# Global Calculator
# Technical documentation

## Manufacturing sector

Technical documentation (Part 3/3 Backup)

**2015**

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 technical documentation

Global Calculator

- This technical documentation highlights the assumptions used in the manufacturing sector of the global calculator model. Introduction material generic to all sectors should be read prior going through this technical document.

- Most of this documentation has been performed to support workshop discussions on the technical choices in the manufacturing sector (in steel, cement, chemicals & across the sector as a whole)

- The global calculator aims at supporting the debate. You are more than welcome to share feedback on the calculator and on this documentation. We aim at continuously refining this analysis with your feedbacks. The expert feedback is incorporated in the analysis through various steps:
  1. It is flagged as feedback to include in the analysis
  2. The analysis documents are refined accordingly
  3. The model is updated and the model results are shown in the presentation

  The dates of the figures used in the model are written Most of the figures in this document date from July 2014. Please note that some minor modifications have been placed in the model since July 2014. In case of differences between the presentation and the model, the model has the most recent estimates.

- All this documentation is open source (1)

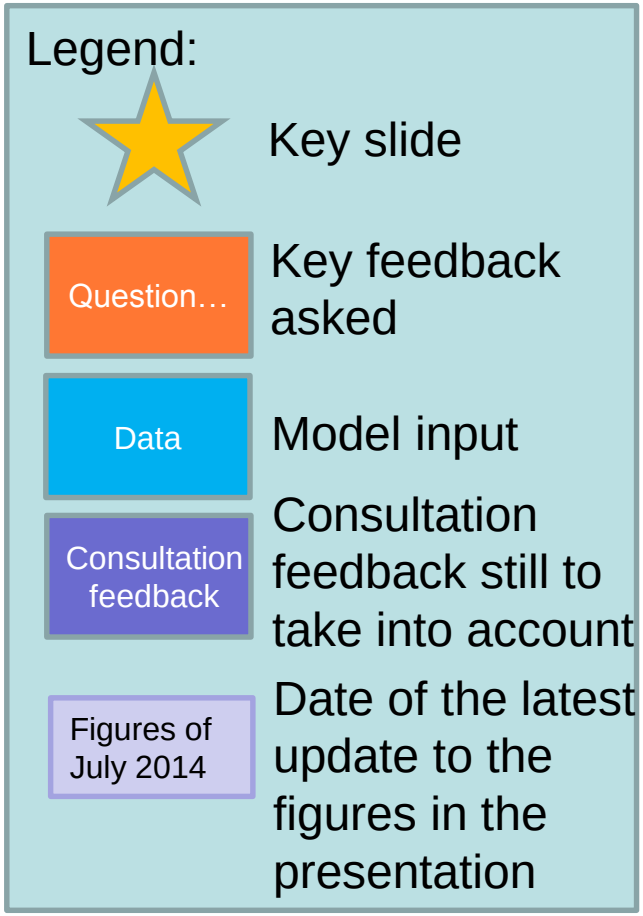
NOTE: (1) The Global Calculator spreadsheet and supporting documentation is made available under (and subject to the terms of) the Open Government Licence (www.nationalarchives.gov.uk/doc/open-government-licence/version/2/). The web tool is published under (and subject to the terms of) the Creative Commons Licence (attribution, non-commercial, see: http://creativecommons.org/licenses/by-nc/4.0/legalcode).

As set out in those licences, DECC, IEA and the Climate-KIC consortium provide no express or implied warranties concerning the tool and its contents and, accordingly, those parties accept no liability arising from use of the tool or its contents.

# Legend associated with the consulting process

Global Calculator

- Several slides in this technical documentation document are tagged to reflect the stakeholder consultations



# Agenda

Global Calculator

**Backup**

**Existing studies**

Industry overview

Steel

- Existing studies
- Other informations on the sector

Chemicals

- Existing studies
- Other informations on the sector

Cement

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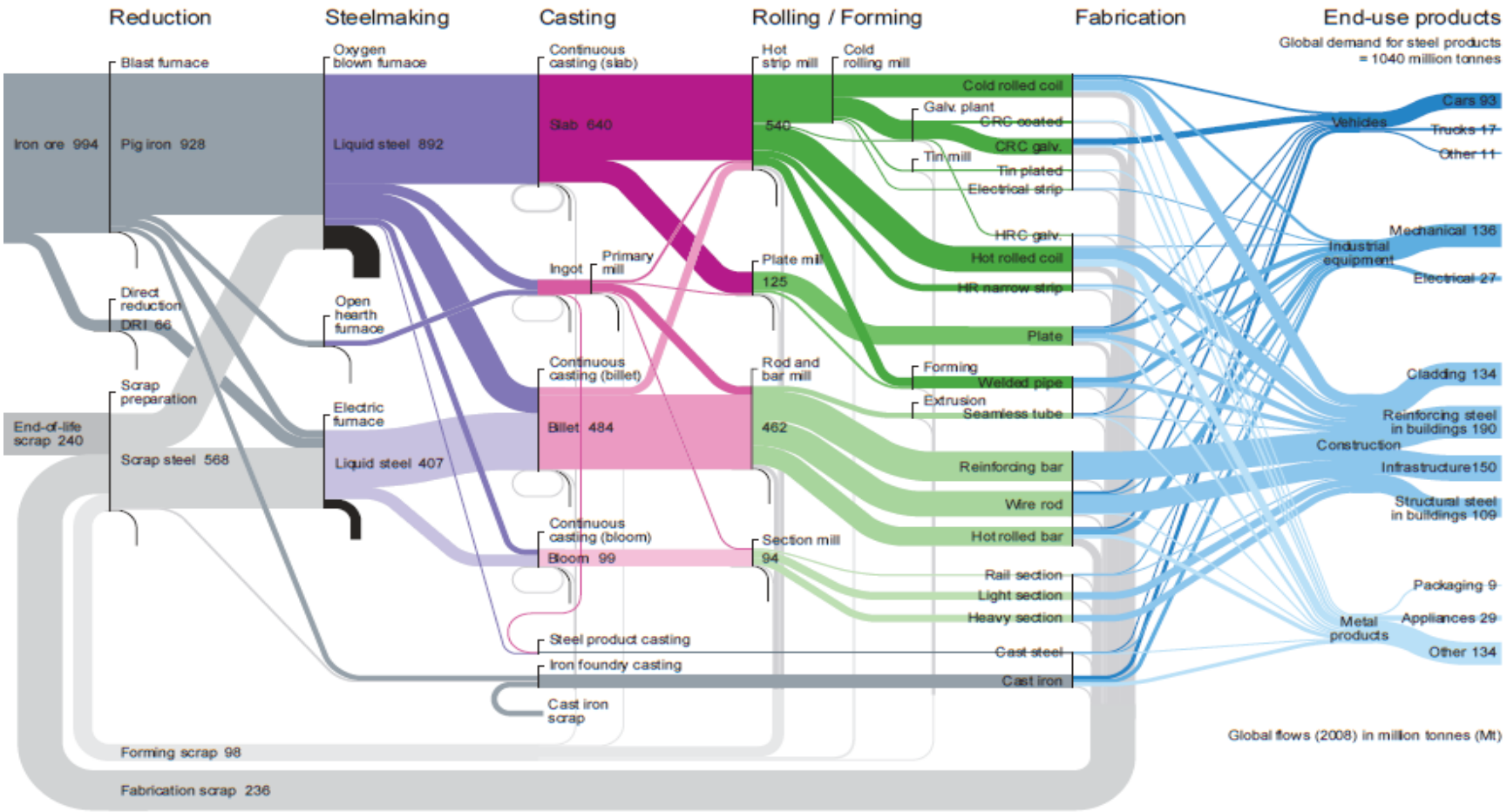
# With both eyes open is a key analysis on the flows from resources to end products

Global Calculator

**Sankey of global steel flows**

(Mt 2008)

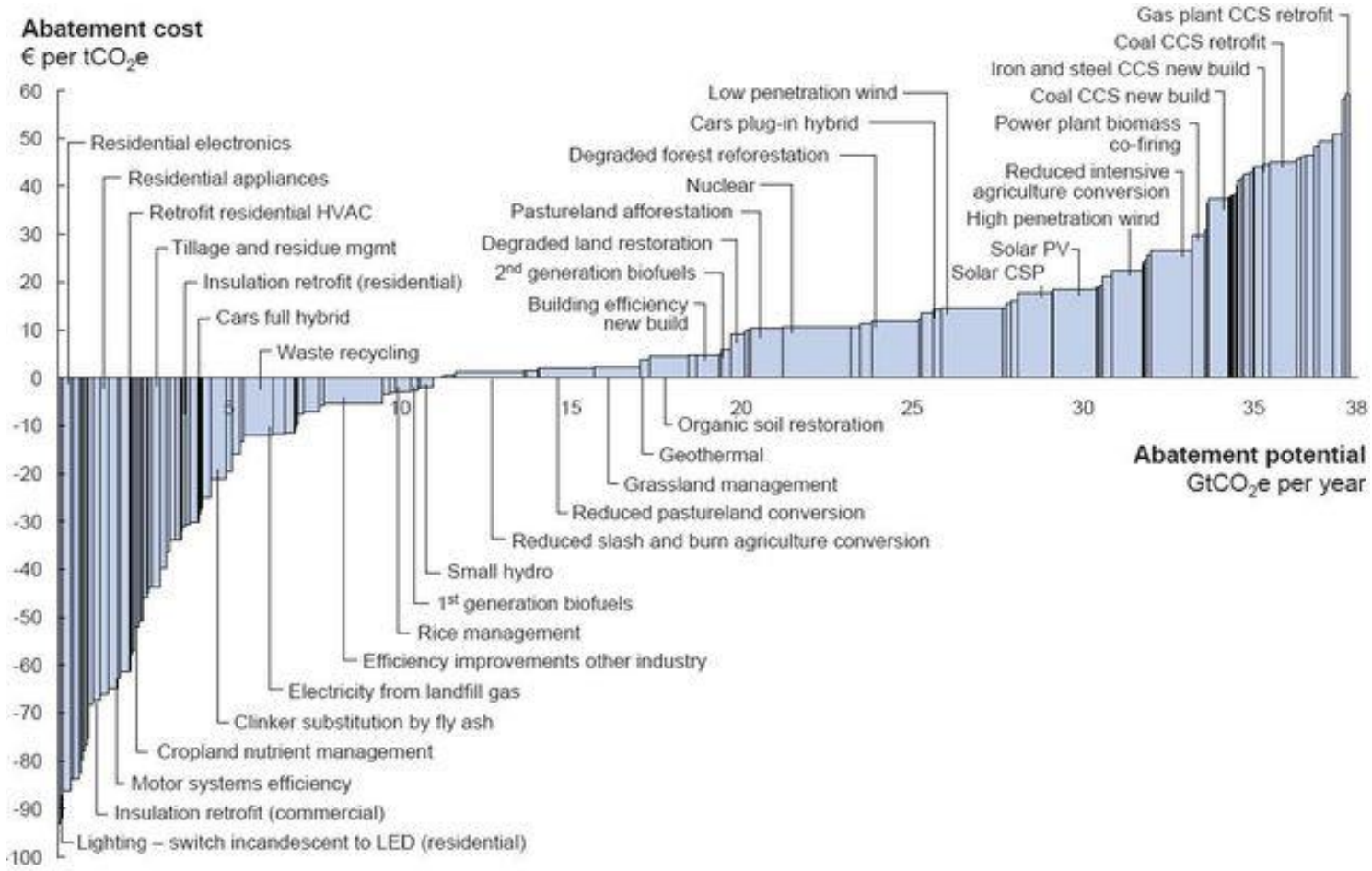



SOURCE : With both eyes open

# 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 1.1** Global marginal abatement costs and example marginal abatement options in the 2DS

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Marginal cost (USD/tCO$_2$)** | 30-50 | 80-100 | 110-130 | 130-160 |
| **Energy conversion** | Onshore wind<br>Rooftop PV<br>Coal w CCS | Utility scale PV<br>Offshore wind<br>Solar CSP<br>Natural gas w CCS<br>Enhanced geothermal systems | Same as for 2030, but scaled up deployment in broader markets | Biomass with CCS<br>Ocean energy |
| **Industry** | Application of BAT in all sectors<br>Top-gas recycling blast furnace<br>Improve catalytic process performance<br>CCS in ammonia and HVC | Bio-based chemicals and plastics<br>Black liquor gasification | Novel membrane separation technologies<br>Inert anodes and carbothermic reduction<br>CCS in cement | Hydrogen smelting and molten oxide electrolysis in iron and steel<br>New cement types<br>CCS in aluminium |
| **Transport** | Diesel ICE<br>HEV<br>PHEV | HEV<br>PHEV<br>BEV<br>Advanced biofuels | Same as for 2030, but wider deployment and to all modes | FCEV<br>New aircraft concepts |
| **Buildings** | Solar thermal space and water heating<br>Improved building shells | Stability of organic LED<br>System integration and optimisation with geothermal heat-pumps | Solar thermal space cooling | Novel buildings materials; development of "smart buildings"<br>Fuel cells co-generation |

Notes: HVC = high-value chemicals, FCEV = fuel-cell electric vehicle, LED = light emitting diode.

