Global Calculator
Cross sector Workshop

Products & Manufacturing of the Global Calculator

Workshop of May 9th 2014 (version of July 17th)

Brussels

Legend:

- ★ Key slide
- Question… — Key feedback asked
- Data — Model input
- Consultation feedback — Consultation feedback still to take into account

Department of Energy & Climate Change

CLIMACT

WORLD RESOURCES INSTITUTE

eit Climate-KIC

CLIMATE MEDIA FACTORY

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

Preliminary information on this preread

Global Calculator

- This document
  - Supported various workshop discussions (including April 25th 2014)
  - Addresses cross-industry assumptions to refine the model
  - Does not aim at addressing industry specific assumptions; these are addressed through sector specific consultations which are available through these links (cement, steel, chemicals)

- 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

Agenda

Global Calculator

Content

- **Introduction to the Global Calculator** — **9-10h**
- **2011 overview of energy and materials** — 10-11h00
  - Current energy demand
  - Current product demand
  - Modelling dynamics : Activity ➔ Product➔ Material➔ Resources
- **2050 growth of materials and emissions**
  - Materials growth — 11h00-12h00
    - Growth depending on ambition level
    - Discussion on Material Switch
  - GHG emissions growth — 12h00-14h00 (&lunch)
    - Growth depending on ambition level
    - Discussion on ambition level alignment
    - Discussion on CCS
- **Other** — 14h00-14h30
  - Electricity demand response potential

The following stakeholders will be provided with an opportunity to review the cross sector assumptions [(1)]

Global Calculator

Federations and organisations

WBCSD, Cement sustainability Initiative
- Roland Hunziker

Worldsteel Association
- ● Henk Reimink, Clare Broadbent

CEFIC
- ● Peter Botschek, Isabelle Chaput (alumni)

CEPI
- Marco Mensink

Zero Emissions Platform (ZEP)
- Gert-Jan van der Panne

European Wood Federation (CEI Bois)

Institute of Industrial perspective (alumni)
- Julia Reinaud

World Aluminium
- ● Chris Bayliss

Legend	
●	Presence at workshop or later

Academic, consultancies & research groups

- ● **Dechema** Florian Ausfelder
- **Fraunhofer institute,** Marlene Arens
- ● **Steel VDEh** Marten Sprecher
- **Tsinghua University**
- ● **UK Engineering** and Physical Sciences Research Council (EPSRC), author of With both eyes open, Jonathan M Cullen
- **LBNL** (China Energy Group)
- **BEE** (India)
- **TERI**

Companies in other sectors

- ● **Dow** Michael Mazor
- **Vinci**
- **Toyota**
- **Bombardier**
- **GE**

NGOs & cooperation agencies

- ● **Greenpeace**, Jan Vande Putte
- **WWF**
- **GIZ**

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

Agenda

Global Calculator

Introduction to the global calculator

Background

Global Calculator

Team & Model structure

Expert & Literature review

Warning messages

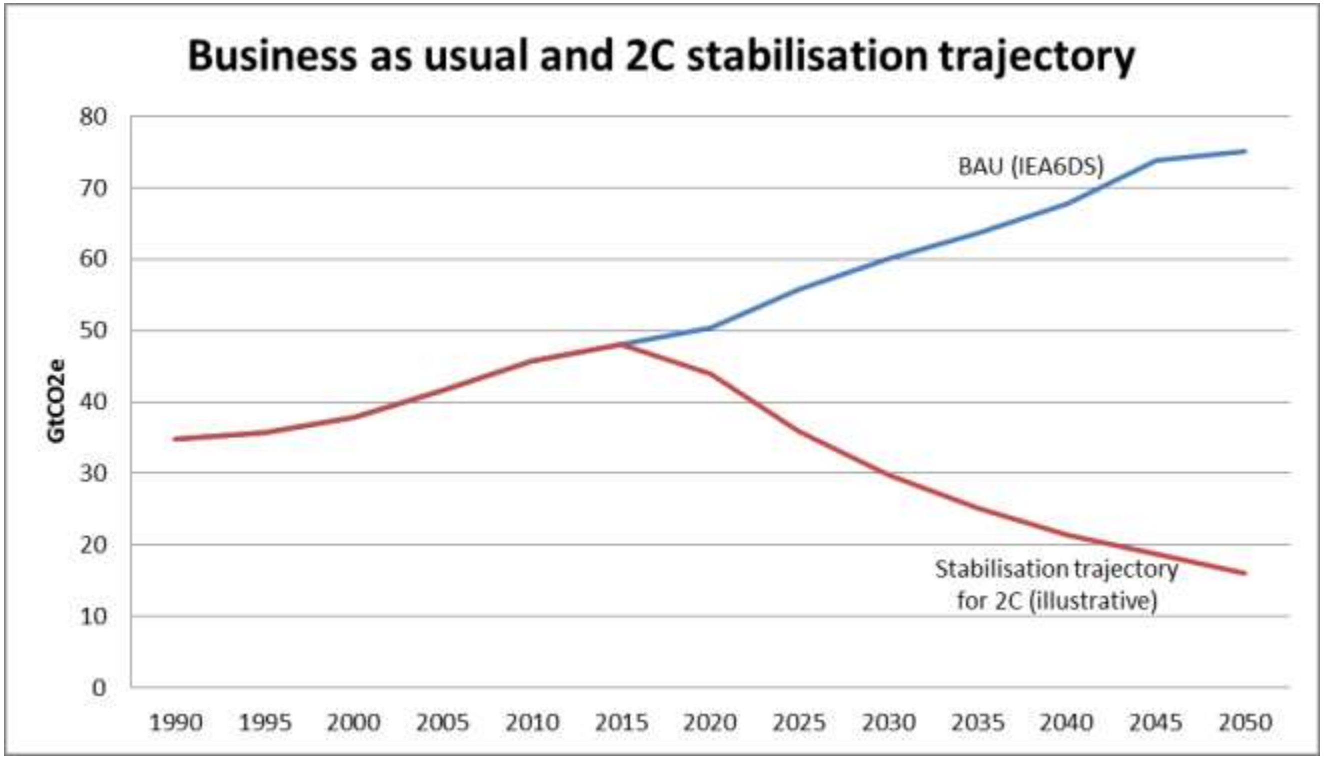
2011 overview of energy and material demand

2050 growth of materials and emissions

Aluminium assumptions summary

Countries have committed to keep the global mean temperature rise to 2C warming

Global Calculator



The UNFCCC negotiations in December 2015 will be critical.

The UK set a legal requirement to reduce its emissions by 80% by 2050 from 1990 levels

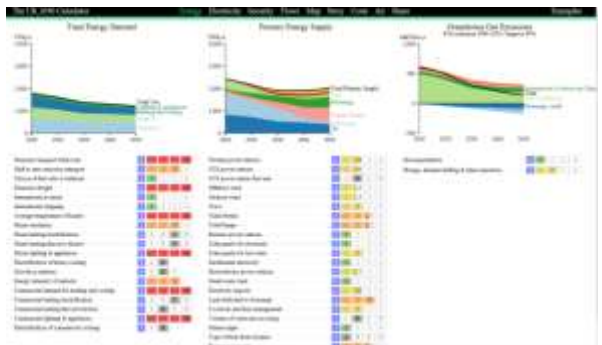
Global Calculator

Despite having sophisticated optimising models, the UK built its “2050 Calculator”

What proportion of energy might the UK import in 2050?

Can we meet our targets without using nuclear?

How much will it cost?



How much bioenergy can the UK produce?

Will we still be able to fly?

How can we deal with intermittency of renewables?

What might be the impact on the UK landscape?

Demo of UK Calculator

http://2050-calculator-tool.decc.gov.uk/

The UK Calculator has had an impact within and outside of government

Within government	Outside government

Informing UK Government energy strategy

- Electricity market reform
- Heat strategy
- Bioenergy strategy
- Carbon Plan 2011
- Urgent analysis (e.g. for Cabinet ministers, and post Fukushima)

Energising debate among NGOs, businesses and politicians

- Expert pathways
- Calculator adopted as an analytical and educational tool
- Briefing for MPs, and cited in Hansard

Other countries have built or are building 2050 Calculators

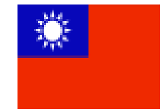
Global Calculator


UK


China

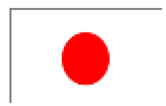

India


South Africa

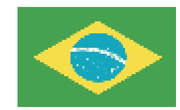

Taiwan


Belgium


South Korea


Japan


Mexico

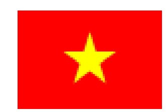

Brazil


Indonesia


Colombia


Bangladesh

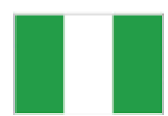

Thailand


Vietnam

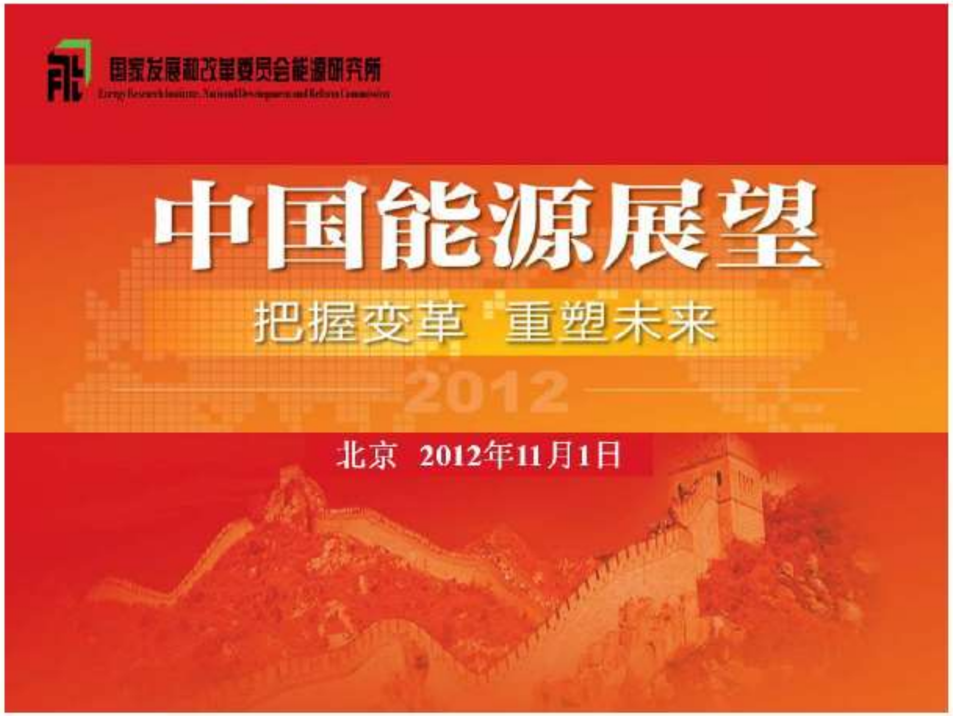

Hungary

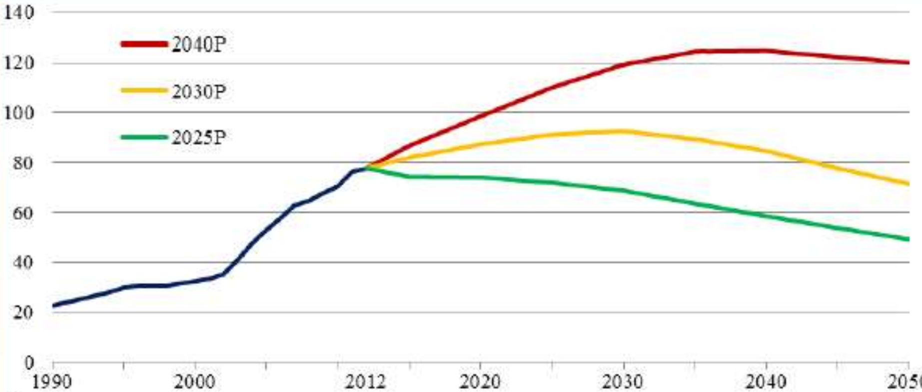

Serbia and SEE

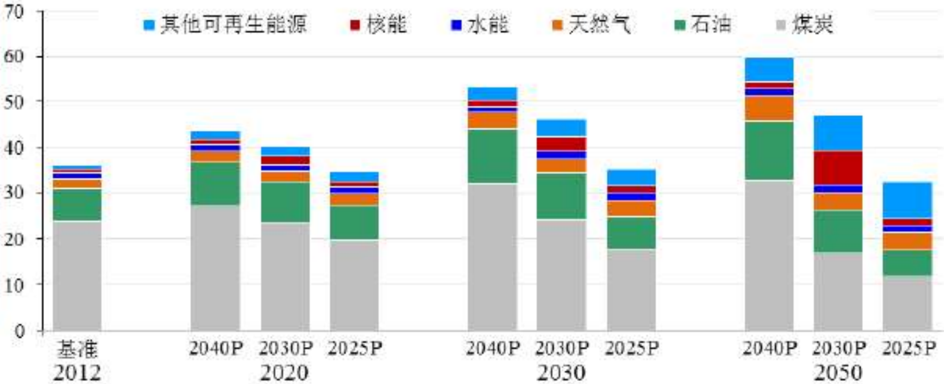

Algeria


Nigeria

Support further research







- The tool support the forthcoming publication of "China Energy Outlook 2014"
- This series publications won high praise for both academic and practical value, http://www.eri.org.cn/news_zj.php?cid=27&aid=2172

