050 [1] • Ammonia: from 24 kg/capita in 2010 to 28-32 kg/capita in 2050 [1] • Methanol: from 8 kg/capita in 2010 to 22-27 kg/capita in 2050 [1] • Other chemicals: are assumed to follow the trend of HVC
Regional changes	• The largest growth in HVC demand is expected to occur in Africa and Middle East • European growth is expected to be much more modest • Shale gas could have a strong positive impact on US demand
Market segment changes	No major shift between transport, infrastructure and buildings is expected But plastics expected to replace other materials in each of these sectors

In conclusion	• IEA ETP 2012 forecast:
	  • 635-872 M tons HVC in 2050
	  • 268-310 M tons Ammonia in 2050
	  • 213-254 M tons Methanol in 2050

SOURCE: (1) IEA ETP 2012 (2) With both eyes open

1

Rationale for expected 2050 chemicals demand (2/2)

Global Calculator

Technologies & Products	Evolution driven by	Assumptions (if by product demand)
Packaging	Product demand lever	80-110% evolution by 2050
Consumer products	Product demand lever	80-110% evolution by 2050
Cars & light trucks	Transport model	/
Windmill (blades in carbon fibre)	Estimate from the supply sector	/
PV	Estimate from the supply sector	/
Buildings	Building model	/
Fertilizers	Land model	/

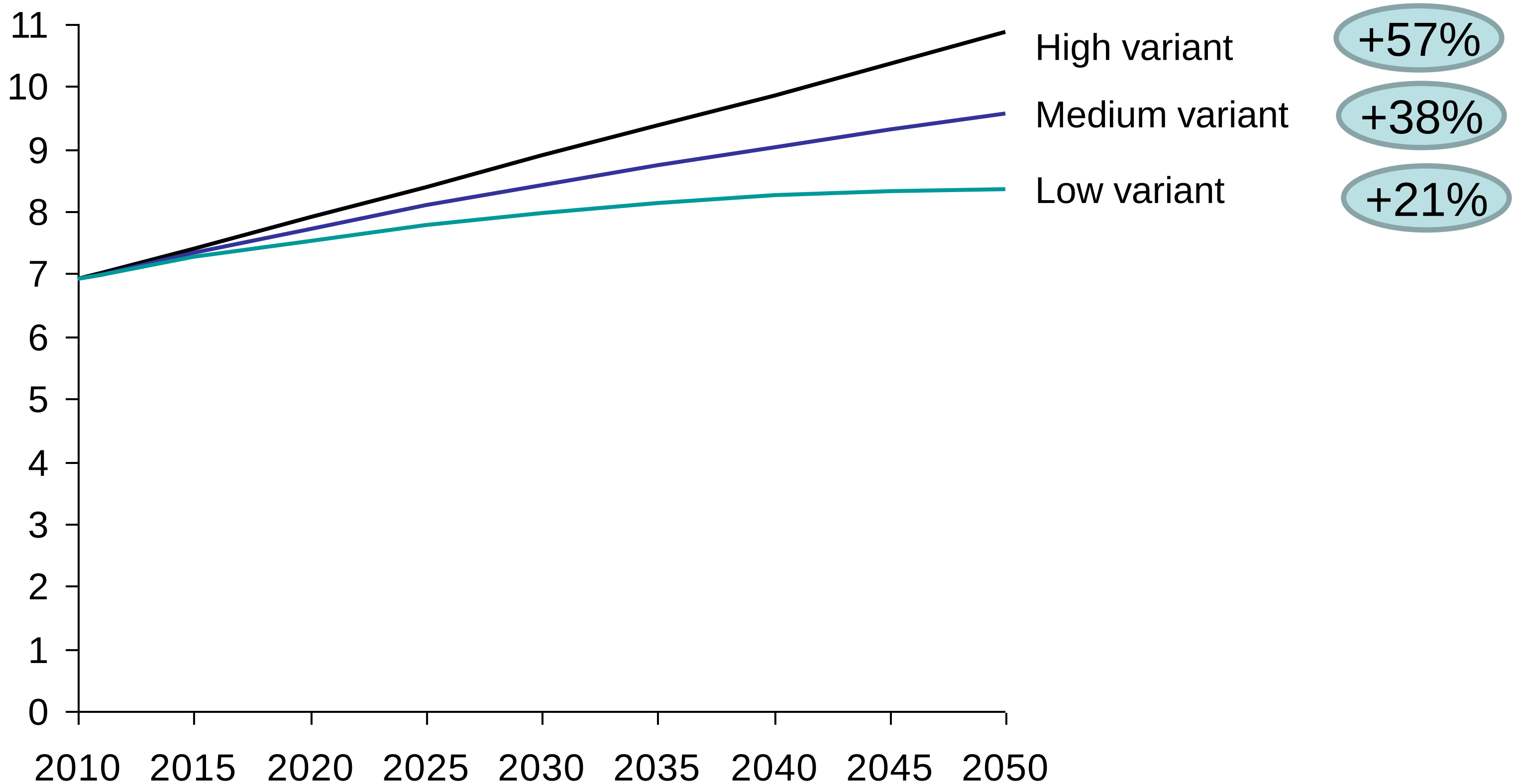
SOURCE: (1) Global Calculator team assumptions

1 By 2050, the world population is expected to grow by ~20 to 60%

Global Calculator

World population (billions)

2010-2050 growth (%)



SOURCE: http://esa.un.org/unpd/wpp/unpp/panel_population.htm 2012 revision

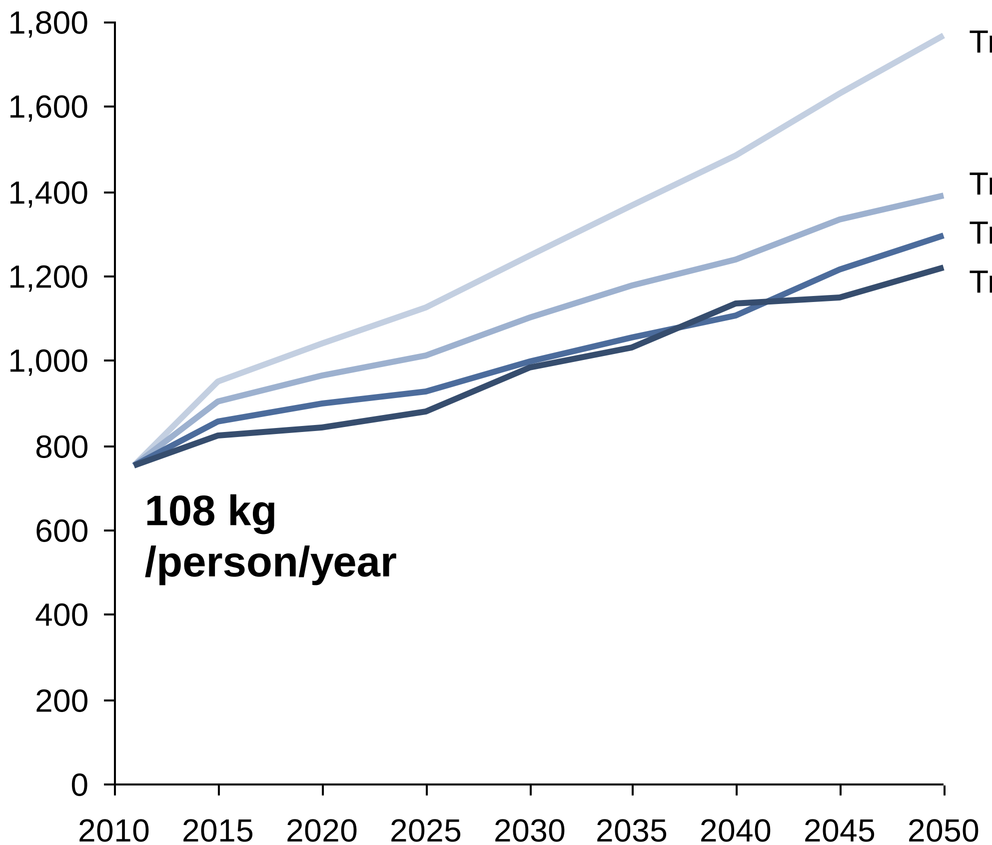
Global calculator growth forecasts

1

Production according to trajectories 1, 2, 3 & 4
(based on sectors demand, before design, switch & recycling)

Global Calculator

Chemicals production per year for different ambition levels [1]
(M tons)



Delta 10-50,%	Implied demand per person
+136%	185 kg /person/year
+86%	146 kg /person/year
+73%	136 kg /person/year
+63%	128 kg /person/year

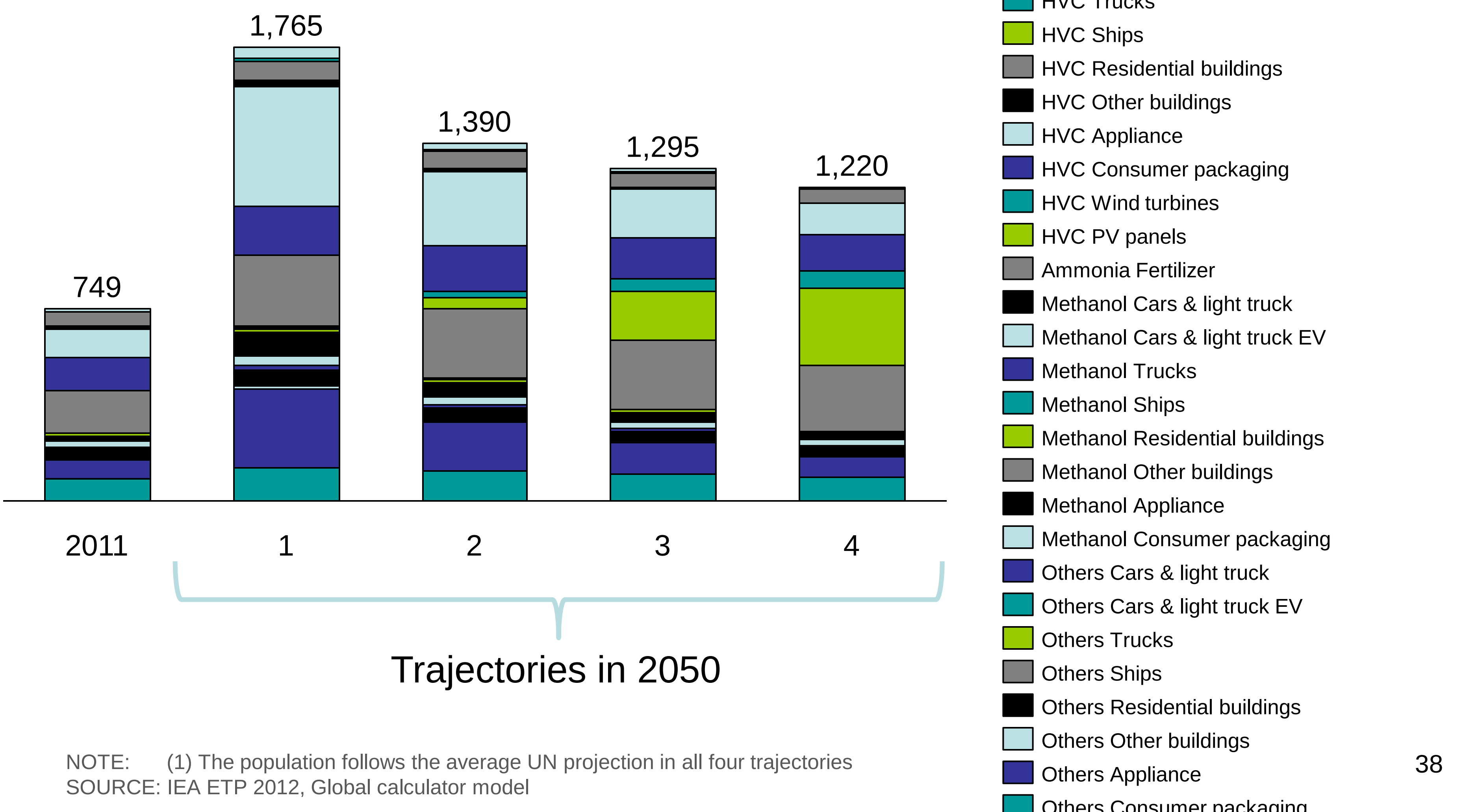
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: Global calculator model

Global calculator growth forecasts

Key driving demand sectors in trajectories 1, 2, 3 & 4

Global Calculator

Chemicals production per year for different ambition levels [1]
(M tons)



NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Global Calculator

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Chemicals manufacturing with lower energy intensity

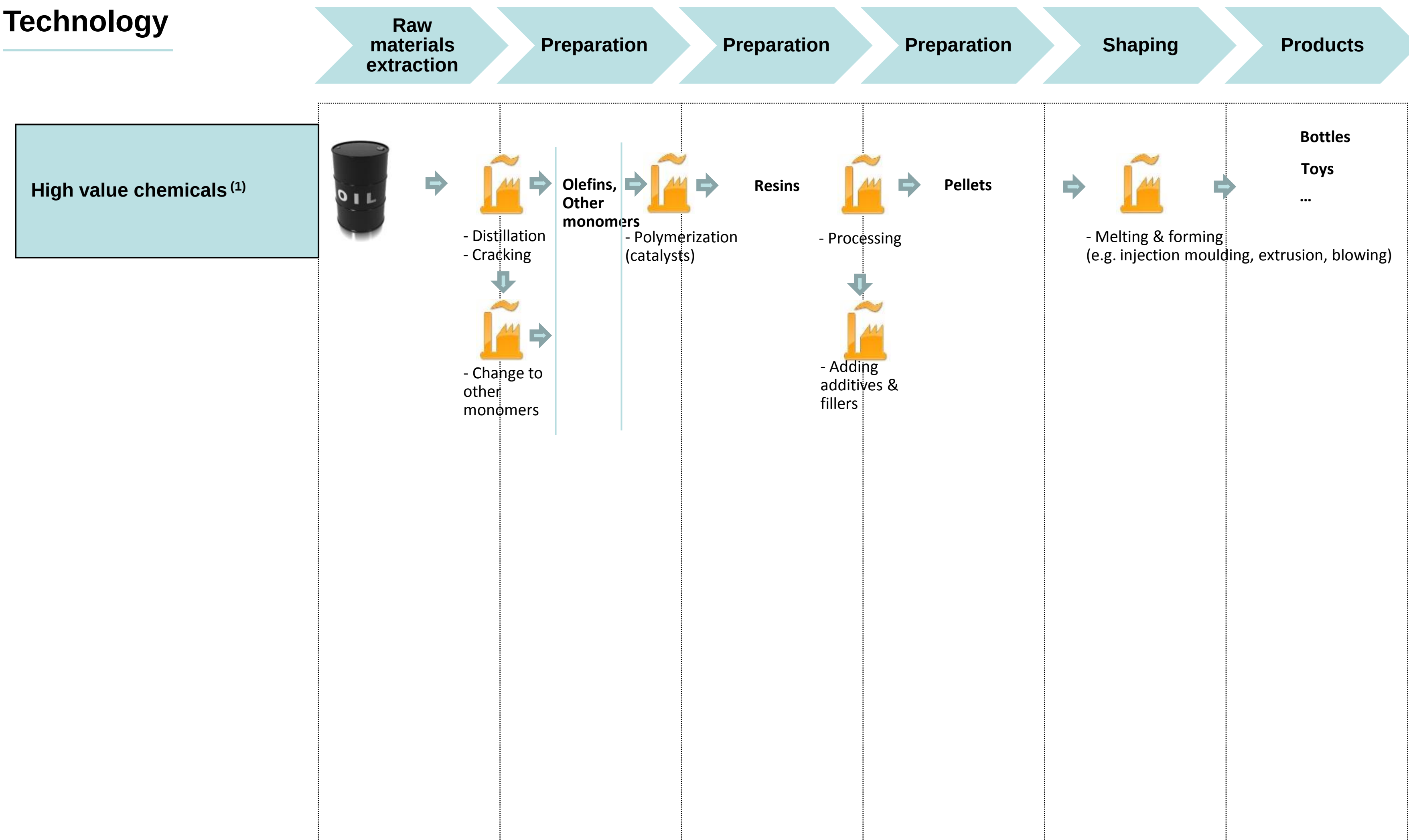
Chemicals manufacturing process

Estimation of the reduction potentials

Resulting scenarios

130 different industrial processes are used to manufacture the largest 18 volume chemicals, however 4 chemicals families are being assessed