**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.*

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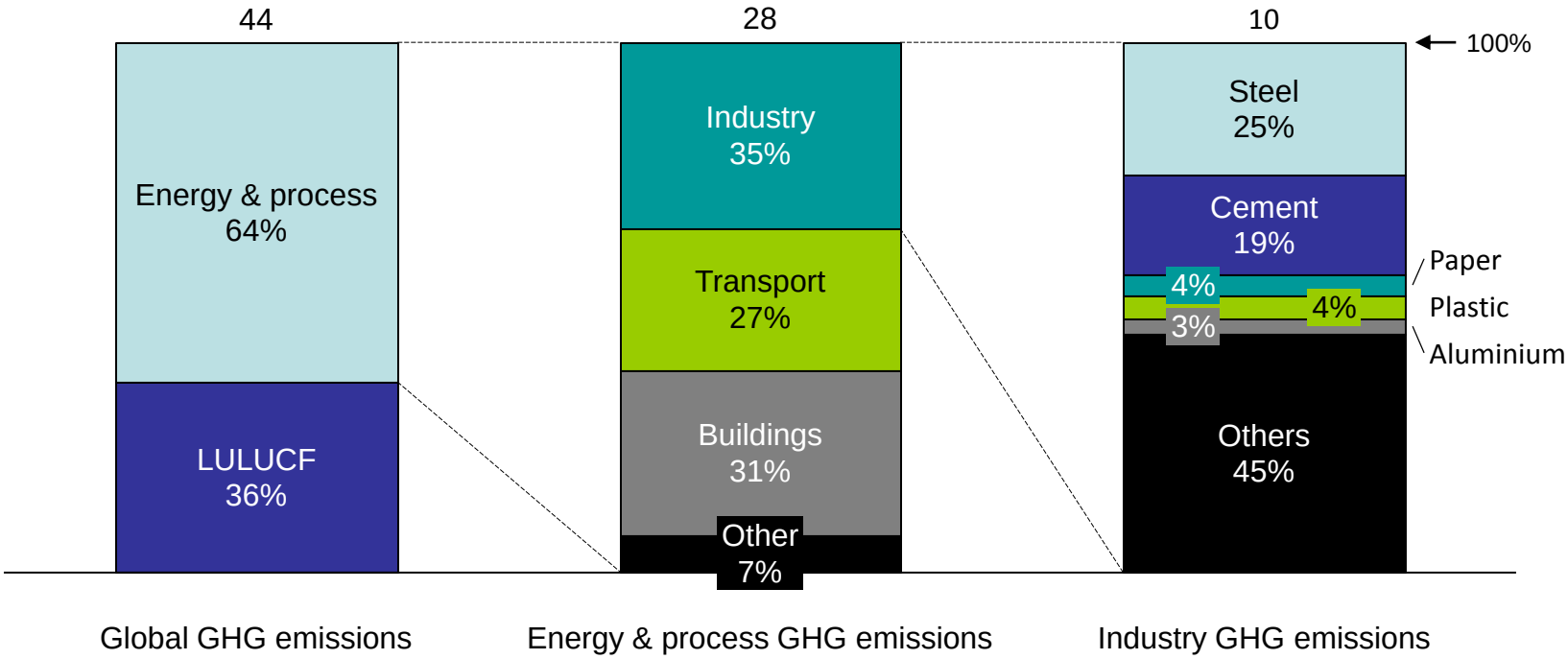
# Industry represents 22 % of total emissions and is made up of 5 main industries

Global Calculator

**Global anthropogenic GHG emissions in 2005** ($GtCO_2e$)

Backup



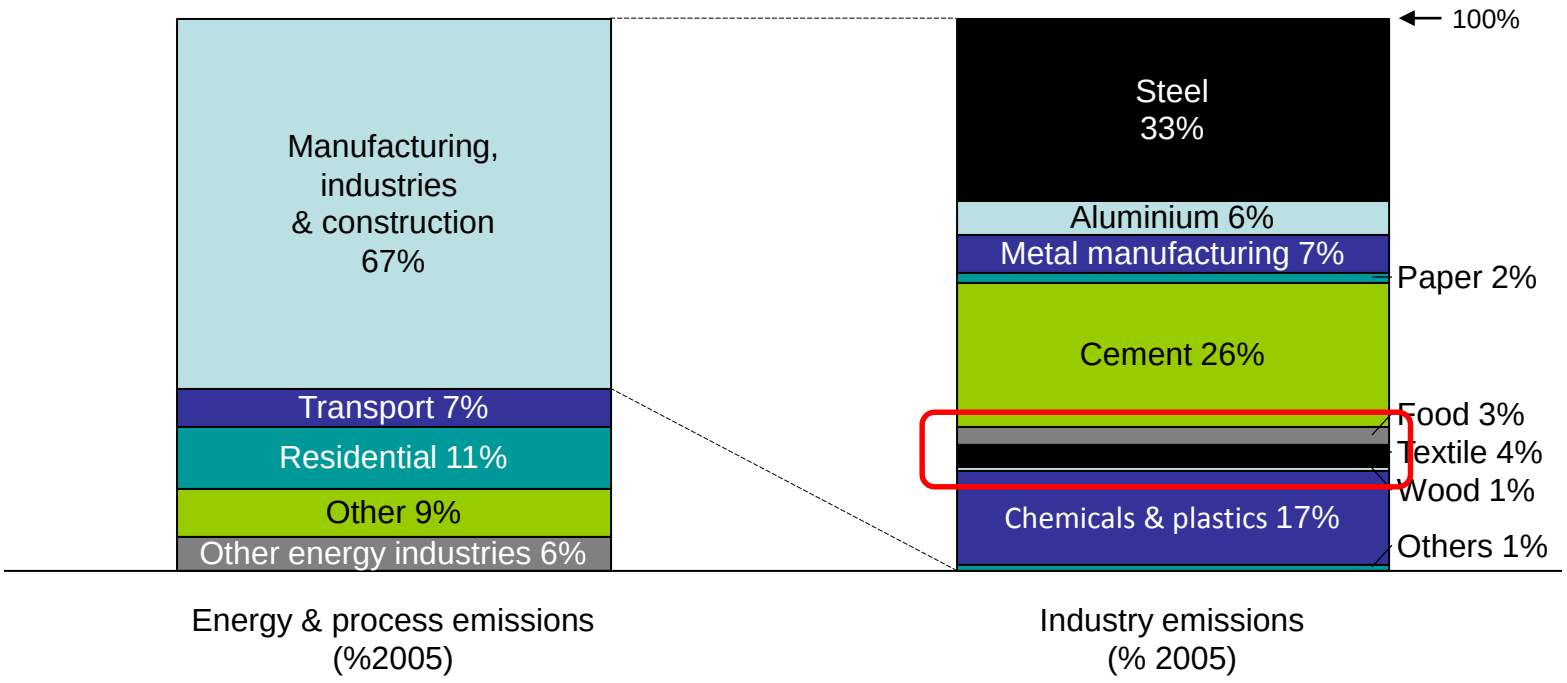

SOURCE: IEA 2008 on year 2005 through with both eyes open

# 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** (%)

Backup




SOURCE: China government statistics: Linwei, 2011 for year, through with both eyes open

# Large developing economies are moving up in global manufacturing

Global Calculator

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

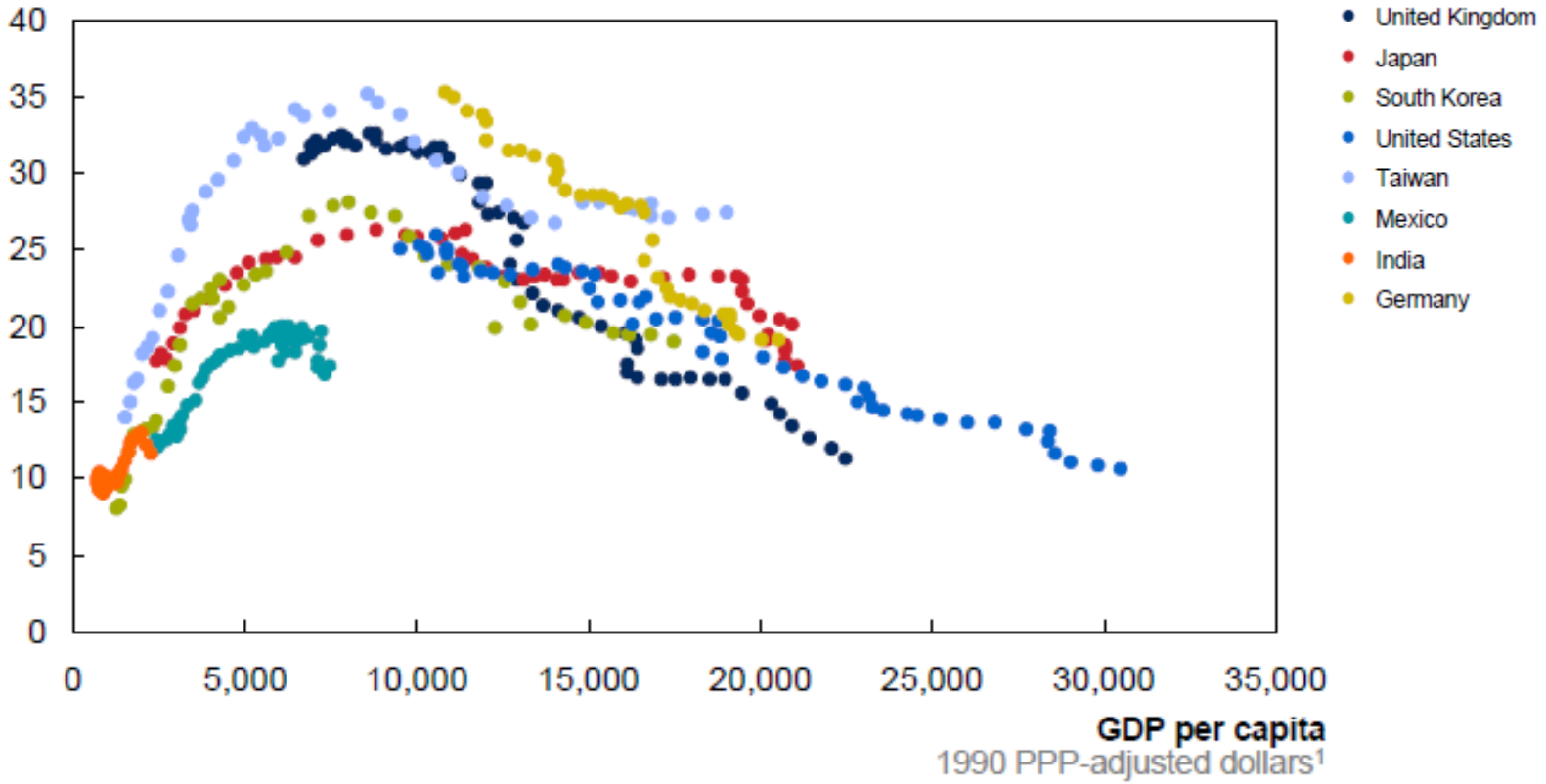

1 South Korea ranked 25 in 1980.
2 In 2000, Indonesia ranked 20 and Russia ranked 21.
NOTE: Based on IHS Global Insight database sample of 75 economies, of which 28 are developed and 47 are developing. Manufacturing here is calculated top down from the IHS Global Insight aggregate; there might be discrepancy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