Agenda

Global Calculator

Introduction to the global calculator

Background

Global Calculator

Team & Model structure

Expert & Literature review

Warning messages

2011 overview of energy and material demand

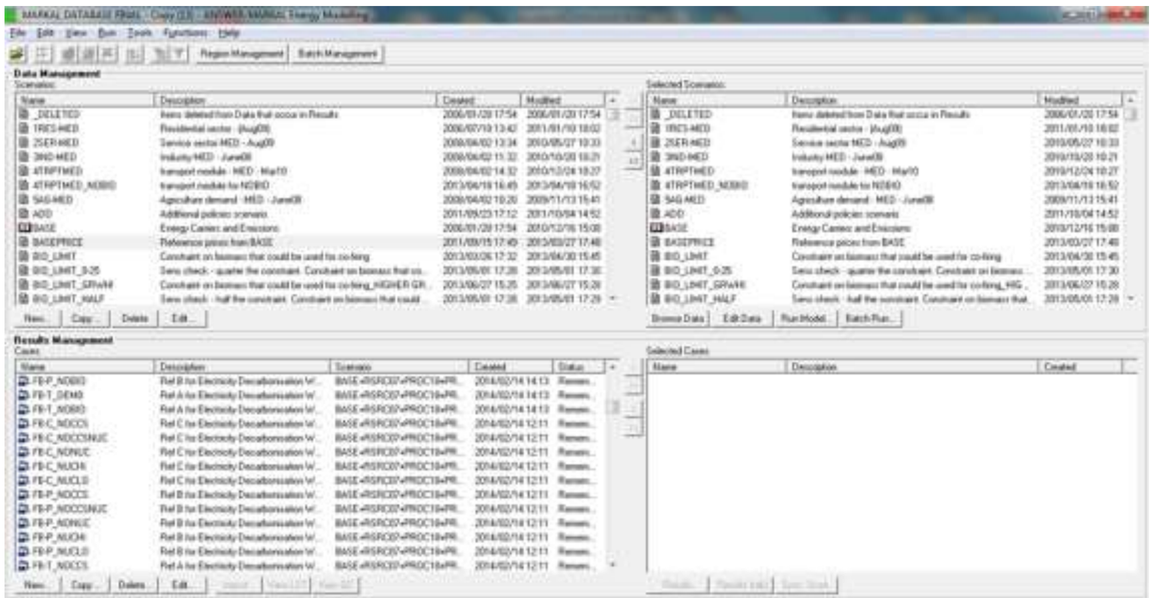
2050 growth of materials and emissions

Aluminium assumptions summary

But the Country Calculators cannot give a global picture, so we started scoping out a Global Calculator

Global Calculator

A difficulty with the current suite of global climate and energy models is that they tend not to be very user friendly. For example, MARKAL screenshot:



So we decided to build a Global Calculator model.

We want to help people debate global climate, energy, food and land issues using a common platform

Global Calculator

"We know there's no way all 7 billion of us can consume at western levels while keeping within environmental limits."

Alex Evans, NYC Centre on International Cooperation

"The potential of renewable energy is vast and far greater than that of nuclear power or climate changing fossil fuels."

Greenpeace

"While it may be theoretically possible to stabilize the climate without nuclear power, in the real world there is no credible path to climate stabilization that does not include a substantial role for nuclear power."

Open letter from leading climate scientists

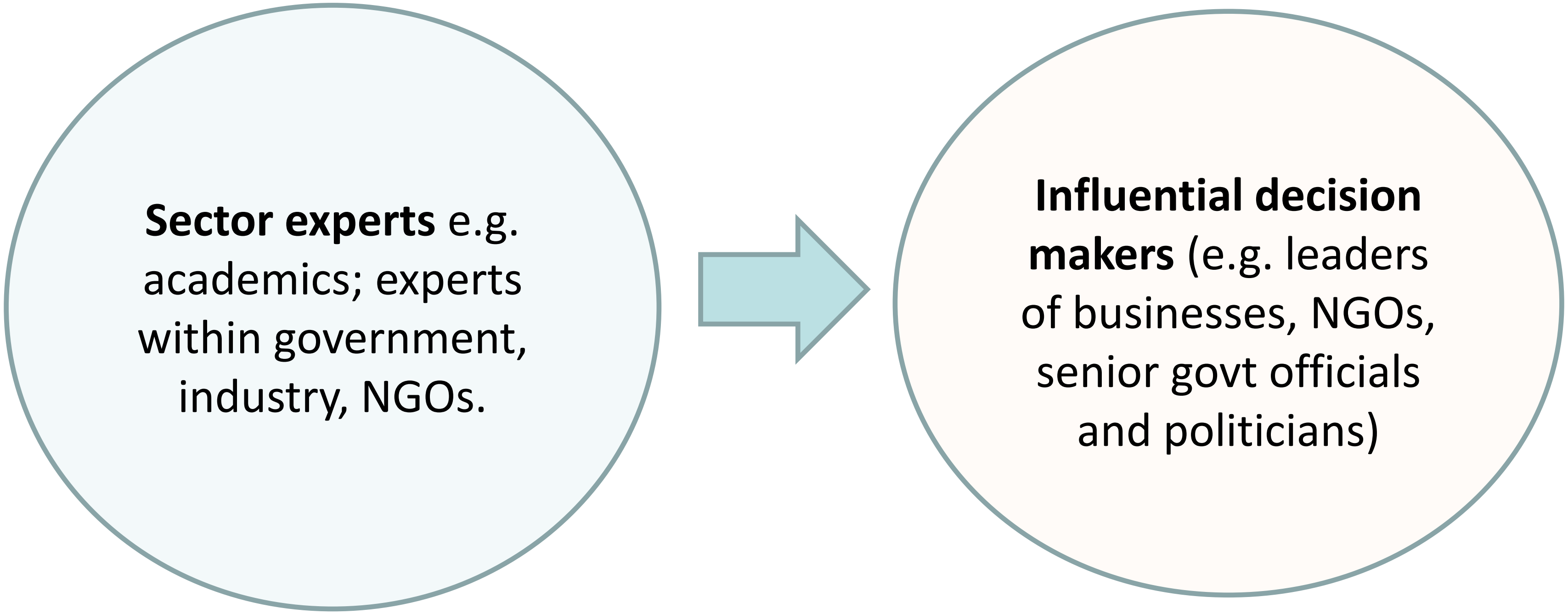
"I think the cost of energy will come down when we make this transition to renewable energy."

Al Gore

"Earth provided enough to satisfy every man's need, but not every man's greed."

MK Gandhi

The Global Calculator will help experts communicate more effectively with influential decision makers



It will help answer questions of interest to businesses…

User	Questions answered
Multinational businesses	Scenario analysis tool for showing how global energy, land and food system "adds up" and showing the business opportunities that could arise from decarbonisation. e.g.

- Industry: if big shift to recycling and more durable products, what does this mean for industrial production?
- Transport: what's the size of the potential future market for EVs (would there be enough rare earth materials to manufacture vehicle batteries)?
- Food: what's the global availability of land for food vs bioenergy, and what might this mean for production methods?

Global Calculator

User	Questions answered
Environmental NGOs and governments	Show at a glance how pathways from other models compare (e.g. IEA 2, 4 and 6D pathways).
All users	To make the case for tackling climate change by: • Showing detrimental impacts • Illustrating aspirational low emission pathways

But it will not be designed to answer more complex price impact and burden sharing questions

It will not be designed to answer questions such as:

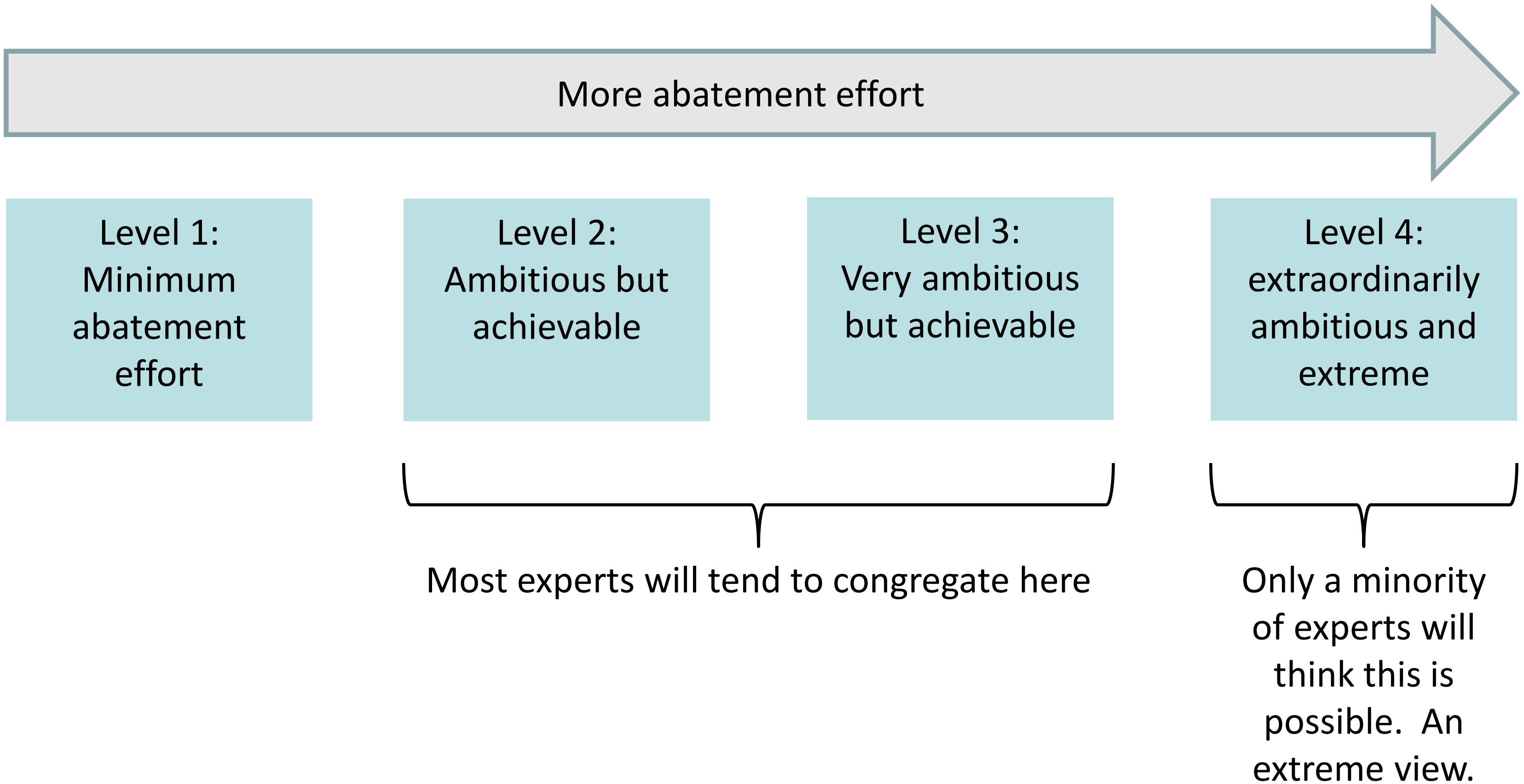
- **Price impacts**: what is the impact of a global carbon tax of x/tCO_2$?
- **Burden sharing**: if the US did X and China did Y, how would other countries respond and what would happen to global emissions and climate impacts?

But it will be able to illustrate pathways from other models exploring these questions.

Levels 1 to 4 represent the least/most abatement effort that experts believe possible

Global Calculator

The level 1-4 range is simply a synthesis of what a wide range of credible experts believe could be possible by 2050.



Demo of prototype Global Calculator tool

Global
Calculator

http://gcp.pik-potsdam.de/glob-calc-v3.html Username: gcp Password: ObErOn7!