Global Calculator

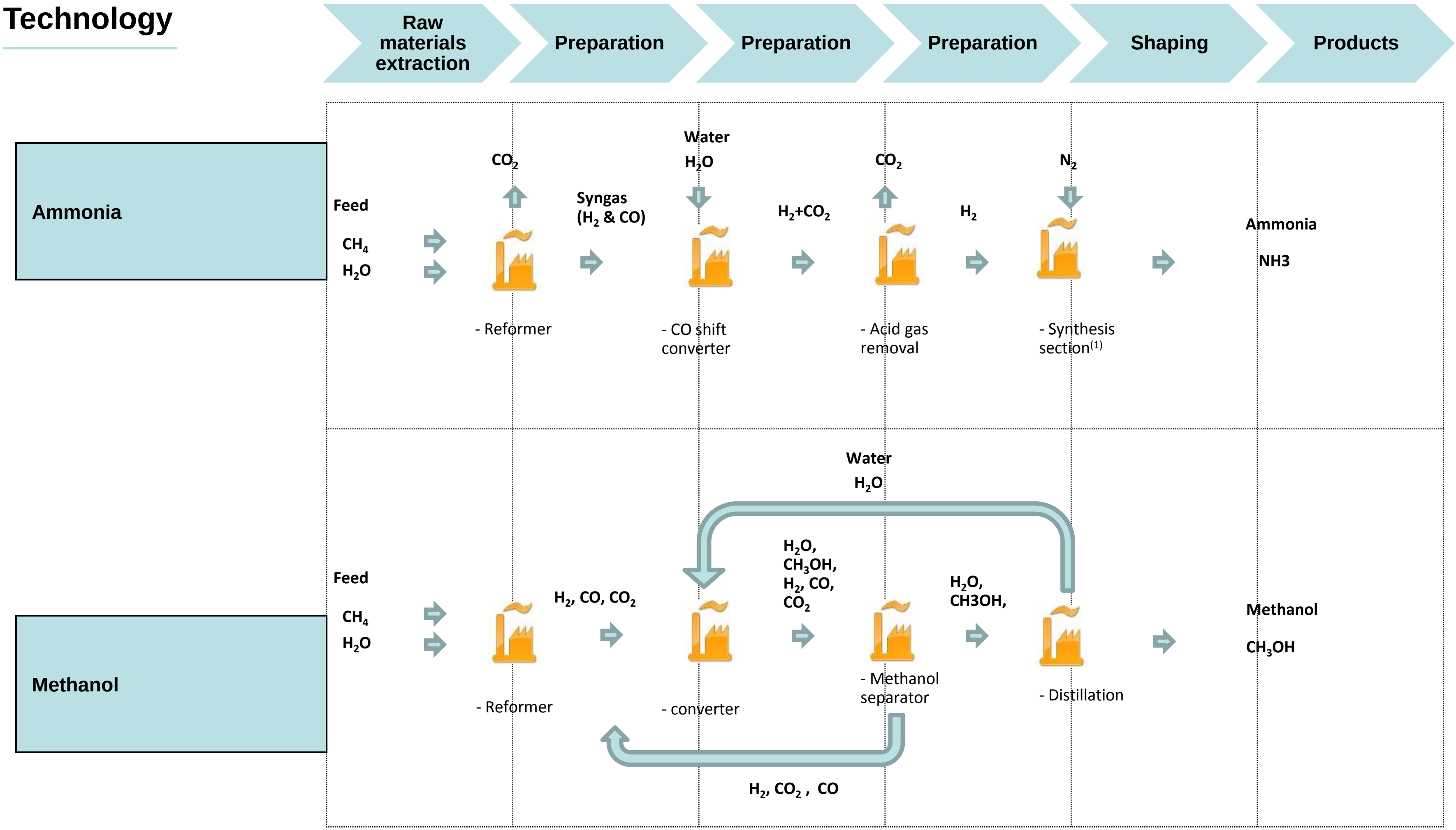


NOTE: (1)Ethylene, Propylene, BTX aromatics(benzene, toluene and mixed xylenes)
SOURCE: Climact

4 chemicals families are being assessed

Global Calculator

Technology

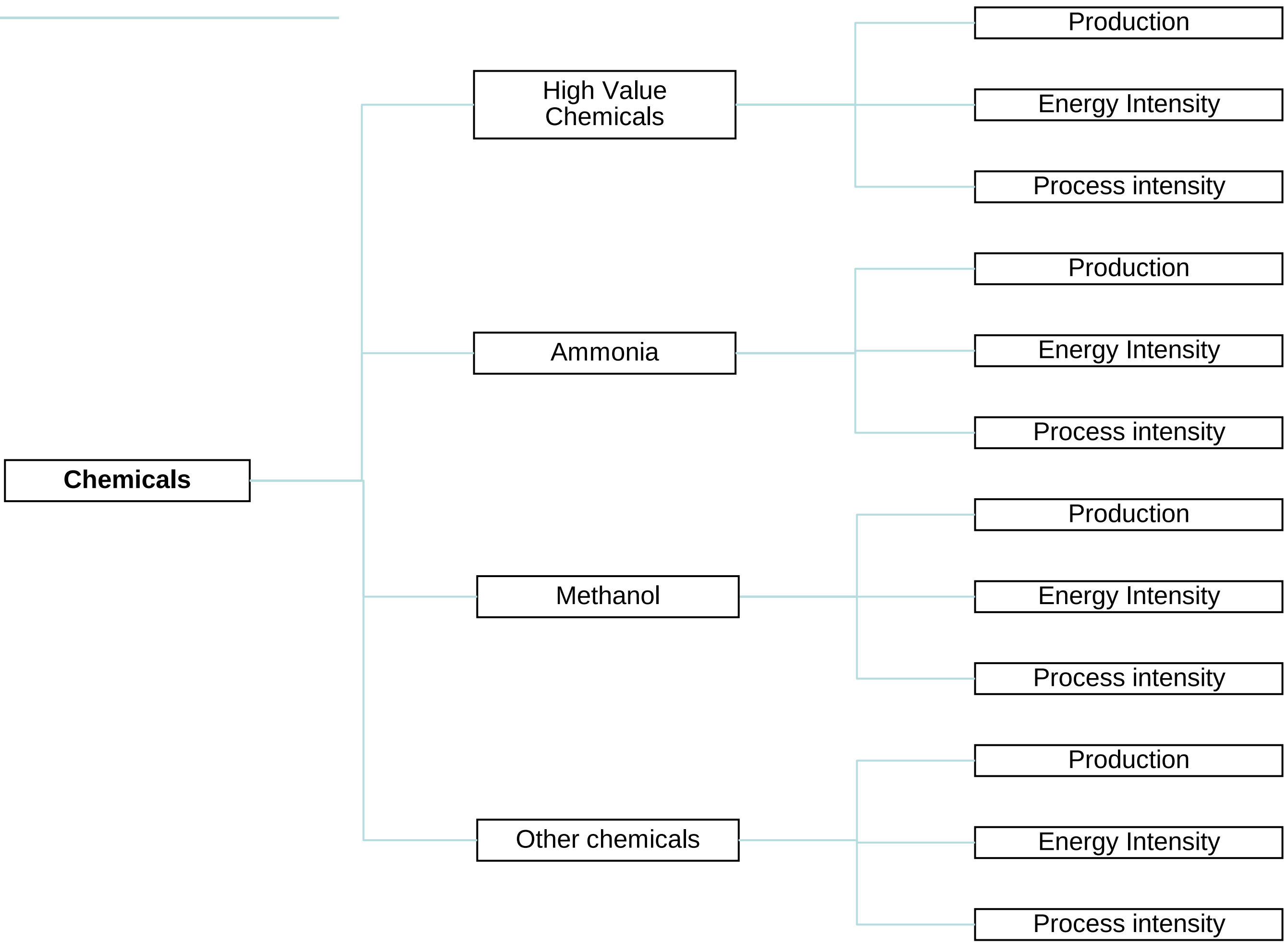


NOTE: Haber-Bosch process
SOURCE: ICCA Catalytic roadmap

Chemicals emissions are being modelled

Global Calculator

Chemicals emission tree



SOURCES: Climact

Global Calculator

Chemicals manufacturing with lower energy intensity

Chemicals manufacturing process

Estimation of the reduction potentials

Resulting scenarios

Structure of the levers

The following levers are applied sequentially

Order and applicability of levers per chemical family

Lever	HVC	Ammonia	Methanol	Other
Material switch	✓	✓	✓	✓
Green plastics	✓	/	/	/
Products recycling	✓	/	/	/
Materials recycling	✓	/	/	/
Improved design	✓	/	/	/
Process changes	✓ Catalytic naphta cracking	✓ Hydrogen production	✓ Hydrogen production	/
Fuel switches	✓	✓	✓	✓
Energy efficiency	✓	✓	✓	✓
CCS	✓	✓	✓	✓

Material demand / product:
Design, Switch & Recycling levers are assessed

List of actions & levers assessed

Design

- Changing product and material specifications to answer the same needs with less materials

Smart design

Switch

- Change materials to enable a low carbon product (over the product lifetime)

In buildings/Infr. :
To bio-based plastics
& to timber

Recycling

- Recycle the product or the material

Product recycling

Material recycling

Bio-based plastics

CCU discussion

SOURCE: Climact

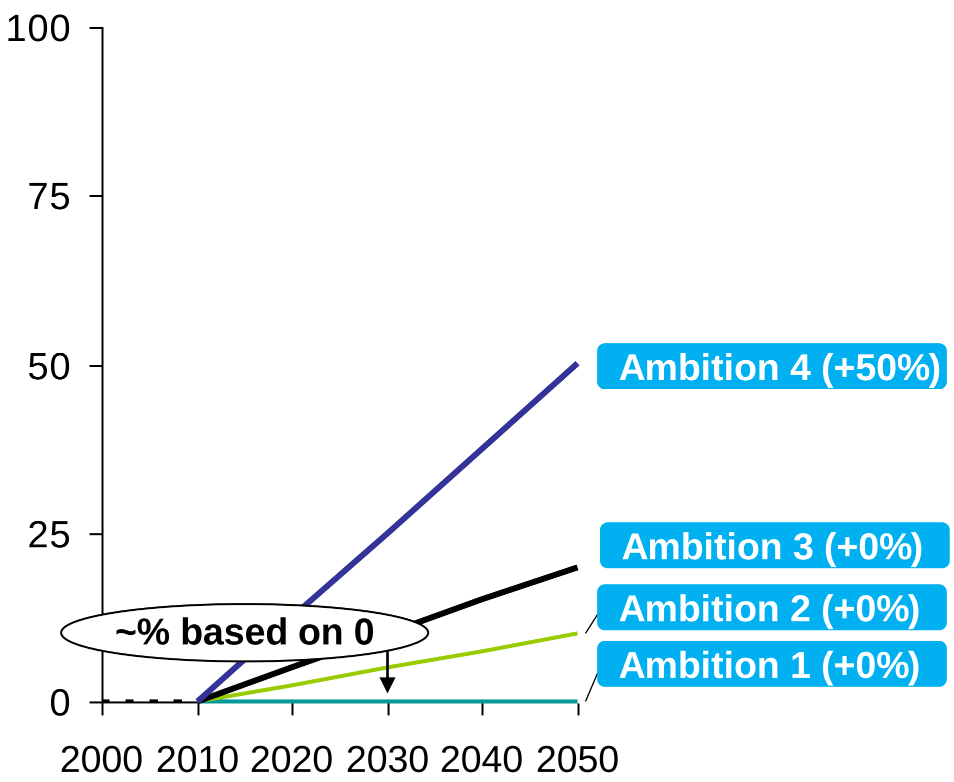
2

Product mix: Improved design

Chemicals recycling rates are much lower than in other industries

Global Calculator

Reduced material demand through improved design (%)



SOURCE: (1) With both eyes open

Rationale

- Improved composites and polymers will have significantly better properties
- Production of plastics leads to limited yield loss (some moulding enable no loss at all)

In a later version of the model, Plastics Europe should be contacted to review these assumptions

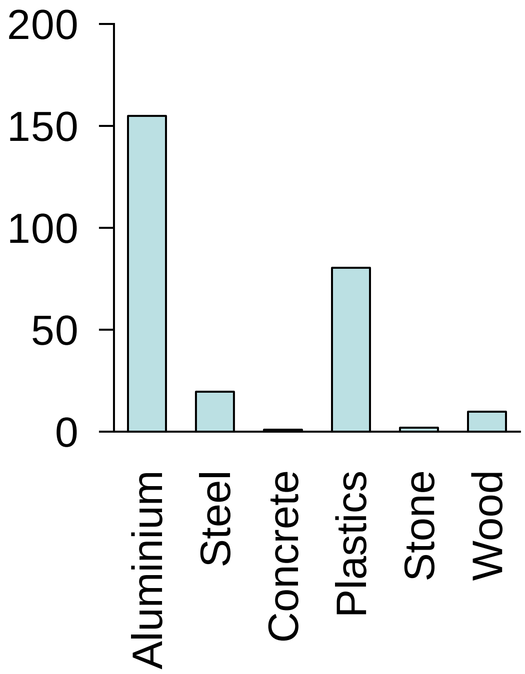
2

Product mix: Material switch

Steel is a relatively cheap material

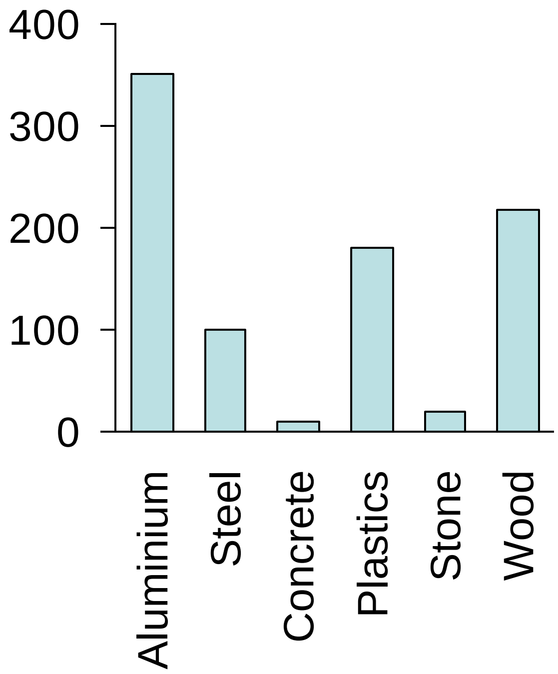
Global Calculator

Embodied energy
(Gj/t)



Embodied energy to convert the material in useful form

Relative useful costs (1)
(% relative to steel at 100%)



Relative cost per tonne to convert the materials in useful form

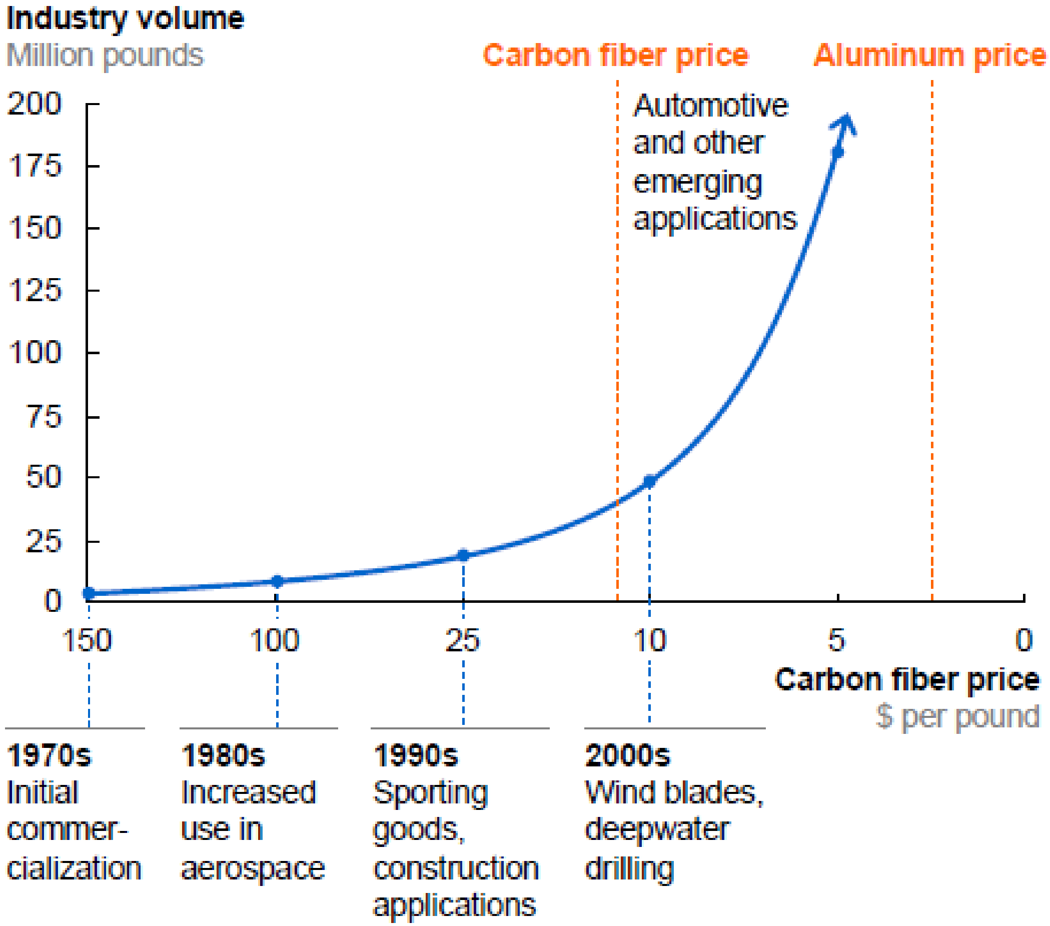
- Compared to other materials, plastics have relatively high embedded energy and useful costs
- If plastics substitutes other materials, it will be for its ease of mouldability or characteristics during product life

NOTE : (1) Refer to “With both eyes open” for more details on the definition of useful costs
SOURCE: (1) With both eyes open

2 Large scale adoption of carbon fibre is hindered by high costs

Global Calculator

Carbon fibre market evolution
(Million pounds)



Penetration barriers

- High cost relative to aluminum is main barrier to adoption
- Penetration in high-end industries will continue, given relative price inelasticity
- Industries also face large sunk cost upon switching to carbon fiber, given change of technology required

SOURCE: Deutsche Bank; expert interviews; Zoltek; McKinsey Global Institute analysis

Chemicals

Chemicals can substitute other materials if they enable emissions during the whole product life cycle

In a later version of the calculator, include feedback from:

- Plastics Europe
- Car manufacturers

Materials which can replace /be replaced by chemicals

	Characteristics		Chemicals replacement assumption			
	Advantages	**Weaknesses**	**HVC**	**Ammonia**	**Methanol**	**Other**
Aluminium	Recyclability Lower cost & embodied energy	Density	Not modelled	Not modelled	Not modelled	Not modelled
Steel	Recyclability Lower cost & embodied energy	Density Corrosion	Substitutes steel in vehicles & buildings /infrastructure (3)	Not modelled	Not modelled	Not modelled
Concrete	“Recyclability”, Low cost & embodied energy, no corrosion	Weak in tension	Insulation materials substitutes cement in buildings/infrastructure (1)	Not modelled	Not modelled	Not modelled
Stone & Masonry	Lower embodied emissions	Must be reinforced with mortar. Cannot be reinforced or moulded	Not modelled	Not modelled	Not modelled	Not modelled
Biomass (Timber /paper)	high strength and stiffness per density (1)	Less durable, sensitive to fire and rot, less stable	Not modelled (1)	Not modelled (1)	Not modelled (1)	Not modelled (1)