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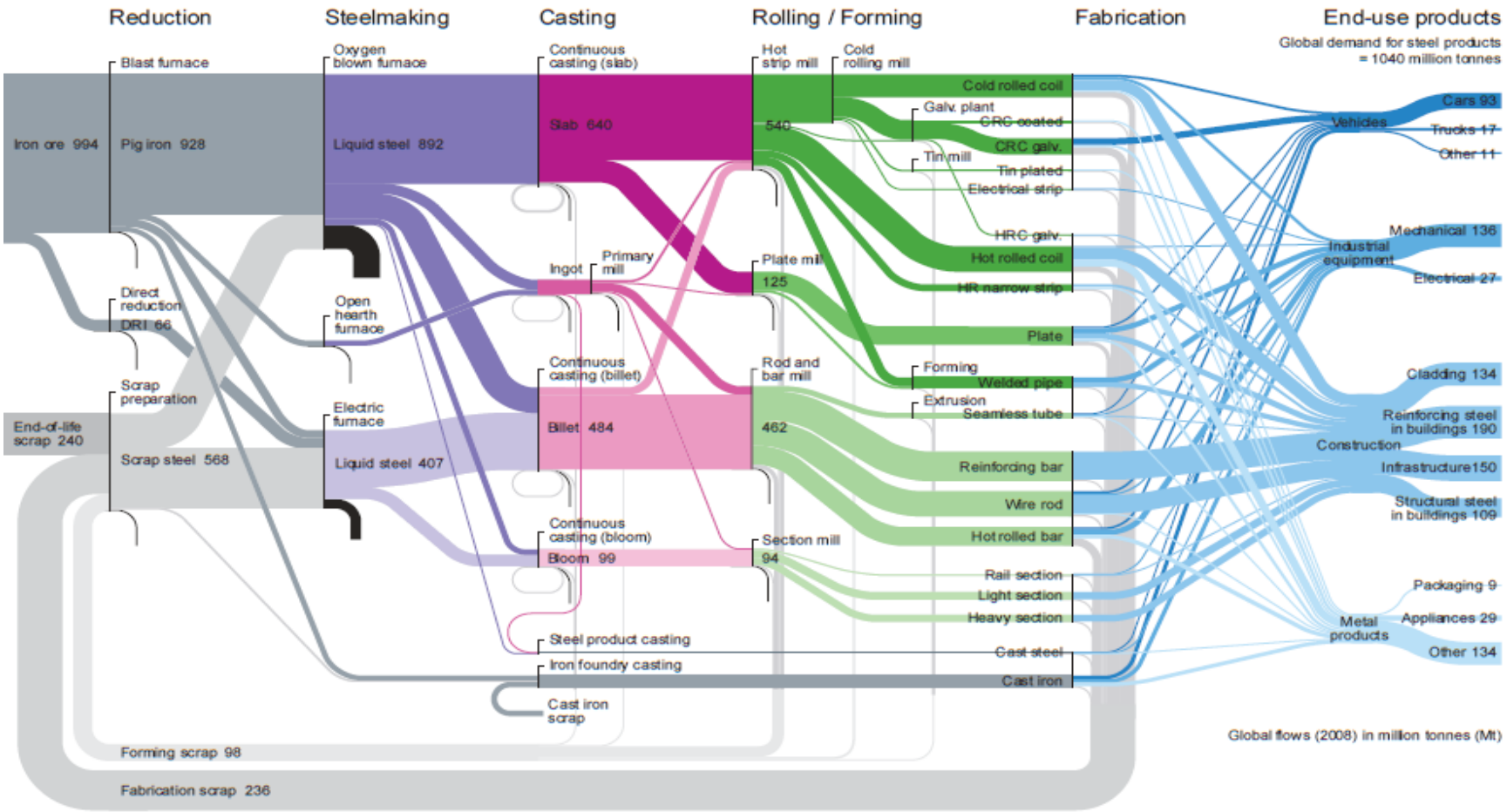
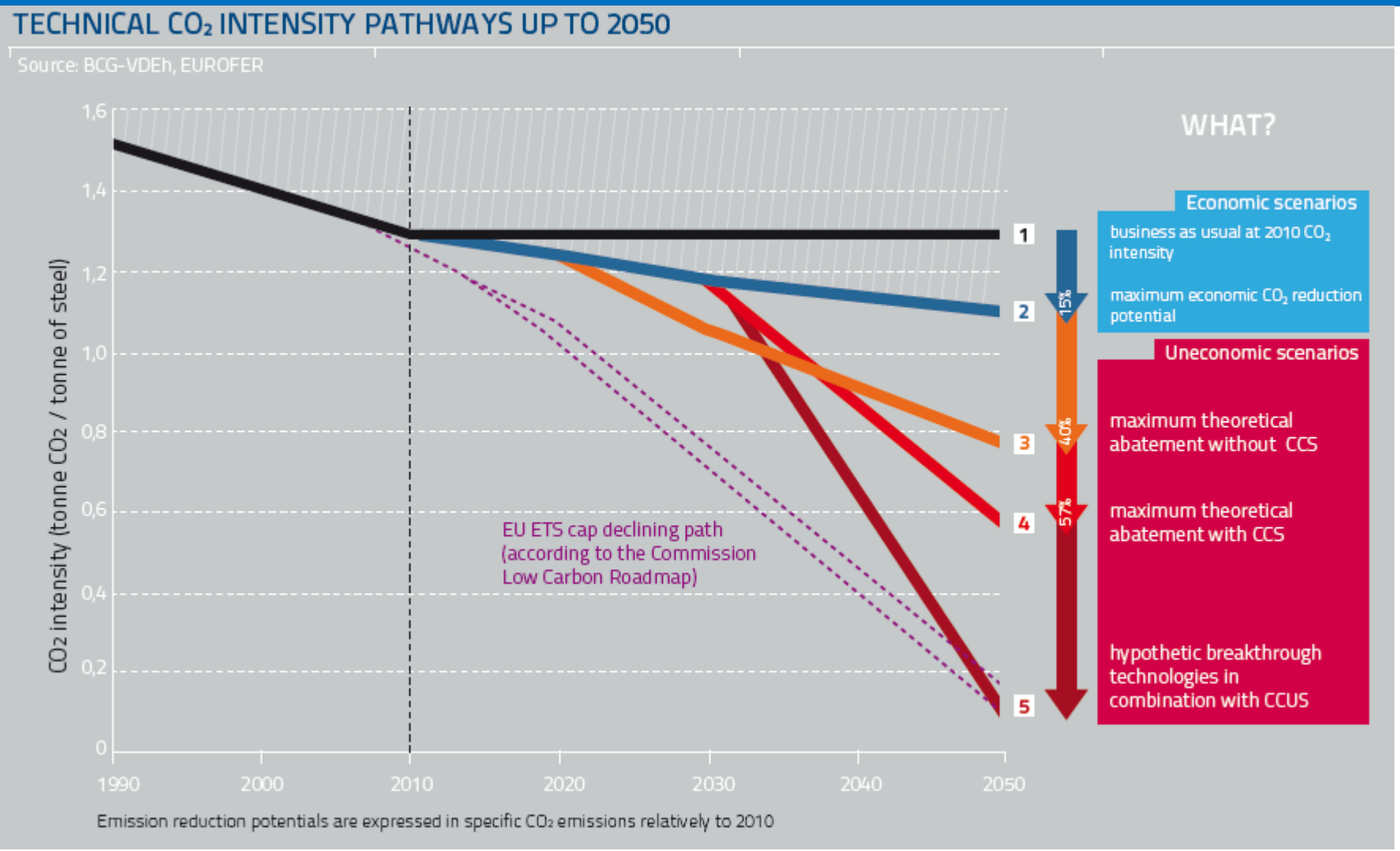



SOURCE : With both eyes open

# Eurofer 2013 roadmap

Global Calculator



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

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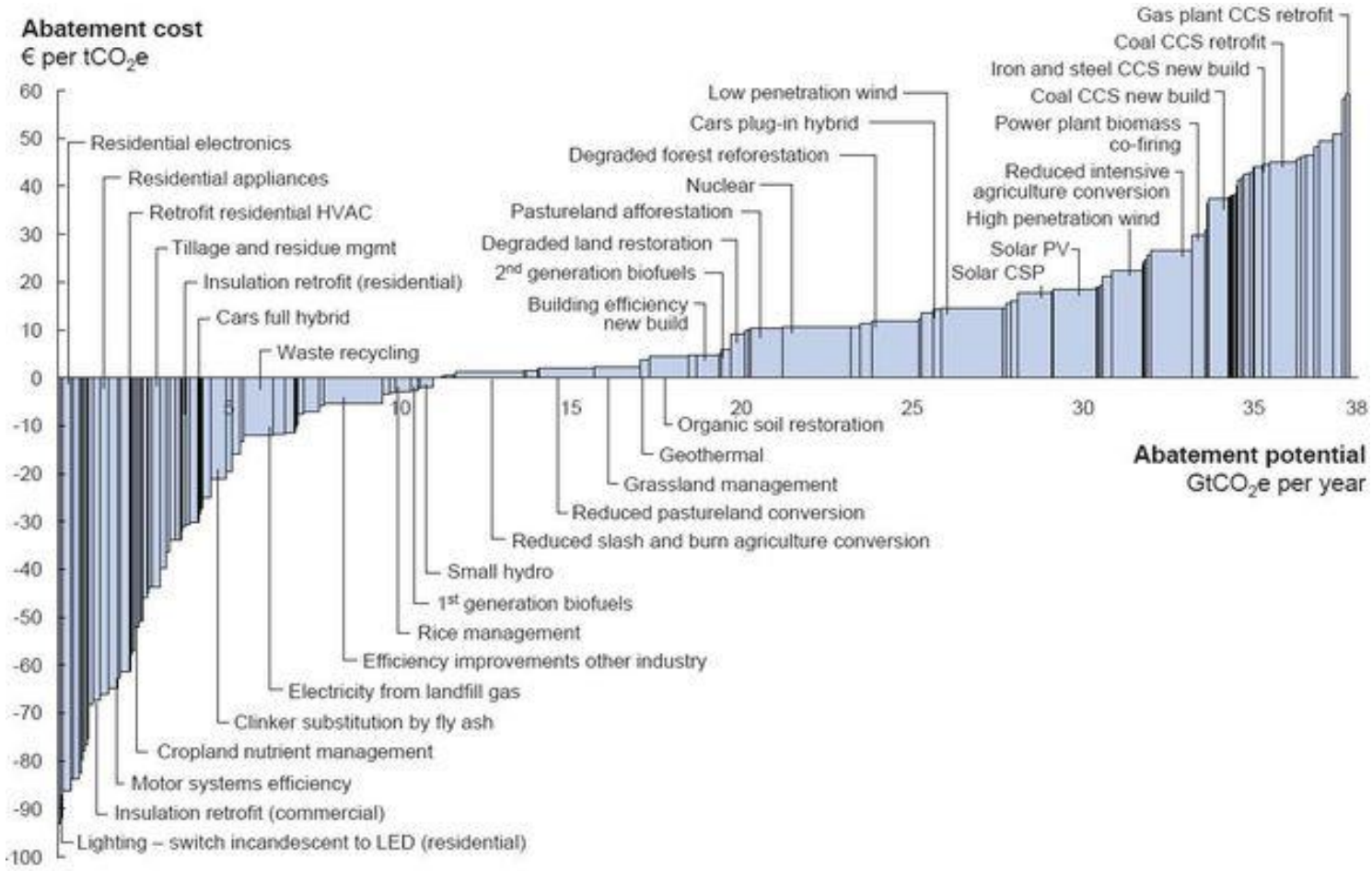
## Example of a study – McKinsey global abatement cost curve

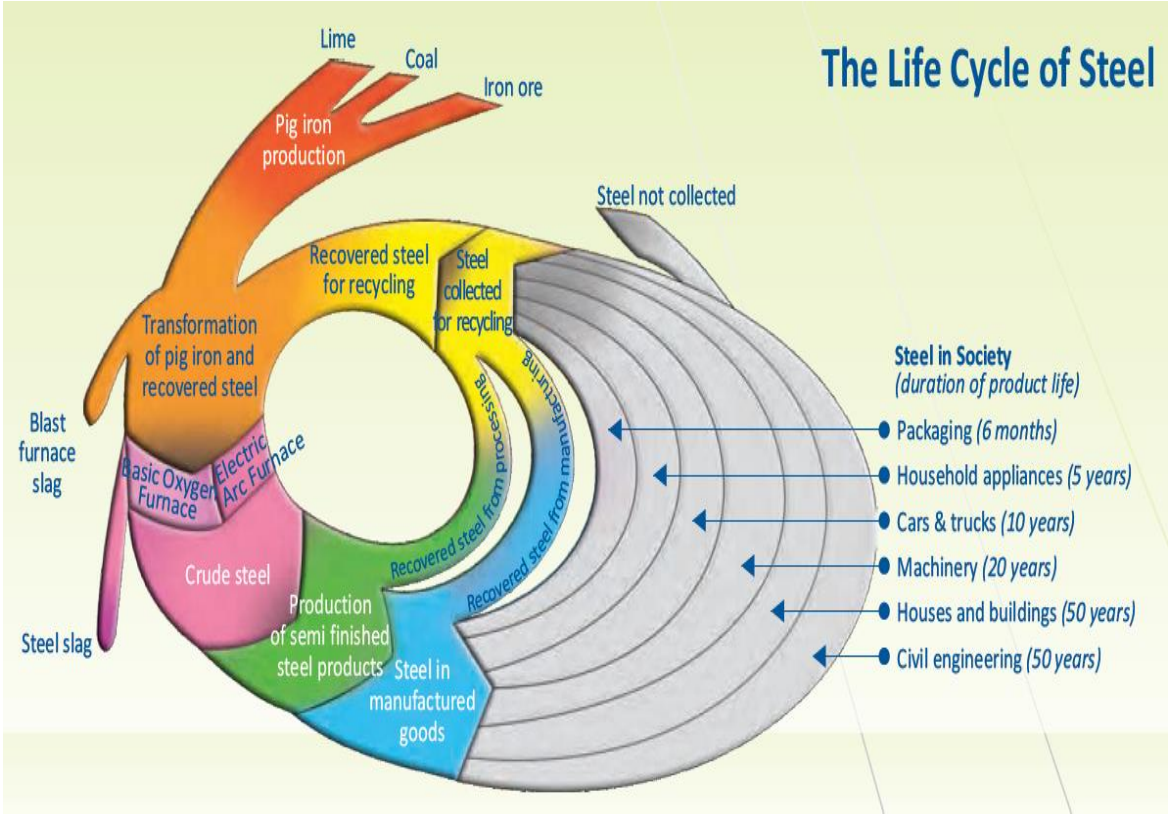



Note: The curve presents an estimate of the maximum potential of all technical GHG abatement measures below €60 per $tCO_2e$ if each lever was pursued aggressively. It is not a forecast of what role different abatement measures and technologies will play.
Source: Global GHG Abatement Cost Curve v2.0

# The life cycle of steel shows the importance of scrap collection

Global Calculator

**Life cycle of steel**




Despite of excellent recyclability of steel, continuous growth in world demand and long lead time of recycling still urge for an important fraction of pig iron production

SOURCE : GSV

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

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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.*