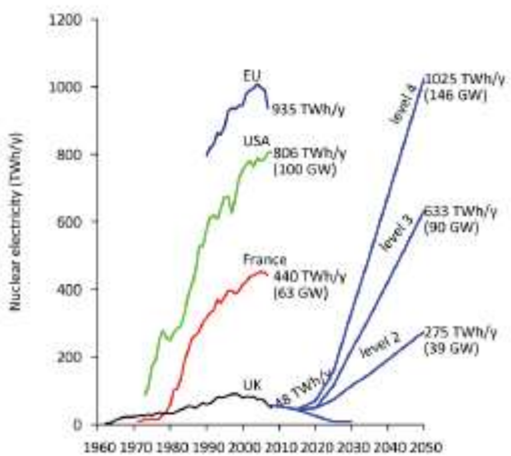
(please note the confidentiality agreement)

Level 1 represents the minimum level of abatement effort

Global Calculator

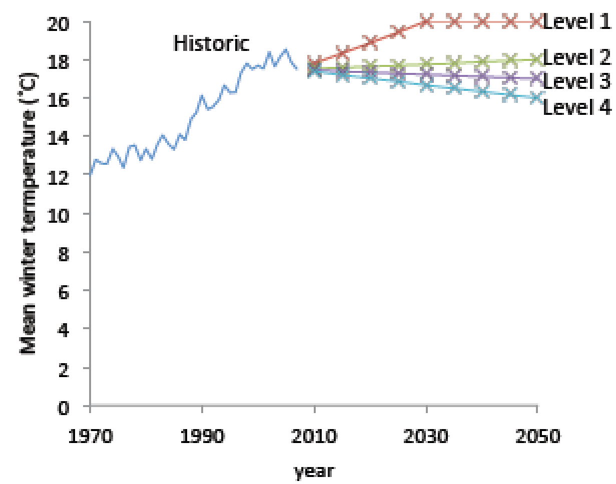
Technology levers: minimum or no technological roll out.

e.g. UK nuclear



Behavioural levers: minimal abatement effort. Maximum demand that could plausibly be envisaged. In level 1 there is no decoupling of economic/population growth and demand.

e.g. UK average home temperature



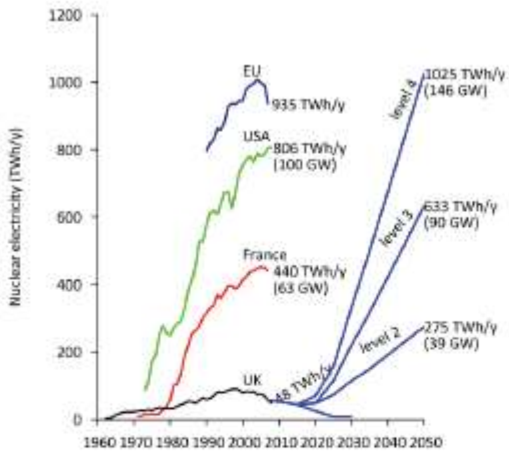
Level 1 should not be interpreted as BAU. It may actually be more pessimistic.

Level 2 is described by most experts as ambitious but achievable; and level 3 is described as very ambitious but achievable

Global Calculator

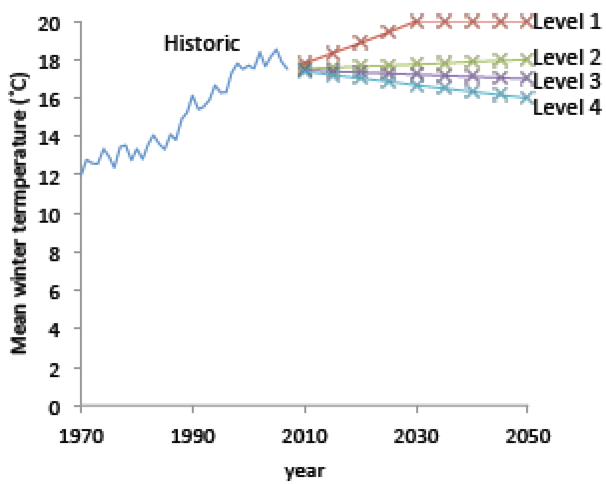
Technology levers: technological roll out at ambitious / very ambitious rates.

e.g. UK nuclear



Behavioural levers: ambitious / very ambitious behaviour change and abatement effort in this sector.

e.g. UK average home temperature

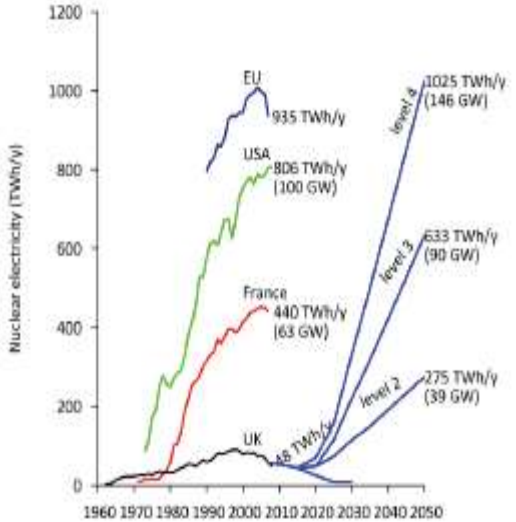


Level 4 for technology levers reflects the maximum theoretical potential of a technology

Global Calculator

Technology levers: the maximum technology roll out that is technically possible by 2050, not constrained by cost.

e.g. UK nuclear



Level 4 is:

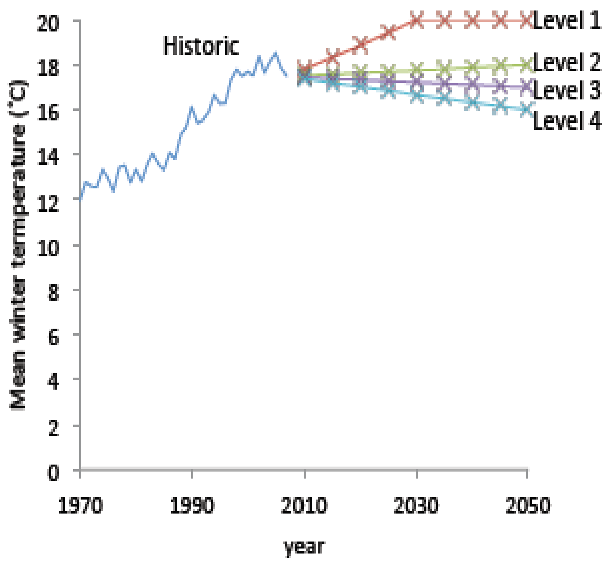
- Extraordinarily ambitious and extreme – an "Apollo" level of effort
- The maximum technology roll out as suggested by the most ambitious expert
- Only constrained by:
  - Build/installation rate: e.g. roll out of nuclear will be constrained by the fastest it is possible to build plants (determined by a "top runner" build rate)
  - Natural resources: e.g. roll out of wind and solar will be constrained by the availability of windy/sunny locations.

Level 4 for behavioural levers reflects the maximum behaviour change that could be argued to be socially acceptable

Global Calculator

Behavioural levers: the greatest behaviour change that could be argued to be socially acceptable.

e.g. UK average home temperature



Level 4 is:

- Extraordinarily ambitious and extreme. Revolution in behaviour.
- Only constrained by what could be considered socially acceptable and consistent with economic and population growth.
  - e.g. Demand for manufactured goods level 4 could be consistent with a world in which users are buying fewer goods because good are more durable and there is more recycling.

Level 4 is <u>not</u> economic apocalypse! The economy could still grow, consistent with projections.

There are benefits to defining level 4 as an extreme effort

Benefits of defining level 4 as extreme effort:

- ☑ **Identify the whole solution space**. Many users find playing with level 4s to be a useful way of contextualising the issues. Even if they don't seriously advocate that level of action, they find it helpful to have an awareness of what the extreme looks like.

- ☑ **Common platform for debate**. Level 1 to 4 is inclusive of all credible experts views, so they can all use the tool as a common platform for debating their proposals. Helpful for securing buy in from experts.

- ☑ **Future is uncertain!** Much could change over the next 35 years, e.g. technology breakthroughs, cost reductions, behaviour change. Defining the range too narrowly risks underestimating future uncertainty.

Current / planned policy is not reflected in the levels 1-4…
Level 1 is not the "business as usual" scenario because it does not attempt to take account of existing/planned policy. Level 1 is actually likely to be higher emissions than business as usual.

… instead, it's reflected in example pathways
e.g. The IEA 4DS is all current and planned policy.

Next steps and how you can help

Global Calculator

You can help in the following ways:

by end April /early May	• Send evidence on specific issues raised in the April workshops
After release in July	• Send the link to 5 people in your organisation • develop an example pathway we can include in the November/December version of the tool • Put link to tool on your web sites • Use and adapt the tool for your own purposes (it’s an Open Government licence) • Help with translation for the December re-release. • Become a Global Calculator Ambassador... [see next slide]”

Global Calculator

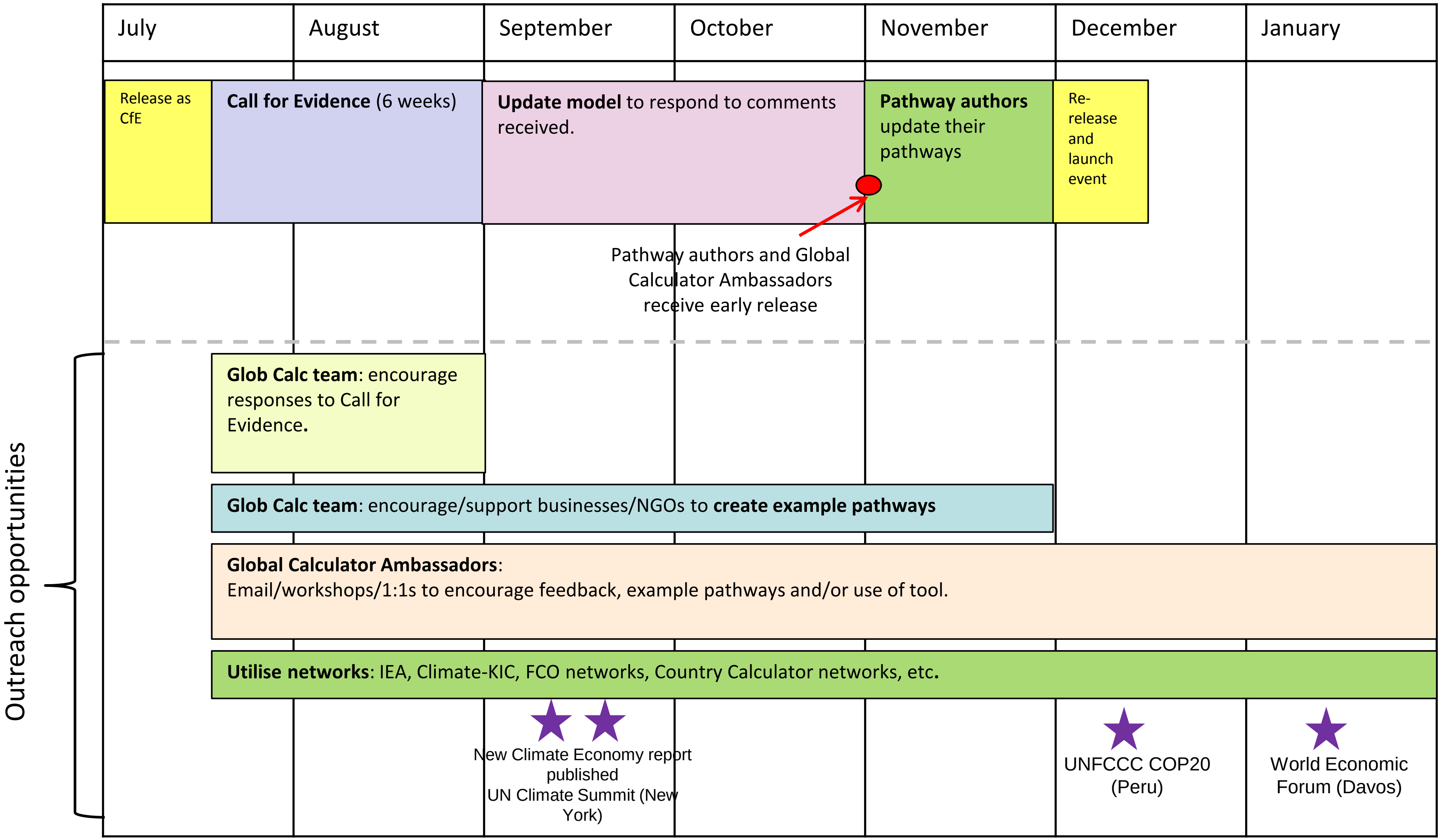
Global Calculator Ambassadors will be:

- Given access to an early release of the tool (e.g. 2-7 days early, depending on our project timings nearer the time)
- Encouraged to present the Global Calculator at any conferences/event, etc they attend using a standard slide pack prepared by our team.