NOTES: (1) Development of mega cities increases demand for noise and heat insulation products. Performance will take a larger role (e.g. to gain space)
(2) Green chemistry is modelled in another lever
(3) 15% of plastics in cars today. With trend towards EV, there will be more emphasis on the need for light weight materials

2 Product mix : Material switch
Proposed lever ambitions

Global Calculator

Level 1	Level 2	Level 3	Level 4
Minimum effort (following current regulation)	**Moderate effort** easily reached according to most experts	**Significant effort** requiring cultural change and/or important financial investments	**Maximum effort** to reach results close to technical and physical constraints

• **Vehicles:** 0% switch
• **Buildings:** 0% switch
	• **Vehicles**
	  • 5% steel ➔ plastics
	• **Buildings/Infra:**
	  • 5% cement ➔ green plastics
		• **Vehicles**
		  • 10% steel ➔ plastics
		• **Buildings/Infra:**
		  • 10% cement ➔ green plastics
			• **Vehicles**
			  • 20% steel ➔ plastics
			• **Buildings/Infra:**
			  • 20% cement ➔ green plastics

Lever cost (€/t chemicals)	
Steel➔ Plastics	0
Concrete➔Plastics	0

NOTE: (1) Amount of one material required to replace another material is approximated through the specific Young modulus
(2) Assumption this material switch does not impact the product life

Product mix: Bio-based plastics (1/4)
The “bio” can be in one of two dimensions

Share of green plastics
(%) (1)

	Plastic is Non bio- degradable	Plastic is Bio-degradable
From renewable materials	**Biopolymers** • e.g. BioPE (PP/PET), biosourced PA, PTT	**Biopolymers** • e.g. PLA, PHA, • Amidons
From fossil materials	**Conventionnal polymers** • Nearly all conventional plastics • e.g. PE, PP, PET	**Biopolymers** • e.g. PBAT, PBS, PCL

Addressed by bio-based plastics lever (renewable materials row)

Addressed by recycling lever (non bio-degradable column)

Not modelled; considered a small part of the total (bio-degradable column)

NOTES: Biomass availability is constrained, and enters in competition with biomass use for food, other products and energy.
The Global calculator illustrates the impacts of using biomass
Some estimates lead to 10% of biomass in feedstock, (these figures include a wider scope e.g. biofuels and waste from slaughter houses)
SOURCE: (1) Fost+ environmental impact of biopackaging

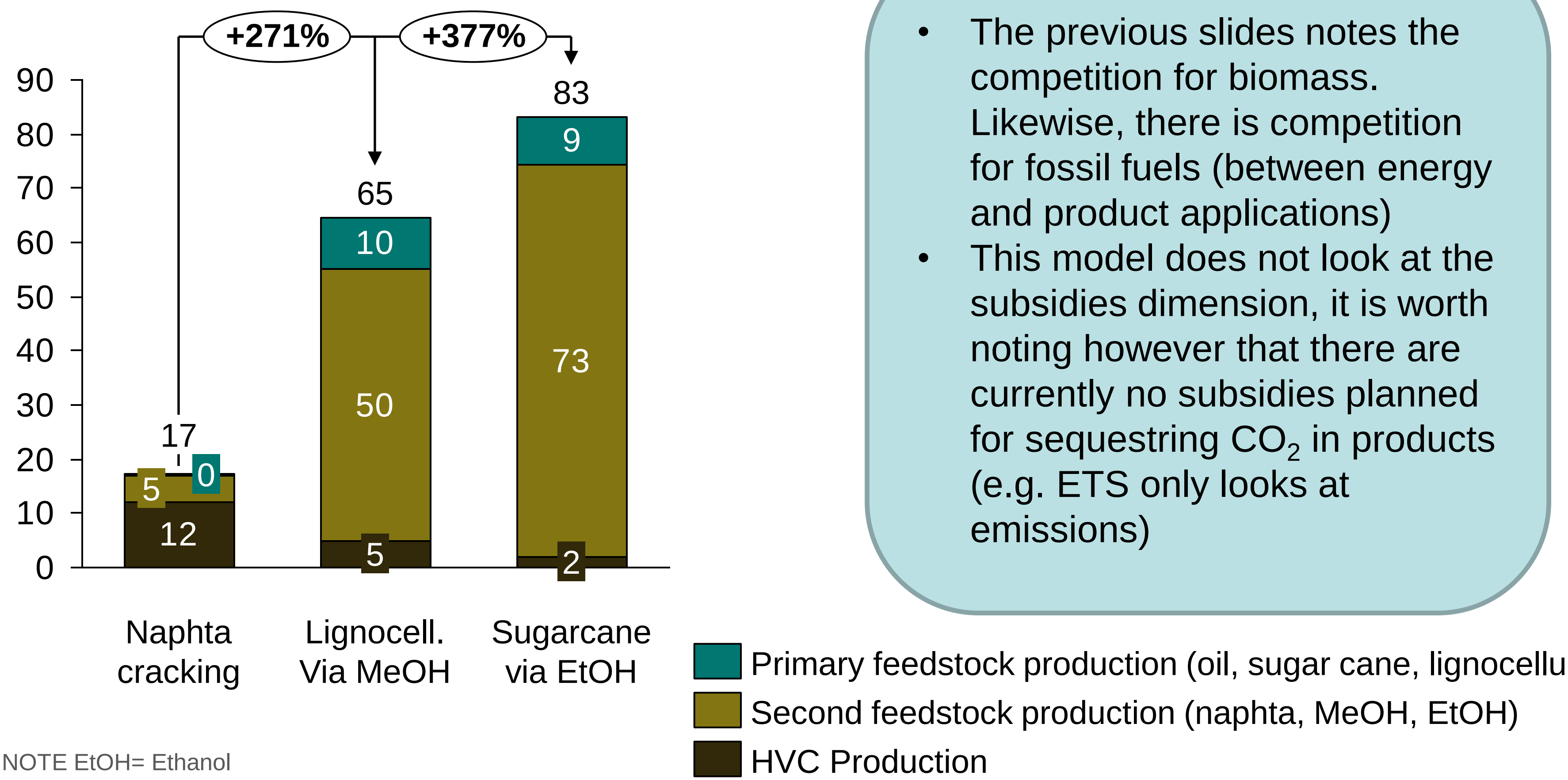
2

Product mix: Green plastics (2/4)

Using biomass feedstock can be significantly more energy intensive than the established fossil-based routes

Global Calculator

Energy use for biomass versus fossil routes to HVC
(GJ/t HVC)



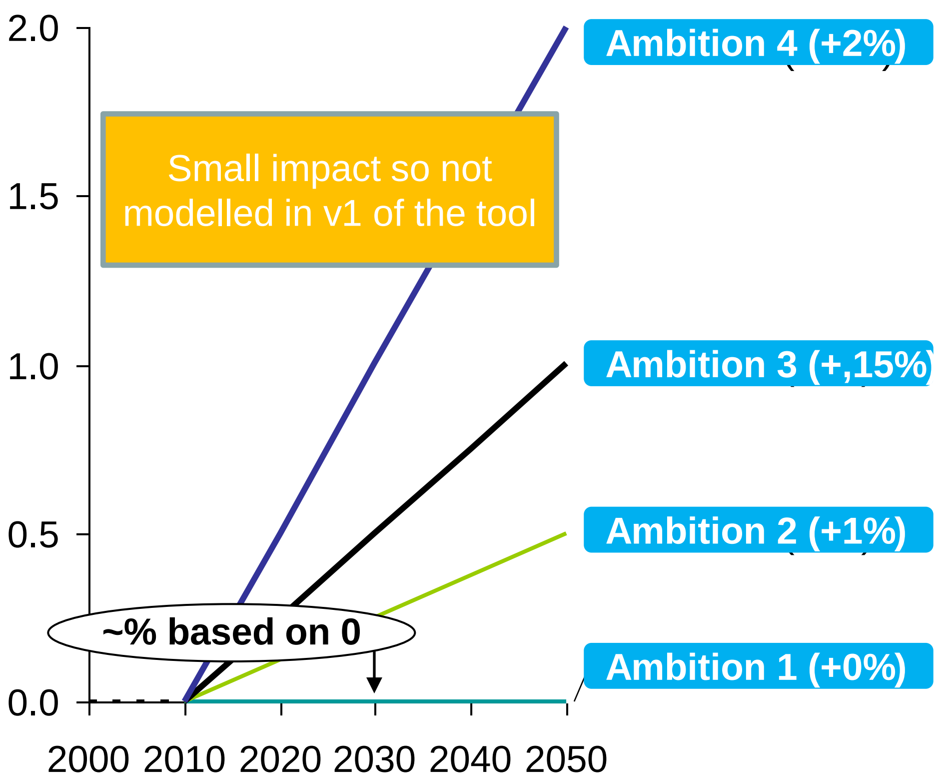
- The previous slides notes the competition for biomass. Likewise, there is competition for fossil fuels (between energy and product applications)
- This model does not look at the subsidies dimension, it is worth noting however that there are currently no subsidies planned for sequestring CO_2 in products (e.g. ETS only looks at emissions)

NOTE EtOH= Ethanol
SOURCE: (1) DECHEMA

Product mix: Green plastics (3/4)

Only a small proportion of plastics can be made from biomass

Share of green plastics within HVC
(%)



Rationale on green plastics rates

- Several monomers, such as the ethylene olefins, can be produced from plants (e.g. sugar cane)(2)
- More generally the feedstock can be made from biomass
- Bioplastics also tend to be more biodegradable than oil based plastics (but all 4 combinations are possible)
- Overall, the energy consumption of the relevant biomass routes is 3.5 to 5 times that of the fossil route (2). We assume it requires no more fossil energy
- Catalysis process changes (lever addressed later) facilitate the inclusion of biomass feedstock

Lever cost (€/t chemicals)	
Specific consumption	*4

NOTE: (2) The largest commercial activity currently takes place in Brazil, where the Brazilian petrochemical company Braskem operates the first industrial-scale sugarcane-based ethanol plant (200 kt/yr capacity) for subsequent polyethylene production.

SOURCE: (1) With both eyes open (2) ICCA

2 Product mix: Green plastics (4/4)

Caveat on modelling

CCU & Hydrogen are not modelled at significant scale in this version of the tool

- For higher rates of Carbon Capture & Usage (CCU), the development of a hydrogen supplychain will be required
- (hydrogen supply chain is not modelled in industry in the first version of the calculator)

In a future version of the model, consult Plastics europe to assess how much plastics is recycled today

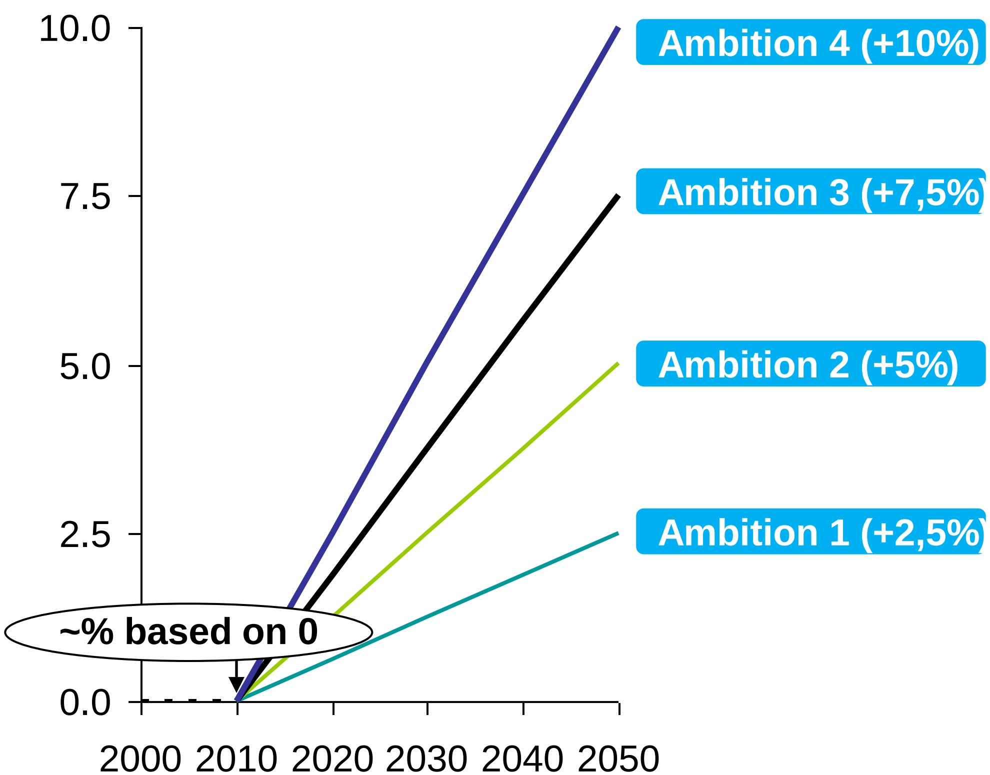
2

Product mix: Products recycling

The chemicals product recycling lever is assessed

r Calculator

Recycling share
(%)



Rationale on product recycling

Design will evolve to make products more recyclable

Product recycling is difficult because of the large amount of different plastic applications, and the cheap price of plastics

2 application areas are identified:

- Packaging in the UK
  - ~20kg packaging /person/year is in the end consumer waste
  - ~30kg packaging /person/year is for moving goods from factory to factory or shops
  - There is a potential to further recycle packaging products, especially the reuse of industrial packaging
- Construction
  - Pipes could be dismantled and reused
  - Car components could be reused

Lever cost
(€/t chemicals)

0 (also generates value)

NOTE: (1) Only applied to non biodegradable plastics

Product mix: Materials recycling

Chemicals recycling rates are much lower than in other industries

Rationale on plastics recycling rates

- Low plastics value and higher recycling complexity make plastic recycling less attractive
- Higher complexity comes from :
  - the higher variability of plastic manufacturing processes and additives (to change colours & properties) & fillers (cheaper materials which increase strength & hardness)
  - The fact plastics are harder to isolate from other waste streams (e.g. it is weakly magnetic)
  - Only thermoplastics can be recycled (not the thermosets) [(2)]

Solutions

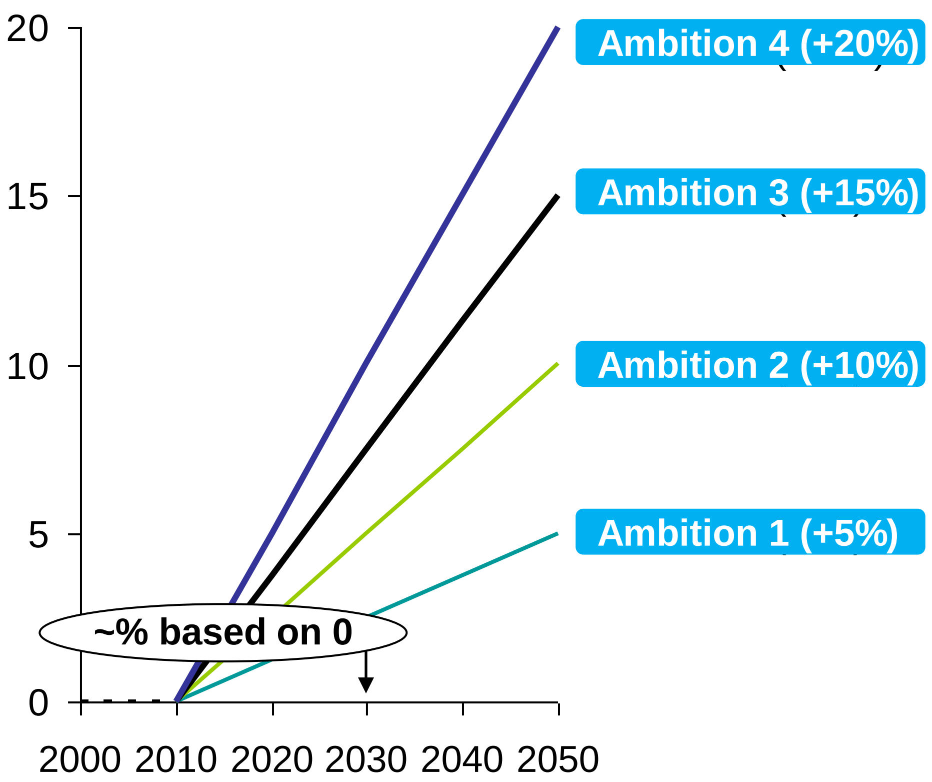
- Production scraps can easily be recycled (not much improvement potential is expected here)
- Improved separation of plastics waste streams from municipal waste (difficult because diverse)
- Improved sorting of plastics waste stream (difficult because similar density and optical properties)
- There are 4 levels of recycling :
  - Primary recycling: material is directly re-extruded
  - Secondary recycling: plastics is ground in small chips, washed, dried & converted in resins (lower quality)
  - Tertiary recycling: plastics are broken down chemically to produce new feedstock (e.g. by pyrolysis)
  - Quaternary recycling: recovery of energy through incineration (this is addressed in the supply/waste analysis, not in manufacturing)

NOTE: (2) There are 2 families of plastics A) Thermoplastics which represent most of the plastics. These can be melted and reformed several times. B) Thermosets, which represent a smaller portion of the plastics. These change irreversibly on being heated, mixed, irradiated, and cannot be recycled (e.g. glass & carbon fibers)
SOURCE: (1) With both eyes open

2 **Product mix: Materials recycling**
A higher proportion of plastics can be made from plants

Global Calculator

Recycling share
(%)



Simplifying assumption: applyied to all chemicals, even though ammonia fertilizers will not have recycling potential

Lever cost (€/t chemicals)
0 (also generates value)

SOURCE: (1) With both eyes open

3

Carbon intensity of material production

The chemical sector has significantly improved historically but major improvements are still available

Global Calculator

Historical improvements

The sector has recently strongly improved it’s energy efficiency

For example, in the US, energy intensity of the chemical sector improved by 39% and GHG emissions intensity was reduced by 10% between 1994 and 2007 [1]

Remaining improvement levers

Various levers are available:

- Better heat integration
- Catalyst tweaks
- State- of-the-art equipment
- Better catalysts
- Separations
- …