# Agenda

Global Calculator

## Backup

- Existing studies
- Industry overview
- **Steel**
  - Existing studies
  - **Other informations on the sector**
- Chemicals
  - Existing studies
  - Other informations on the sector
- Cement
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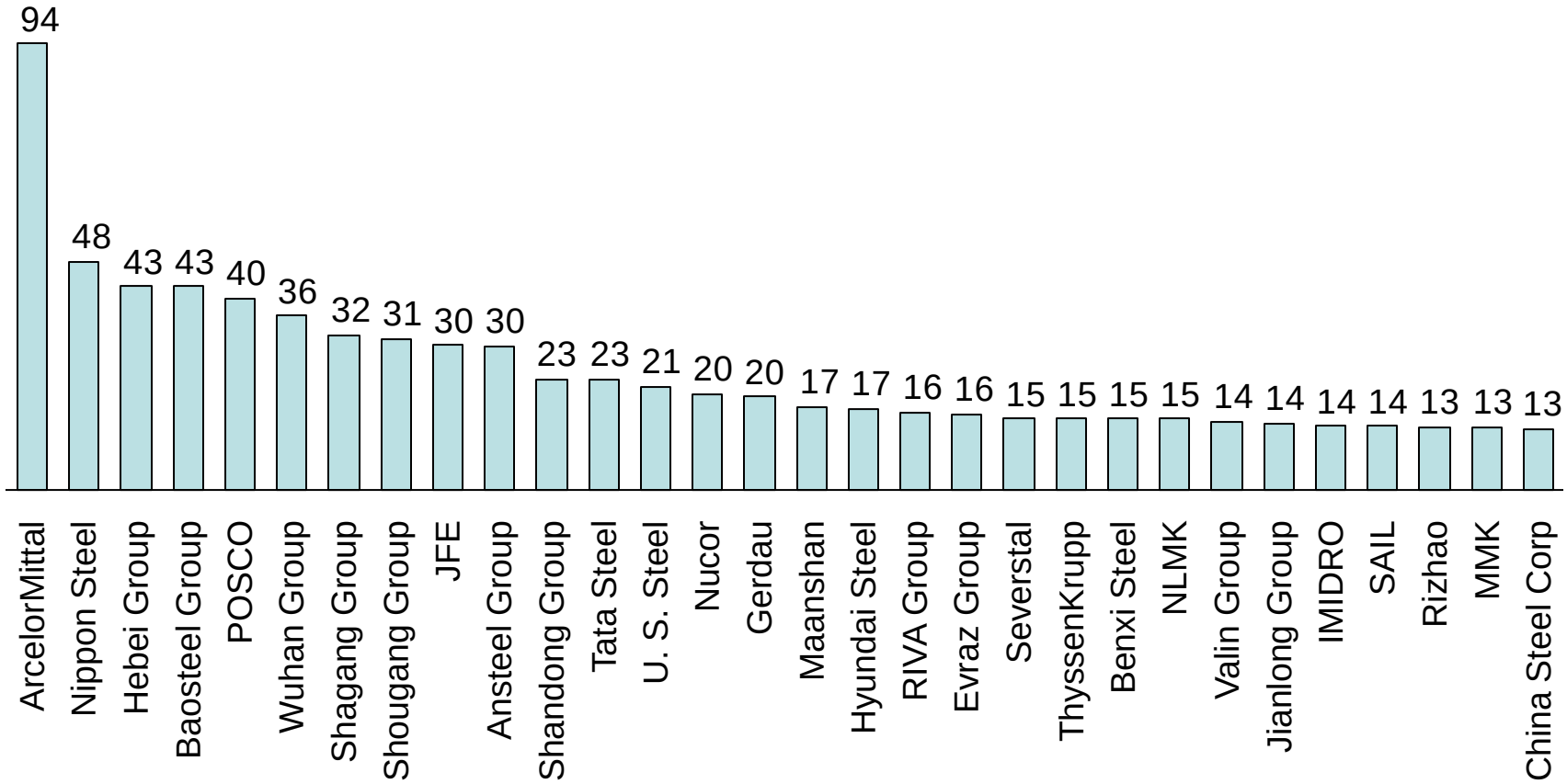
  - Other informations on the sector

# Largest steel producers

Global Calculator

**Crude steel production of 30 largest producers**
(M tons per year 2012)

BACKUP

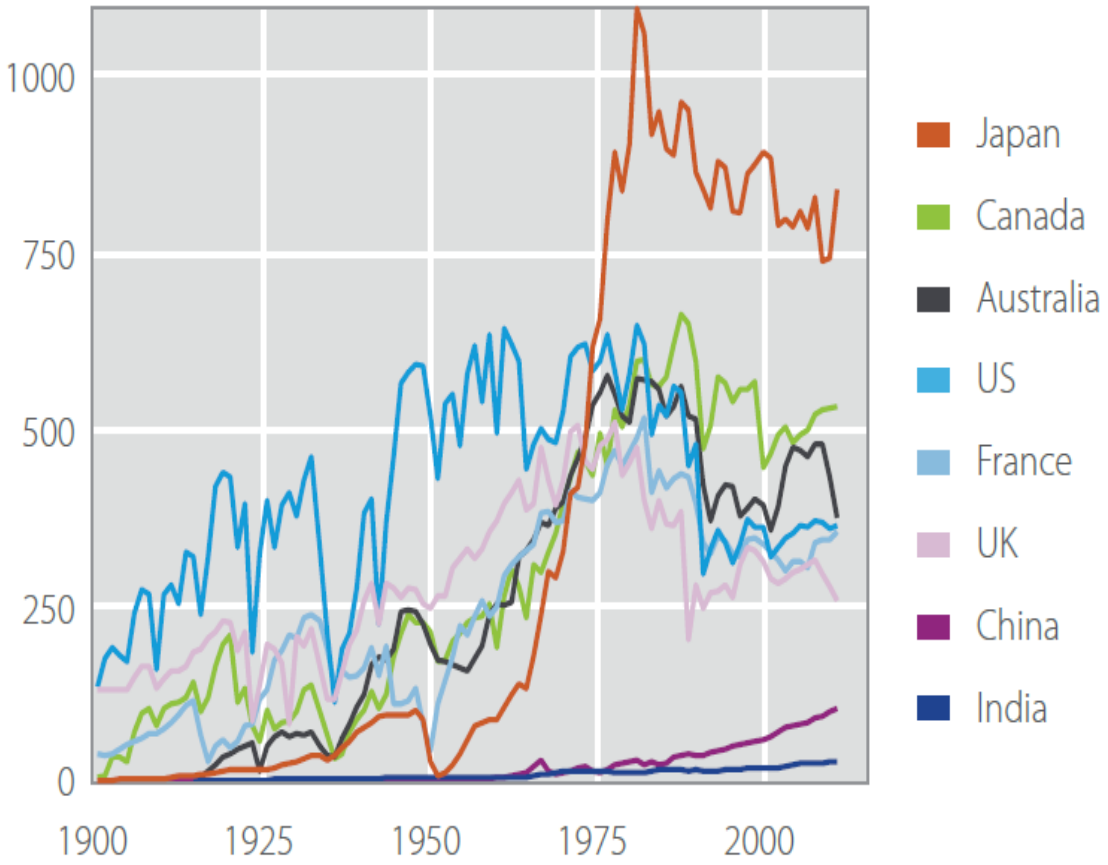



SOURCE: World Steel in figure 2013

# Historically steel production has tended to reach a plateau level with respect to population

Global Calculator

**Steel production per person**
(kg/person/year)




BACKUP

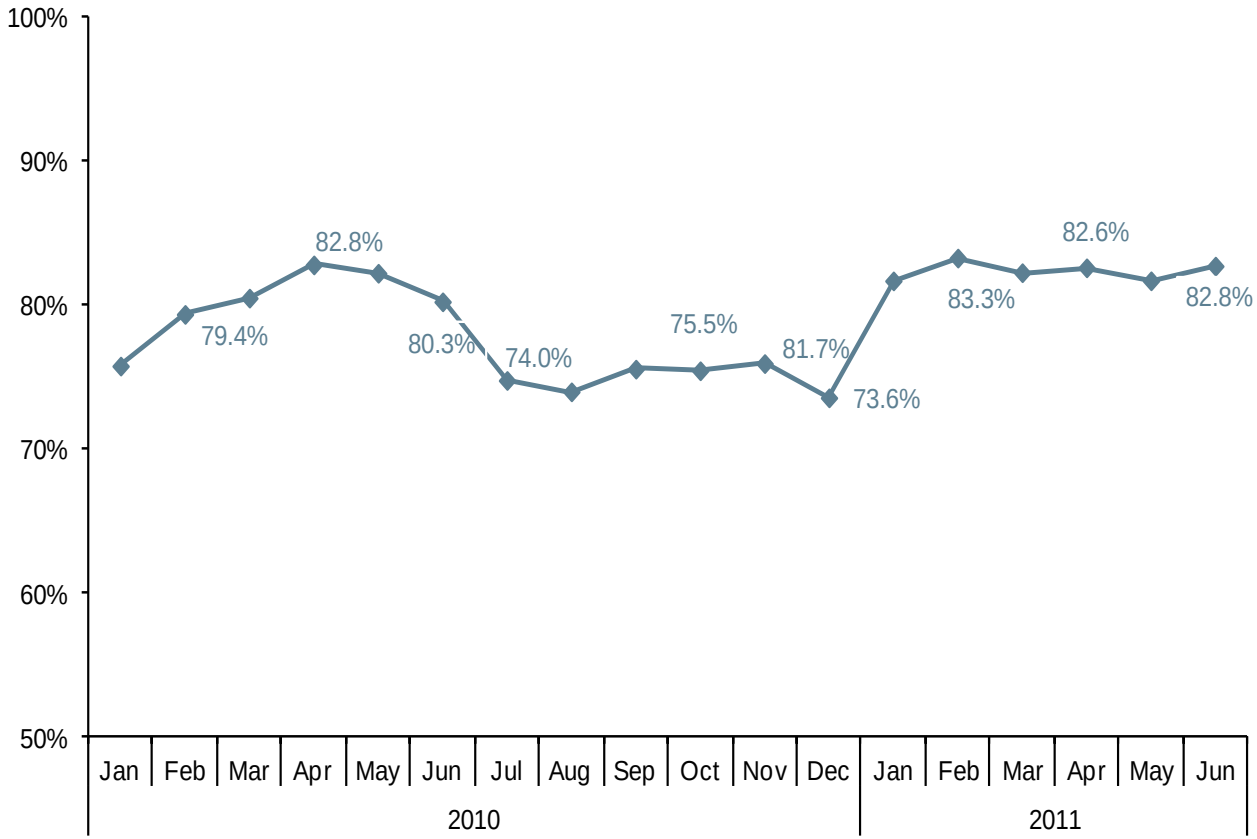
- The plateau effect comes from the fact that as of a certain level of GDP, steel demand does not grow further (e.g. does not require more houses or cars)
- This is not representative of the consumption per capita

SOURCE : With both eyes open (research by Professor Daniel Mueller at the Nowegian University of Science and Technology (NTNU) and Tao Weng

# There is however an overcapacity in the steel sector since the 2008 economic crisis

Global Calculator

**World steel capacity utilisation ratio**
(%)




BACKUP

- A capacity utilisation of 80% is too low and the consequence of an overcapacity

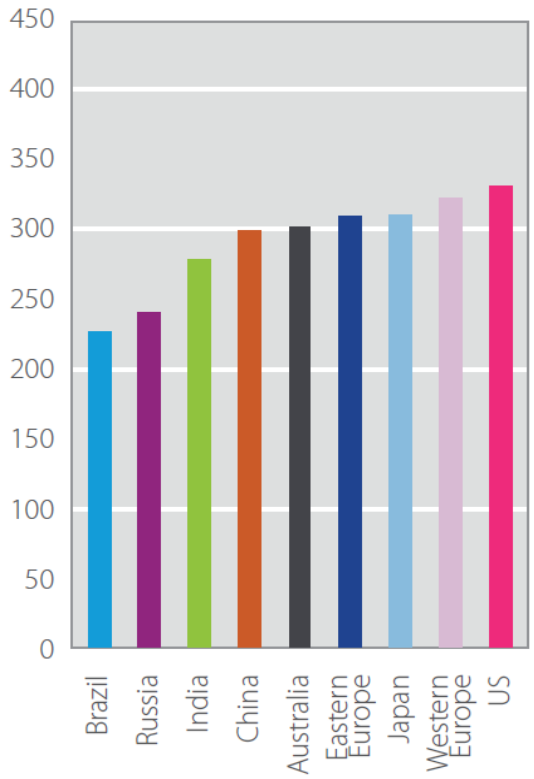
SOURCE : World steel association

# International prices strongly differ between regions

Global Calculator

**Price of crude steel per region**
(US$/ton crude steel)

BACKUP

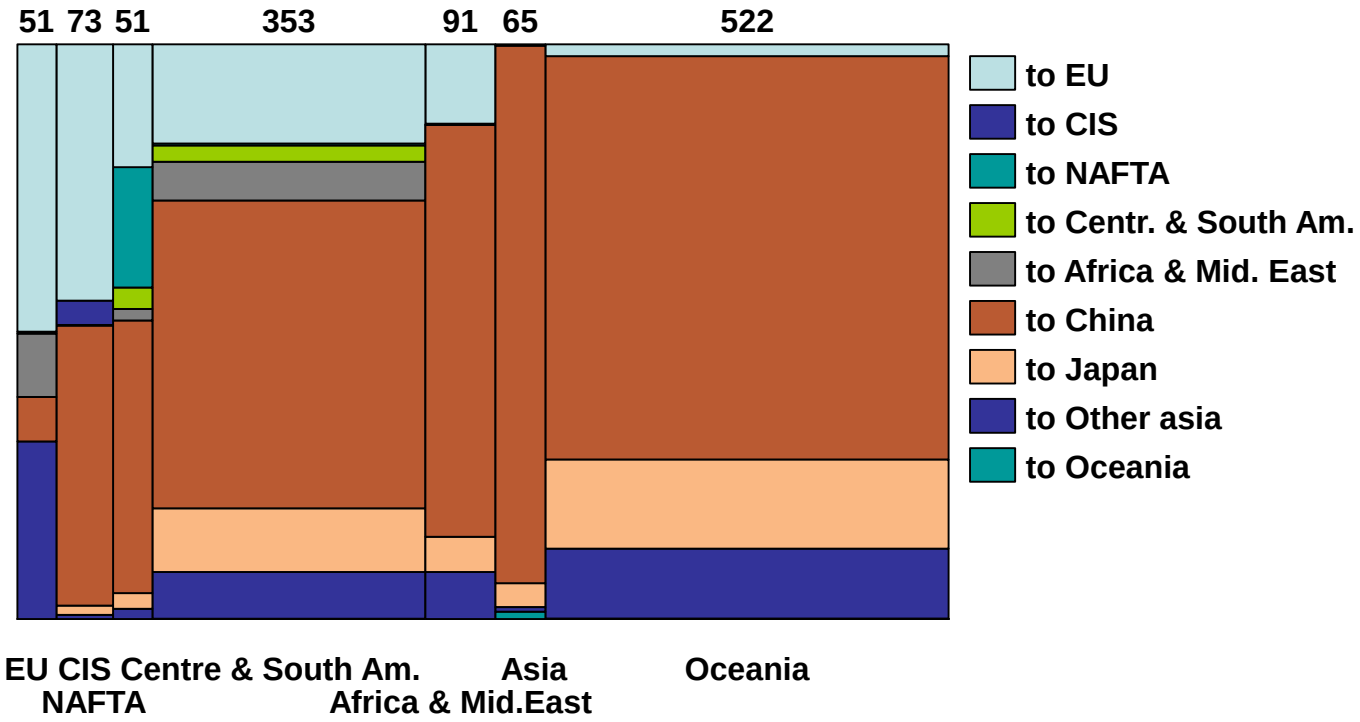



NOTE: This view does not reflect the recent shale gas developments
SOURCE : With both eyes open p91