Would you like to join the email distribution list to be a Global Calculator Ambassador? *If so, please contact Kerenza.McFaul@decc.gsi.gov.uk*

There are various opportunities for outreach during July to January 2015

Global Calculator



Agenda

Global Calculator

Team structure

Sophie Hartfield
Team leader, (DECC)
Department of Energy & Climate Change

Tom Bain
Lead modeller
(DECC)
Department of Energy & Climate Change

Dipankar Ghosh
Electricity and fossil fuels
(E&Y)
EY Building a better working world

Julien Pestiaux
Transport
(Climact and WRI)
World Resources Institute
CLIMACT

Michel Cornet
Manufacturing
(Climact)
CLIMACT

Zhang Bo
Buildings (Chinese ERD/ERI)
Energy R&D International

Alexandre Strapasson
Land/bio/food
(ICL)
Imperial College London

Erica Thompson
Climate science and impacts
(LSE)
LSE The London School of Economics and Political Science

Ephraim Broschkowski
Visuals
(CMF)
Climate Media Factory

Davide D’Ambrosio IEA support on data, peer review and stakeholder engagement

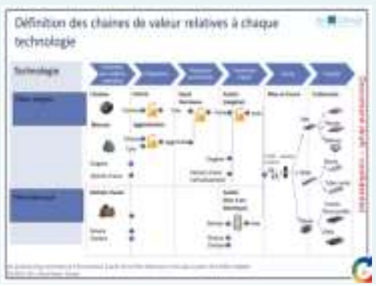
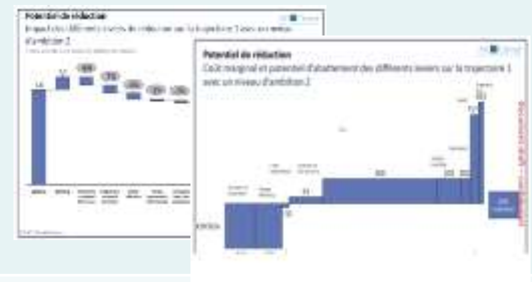
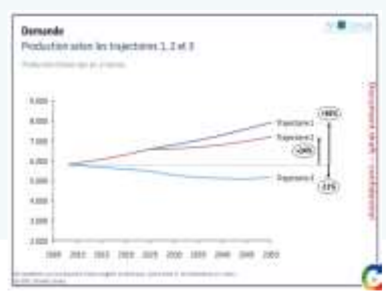
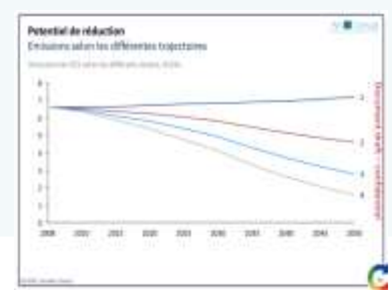
Funded by Climate-KIC

Support from Climate-KIC partners: Utrecht University, Netherlands; Potsdam Institute, Germany; Walker Institute, UK; Rothamsted Research, UK; University of Versailles Saint-Quentin-en-Yvelines, France; Met Office, UK; and Tyndall Centre, UK.

A detailed analysis is performed for each industrial sector

Global Calculator

Methodology

	Understanding the industry and product link	Modelling demand trajectories	Modelling trajectories with intensity levels
Analyses	**Value chain definition** 	**Analyses of growth and competitiveness** 	**Potential of CO_2 reduction incl. costs** 
Results	**Modelling the emissions tree** 	**Demand trajectories** 	**Trajectories with different intensity levels (incl. CCS)** 

SOURCE: Climact

There are 3 main lever groups, split into 8 lever families which contain levers per product and material type

Global Calculator

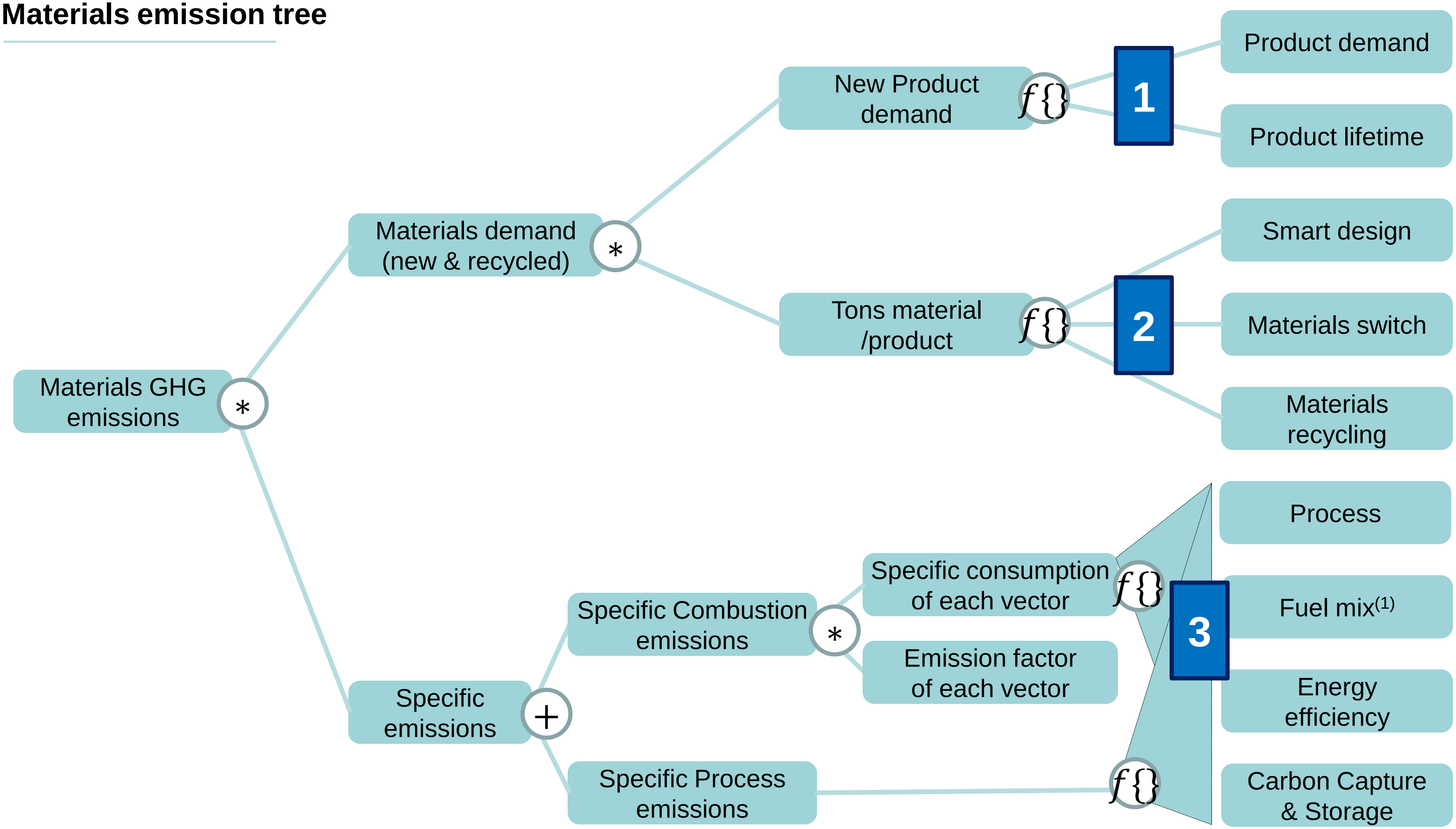
	Lever groups	Lever families	Lever descriptions
1	**Product demand**	1. Reduce demand [(1)] & increase lifetime [(2)]	• End consumer demand of products • Solutions for sharing the product amongst different users
2	**Material demand per product**	2. Smart design 3. Materials switch 4. Materials recycling	• Amount & type of materials required to supply the products (includes new product types and substitution materials) • Materials recycling potential
3	**Carbon intensity of material production**	5. Process change 6. Fuel switch 7. Energy efficiency 8. Carbon capture and storage	• Production CO_2 intensity of various improvements levers in each industry (~60improvements types)

NOTES: (1) These levers don't apply in the materials analysis when the product demand is defined by the other sectors
(2) For consumer goods: cars & household goods

Leading to the following emission trees

Global Calculator

Materials emission tree



NOTE: (1) The fuel mix does not influence the specific process emissions

For manufacturing, the analysis starts from the demand for products and derives material production and resource use (1/2)

Global Calculator

Value chain | **Illustrations**

Resources

Materials analysis: Rare materials | Iron ore | Sand | Other

Energy analysis: Uranium | Fossil hydro-carbons | Biomass | Other

↓

Materials

Steel | Cement | Aluminium | Chemicals | Pulp & paper | Timber | Other

↓

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

The analysis starts from the demand for products and derives material production and resource use (2/2)

Global Calculator

Selection of products and materials and resources (excluding energy resources)

Sector	Products	Materials	Resources
Energy	Nuclear & Fossil plants	➔ Infrastructures	/
	Wind turbines	Steel, ~~Aluminium~~	Iron ore, ~~bauxite,~~
	PV	Chemicals, Steel & Aluminium	Hydrocarbons, rare metals
	Transmission, distribution networks	Steel, Aluminium	Iron ore, bauxite
	Other	/	/
Infrastructures	Infrastructure, Buildings	Steel, Aluminium, cement, timber	Iron ore, bauxite, biomass, clinker substitutes
	Industrial & mechanical equipment	Steel, Aluminium	Iron ore, bauxite
	Roads	Cement, ~~Asphalt~~	clinker substitutes
	Rail	➔ Infrastructures	/
	CCS pipes	Steel	Iron ore
	Other	/	/
Consumer goods	Vehicles (cars, light trucks, truck, ships)	Steel, Aluminium, chemicals	Iron ore, bauxite, Lithium, fossil fuels
	Metal goods, consumer packaging, domestic appliances, clothing	Chemicals, steel, aluminium	Iron ore, bauxite, metals, hydrocarbons
	Other	/	/
Other	Other	/	/

Comments
- Only significant relationships will be kept so to reduce complexity and feedback loops, other are ~~skipped~~
- e.g. if wind turbines represent only 5% of the aluminium demand, asphalt is less energy intensive
- E.g. asphalt is not a major source of GHG emissions, excluding aggregates, it overlaps with cement and plastics

Illustration of the product to materials link for steel

Global Calculator

Steel driving products (2011)

- **Steel** – 1518 Mt steel; 2991 M tCO_2e; 1,97 tCO_2e/t steel
  - **Transport** – 13%: 194 Mt steel
    - **Cars & light trucks** – 8%: 123 Mt steel
    - **Trucks** – 2%: 28 Mt steel
    - **Ships** – 2%: 23 Mt steel
    - **Rail** – 1%: 20 Mt steel
  - **Industrial equipment** – 16%: 246 Mt steel
    - **Electrical equipment** – 3%: 46 Mt steel
    - **Mechanical equipment** – 10%: 153 Mt steel
  - **Construction** – 55%: 832 Mt steel
    - **Infrastructure** – 22%: 332 Mt steel
    - **Residential Buildings** – 28%: 422 Mt steel
    - **Other Buildings** – 5%: 77 Mt steel
  - **Metal products** – 16%: 247 Mt steel
    - **Metal goods** – 13%: 193 Mt steel
    - **Consumer packaging** – 1%: 11 Mt steel
    - **Domestic appliances** – 3%: 43 Mt steel
  - **Energy** – 0,6%: 10Mt steel
    - **Windmills** – 0,4%: 6 Mt steel
    - **PV Panels** – 0,02%: 0,3 Mt steel
    - **Pipes** – 3%: 40 Mt steel

NOTES: (1)There are other products, these have been diluted amongst the existing categories

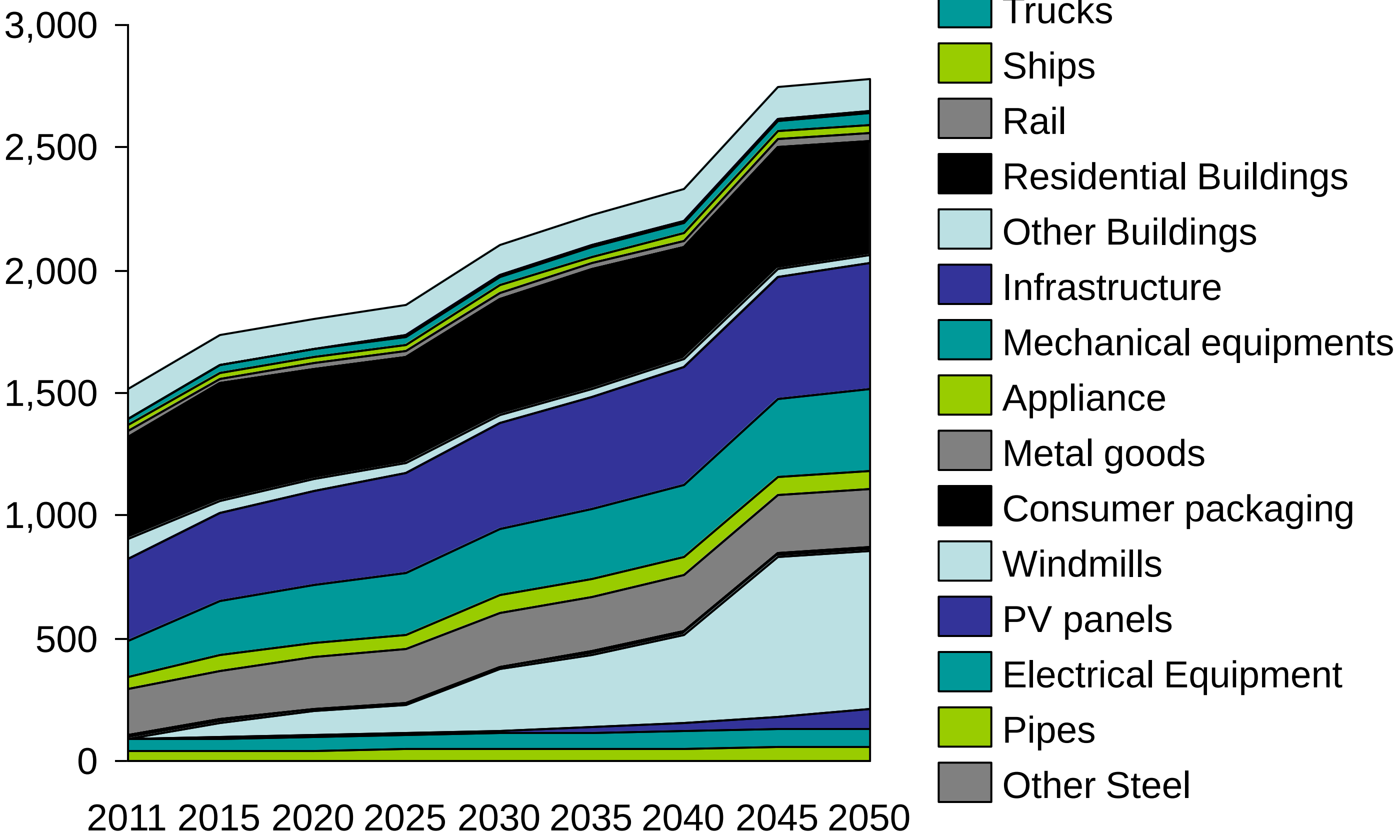
(2) Half the "Construction" steel is used for rebar with cement

SOURCES: With both eyes open, Copyright 2012 UIT Cambridge Ltd, adapted by Climact to 2011 figures

In the model, material demand is driven by product demand

Global Calculator

Steel demand evolution
(Mtons, before design & switch)



Steel example in a pathway with ambition 3

- Product demand determines material demand
- How should product demand be determined?