SOURCE: (1)ICCA catalytic roadmap

3

Carbon intensity of material production

Process improvements, fuel mixes, energy efficiency & CCS are then assessed

Global Calculator

List of actions & levers assessed

Process improvement	Fuel substitution	Energy efficiency	End of pipe technologies
• Towards fuels which emit less CO_2	• Modification of processes	• Reduce mechanical and thermal losses • Recuperate thermal energy (CHP)	• Carbon capture and storage
Various	Biomass Waste	Insulation CHP/ heat recovery Various	CCS implementation

NOTE: Process choice has consequences on applicability of other levers Some combinations are exclusive whilst others can be added in sequential order
SOURCE: (1) (redundant with Ulcored while we represent HIsarna in this analysis

Process improvements

Several process improvements could entirely change the energy consumption structure

Process improvement examples

High value chemicals	• Olefin production via catalytic cracking of naphtha and via methanol, moving away from steam cracking	Could deliver energy savings of 10% to 20% [(2)]
	• Olefin production via methanol	Not modelled, we simplify assuming all HVC switch to the catalytic process
	• Propylene Oxide (PO)production via the hydrogen peroxide propylene oxide (HPPO) process	Could deliver energy savings of 10-12% [(1)], but is not modelled cfr supra
Ammonia	• Hydrogen based production of ammonia	+26 GJ/ t ammonia (NH3) Vector switch to 100% electricity
Methanol	• Hydrogen based production of methanol	+15,7 GJ/ t methanol (NH3) Vector switch to 100% electricity
Other chemicals	• Improved hydrogen generation for steam methane reformers • Synthesis of aromatics from lignin, ethanol or methane • Direct synthesis of hydrogen peroxide from hydrogen and oxygen • Direct epoxidation of propylene with oxygen	

SOURCE: (1)ICCA Catalytic roadmap (2) Ren, Patel and Blok, 2006

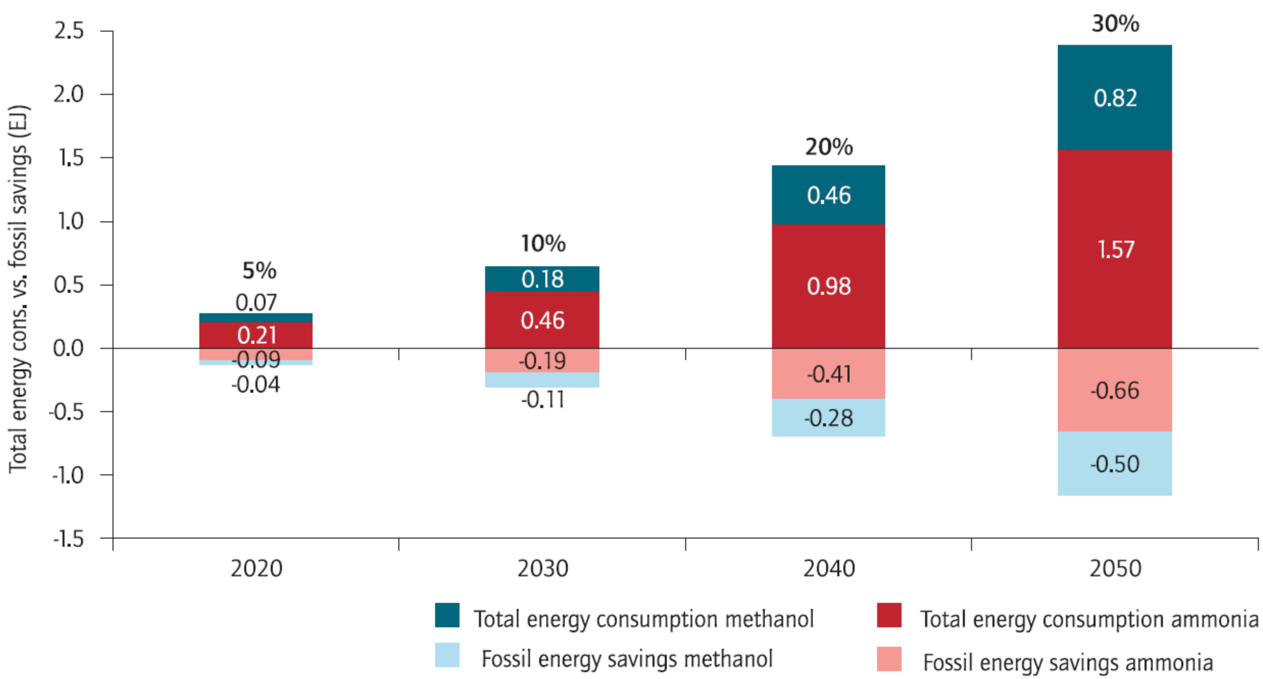
3 Process improvements

Production of hydrogen from renewables currently uses a lot of energy

Global Calculator

Additional energy demand versus fossil energy savings for replacement of current ammonia and methanol processes by hydrogen-based routes

(% implementation of hydrogen route)



- Ammonia synthesis based on hydrogen from renewable energy sources requires roughly 26 GJ/ t ammonia (NH3) more energy
  (and we assume a vector switch to electricity)
- For methanol (MeOH) from hydrogen and coal, an additional 15.7 GJ/tMeOH are required compared to the gas steam reforming route and additional 5.6 GJ/tMeOH compared to the coal partial oxidation route
  (and we assume a vector switch to electricity)

SOURCE: (1) DECHEMA, ICCA catalytic roadmap

3

Process improvements

Production of hydrogen from renewables currently uses a lot of energy

Global Calculator

Chosen ambition levers

	Process description	Level 1	Level 2	Level 3	Level 4	Modelling
High value chemicals	• Olefin production via naphtha catalytic cracking	0%	-5%	-10%	-20%	Reduction of specific consumption (1)
	• Olefin production via methanol	/	/	/	/	
	• Propylene Oxide (PO)production via (HPPO) process	/	/	/	/	Benefits related to the application of HPPO are included in the above reduction
Ammonia	• Hydrogen based production of ammonia	0%	0%	0%	30%	% switch to new technology +26 GJ/ t ammonia (NH3) Vector switch to 100% electricity
		Not modelled in v1 of the tool				
Methanol	• Hydrogen based production of methanol	0%	0%	0%	30%	% switch to new technology +15,7 GJ/ t methanol (NH3) Vector switch to 100% electricity
		Not modelled in v1 of the tool				
Other chemicals	• Improved hydrogen generation for steam methane reformers • Synthesis of aromatics from lignin, ethanol or methane • Direct synthesis of hydrogen peroxide from hydrogen and oxygen • Direct epoxidation of propylene with oxygen	0%	-5%	-10%	-20%	Assuming same evolution as HVC

Lever cost (1)

Input (fuel & material)	Fuel costs
Other opex	0
Capex	0

NOTE: (1) this is not based on coal, that would increase emissions
SOURCE: (1) DECHEMA, ICCA catalytic roadmap

3

Fuel switches

A significant portion of fuels (excl. feedstock) can be switched to biomass

Global Calculator

Chosen ambition levers

	Switch description	Level 1	Level 2	Level 3	Level 4	Modelling
High value chemicals	• Solid & liquid to gaseous	0%	10%	20%	30%	Same specific consumption
	• Solid & gaseous hydrocarbons to biomass (2)	0%	5%	10%	20%	Specific consumption of biomass 5% higher
Ammonia	• Solid hydrocarbons to biomass (2)	0%	5%	10%	20%	Specific consumption of biomass 5% higher
Methanol	• Solid hydrocarbons to biomass (2)	0%	5%	10%	20%	Specific consumption of biomass 5% higher
Other chemicals	• Solid hydrocarbons to biomass (2)	0%	5%	10%	20%	Specific consumption of biomass 5% higher

Lever cost (1)

Input (fuel & material)	Fuel costs
Other opex	0
Capex	0

NOTE: (2) Not related to feedstock (addressed in green plastics lever)
SOURCE: (1) Climact

3

CHP

Up to 20% of the sector electricity can be covered by Combined heat and power units

Global Calculator

Chosen ambition levers

	Level description	Level 1	Level 2	Level 3	Level 4	Modelling
High value chemicals	• % of the electricity consumption covered by the CHP	5%	10%	15%	20%	• In this 1st version of the tool, it is approximated by x kwh of electricity which can be replaced by x kwh of gas • This covers the autoproducers • This does not cover the large CHP units which are classified as Electricity producers
Ammonia	• % of the electricity consumption covered by the CHP	5%	10%	15%	20%	
Methanol	• % of the electricity consumption covered by the CHP	5%	10%	15%	20%	
Other chemicals	• % of the electricity consumption covered by the CHP	5%	10%	15%	20%	

Lever cost (1)

Input (fuel & material)	Fuel costs
Other opex	0
Capex	0

NOTE: (2) Not related to feedstock (addressed in green plastics lever)
SOURCE: (1) Climact high level assumption

Energy efficiency

Additional energy efficiency is possible after the previous levers

Energy efficiency rationale (in addition to the technology modifications addressed earlier)

High value chemicals	• Could deliver energy savings ~20% in addition to the process change [2]
Ammonia	• Applied on the part not switching to hydrogen based production • Stochiometric : 19,8 GJ/t NH_3 BAT 2050 : 24 GJ/t NH_3 [3] • Standard technology 39 GJ/t NH_3 - new BAT technology 28 GJ /t NH_3(-30%)[1] • Retrofit options for improvements of reformer section and CO_2 removal section • Potential for low pressure (improved catalysts) and improved process control
Methanol	• Applied on the part not switching to hydrogen based production • Assumption same as ammonia
Other chemicals	• Assumption same as HVC

NOTE: Not related to feedstock (addressed in green plastics lever)
SOURCE: (1) Source : SERPEC study
(2)ICCA Catalytic roadmap
(3) Source: VITO analysis

Energy efficiency
Some details are available per industry group

Energy efficiency improvements

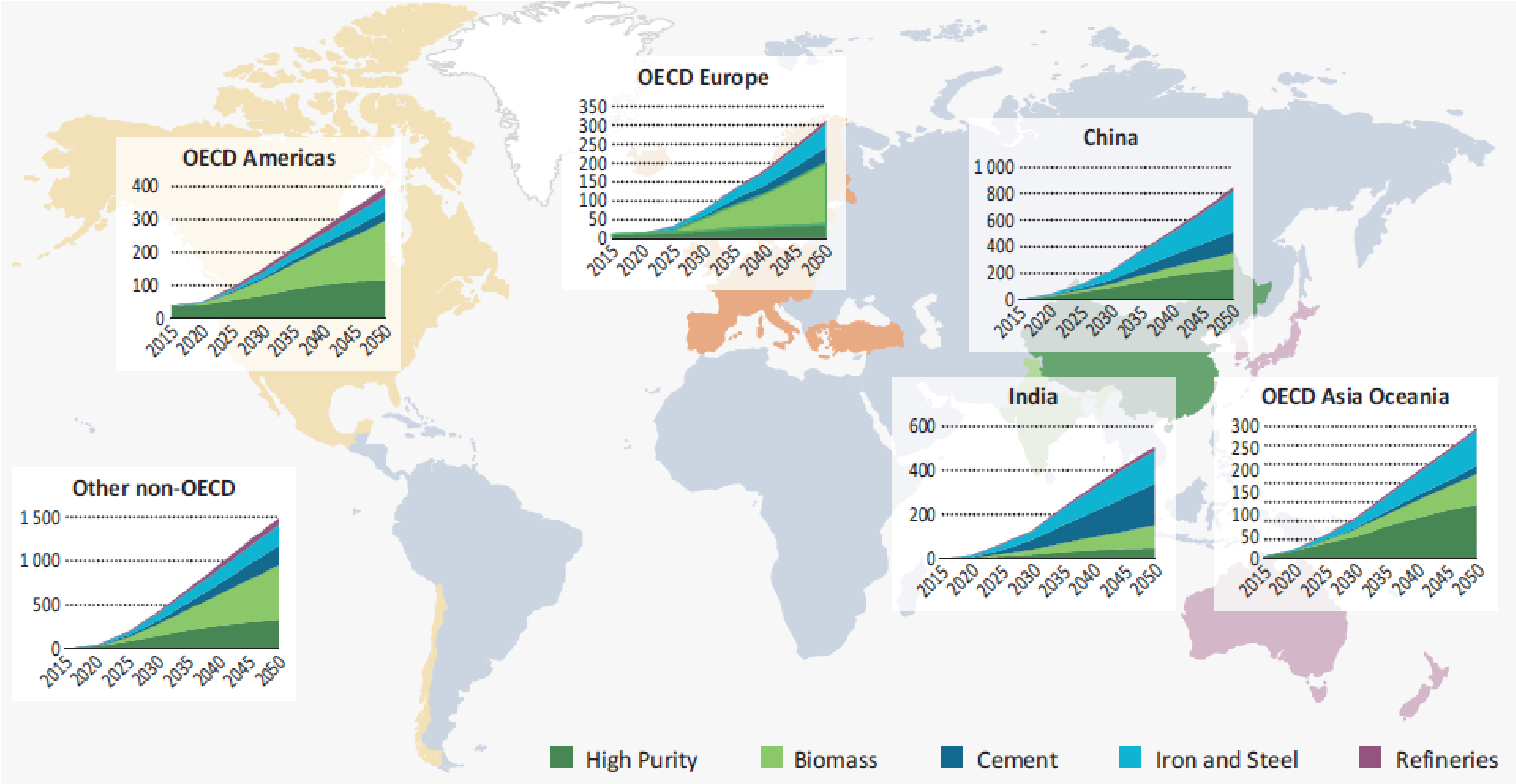
	Description	Level 1	Level 2	Level 3	Level 4	Modelling
High value chemicals	Newer plants &retrofits	0%	-5%	-10%	-20%	Specific consumption reduction
Ammonia	Newer plants &retrofits	0%	-7,5%	-15%	-30%	Specific consumption reduction
Methanol	Newer plants &retrofits	0%	-7,5%	-15%	-30%	Specific consumption reduction
Other chemicals	Newer plants &retrofits	0%	-5%	-10%	-20%	Specific consumption reduction

Lever cost (2)	
Input (fuel & material)	-x
Other opex	0
Capex	+x

SOURCE: (2) Climact assumption

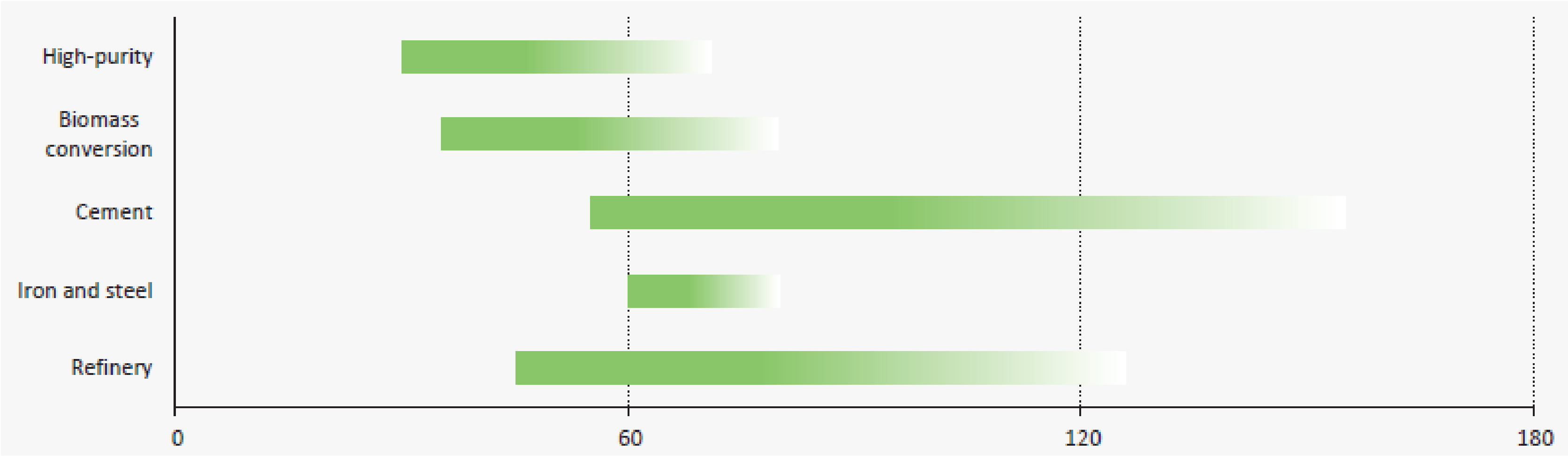
Carbon Capture & Storage
Projections by region

Capture rate
($MtCO_2$/year)



SOURCE: IEA ETP 2012

Typical ranges of costs of emission reductions from industrial applications of CCS (USD/tCO_2e avoided)



In addition, an electricity consumption of 0,33 TWh/MtCO_2e captured is modelled

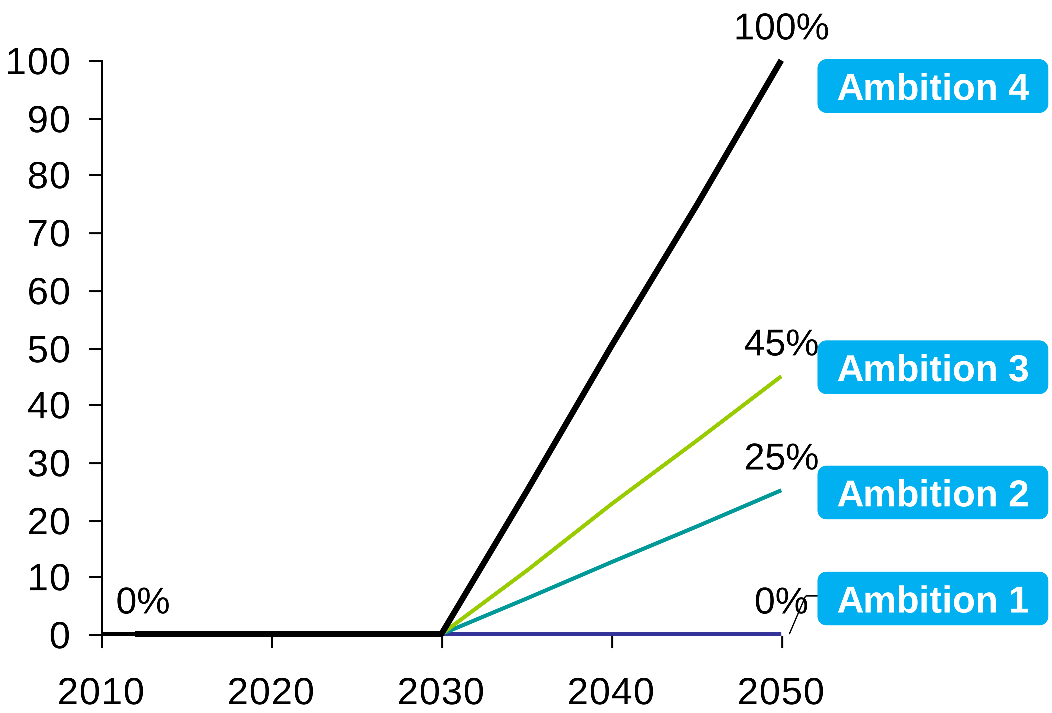
NOTE: The range of costs shown here reflect the regional average costs of applying CCS in each sector, and, therefore, the overall cost of abatement in a sector will be affected by the assumed level of CCS uptake in each sector (IEA, 2009 and IEA and UNIDO 2011). These costs include the cost of capture, transport and storage, but do not assume that storage generates revenues (i.e. CO_2 storage through enhanced oil recovery (EOR) is not considered as a storage option.