# Europe is major importer of Iron ore, Central and South America are major Exporters

Global Calculator

**Important export of iron ore**
(2012, million tons actual weight)




BACKUP

- Oceania, Central and South America are major exporters
- China is the largest importer, followed by the EU and Japan

SOURCE : World steel in figures 2013

# Agenda

Global Calculator

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# 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

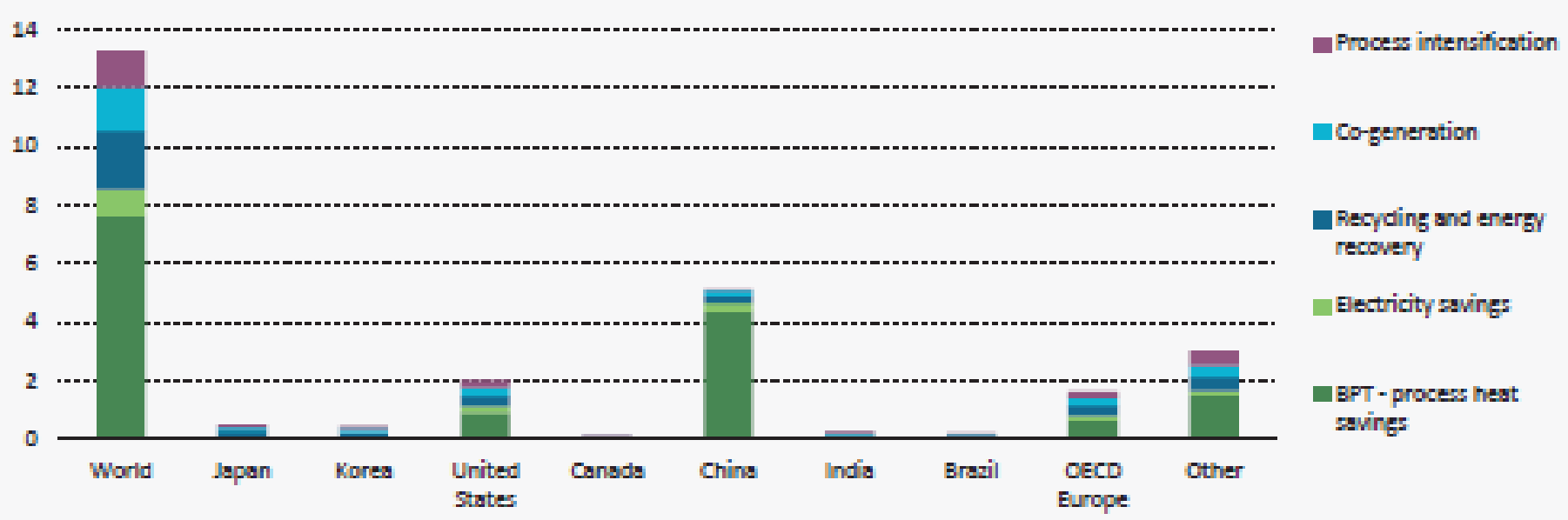
SOURCE: ICCA roadmap catalysts

# 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.<br>Global share of bio-based feedstock to increase and reach between 4% and 5% of total feedstock used in 2050. |
| Hydrogen | | | Deployment after 2040.<br>Marginal market share by 2050. |
| CCS for ammonia | | Two plants by 2013. | 31 plants by 2020 and 122 plants by 2030. |

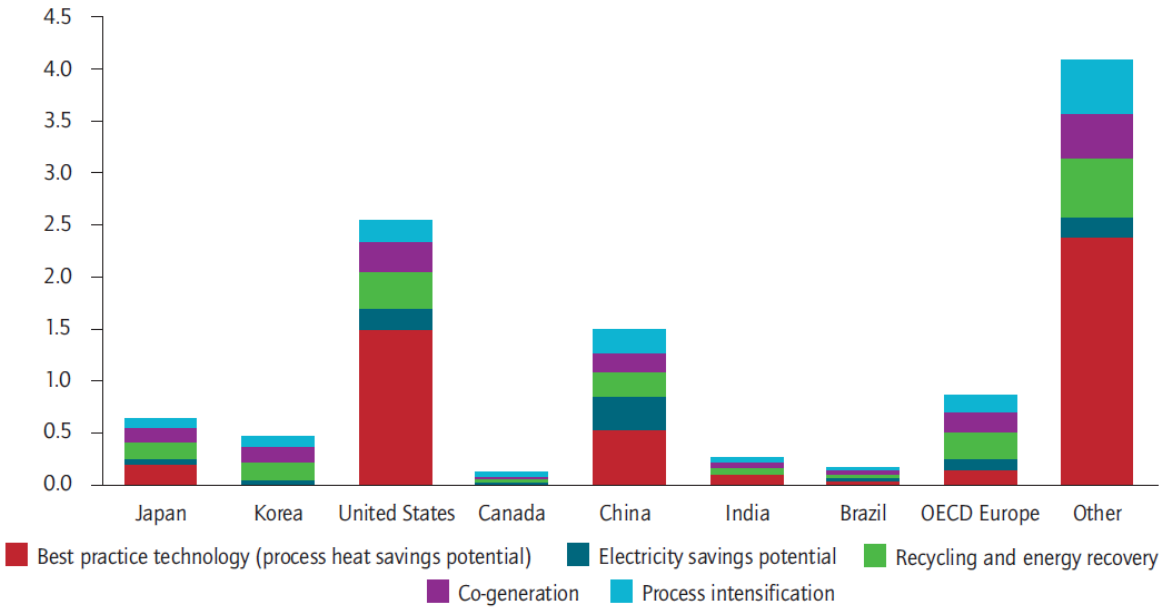
SOURCE: ETP 2012

# 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

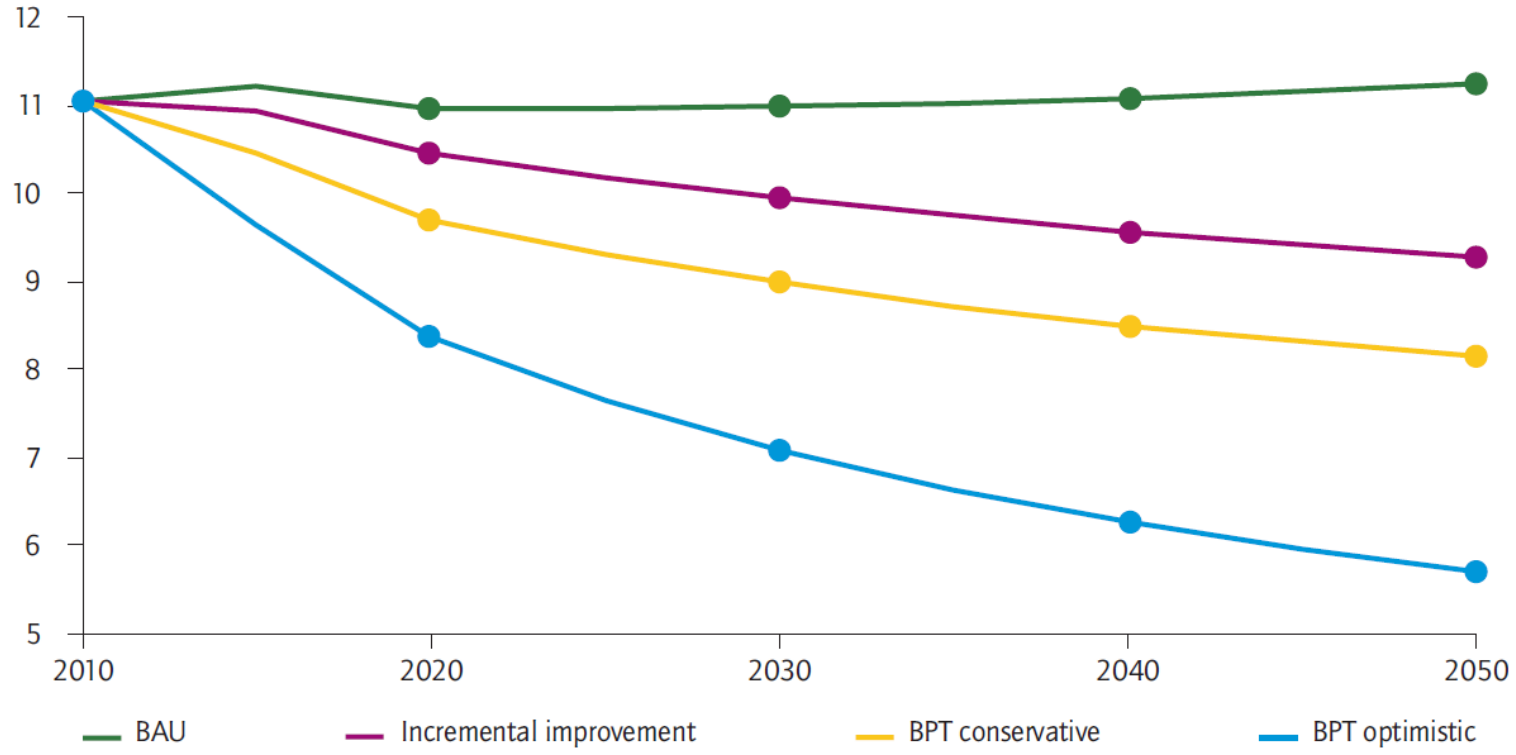
SOURCE: IEA via ICCA

# 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)



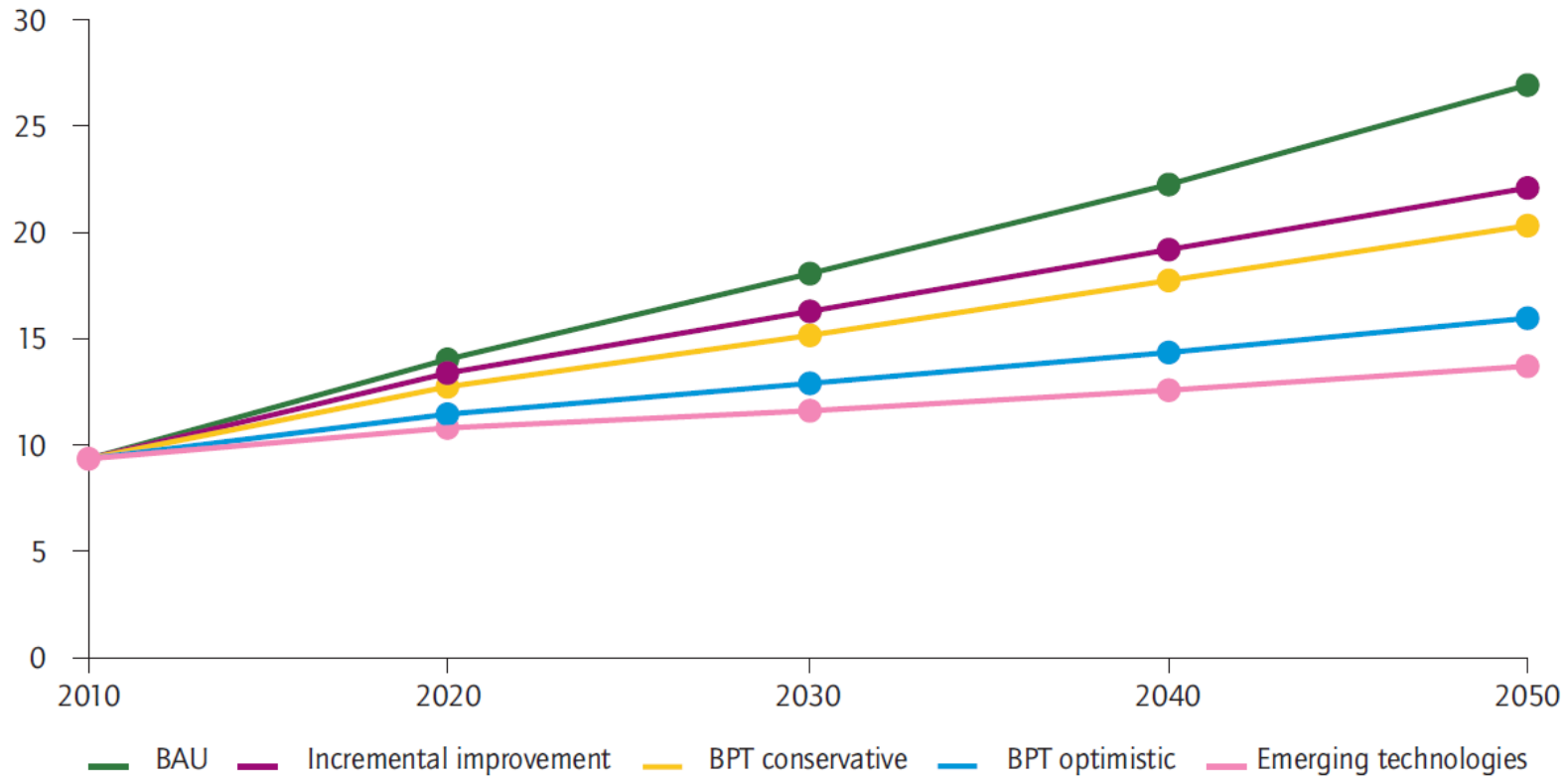

SOURCE: DECHEMA
NOTE: Energy consumption for olefins in this figure is based on the deployment of the catalytic cracking process