SOURCE: Global Calculator model

Most product demand is defined by each sector's activity, Some products are driven by the "Product demand" lever,

Global Calculator

Key drivers of demand to be challenged

Sector	Products	Model Technologies (grouped)	Demand driven by	Rationale
Transport	Car & Light trucks	Bike, Cars, Motorbike	By transport sector	/
	Trucks	Trucks, Bus		/
	Rail	Trains		/
	Airplanes	Planes		/
	Trucks & ships	Trucks, Ships		/
	Infrastructure [(1)]	Roads		/
	Batteries	Electric vehicles		/
Buildings	Buildings	Residential/Non-residential	By buildings sector	/
	Infrastructure [(1)]	Bridges, Roads, Airports	By transport sector	to avoid iteration loop and have it defined in one place
	Mechanical equipment's	Cooker, HVAC	By Buildings sector	/
	Appliances	Various appliances, stoves, lighting		/
Consumer goods	Paper	Print, graphic	By "Product demand " lever	/
	Metal goods	Consumer products	By "Product demand " lever	/
	Consumer packaging	Consumer packaging	By "Product demand " lever	/
	Fertilizers	Ammonia production	By Population	By Land & food sector in v2
Energy/ Electricity	Wind	Onshore, offshore	By energy sector	/
	PV	Solar PV		/
	Electrical Equipements	Transformers	Skipped	to avoid iteration loop
	Electrical cables	Transmition lines		
	Pipes			Not modelled in v1
	Infrastructure [(1)]	Energy Plants& network	By transport sector	to avoid iteration loop and have it defined in one place
Industry	Infrastructure [(1)]	Plants of each kind of material	By transport sector	to avoid iteration loop and have it defined in one place
	Paper	Paper	By "Product demand " lever	/

NOTE: (1) Infrastructure is present in three sectors: Energy, Industry and Transport. The allocation is as follows x,y,z.
It's demand evolution is currently following the transport demand only.

Reduction potential

Modelling choices on Scope

Impact in Product life is addressed by the other sectors	• To reduce overall emissions, we must take an overall perspective including both the production and the use phase • For example steels produce efficient transformers and motors enabling to reduce more CO_2 emissions than what was required during the production phase[1]
Use of by products is accounted for in the other sectors	• The material production can result in the generation of by-products that reduce CO_2 emissions by substituting natural resources in other industries • For example, blast furnace slag is used by the cement industry allowing it to reduce its CO_2 emissions significantly [1]

- Taking these dimensions into account typically provides a view on the material impact as a CO_2 mitigator
- Applied to steelmaking and steel use in Europe, such an approach shows that steel can save six times as much CO_2 where it is used than is emitted in production [2]

NOTES: Global calculator assumptions

SOURCES: (1) Worldsteel, steel's contribbution to a low carbon future

(2) Eurofer A steel Roadmap for a low carbon Europe 2050 (1013)

Material demand / product: Design, Switch & Recycling

Levers are assessed in each industry

Global Calculator

List of actions & levers assessed

Industry groups		Design	Switch	Recycling
Steel		• Product Design • High strength steel	• In vehicles : To aluminium & to plastics (fibres) • In buildings/Infrastructure : to timber	• Product recycling • % scrap based (for each various technologies exist)
Chemicals	All	• Product design	• /	• Product recycling • Material recycling
	High value		• Substitutes steel, aluminium & cement in vehicles & buildings/infrastructure	• Green chemistry
	Ammonia	• Fertilizers composition	• /	
	Methanol		• /	
	Other	• Green chemistry	• /	
Aluminium		• Product design	• In Planes: To plastic (fibres)	• Product recycling • Material recycling
Cement		• Product design	• In buildings/Infr. : To plastics & to timber	• Composed/metallurgical cement
Pulp & paper				• More recycled paper • Other cellulose sources • Bio-refineries
Timber		• Product design	• Switch from steel &cement	

SOURCE: Climact

Carbon intensity of material production

An additional ~50 levers then reduce the carbon intensity

List of actions & levers assessed

Industry groups		Process improvements	Alternative fuels	Efficiency	CCS
Steel		• Carbon material reduction • Portion of Classic BOF/ Top gas recycling & Hisarna/ EAF DRI/ EAF scrap • Smelt reduction, Hydrogen, Electrolysis	• Coke to gas injection • Coal PCI to biomass	• Material efficiency • Energy efficiency • CHP	• CCS
Chemicals	All	• Process intensification • Catalyst optimization	• Oil to gas	• Clustering and sustainable integration • CHP	• CCS
	High value	• Included in energy efficiency		• Energy efficiency	• CCS
	Ammonia	• Included in energy efficiency		• Energy efficiency	• CCS
	Methanol			• Energy efficiency	• CCS
	Other	• Included in energy efficiency • Selective catalytic reduction	• Hydrogen production by electrolysis • Natural gas or biomass	• Energy efficiency • Switch Mercury to membrane	• CCS
Aluminium		• Included in energy efficiency	• Gas injection	• Material efficiency • Energy efficiency	• CCS
Cement		• Dry process	• Coal & oil to waste & biomass	• Energy efficiency • CHP /heat recovery	• CCS
Pulp & paper		• Black liquor gasification • Drying innovation	• Coal & oil to gas • Coal & oil to biomass	• Energy efficiency • CHP	• CCS
Timber		• /	• /	• /	• /

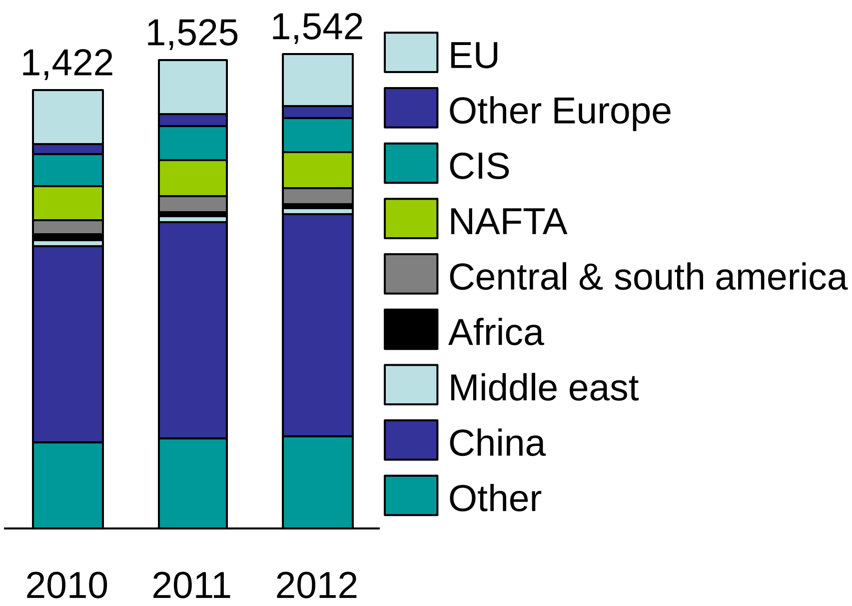
SOURCE: Climact

Regional differences are assessed when evaluating the global estimates, they are not modelled

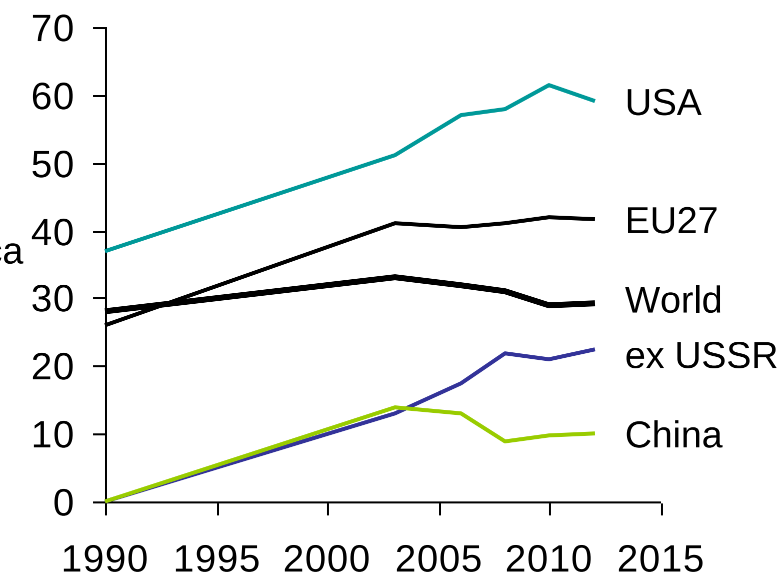
Global Calculator

STEEL EXAMPLE

Crude steel output [1] (Mt)



Historic evolution of the Electric steel production in the total crude steel production[2] (%)



SOURCE: (1) World steel in figures 2013
(2) IISI, Worldsteel in figure 2013, Eurostat, Groupement de la Sidérurgie

Agenda

Global Calculator

Introduction to the global calculator

Background

Global Calculator

Team & Model structure

Expert & Literature review

Warning messages

2011 overview of energy and material demand

2050 growth of materials and emissions

Aluminium assumptions summary

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

Global Calculator

Main sources used for the steel analysis

Organisation	Source
World Steel Association	• World Steel in Figures 2013 • Steel Statistical year book 2013 • Sustainable steel: Policy and indicators 2013 • Steel's Contribution to a Low Carbon Future • The three Rs of sustainable steel (Reduce, Reuse, Recycle), 2010
Eurofer	• Low Carbon Steel Roadmap 2050 (IEA involved, led by BCG and German Steel Institute)
EU JRC	• Prospective Scenarios on Energy Efficiency and CO2 Emissions in the EU Iron & Steel Industry
UN work	
ULCOS	• Official website
Midrex	• MidrexStats2011-6.7.12
IEA	• 2013 Key world energy statistics • 2012 technology perspectives
Cambridge	• With both eyes open
	• NTNU & Cambrige University (2014 04 10 International Materials Education Symposium)
US Environmental Protection Agency	• Available and emerging technologies for reducing greenhouse gas emissions from the iron and steel industry. North Carolina: US EPA. , 2010
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

Main sources used for the Chemicals 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

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

Global Calculator

Main sources used for the Aluminium analysis

Organisation	Source
World Aluminium	• A Review of the Global Aluminium Industry: 1972-2012 (2013) • Aluminium Intensive Electric Vehicle Report (2012) • Aluminium for Future Generations Sustainability Update: 2010 data (2011)
Cambridge	• With both eyes open
IEA	• Energy Technology Perspectives 2012, Pathways to a clean energy system
McKinsey	• McKinsey cost abatement curves v2.1
Ecofys	• SERPECC studies
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

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

Global Calculator

Main sources used for the Cement analysis

Organisation	Source
Cambridge	• With both eyes open
IEA	• Energy Technology Perspectives 2012, Pathways to a clean energy system • ETP 2014 data
International Cement Review	• The global cement report (6th edition) • Insights from the global cement report (10th edition) (2013)
IEA-WBCSD	• 2050 Cement Technology Roadmap (2009)
Carbon War Room	• Cement Report 1 (2011)
Mineral product association	• UK cement roadmap (2013)
GNR	• Global Cement Database on CO_2 and Energy Information
European Cement Research academy	• Technical documentation
Cembureau	• the role of cement in the 2050 low carbon economy
IEA	• GHG 2008. CO2 capture in the cement industry. Report 2008/3. Cheltenham, UK: International Energy Agency Greenhouse Gas R&D Programme
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

Main sources used for the Paper analysis

Organisation	Source
Cambridge	• With both eyes open
IEA	• Energy Technology Perspectives 2012, Pathways to a clean energy system
CEPI	• roadmap • Two team project report (presents 8 breakthrough technologies)
Carbon Trust	• Carbon Trust, 2011. Industrial Energy Efficiency Accelerator - Guide to the paper sector (CTG059). London
FAO	• Statistics on link between product demand and materials demand
McKinsey	• McKinsey cost abatement curves v2.1
Ecofys	• SERPECC studies
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

Main sources used for the Timber analysis

Organisation	Source
Cambridge	• With both eyes open
IEA	• Energy Technology Perspectives 2012, Pathways to a clean energy system
CEI Bois	• Wood in carbon efficient constructions: Tools, methods & applications/ Lutter contre le changement climatique: utiliser le bois
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

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

Global Calculator

Main sources used for the CCS specifics

Organisation	Source
IEA	• Energy Technology Perspectives 2012, Pathways to a clean energy system • IEA: Technology Roadmap: Carbon Capture and Storage (2013) • IEA, UNIDO : Technology Roadmap Carbon Capture and Storage in Industrial Applications (2011)
Imperial Grantham	• Briefing paper Carbon Capture Technology (Nov 2010)
ZEP	• Application of CCS in EU energy intensive industries
McKinsey	• McKinsey cost abatement curves v2.1
Ecofys	• SERPECC studies
Previous consultations	• Similar roadmaps performed in Belgium, UK, Algeria, the Balkans & India

Main sources used for the Resources specifics

Organisation	Source
IEA	• US geological survey (USGS)
Cambridge	• With both eyes open
Bath University	• Construction materials database; inventory of carbon energy. Bath database

NOTES: Resource availability is only partially addressed in this release of the calculator
In an ulterior release focusing more on this topic, Ecofys reports on heavy materials and BNL reports should also be assessed.