SOURCE: ETP 2012, IEA

Carbon Capture & Storage

Proposed lever ambitions

Penetration of CCS
(% of plants equipped)



- Large facilities for the production of ammonia, methanol, ethylene oxide, hydrogen and products from coal gasification might have sufficient scale to make CCS financially feasible
- Crackers can also be high-volume sources (1 $MtCO_2$/yr), but their flue gas is more dilute (4% to 7% CO_2, lower concentration than a coal-fired power plant which can be 10% CO_2 to 12% CO_2) and drive up the CO_2 capture costs.
- IEA 2DS suggest a capture of 467$MtCO_2$ for the chemical sector
- 80% capture rate [(1)]
- The specificities of CCS in the steel sector (e.g. energy consumption) should be refined in a later version of the model

Lever cost [(2)]

Input (fuel & material)	0,33 TWh Elec/Mt captured
Other opex	$20 USD/ton captured
Capex	$40 USD/ton captured

SOURCE: (1) IEA ETP 2012

Global Calculator

Iron & steel manufacturing with lower energy intensity

Chemicals manufacturing process

Estimation of the reduction potentials

Resulting scenarios

Model growth forecasts

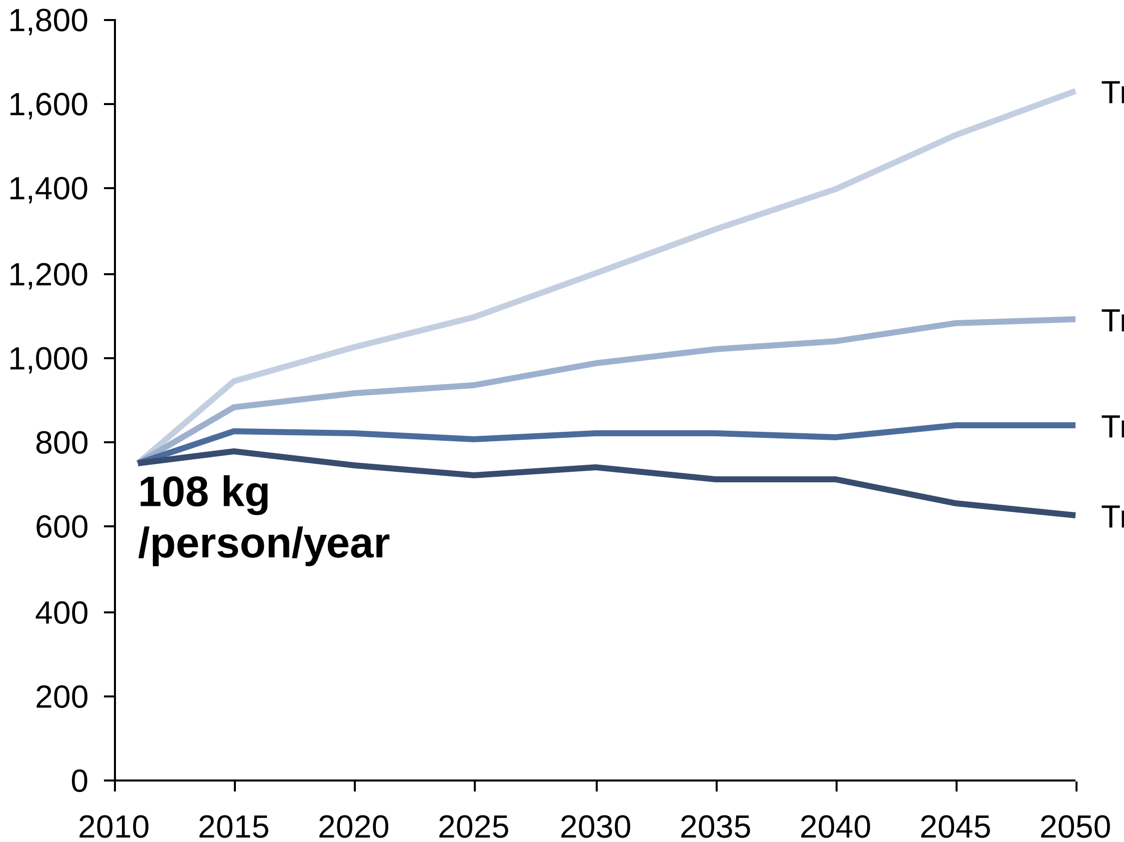
Production according to trajectories 1, 2 and 3 (after design, switch & recycling)

Global Calculator

Chemicals production per year for different ambition levels (1,2)
(M tons)

Delta 10-50,%

Implied demand per person



Trajectory	Delta 10-50,%	Implied demand per person
Trajectory 1	+118%	**171 kg plastics /person**
Trajectory 2	+46%	**114 kg plastics /person**
Trajectory 3	+12%	**88 kg plastics /person**
Trajectory 4	-16%	**66 kg plastics /person**

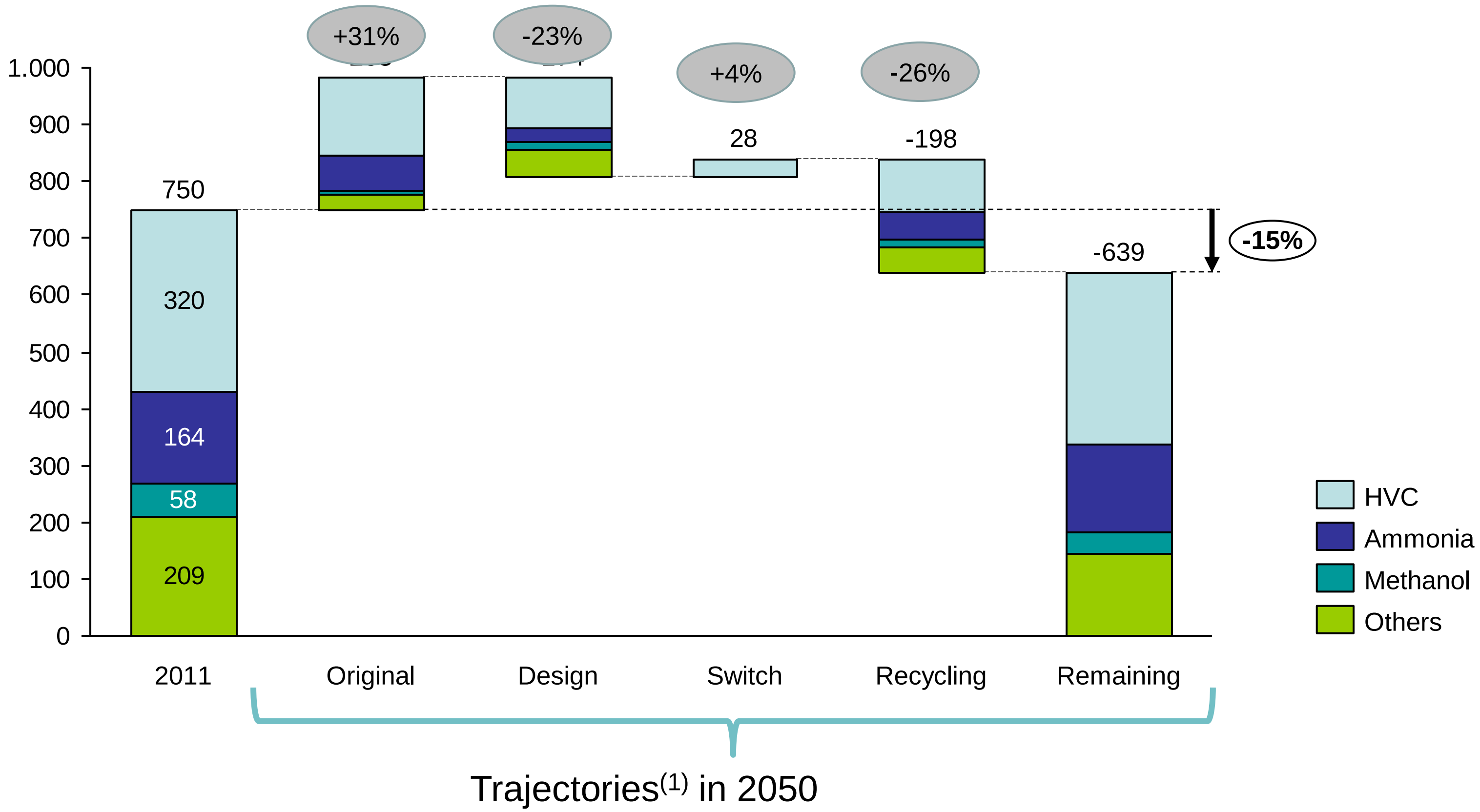
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Other sectors are impacted by these transitions (e.g. additional productions are created in the timber sector)

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3 (1)

Global Calculator

Chemicals production for ambition level 3
(M tons, % of 2011)

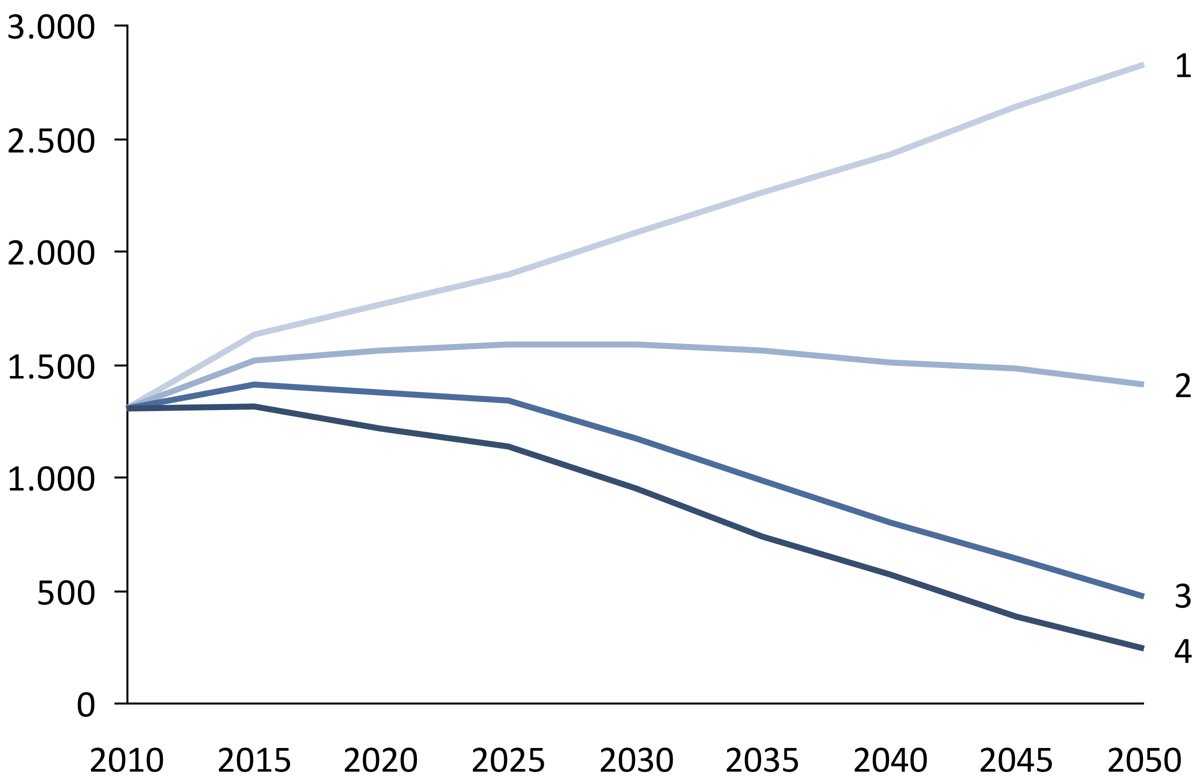


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Reduction potential

Emissions according to different trajectories

GHG emissions for different ambition levels [1,2,3]
($MtonCO_2e$)



	Delta 10-50,%	**Specific emissions**
1	+118%	**1732 kg /ton plastics**
2	+8%	**1287 kg /ton plastics**
3	-64%	**558 kg /ton plastics**
4	-86%	**381 kg /ton plastics**

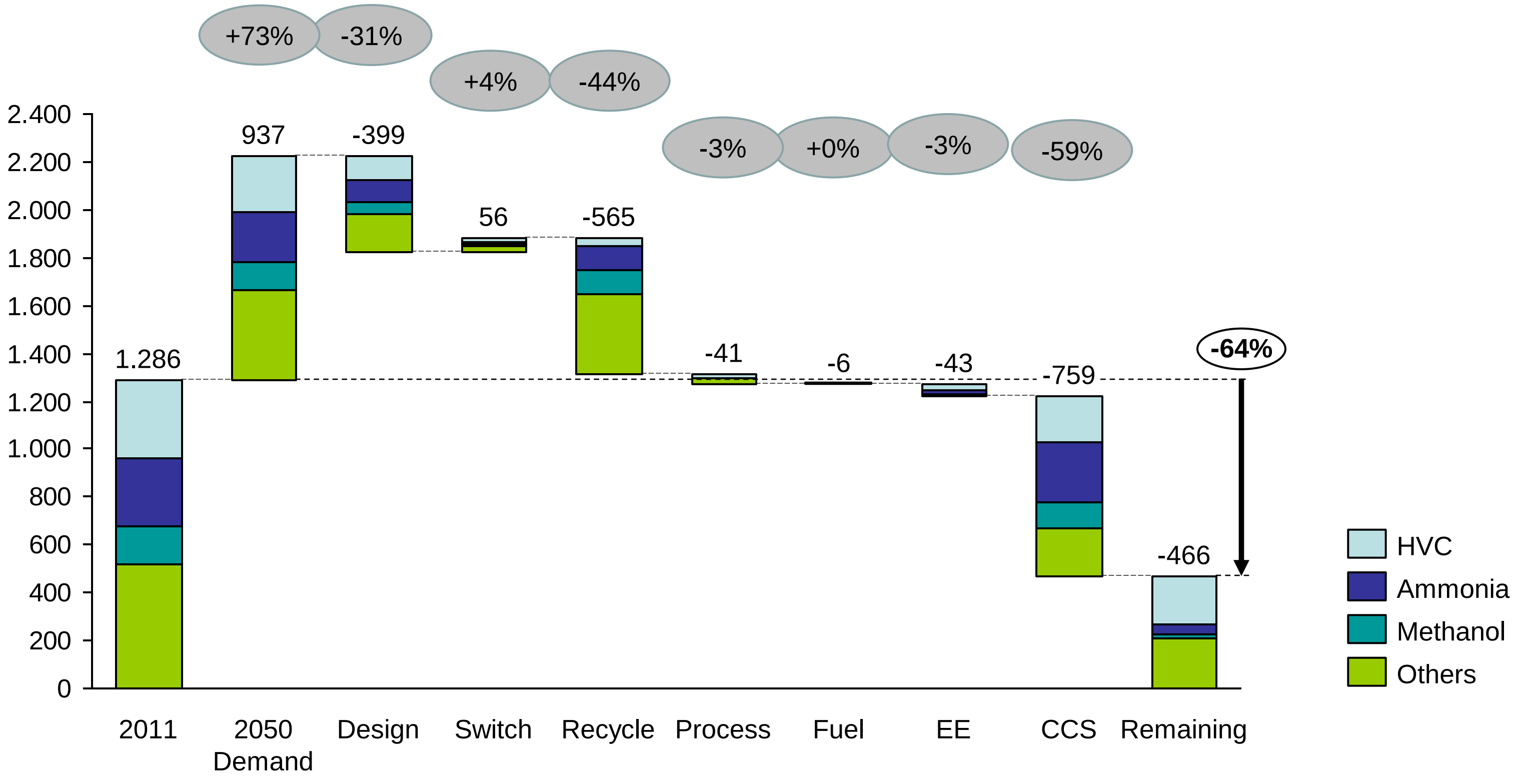
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. with product switch)

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3[(1)]

Global Calculator

Chemicals GHG emissions in 2050, for ambition level 3[(1,2)], using different levers[(3)]
($MtCO_2e$, % of 2010)



NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions are calculated vs the 2010 baseline