# 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)

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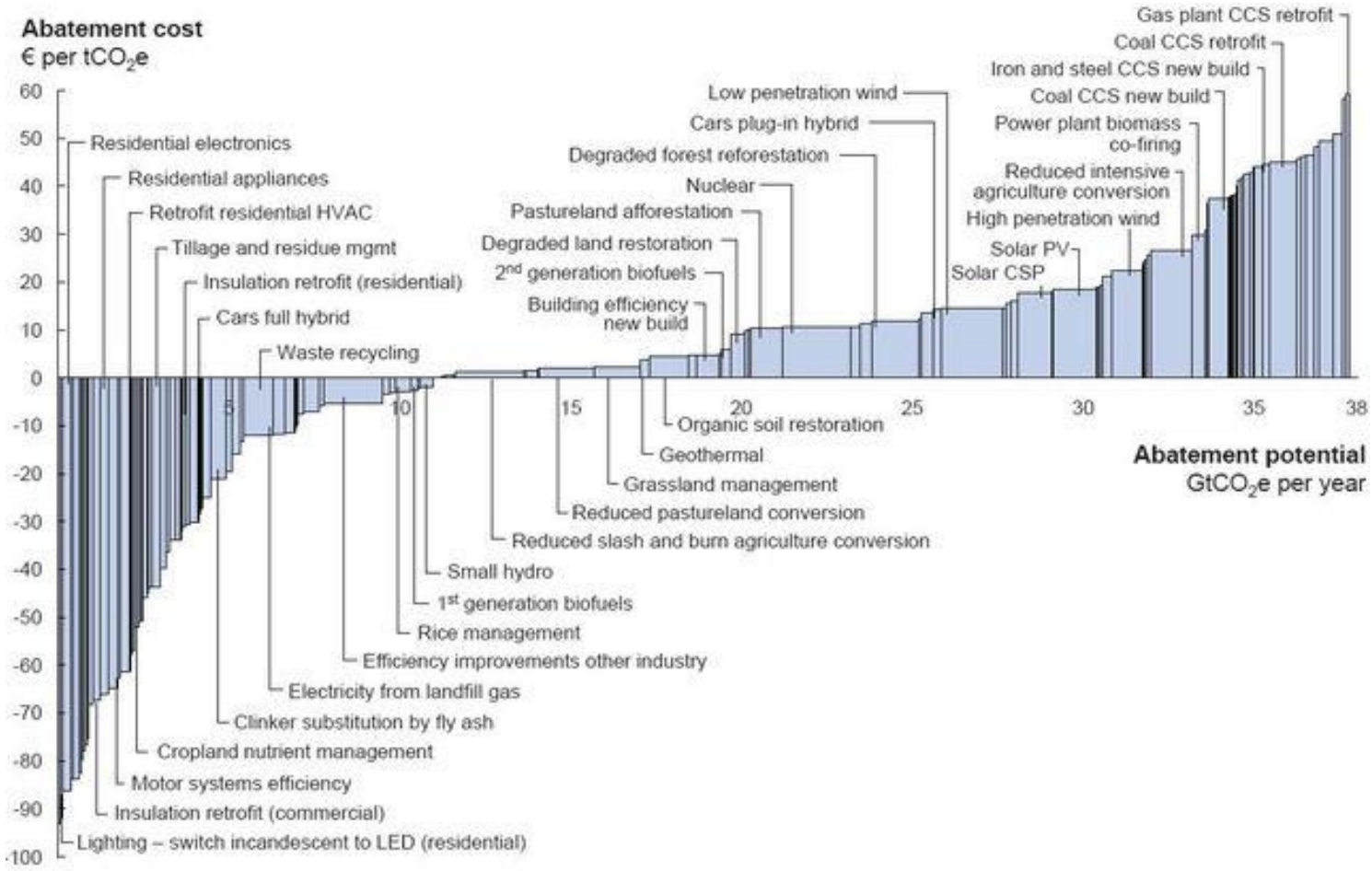


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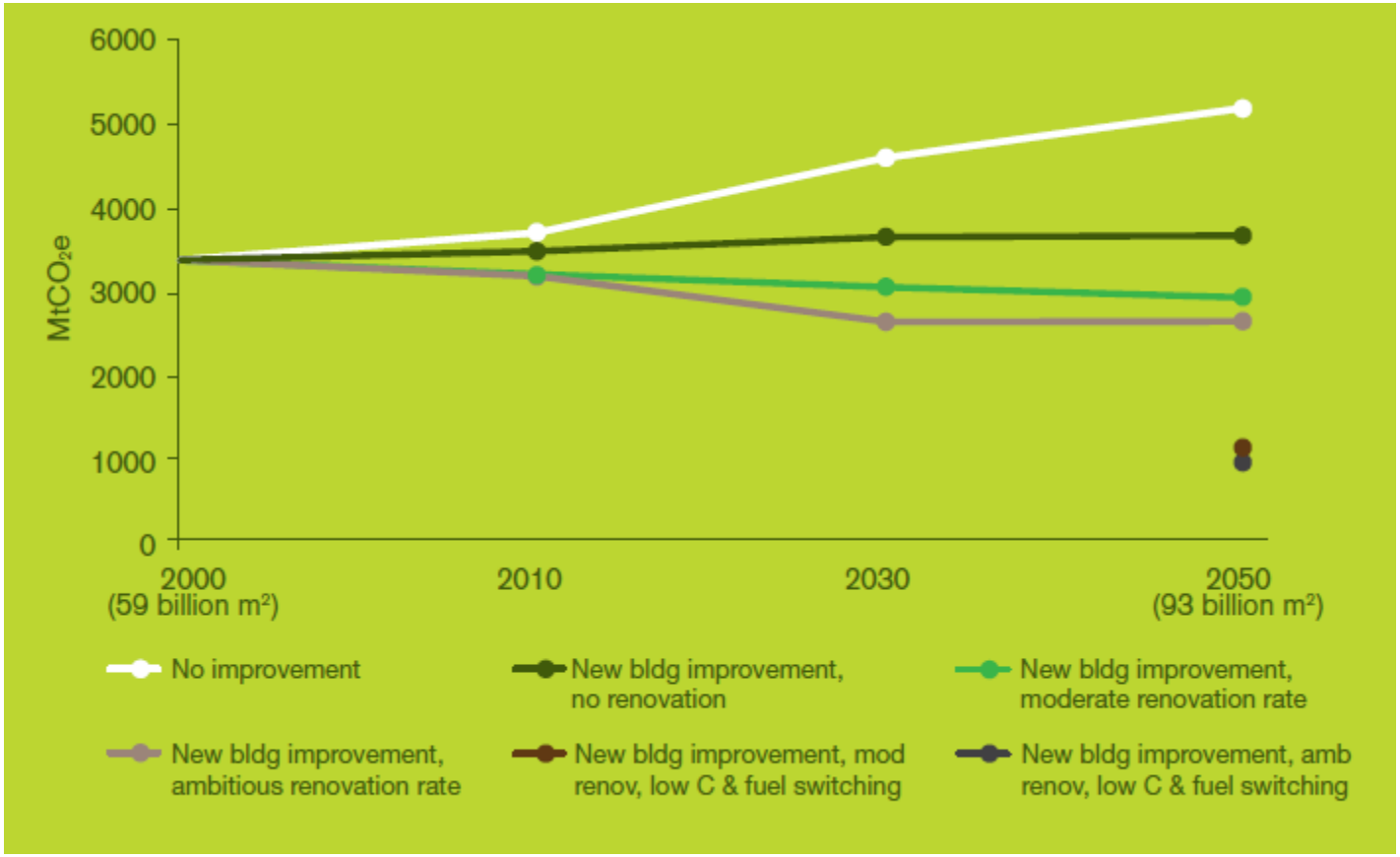
**Key point** *Over the next decade, improvements in energy efficiency in the five major sectors play the greatest part in reducing $CO_2$ emissions from industry.*

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

Global Calculator



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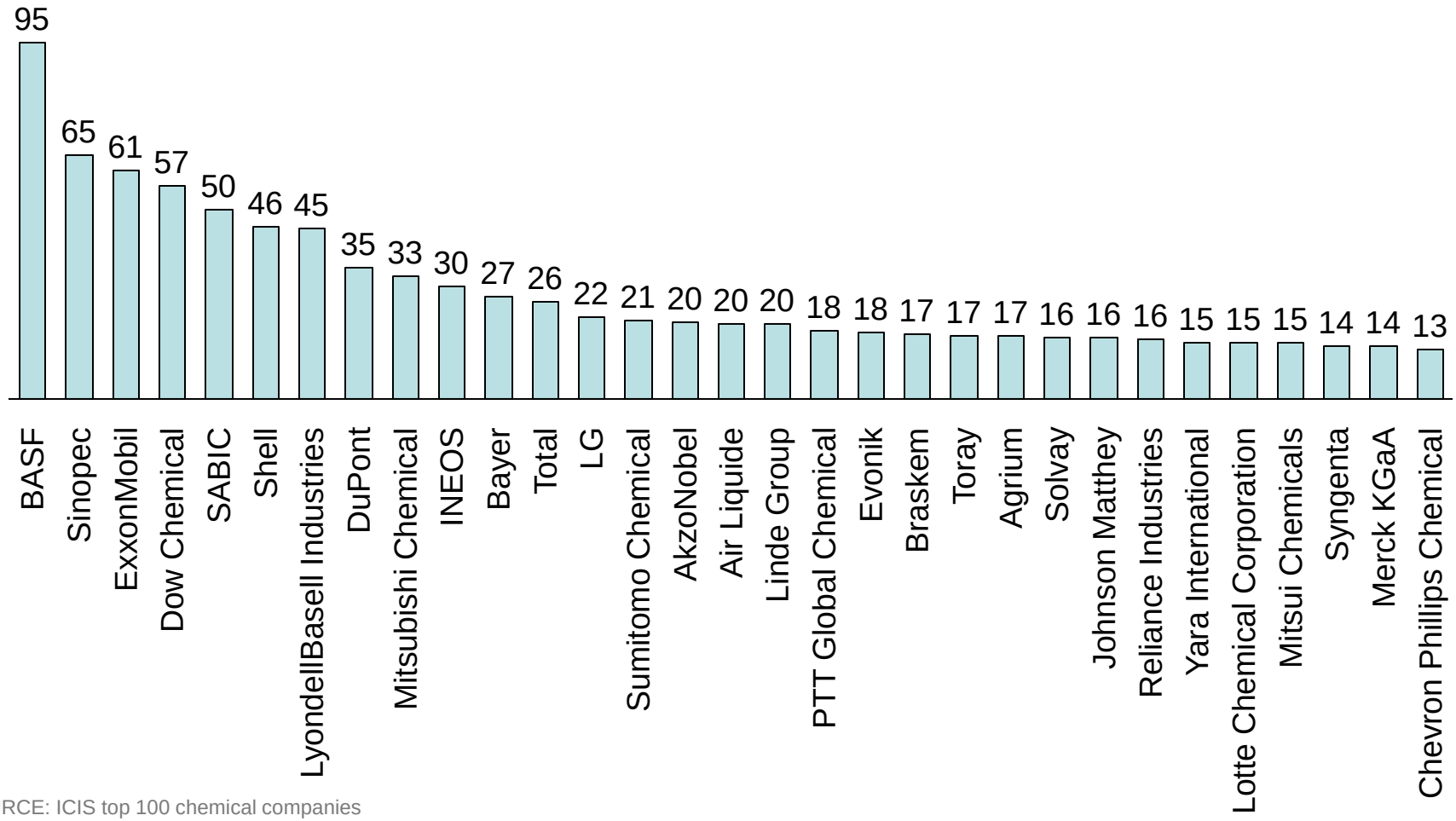
# Largest chemicals producers