Agenda

Global Calculator

The tool could deliver warning messages to keep it simple while keeping the right message, warnings will therefore be displayed under certain conditions

Global Calculator

Preliminary

Materials

Emissions	• Electricity can be a large emission component (in cases the largest for aluminium) • Electricity mix is typically not so related to the national, regional or world electricity mix (typical for aluminium)
Product & material design	• Product and material design is currently not linked to demand (e.g. high strength steel to efficient vehicles)

Material switch	• Material switch is currently not linked to demand (e.g. high strength steel to efficient vehicles)
	• You are heavily replacing some materials by others. Please note this
	    • Modelling is performed at high level
	    • Can change the properties of the products
	• Land use allocation, e.g. lack of area for forest or bioenergy.

Fuel switch	• Land use allocation, e.g. lack of area for forest or bioenergy.
Process improvements & energy efficiency	• You’ve chosen level 4 for steel. This is a heroic level of effort.
CCS	• You’ve selected CCS for your pathway but be aware that, to date, CCS has not been demonstrated at a commercial level.

Post meeting feedback on these messages is highly welcome

The tool should deliver warning messages to keep it simple while keeping the right message, warnings will therefore be displayed under certain conditions

Global Calculator

ILLUSTRATIVE

Energy security

- You are more than x% reliant of fossil fuels (or any other single energy supply, e.g. intermittent renewables) for your energy supply. The world could be exposed to high volatility of fossil fuel prices.
- You have selected a high output of bioenergy but very low energy demand, so there is oversupply of bioenergy.

Electricity

- You've electrified transport/heat but you have not decarbonised electricity generation so emission savings are not being realised.
- You've decarbonised electricity generation but have not electrified much heat or transport, so emission savings are not being fully realised.
- You're using GGR / CCS, but these technologies consume electricity and you have not decarbonised electricity generation, so emission savings are not being fully realised.
- You're generating a lot of electricity from renewables, but these have intermittent supply so you should use more demand shifting and storage.
- You're oversupplying electricity – this is wasting electricity.

The tool should deliver warning messages to keep it simple while keeping the right message, warnings will therefore be displayed under certain conditions

Global Calculator

ILLUSTRATIVE

Technology development required

- You've chosen GGR – this is a speculative technology.
- You've selected CCS for your pathway but be aware that, to date, CCS has not been demonstrated at a commercial level.
- You've chosen level 4 for solar/nuclear/wind/etc [any technology lever]. This is a heroic level of effort.
- Geothermal – should we flag that this is a relatively unproven technology??

Cost

- You've got some stranded assets (e.g. coal electricity generation or replacing manufacturing furnaces).
- You're using a lot of oil so your oil price could be very high. (nb: Be careful not to say, "you've run out of oil.")
- Low oil price but high oil consumption.
- Nuclear costs are particularly uncertain owing to uncertainty over cost of decommissioning.

The tool should deliver warning messages to keep it simple while keeping the right message, warnings will therefore be displayed under certain conditions

Global Calculator

ILLUSTRATIVE

Resources (land, forest, food, etc)

- There is not enough land to meet your diet choices. Consider change in diet, yields, population.
- You have no forest/bioenergy because of your meat consumption.
- Land use allocation, e.g. lack of area for forest or bioenergy.
- Be aware you are have no forest left (if it’s possible for user to do this).
- You’ve generated a high temperature change pathway, but you’ve selected level 4 crop yields.
- BECCS/biochar interaction with conventional bioenergy.
- You have selected “smart manufacturing level 4” but you do not have enough commercial forest to service this.
- You have selected “smart manufacturing level 4” which involves a high degree of substitution of timber for cement – beware that this could have adverse implications for [lifespan of buildings? Energy efficiency of buildings? etc].
- Your pathway requires a lot of land for meat production so the “forest and bioenergy” lever has no impact.

The tool should deliver warning messages to keep it simple while keeping the right message, warnings will therefore be displayed under certain conditions

Global Calculator

ILLUSTRATIVE

Climate science warning

- Emissions peak and start to fall – warning that the IPCC method may be less accurate (over estimate).
- Emissions go off the scale of IPCC SPM10 so no change in temperature assessment can be made.
- Very high change in temperature – warning that climate models can't represent all feedbacks, so levels very uncertain.
- Aerosol emissions are very high/low – note climate impacts (regional).
- CH4 or N2O emissions are higher/lower than the RCP range so the temperature calculation will be too low/high.
- 2050-2100 emissions pathway is ad hoc but has a big impact on the temperature calculation.

Agenda

Global
Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2011 Sector shares in energy demand

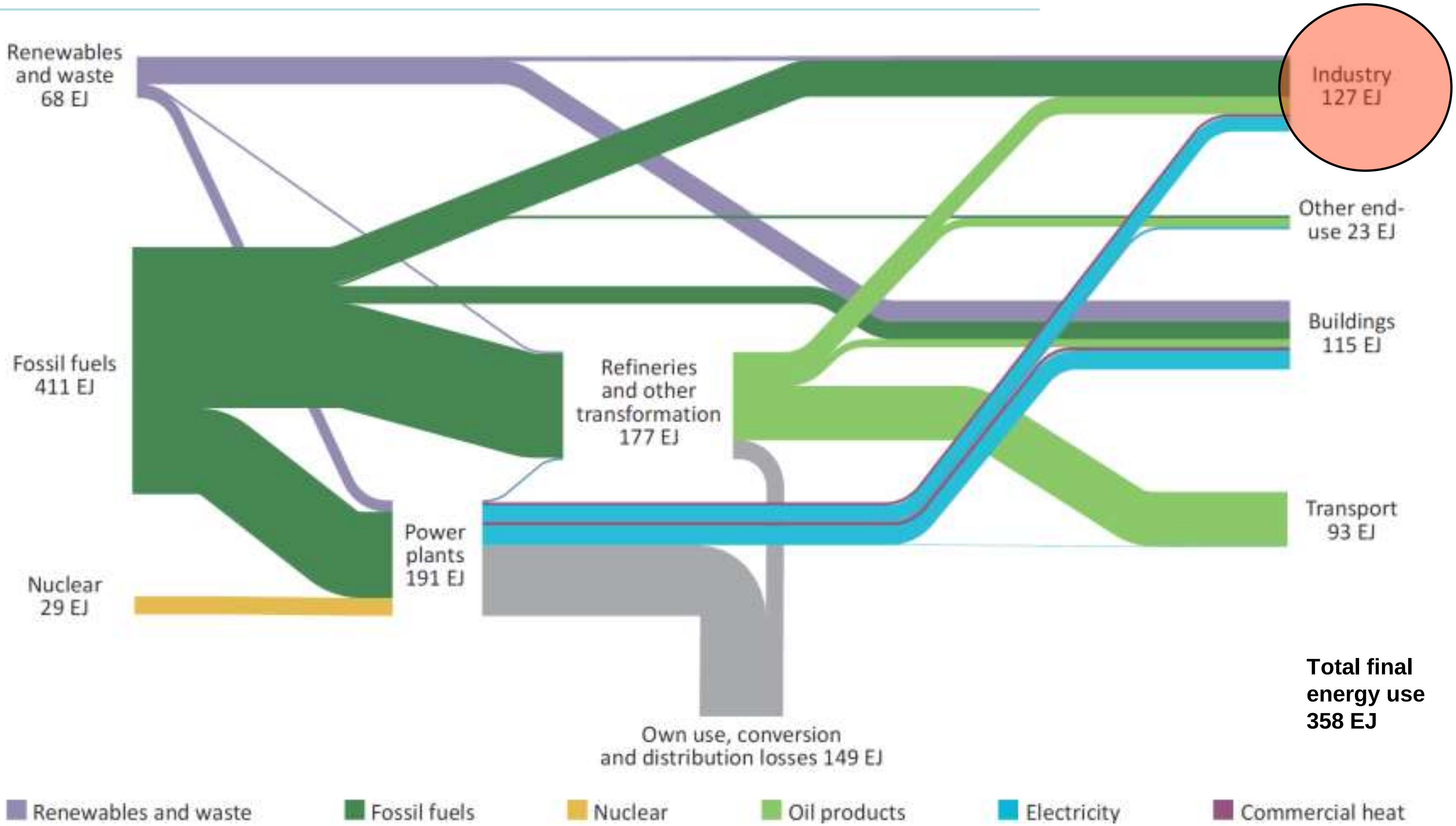
2011 Product demand & link to material demand

2050 growth of materials and emissions

Aluminium assumptions summary

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

Energy Sankey in 2009, (EJ)



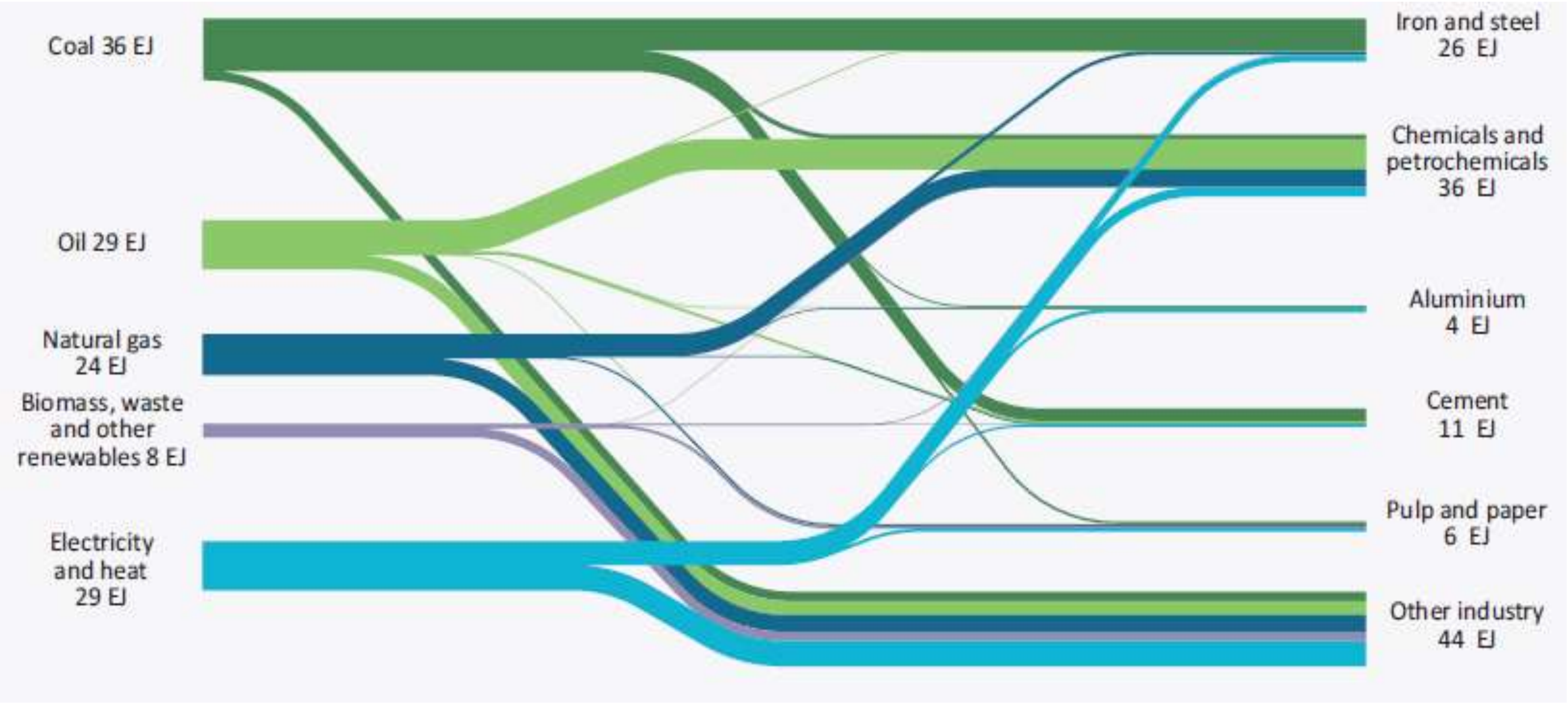
SOURCE: ETP 2012, IEA

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

Patterns differ but most industries heavily depend on fossil fuels. Other industries are more electrified