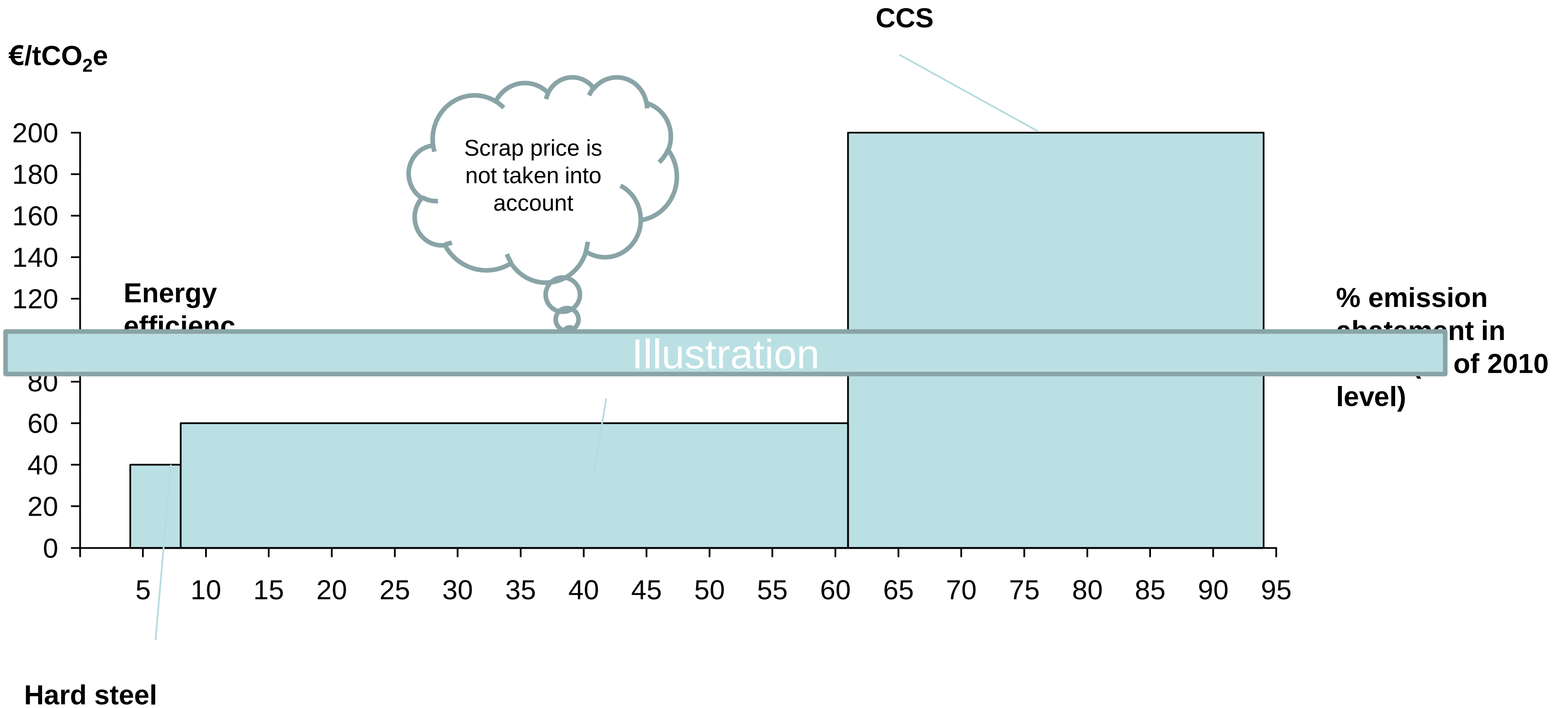
SOURCE: IEA ETP 2012, Global calculator model

Cost

Marginal cost and abatement potential for different levers under trajectory 2 with ambition level 4

GHG abatement curve for the year 2050 (trajectory 2, ambition 4)

€/tCO_2e, % emission abatement in 2050 (% of 2010 level)



NOTE: Hypothesis of cost neutral energy efficiency measures , cost of biomass generic across all sectors

SOURCE: IEA ETP 2012, Global calculator model

Thank you.

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Backup

Several model have been looking at this question already

Global Calculator

ETP 2012 provides a target based optimization model. It makes sure the chemical sector does it's « fair share » in the 50% reduction in energy related emissions

DECHEMA provided an opportunity assessment model, assessing the gap between « theoretical optimums » and « current realities »

- The global calculator is more similar to the DECHEMA model during it's conception
- It enables to model different scenarios
- In a later stage, some scenarios will align to the IEA ambitions

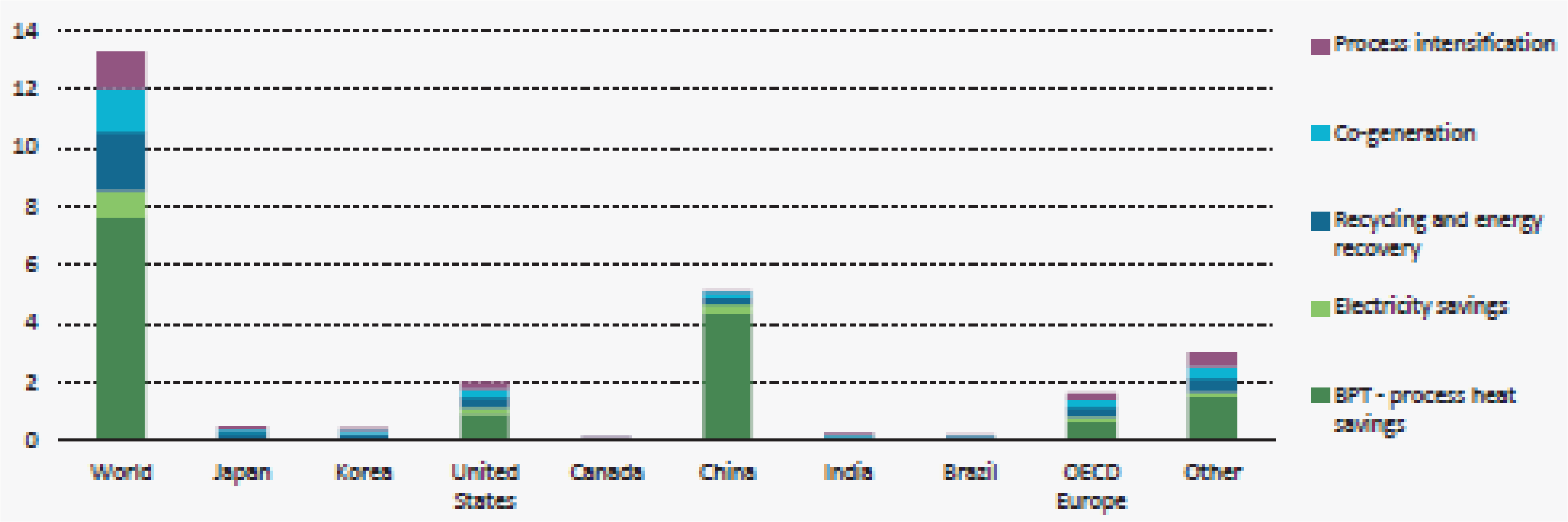
SOURCE: ICCA roadmap catalysts

IEA ETP 2012

Indications are provided on where the improvement potential can come from

Global Calculator

Current energy savings potential for chemicals and petrochemicals, based on best practice technologies (EJ/year)



SOURCE: ETP 2012

IEA ETP 2012

Technology options are assessed

Global Calculator

Main technology options for the chemical and petrochemical sector in the 2 DS

Technology	Research and development needs	Demonstration needs	Deployment milestones
New olefin production technologies	Improve methanol-to-olefin (MTO) processes and oxidative coupling of methane (OCM).		Currently under way with full commercialisation starting after 2020.
Other catalytic processes	Improve performance and further reduce gap to thermodynamically optimal catalytic process by 65% to 80%.	Under way.	Starting in 2020-25.
Membranes	Develop other novel separation technologies.		Expand use of membrane separation technologies.
Bio-based chemicals and plastics	Develop bio-based polymers.	Bio-based monomers.	Wider use of bio-based feedstock from 2025. Global share of bio-based feedstock to increase and reach between 4% and 5% of total feedstock used in 2050.
Hydrogen			Deployment after 2040. Marginal market share by 2050.
CCS for ammonia		Two plants by 2013.	31 plants by 2020 and 122 plants by 2030.

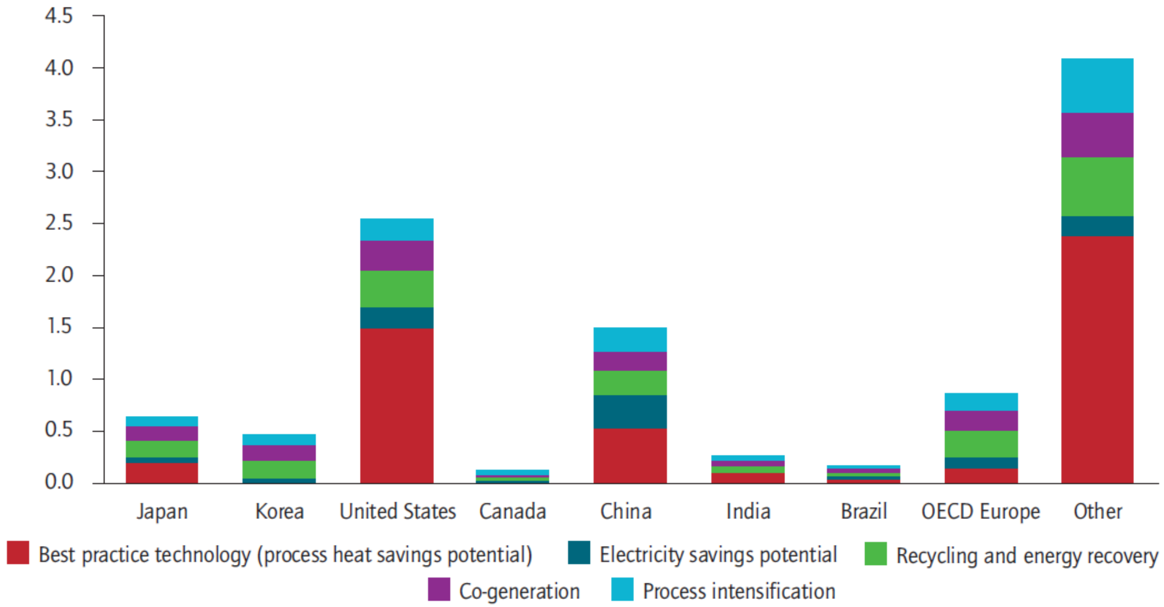
SOURCE: ETP 2012

IEA ETP 2012

Significant growth is expected in production volume of the chemical and petrochemical sector

Global Calculator

Energy savings potentials for chemicals & petrochemicals based on BPT deployment
(EJ, vs 2010 on 2010 production levels)



Global energy savings potential is ~10,5 EJ, with most significant contributions coming from BTP implementations, recycling & energy recovery

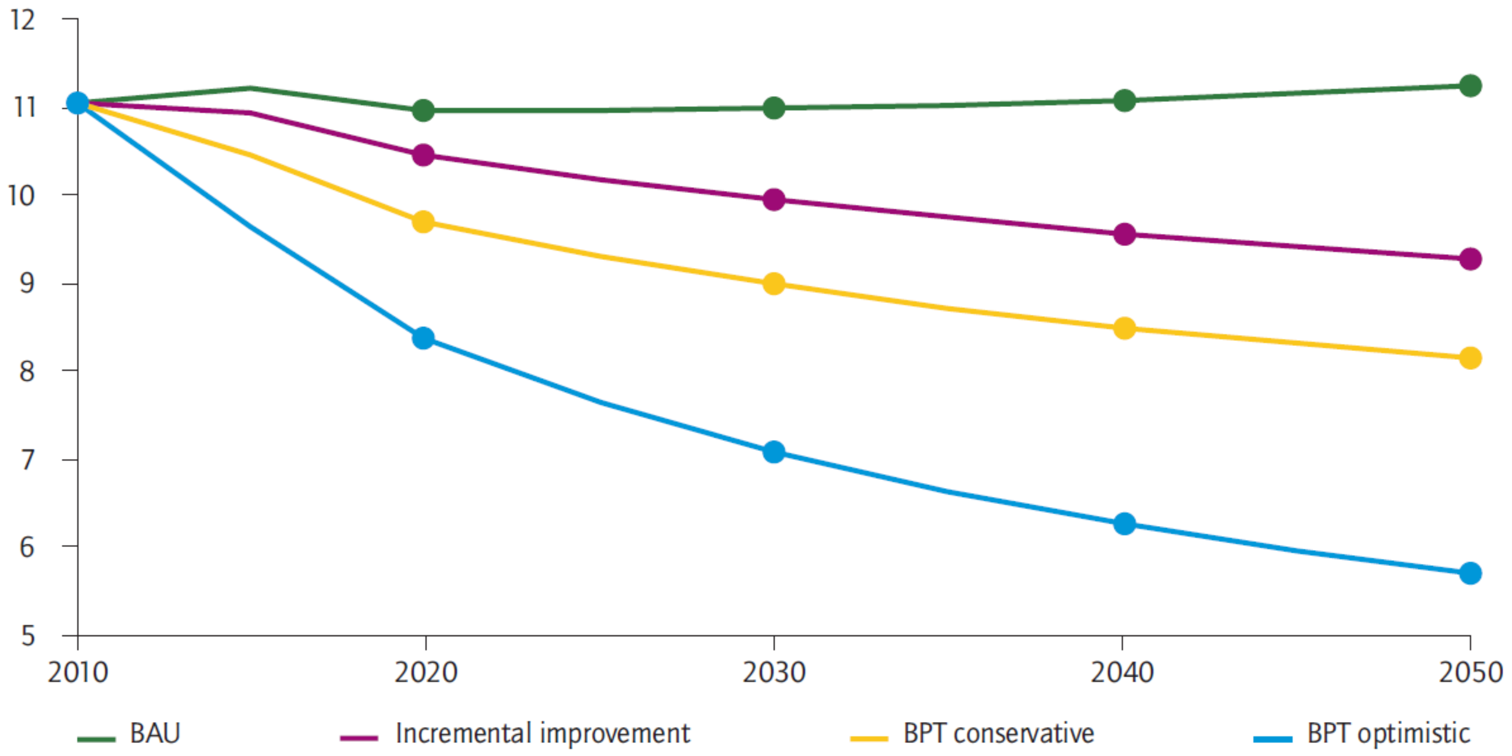
SOURCE: IEA via ICCA

DECHEMA

Strong energy efficiency improvement potentials are forecasted

Global Calculator

Energy intensity evolution along different ambitions (e.g. incremental improvements and deployment of Best Potential Technologies), in the largest 18 chemical volumes
(GJ/ton product)



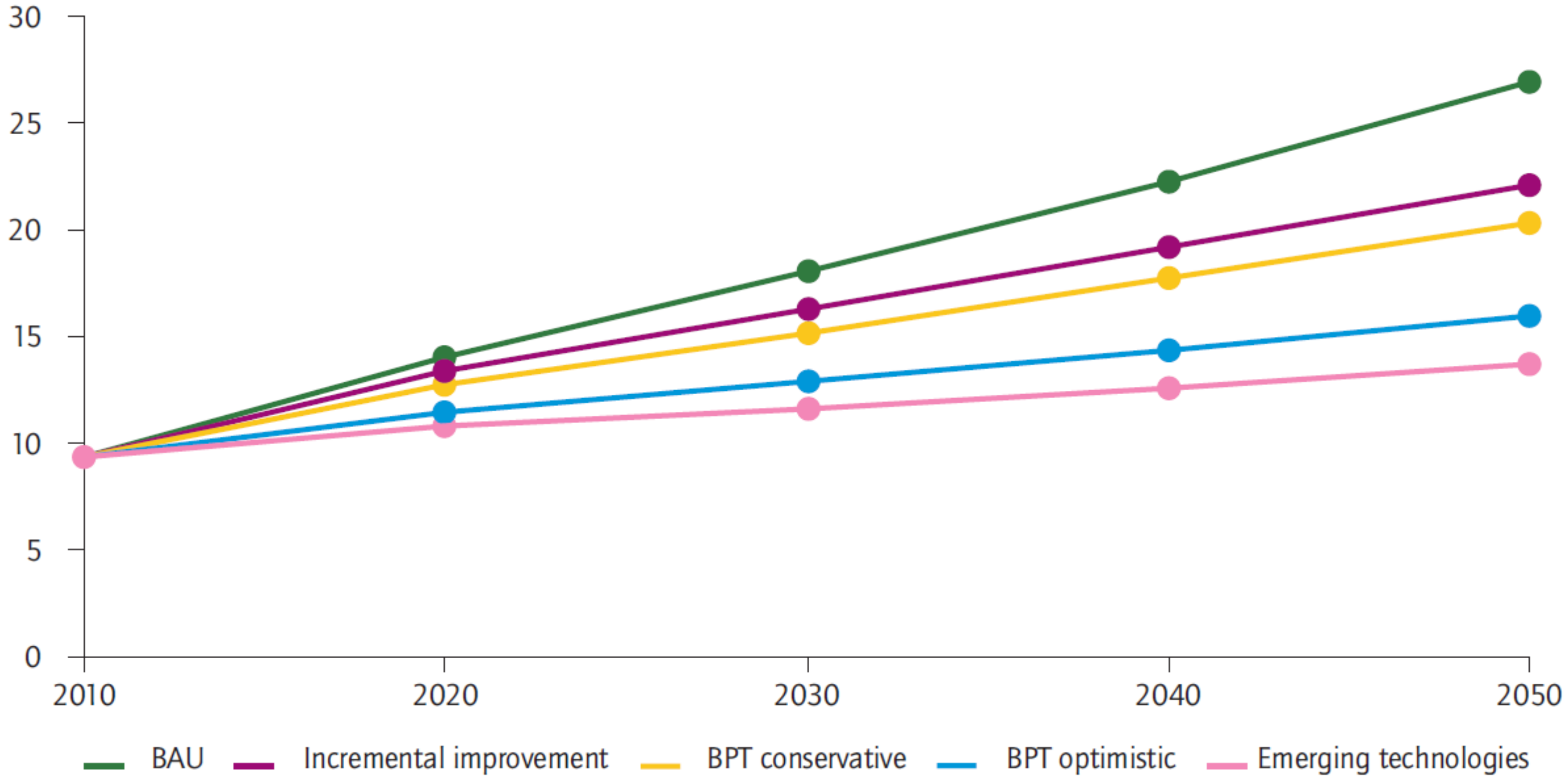
SOURCE: DECHEMA
NOTE: Energy consumption for olefins in this figure is based on the deployment of the catalytic cracking process