Global Calculator

**Chemicals production of 30 largest producers**
($Bln 2012)

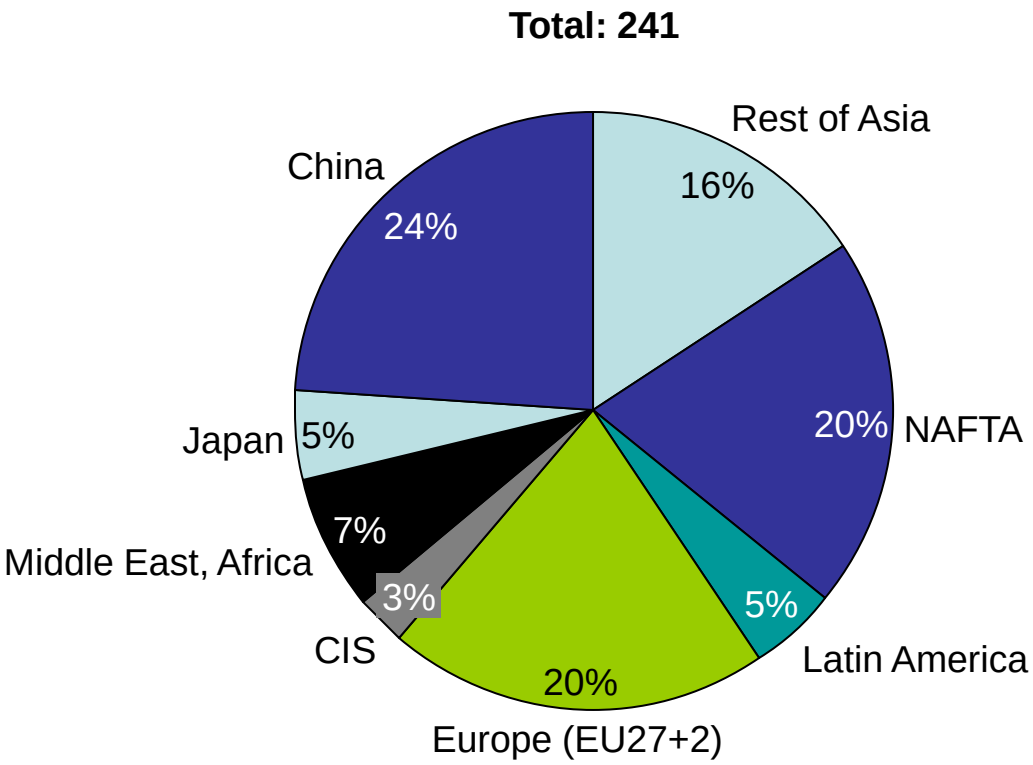



SOURCE: ICIS top 100 chemical companies

# Production per region

Global Calculator

**Plastics production per region**
(Mtons, 2012)



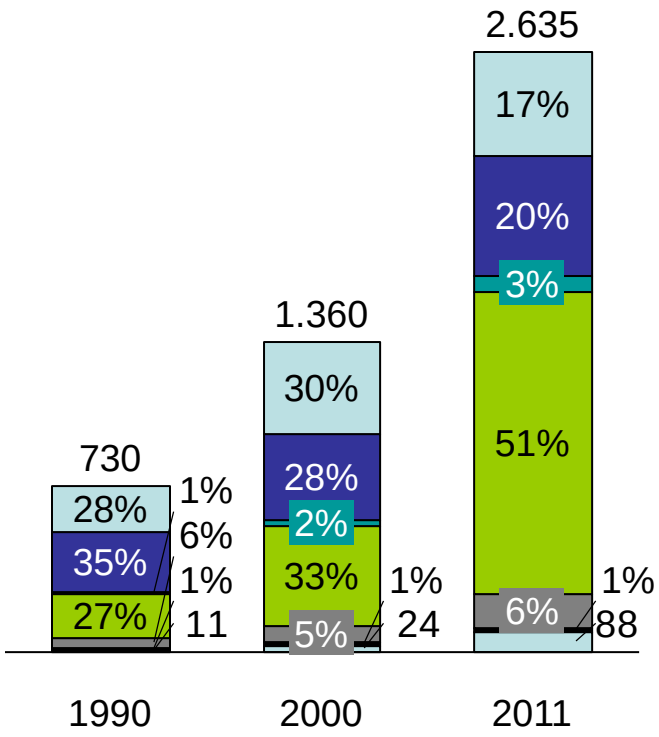

- China remains the leading plastics producer with 23.9%
- Rest of Asia (incl. Japan) accounts for an additional 20.7%
- European production (EU-27+2) accounts for 20.4% of the world's total production

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

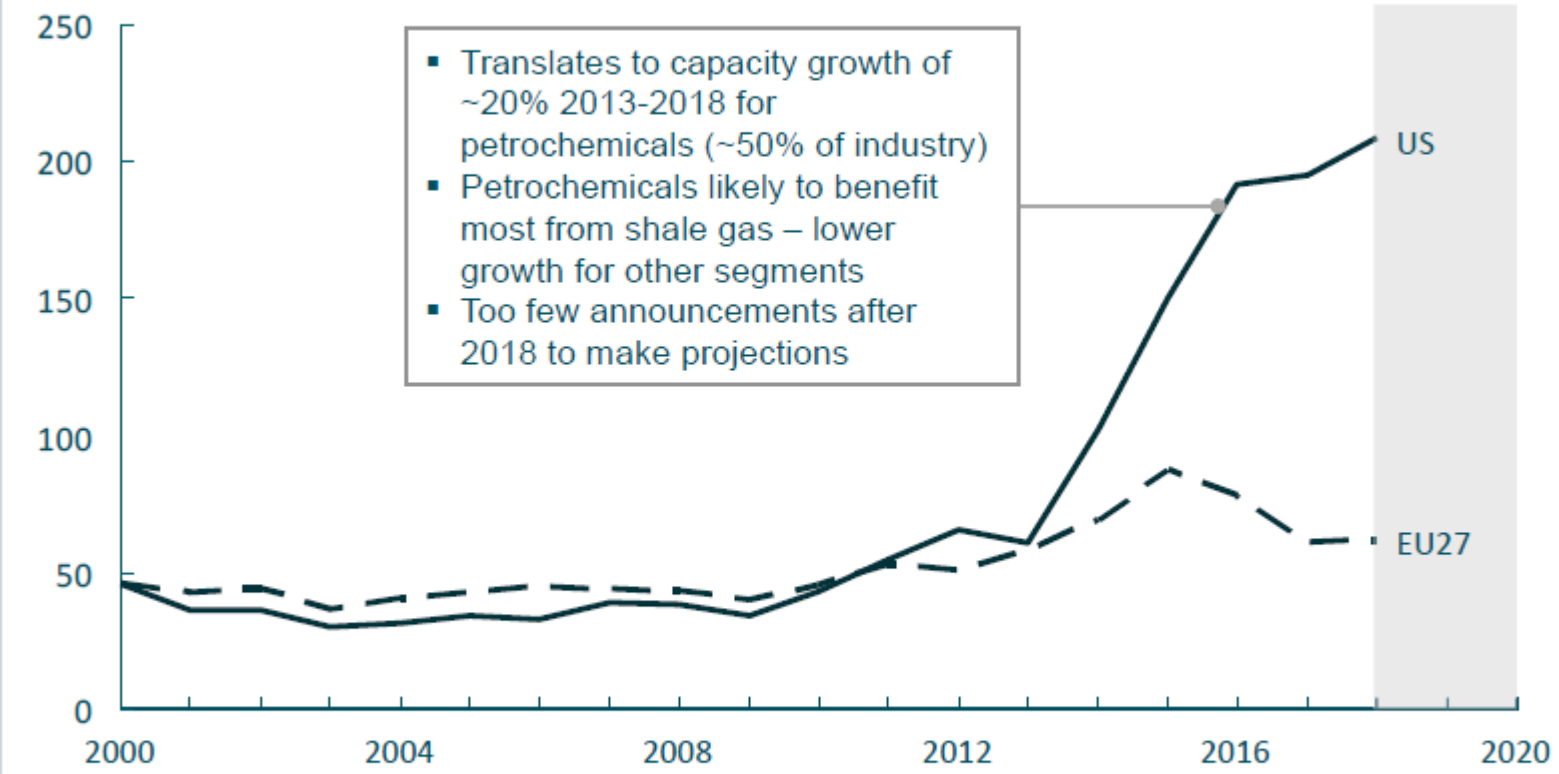
NOTE: Total chemical industry excluding pharmaceuticals; 2 Also includes European non--EU27 Countries (not shown on page)
SOURCE: IHS Economics

# ECF assesses the widening investment gap between US and the EU

Global Calculator

**Actual and announced investments compared to existing production volume**[1]

Petrochemicals only, USD/ton




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

Global Calculator

## In buildings

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

SOURCE: ICCA buildings roadmap

# Agenda

Global Calculator

**Backup**

Existing studies

Industry overview

Steel

- Existing studies
- Other informations on the sector

Chemicals

- Existing studies
- Other informations on the sector

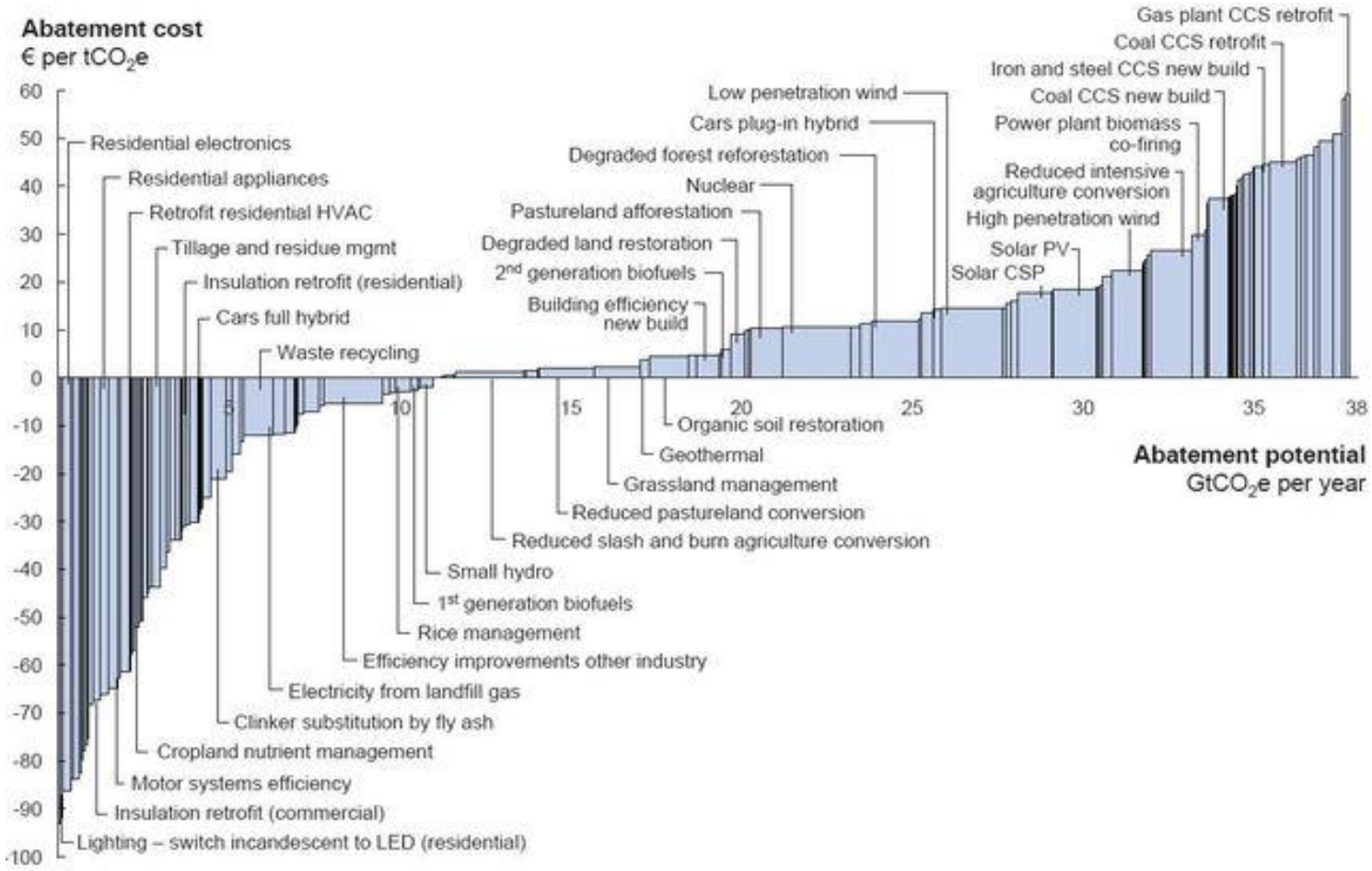
**Cement**

- **Existing studies**
- Other informations on the sector

# 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 1.1** Global marginal abatement costs and example marginal abatement options in the 2DS

| | 2020 | 2030 | 2040 | 2050 |
|---|---|---|---|---|
| **Marginal cost (USD/tCO$_2$)** | 30-50 | 80-100 | 110-130 | 130-160 |
| **Energy conversion** | Onshore wind<br>Rooftop PV<br>Coal w CCS | Utility scale PV<br>Offshore wind<br>Solar CSP<br>Natural gas w CCS<br>Enhanced geothermal systems | Same as for 2030, but scaled up deployment in broader markets | Biomass with CCS<br>Ocean energy |
| **Industry** | Application of BAT in all sectors<br>Top-gas recycling blast furnace<br>Improve catalytic process performance<br>CCS in ammonia and HVC | Bio-based chemicals and plastics<br>Black liquor gasification | Novel membrane separation technologies<br>Inert anodes and carbothermic reduction<br>CCS in cement | Hydrogen smelting and molten oxide electrolysis in iron and steel<br>New cement types<br>CCS in aluminium |
| **Transport** | Diesel ICE<br>HEV<br>PHEV | HEV<br>PHEV<br>BEV<br>Advanced biofuels | Same as for 2030, but wider deployment and to all modes | FCEV<br>New aircraft concepts |
| **Buildings** | Solar thermal space and water heating<br>Improved building shells | Stability of organic LED<br>System integration and optimisation with geothermal heat-pumps | Solar thermal space cooling | Novel buildings materials; development of "smart buildings"<br>Fuel cells co-generation |

Notes: HVC = high-value chemicals, FCEV = fuel-cell electric vehicle, LED = light emitting diode.