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 taken into account in this picture
(2) Energy consumption is dominated by fossil fuels in all sectors

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2011 Sector shares in energy demand

2011 Product demand & link to material demand

2050 growth of materials and emissions

Aluminium assumptions summary

PART HIDDEN IN PREREAD

REMINDER : For manufacturing, 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

Iron & steel
Demand driving products

Global Calculator

Steel driving products
(2011)

Steel

1518 Mt steel
2991 M tCO_2e
1,97 tCO_2e/t steel

Transport	13%: 194 Mt steel	**Cars & light trucks**	8%: 123 Mt steel
		Trucks	2%: 28 Mt steel
		Ships	2%: 23 Mt steel
		Rail	1%: 20 Mt steel
Industrial equipment	16%: 246 Mt steel	**Electrical equipment**	3%: 46 Mt steel
		Mechanical equipment	10%: 153 Mt steel
Construction	55%: 832 Mt steel	**Infrastructure**	22%: 332 Mt steel
		Residential Buildings	28%: 422 Mt steel
		Other Buildings	5%: 77 Mt steel
Metal products	16%: 247 Mt steel	**Metal goods**	13%: 193 Mt steel
		Consumer packaging	1%: 11 Mt steel
		Domestic appliances	3%: 43 Mt steel
Energy	0,6%: 10Mt steel	**Windmills**	0,4%: 6 Mt steel
		PV Panels	0,02%: 0,3 Mt steel
		Pipes	3%: 40 Mt steel

NOTES: (1)There are other products, these have been diluted amongst the existing categories
(2) Half the “Construction” steel is used for rebar with cement

SOURCES: With both eyes open, Copyright 2012 UIT Cambridge Ltd, adapted by Climact to 2011 figures

Iron & Steel
Materials demand is driven by the product demand

Global Calculator

Technologies & Products		Amounts (units, 2011)	Intensity (t steel/product)	Annual Steel production (M tons, 2011)[2]
Transport	Cars & light truck	113 (M Vehicles)	1100 kg/vehicle	123
	Trucks	5,7 (M Vehicles)	4900 kg/vehicle	28
	Ships	1 (k units)	20 000	23
	Rail	5 (k units)	4000	20
Buildings	Buildings Residential	3 930 (km² [4])	107 kg/m² [1]	422
	Buildings Others	830 (km² [4])	93 kg/m² [1]	77
	Infrastructure	1750 (km² [4])	187 kg/m²	332
	Mechanical equipment	160 (M tons)	0,97	153
	Appliance	253 (M tons)	0,17	43
Consumer goods	Metal goods	257 (M tons)	0,75	193
	Consumer packaging	530 (M tons)	0,02kg/kg packaging	11
Energy	Windmills	17,500 2MW turbines	350 tons/2MW turbine[3]	6,1
	PV panels	160 M m²	2kg /m²	0,320
	Electrical equipment	61,1 (M tons)	0,75	46
	CCS + oil pipes	100 000 km	0,4 ton/m	40
Other	Other Steel	~0M (tons)	1	~0

Model demand drivers

Total 1518 Mton (100%)

NOTE: (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

SOURCE: (1) Muiris Moynihan thesis obtains 20kg/m² for residential buildings and 100 kg/m² for commercial

(2) With both eyes open (3) Worldsteel Wind energy case study

Chemicals

Materials demand is driven by the product demand

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 (km^2 (4))	0,014	-	0,002	0,009	54	-	10	35
	Buildings Others	830 (km^2 (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 m^2	5kg /m^2	-	-	-	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

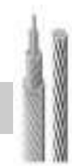
(4) Of ground surface

Aluminium
Demand driving products

- **Aluminium** — 80,5 Mt aluminium
  - **Transport** — 27%: 22 Mt aluminium
    - **Cars & light trucks** — 18%: 14,3 Mt aluminium
    - **Trucks** — 7%: 5,4 Mt aluminium
    - **Other** — 2%: 1,8 Mt aluminium
  - **Industrial equipment** — 20%: 16 Mt aluminium
    - **Electrical equipment** — 4%: 3 Mt aluminium
    - **Electrical cable** — 9%: 7 Mt aluminium
    - **Mechanical equipment** — 7%: 5 Mt aluminium
  - **Construction** — 24%: 19 Mt aluminium
    - **Buildings Residential** — 19%: 15 Mt aluminium
    - **Buildings Other** — 3%: 3 Mt aluminium
    - **Infrastructure** — 2%: 2 Mt aluminium
  - **Metal products** — 29%: 23 Mt aluminium
    - **Packaging** — 13%: 11 Mt aluminium
    - **Appliances** — 7%: 5 Mt aluminium
    - **Metal goods** — 9%: 7 Mt aluminium
    - **PV panels** — 0,3%: 0,3 Mt aluminium










NOTES Electricity can be the largest emission component
Electricity mix is typically not so related to the national, regional or world electricity mix.
In recent years, newer plants tended to rely on more coal based electricity

SOURCE: With both eyes open, Copyright 2012 UIT Cambridge Ltd.

Aluminium

Materials demand is driven by the product demand

Global Calculator

Technologies & Products		Amounts (units, 2011)	Intensity (tons/ product)	Aluminium production (M tons)[2]
Transport	Cars & light truck	113 (M vehicles)	0,13 tons/vehicles	14
	Trucks	5,7 (M vehicles)	0,94 ton/vehicle	5
	Ships	1 (k units)	0 tons/unit	0
	Airplanes	35 000 (units)	500 tons/unit	2
Buildings	Buildings residential	3930 (km^2 [4])	4,4 kg/m^2 [1]	15
	Buildings others	830 (km^2 [4])	3,8 kg/m^2 [1]	3
	Infrastructure	1750 (km^2 [4])	1,2 kg/m^2 [1]	2
	Mechanical Equipment	160 (M tons)	34kg/ton eqpt	5
	Appliance	253 (M tons)	21 kg/ton appliance	5
Consumer goods	Metal goods	257 (M tons)	0,3 tons/ton goods	7
	Consumer packaging	530 (M tons)	0,02 tons/ton packaging	11
Energy	PV panels	160 M m^2	2kg /m^2	0,31
	Electrical Equipment	61,4 (M tons)	0,03 tons/ton eqpt	3
	Electrical cables	24 (M km)	0,3 tons/km	7
Other	Other Aluminium	0 (M tons)	1 ton/ton product	0

Model demand drivers

Total 80,5 Mton (100%)

SOURCE: (1) Model defined, with both eyes open provides 5kg/m^2
(2) With both eyes open base, adapted to IEA figures & new products
(4) Of ground surface

Cement

Materials demand is driven by the product demand

Global Calculator

Technologies & Products		Amounts (units, 2011)	Intensity (tons/ product)	Cement production (G tons, 2011[2])
Buildings	Residential Buildings	3930 million m^2 [4]	305 kg cement per m^2 of buildings [1]	1,200 Gton (33%)
	Other Buildings	830 million m^2 [4]	745 kg cement per m^2 of buildings [1]	618 Gton (17%)
	Infrastructure	1750 million m2 [4]	1023 rest kg cement per m^2 of buildings [1]	1,818 Gton (50%)

Model demand drivers

Total 3,635 Gton (100%)

NOTE: (1) With both eyes open assumes ~60 kg per floor. The model is working with ground surface so including several floor levels. Assuming 8 tons of cement per ton of concrete and a concrete density of 2200kg/m3, one can assess the width of concrete in the buildings. 500kg/m^2 is close to 2 m depth per square meter

Furthermore, residential buildings typically have half as much steel per concrete, than other buildings (commercial/industrial).

(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

SOURCE: (1) Model, matching buildings estimate to cement and steel demand

Paper
Materials demand is driven by the product demand

Global Calculator

Technologies & Products		Amounts (units, 2011)	Intensity (tons/ product)	Paper production (M tons)[1,2]
Consumer goods	Printing & graphic	263 (M tons)	1	263
	Packaging	532 (M tons)	0,517 t paper/ton packaging	275
	Other (e.g. hygiene)	73 (M tons)	1	73

Model demand drivers

Total 611 Mton (100%)

SOURCE: (1) Global calculator

Timber
Materials demand is driven by the product demand

Global Calculator

Technologies & Products		Amounts (units) (units, 2011)	Intensity (tons/ product)	Timber production (M tons)[2]
Buildings	Buildings residential	3930 (km^2 [4])	0,12	479
	Buildings Others	830 (km^2 [4])	0,11	87
Consumer goods	Other timber (incl. Furniture)	243 (tons)	1	243

Model demand drivers

Total 809 Mton (100%)

NOTES: (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

SOURCE: (1) Global Calculator

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- Growth depending on ambition level
- Discussion on Material switch

Resulting GHG emissions

- Resulting emissions depending on ambition level
- Discussion on ambition levels across sectors
- Discussion on CCS

Aluminium assumptions summary

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- **Growth depending on ambition level**
- Discussion on Material switch

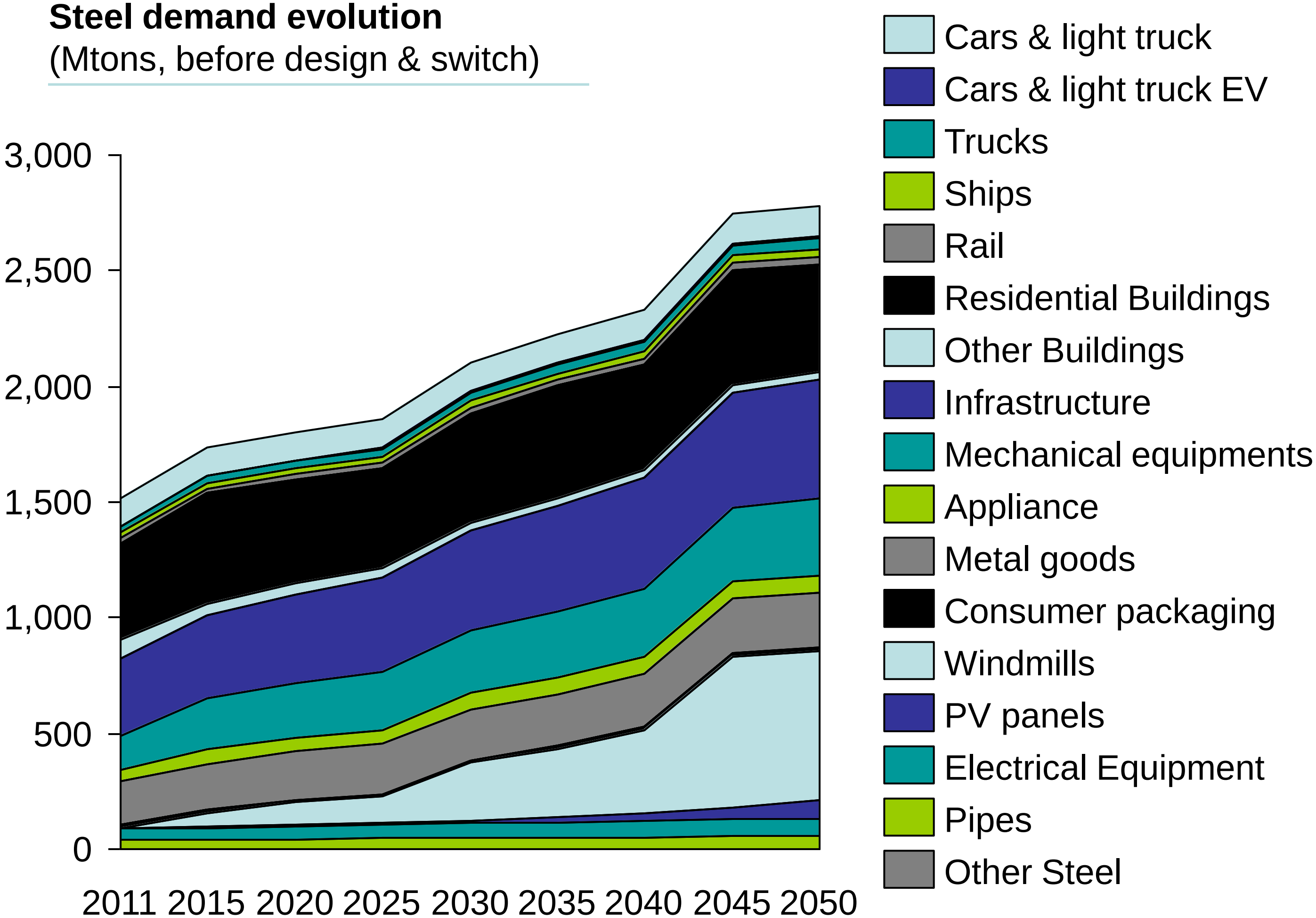
Resulting GHG emissions

- Resulting emissions depending on ambition level
- Discussion on ambition levels across sectors
- Discussion on CCS

Aluminium assumptions summary

REMINDER: In the model, material demand is driven by product demand

Steel demand evolution
(Mtons, before design & switch)



Steel example in a pathway with ambition 3

- Product demand determines material demand
- How should product demand be determined?