DECHEMA

However, combined with the chemical production increase, the total energy consumption is expected to increase

Global Calculator

Total energy consumption evolution along different ambitions (e.g. incremental improvements and deployment of Best Potential Technologies), in the largest 18 chemical volumes
(EJ)

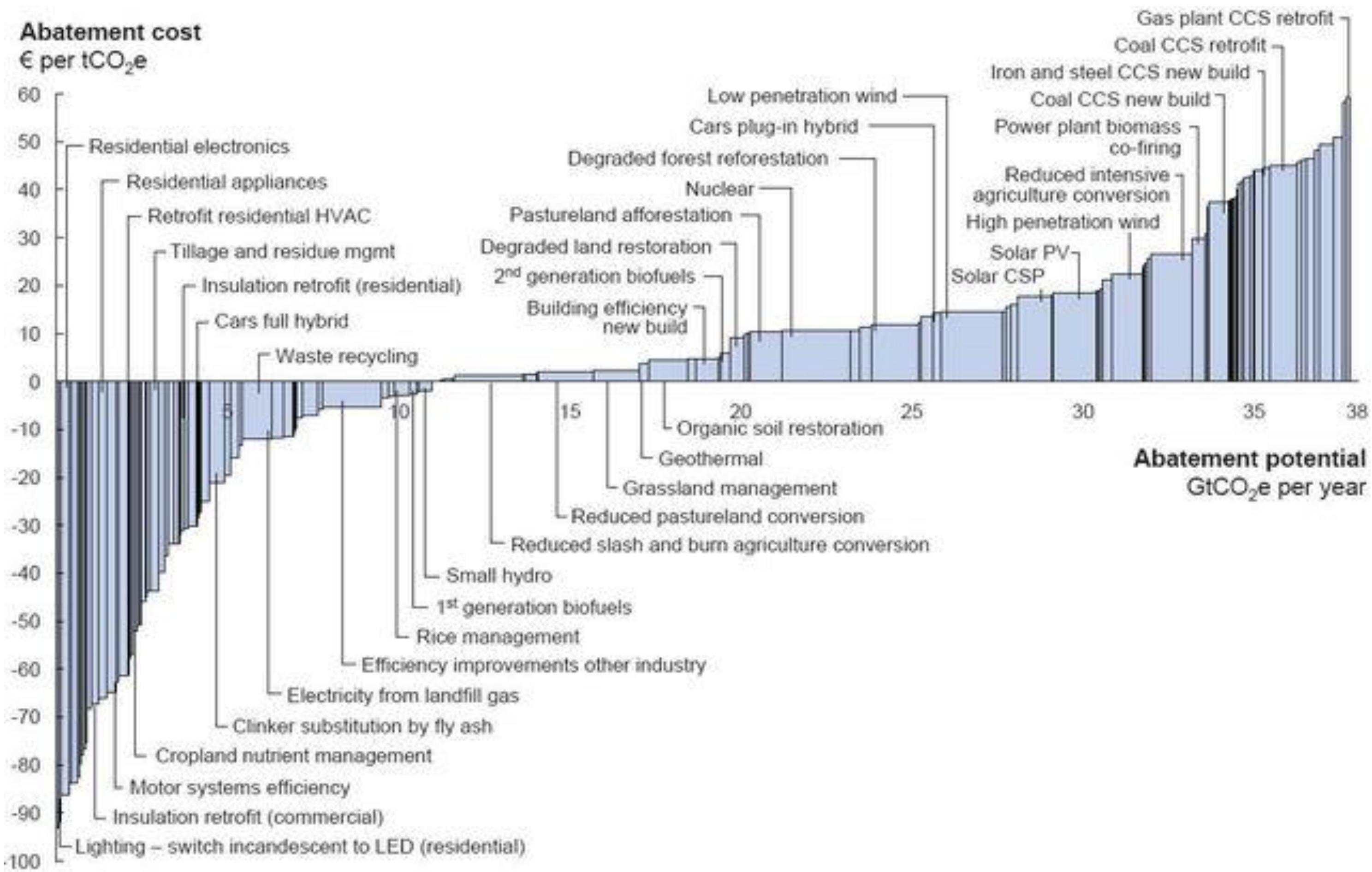


SOURCE: DECHEMA
NOTE: Energy consumption for olefins in this figure is based on the deployment of the catalytic craking process

Existing studies suggest at least a total 50% improvement is feasible

Global Calculator

Example of a study – McKinsey global abatement cost curve



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per tCO_2e if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

Table 2.5 Share of technology contribution to industry CO_2 emissions reduction potential by 2020

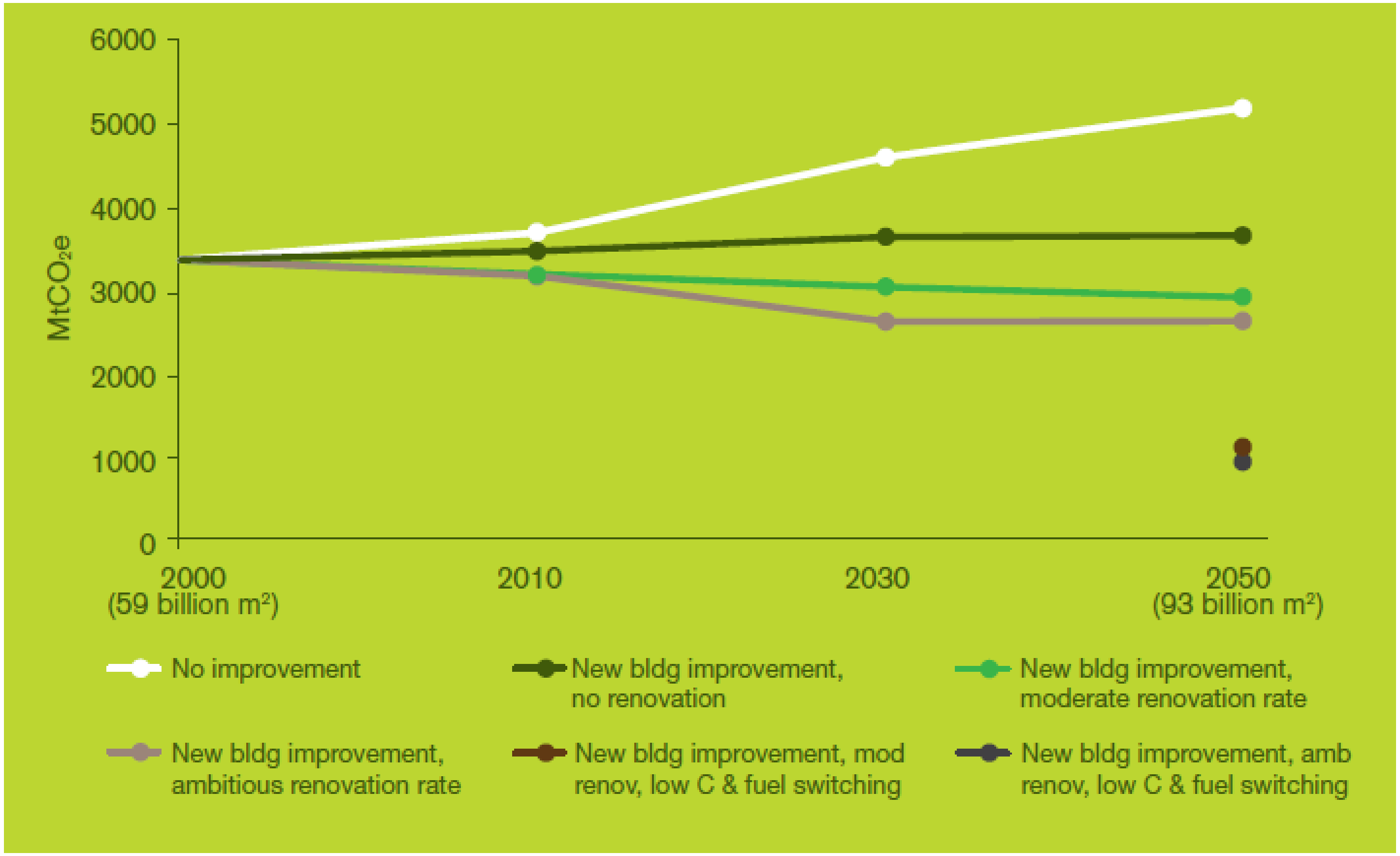
Industry sector	Average energy efficiency	Recycling and energy recovery	CCS	Fuel and feedstock switching/ alternative materials	Total savings (Mt CO_2)
Iron and steel					354
Cement		na			119
Chemicals					440
Pulp and paper					49
Aluminium			na		7
Total					969

Note: Share of emissions reduction potential by 2020 denoted as follows: ≥50%; 10≤ ≤50% ; ≤10%; Average energy efficiency includes improvements to existing facilities and the use of BATs as new facilities are built.

Key point *Over the next decade, improvements in energy efficiency in the five major sectors play the greatest part in reducing CO_2 emissions from industry.*

ICCA Roadmap summary
(including emission reductions in applications (e.g. buildings))

Global Calculator



Global Calculator

Backup

Existing studies

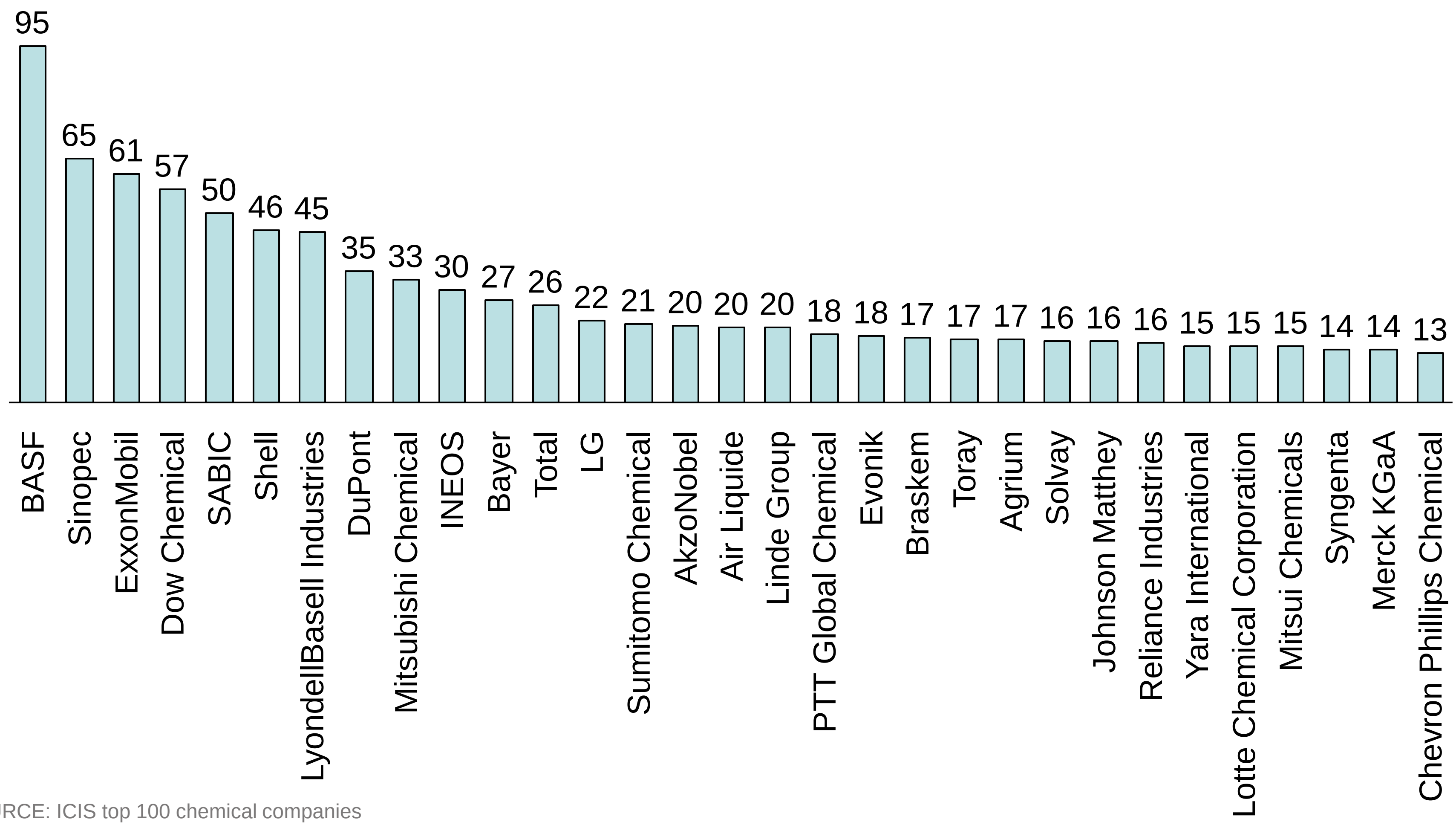
Other informations on the sector

Industry overview

Largest chemicals producers

Global Calculator

Chemicals production of 30 largest producers
($Bln 2012)

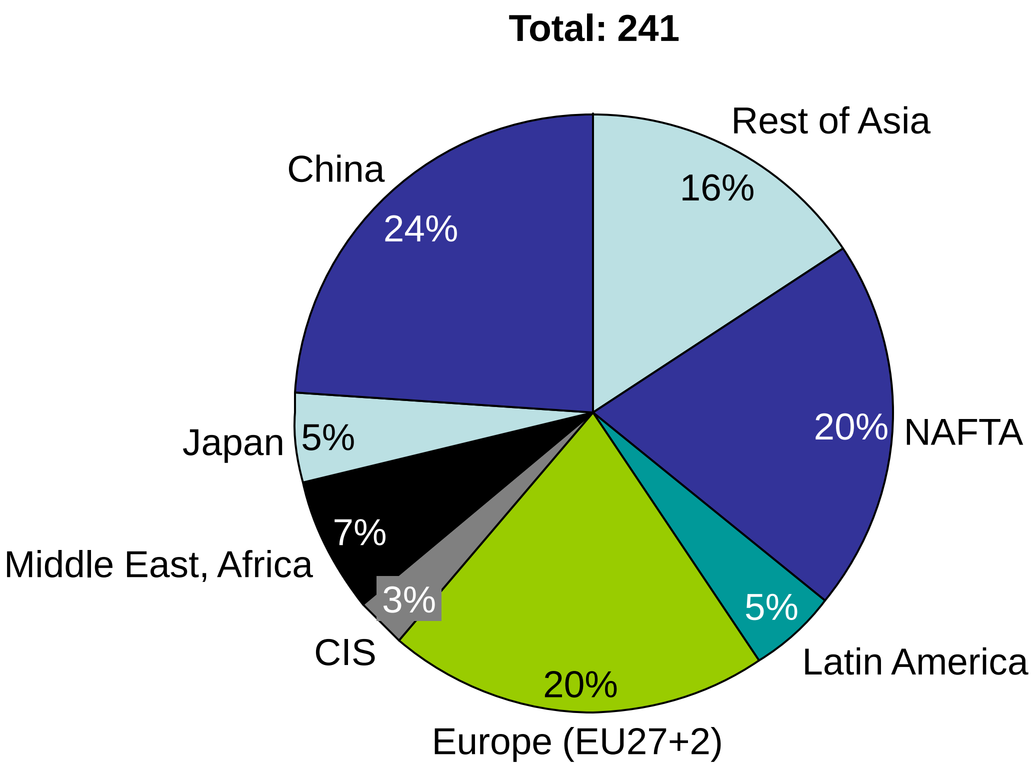


SOURCE: ICIS top 100 chemical companies

Production per region

Global Calculator

Plastics production per region
(Mtons, 2012)



- China remains the leading plastics producer with 23.9%
- Rest of Asia (incl. Japan) accounts for an additional 20.7%
- European production (EU-27+2) accounts for 20.4% of the world's total production

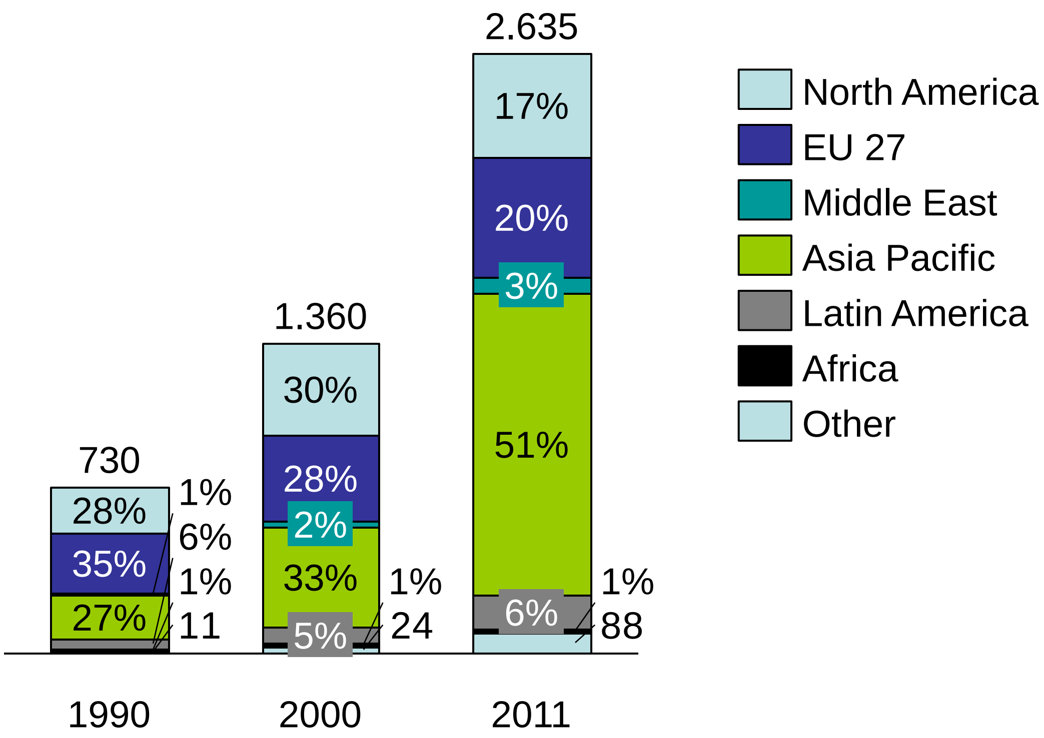
NOTE: Excluding ~47 tons of other plastics types