**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.*

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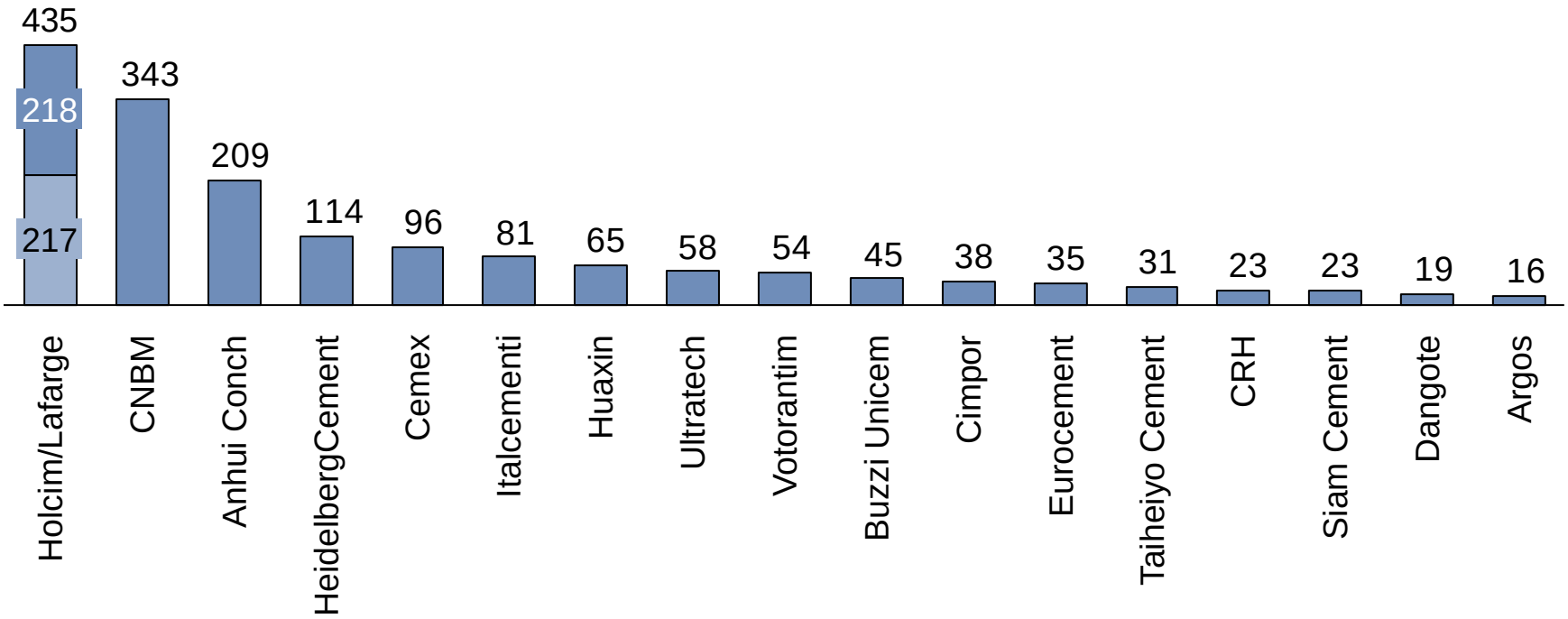
# Largest cement producers

Global Calculator

**Cement capacities of largest producers**
(M tons per year 2012)



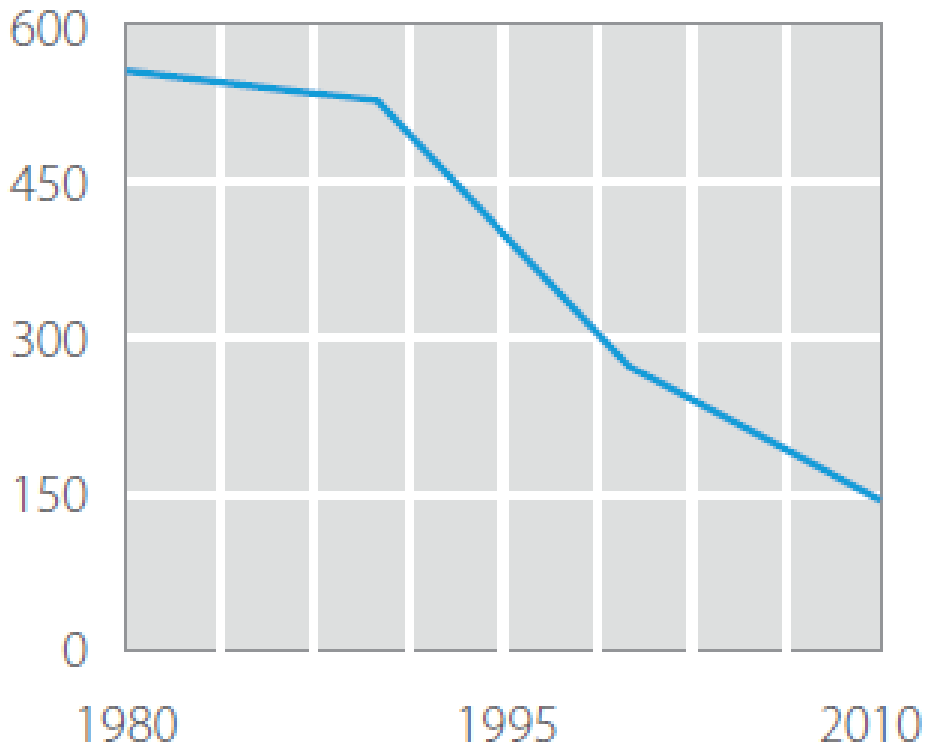

SOURCE: International Cement Review, Global cement industry trends

# Energy efficiency

## Cement productivity has significantly improved in recent years

Global Calculator

**Employees per Mt output**



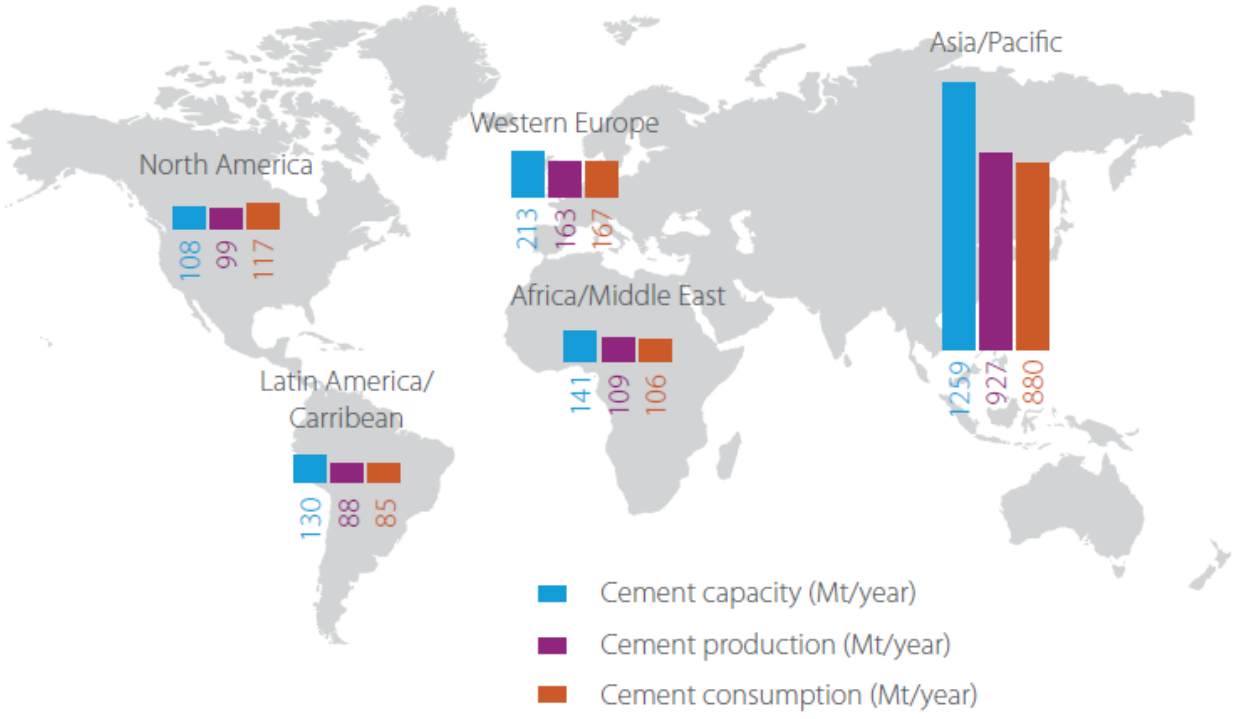

- There have been large historical improvements in cement production productivity

SOURCE: With Both Eyes open

# International trade of cement is limited

Global Calculator

**Cement capacity, production and consumption**
(M tons/year)




BACKUP

- The major continents produce most of their own cement
- Cement resources are well distributed across the planet
- Cement has limited added value by weight

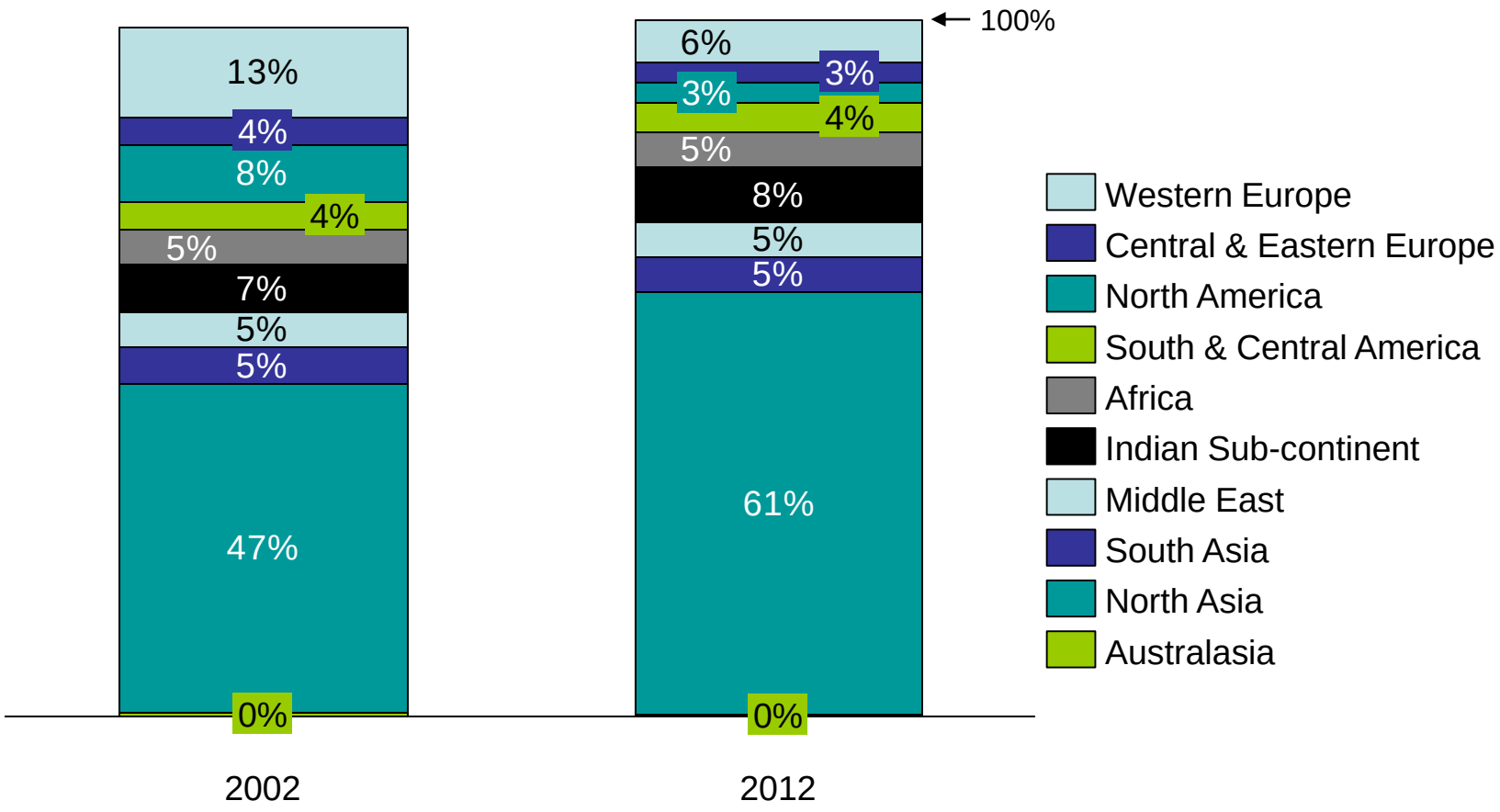
SOURCE: With both eyes open (Batelle 2002, based on 1999 figures)

# North Asia has significantly grown while the share of other markets has declined

Global Calculator

**Evolution of cement demand by region**
(2002-2012 %)

BACKUP




SOURCE: International Cement Review, Global cement industry trends

# Thank you.

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