SOURCE: PlasticsEurope (PEMRG) / Consultic via Plastics Europe Association of Plastics manufacturers

Evolution of the production per region

Global Calculator

Plastics production per region
(Total gross output,€ Bln nominal)

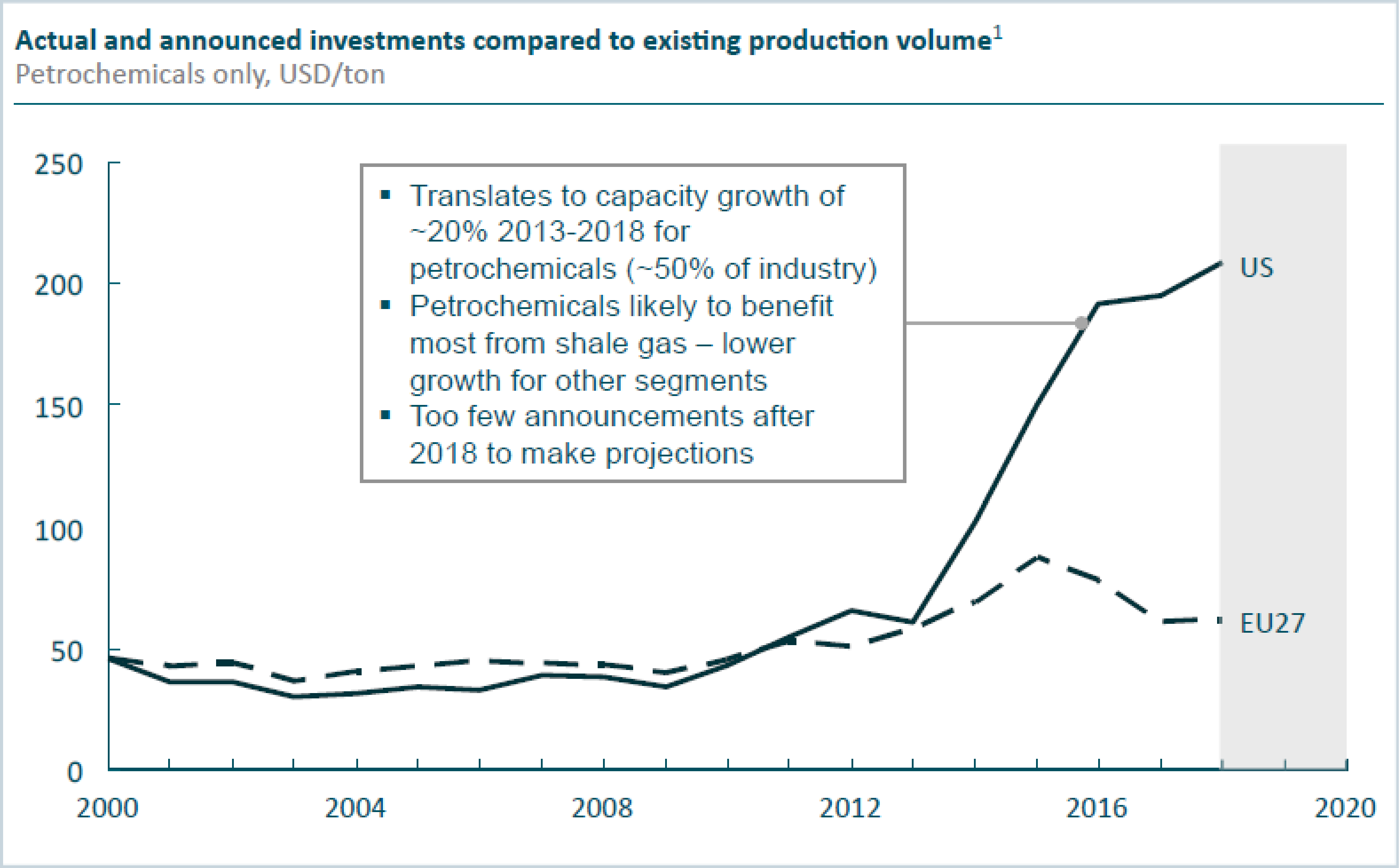


- Asian chemical industry has grown by an extraordinary 9-10 percent per year during this period
- Shale gas impact on US production does not appear visible in 2011

NOTE: Total chemical industry excluding pharmaceuticals; 2 Also includes European non--EU27 Countries (not shown on page)
SOURCE: IHS Economics

ECF assesses the widening investment gap between US and the EU

Global Calculator



1 Data for petrochemicals only, excludes inorganics and specialties. Includes new investments and maintenance capex (maintenance calculated as 1.5% of replacement value), excludes cost of plant conversion (Europe has heavily converted chlorine plants and the US has converted crackers)

SOURCE: McKinsey models

1

What plastics are used for

In buildings

Category	Product
Insulation	• Wall • Roof
Pipe	• Plastic Pipe • Pipe insulation
Wall air barrier	• Frame • Masonery
Air sealing	• Foundation caulk • Window caulk • Weather stripping • Flashing membrane
Cool roof	• Reflective roof coatings and pigments
Windows	• Plastic frame • Surface film • Warm edge spacer

SOURCE: ICCA buildings roadmap

Global Calculator

Backup

Existing studies

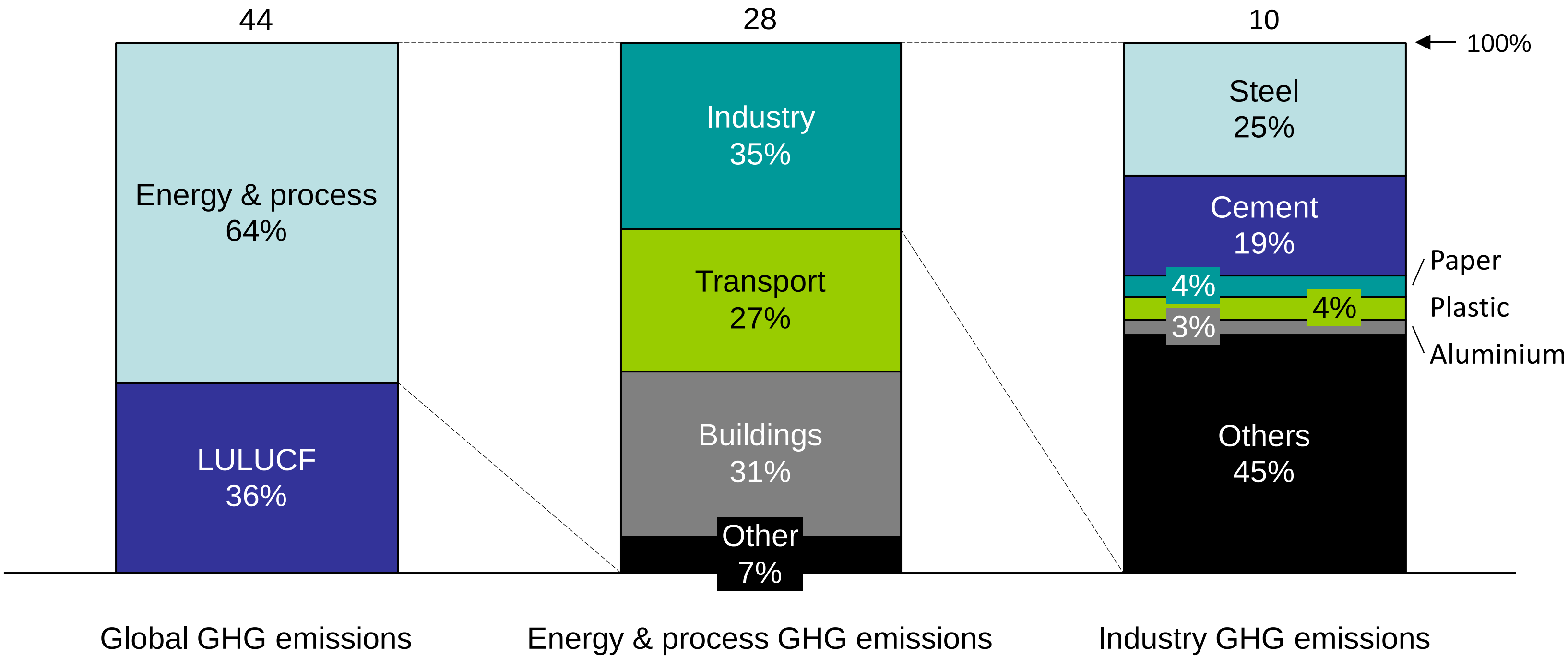
Other informations on the sector

Industry overview

Industry represents 22 % of total emissions and is made up of 5 main industries

Global Calculator

Global anthropogenic GHG emissions in 2005
($GtCO_2e$)

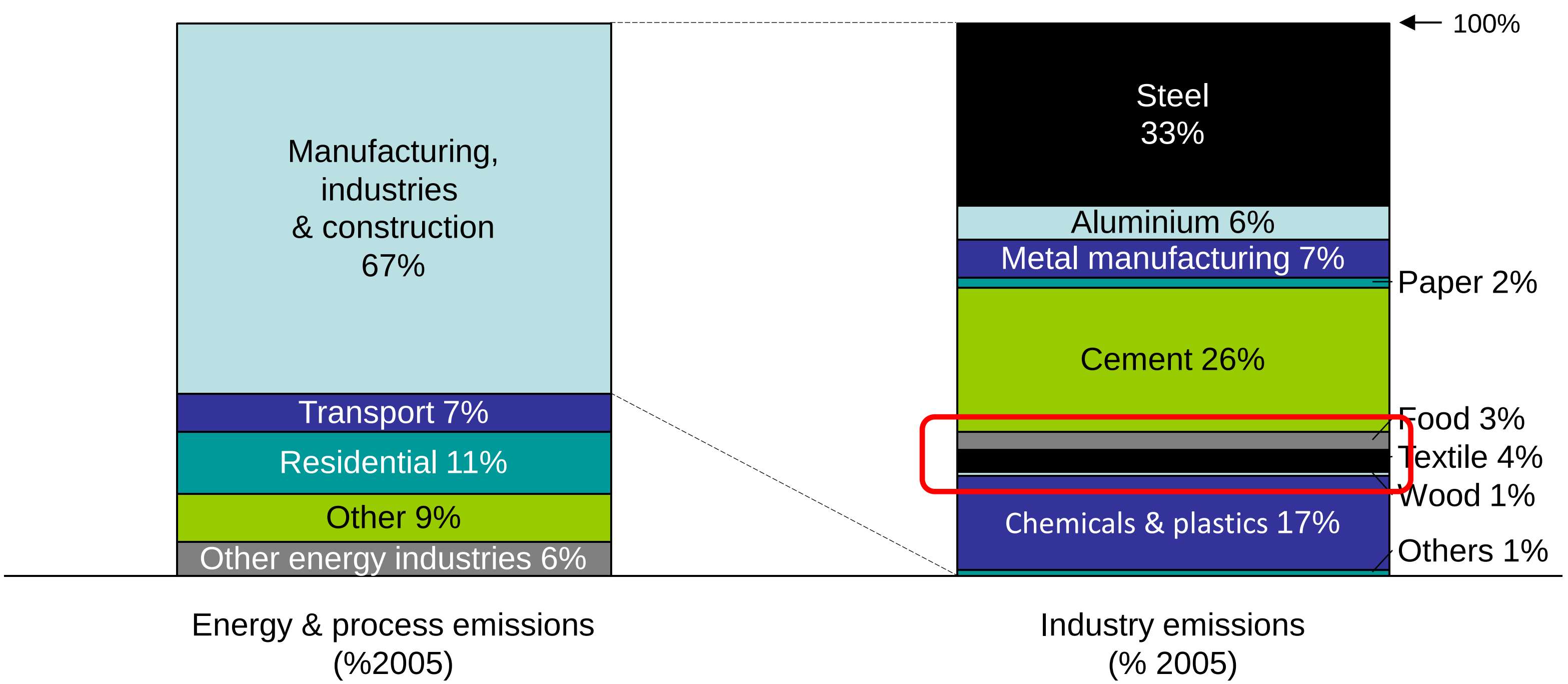


SOURCE: IEA 2008 on year 2005

These 5 sectors are representative of the whole industry. Assembly from materials to finished products is not a major energy or emissions segment

Global Calculator

China anthropogenic GHG emissions in 2005
(%)



SOURCE: China government statistics: Linwei, 2011 for year

Large developing economies are moving up in global manufacturing

Global Calculator

Top 15 manufacturers by share of global nominal manufacturing gross value added

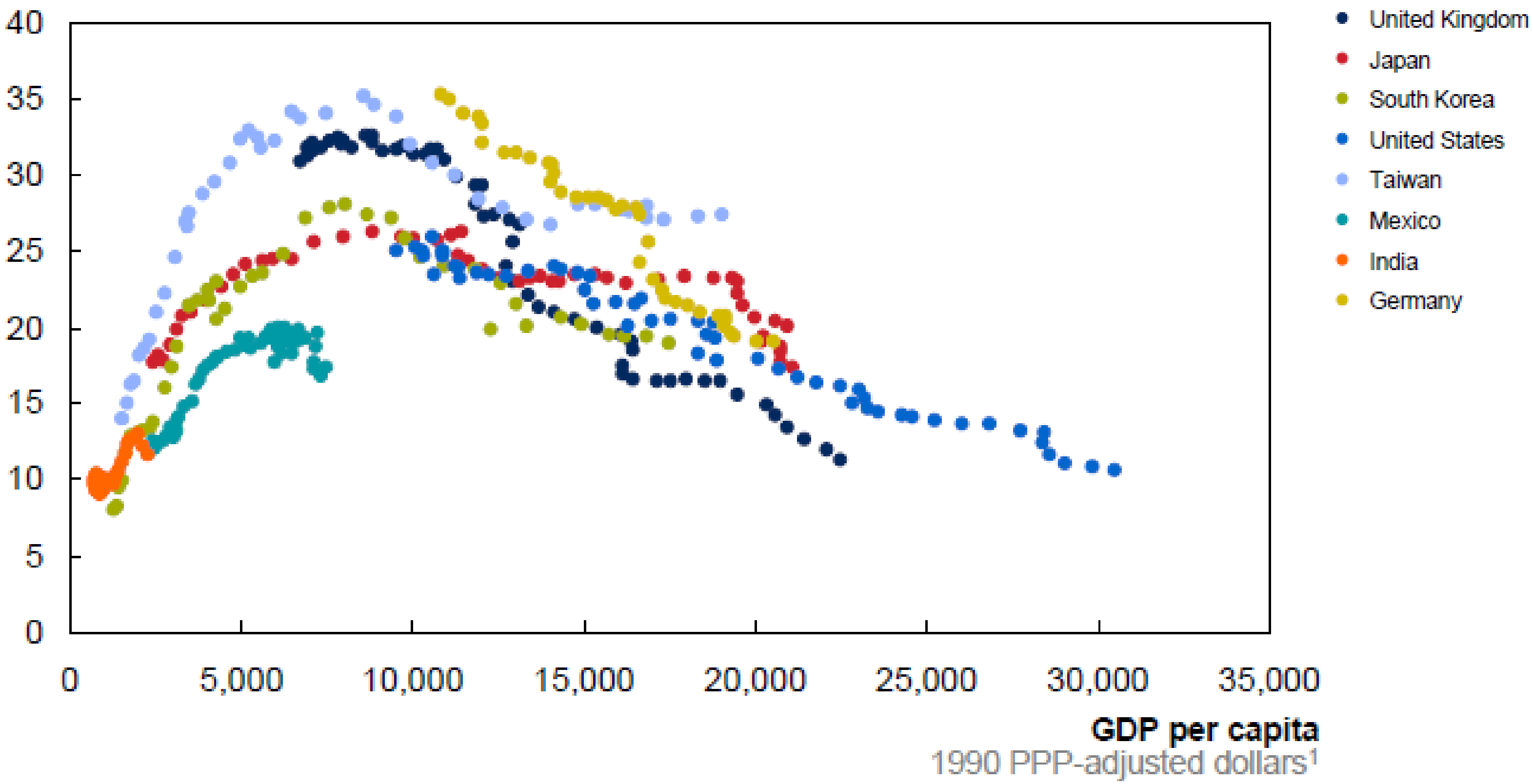
Rank	1980	1990	2000	2010
1	United States	United States	United States	United States
2	Germany	Japan	Japan	China
3	Japan	Germany	Germany	Japan
4	United Kingdom	Italy	China	Germany
5	France	United Kingdom	United Kingdom	Italy
6	Italy	France	Italy	Brazil
7	China	China	France	South Korea
8	Brazil	Brazil	South Korea	France
9	Spain	Spain	Canada	United Kingdom
10	Canada	Canada	Mexico	India
11	Mexico	South Korea[1]	Spain	Russia[2]
12	Australia	Mexico	Brazil	Mexico
13	Netherlands	Turkey	Taiwan	Indonesia[2]
14	Argentina	India	India	Spain
15	India	Taiwan	Turkey	Canada

1 South Korea ranked 25 in 1980.
2 In 2000, Indonesia ranked 20 and Russia ranked 21.
NOTE: Based on IHS Global Insight database sample of 75 economies, of which 28 are developed and 47 are developing. Manufacturing here is calculated top down from the IHS Global Insight aggregate; there might be discrepancy with bottom-up calculations elsewhere.
SOURCE: IHS Global Insight; McKinsey Global Institute analysis

Manufacturing's share of total employment fall as the economy grows wealthier, following an inverted U pattern

Global Calculator

Manufacturing employment
(% of total employment)



1 Adjusted using the Geary-Khamis method to obtain a 1990 international dollar, a hypothetical currency unit that allows international comparisons adjusted for exchange rates and purchasing power parity (PPP).

SOURCE: GGDC 10-Sector Database: "Structural change and growth accelerations in Asia and Latin America: A new sectoral data set," *Cliometrica*, volume 3, Issue 2, 2009; McKinsey Global Institute analysis