SOURCE: Global Calculator model

REMINDER: Most product demand is defined by sector activity, Some products are driven by the “Product demand” lever,

Global Calculator

Key drivers of demand to be challenged

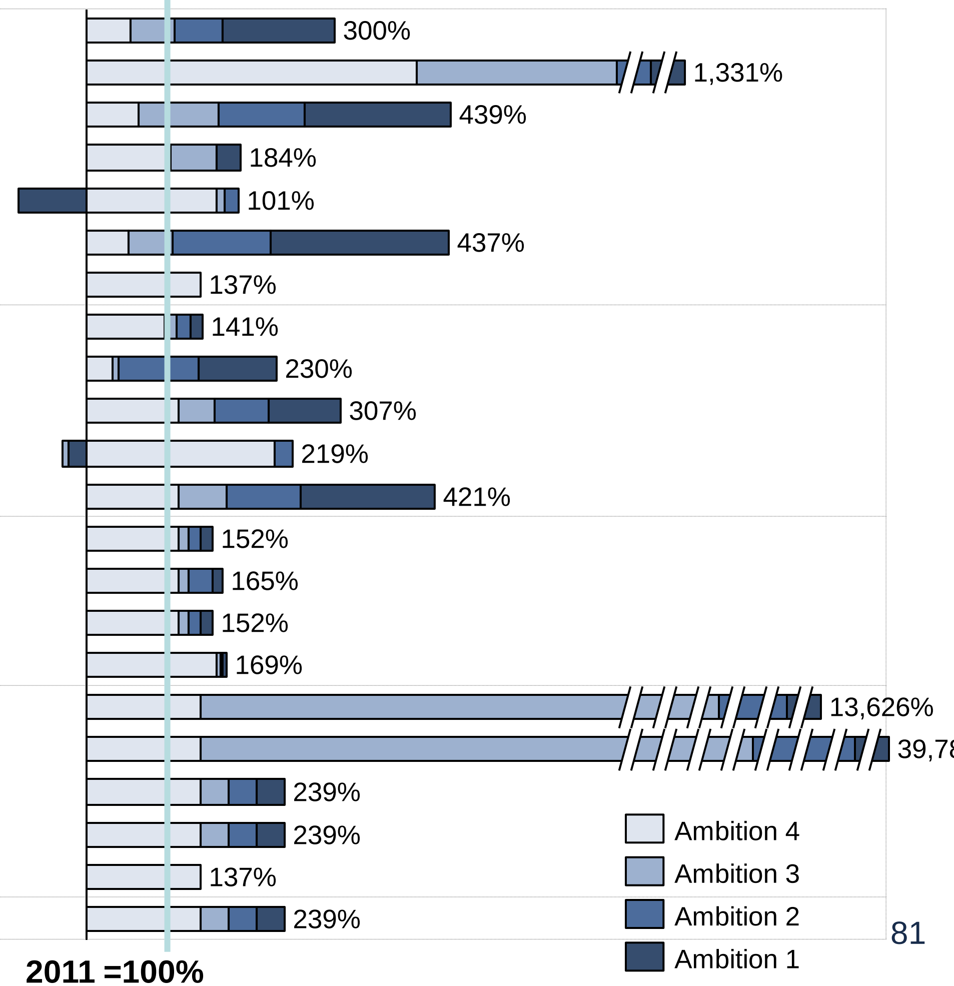
Group	Products	Model Technologies (grouped)	Demand driven by	Rationale
Transport	Car & Light trucks	Bike, Cars, Motorbike	By transport sector	/
	Trucks	Trucks, Bus		/
	Rail	Trains		/
	Airplanes	Planes		/
	Trucks & ships	Trucks, Ships		/
	Infrastructure (1)	Roads		/
	Batteries	Electric vehicles		/
Buildings	Buildings	Residential/Non-residential	By buildings sector	/
	Infrastructure (1)	Bridges, Roads, Airports	By transport sector	to avoid iteration loop and have it defined in one place
	Mechanical equipment's	Cooker, HVAC	By Buildings sector	/
	Appliances	Various appliances, stoves, lighting		/
Consumer goods	Paper	Print, graphic	By “Product demand “ lever	/
	Metal goods	Consumer products	By “Product demand “ lever	/
	Consumer packaging	Consumer packaging	By “Product demand “ lever	/
	Fertilizers	Ammonia production	By Population	By Land & food sector in v2
Energy/ Electricity	Wind	Onshore, offshore	By energy sector	/
	PV	Solar PV		/
	Electrical Equipements	Transformers	Skipped	to avoid iteration loop
	Electrical cables	Transmition lines		
	Pipes			Not modelled in v1
	Infrastructure (1)	Energy Plants& network	By transport sector	to avoid iteration loop and have it defined in one place
Industry	Infrastructure (1)	Plants of each kind of material	By transport sector	to avoid iteration loop and have it defined in one place
	Paper	Paper	By “Product demand “ lever	/

NOTE: (1) Infrastructure is present in three sectors: Energy, Industry and Transport. The allocation is as follows x,y,z.
It’s demand evolution is currently following the transport demand only.

The model simulates various product evolutions

Global Calculator

Group	Product	2011 demand (units)		2050 demand per ambition[(1)] (% evolution vs 2011)
Transport	Cars & light truck	111,3	Million units	300%
	Cars & light truck EV	1,5	Million units	1,331%
	Trucks	5,7	Million units	439%
	Ships	1	K units	184%
	Rail	5	K units	101%
	Airplanes	35	K units	437%
	Batteries	/	Million units	137%
Buildings	Residential Buildings	3932	Million m2	141%
	Other Buildings	830	Million m2	230%
	Infrastructure	1750	Million m2	307%
	Mechanical equipment	160	Million tons	219%
	Appliance	43	Million tons	421%
Consumer goods	Print & Graphic Paper	253	Million tons	152%
	Metal goods	257	Million tons	165%
	Consumer packaging	530	Million tons	152%
Food	Fertilizer	164	Million tons	169%
Energy	Windmills	17600	Units	13,626%
	PV panels	160	Million m2	39,7…
	Electrical Equipment	61	Million tons	239%
	Electrical cables	24	Million km	239%
	Pipes	100 000	km	137%
Other	Other	0,0	Million tons	239%

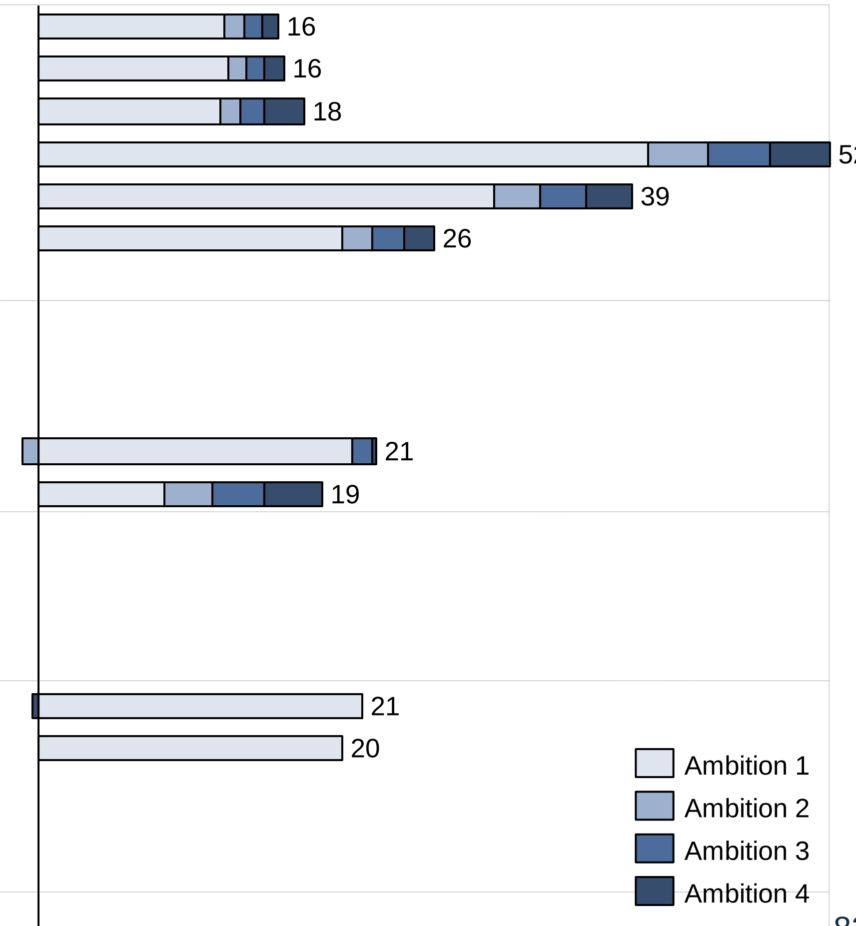


NOTE (1) Population follows the average UN projection in all ambitions

The model simulates various product evolutions

Group	Product	2011 lifetime (years)
Transport	Cars & light truck	12,2
	Cars & light truck EV	12,4
	Trucks	12,4
	Ships	40
	Rail	30
	Airplanes	20
	Batteries	/
Buildings	Residential Buildings	/
	Other Buildings	/
	Infrastructure	/
	Mechanical equipment	21,9
	Appliance	11,9
Consumer goods	Print & Graphic Paper	/
	Metal goods	/
	Consumer packaging	/
Food	Fertilizer	/
Energy	Windmills	24,1
	PV panels	20,0
	Electrical Equipment	/
	Electrical cables	/
	Pipes	/
Other	Other	/

Lifetime per ambition (years)



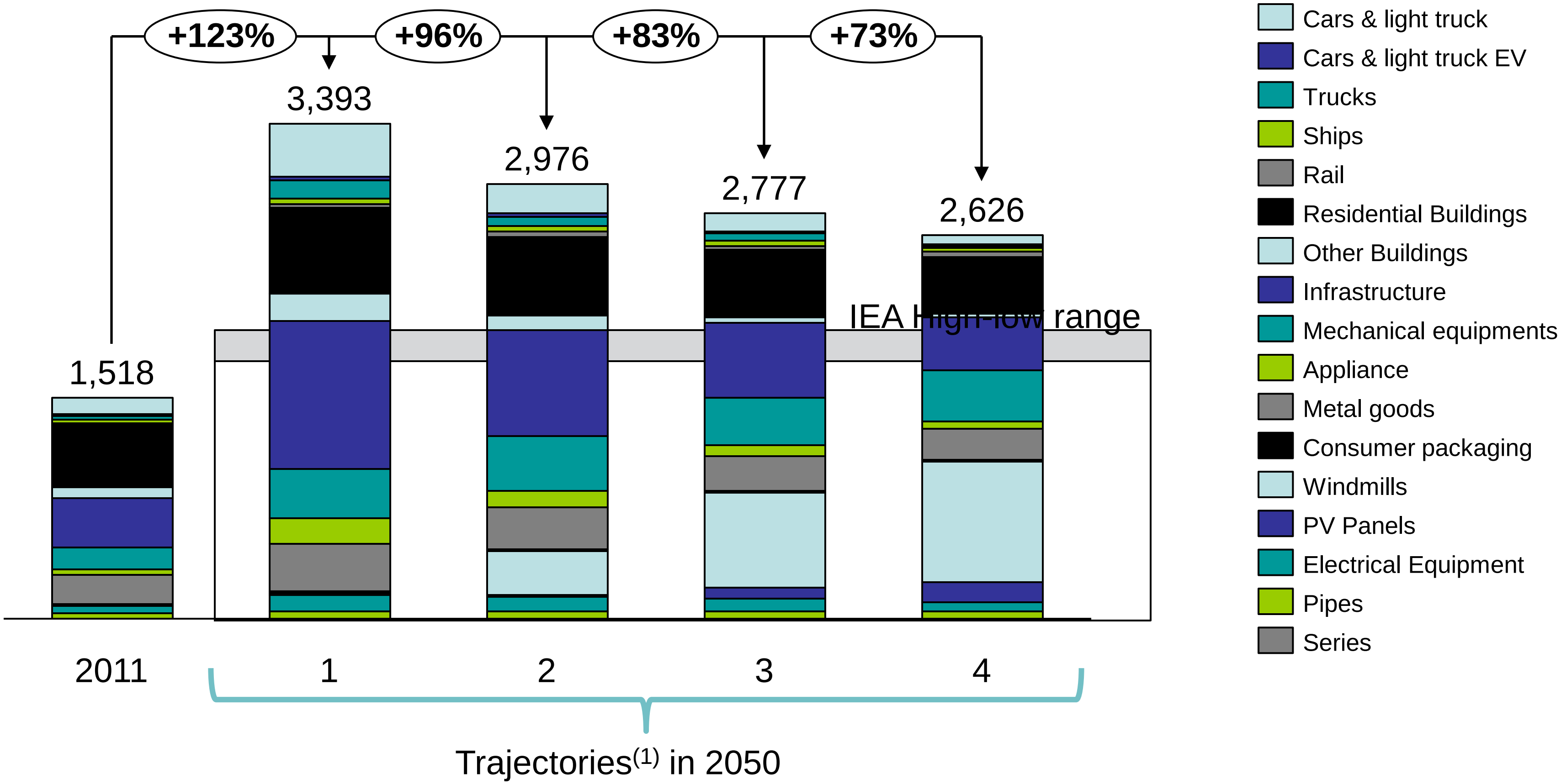
NOTE (1) Population follows the average UN projection in all ambitions

Iron & Steel

Materials demand growth in trajectories 1, 2, 3 & 4 (1)

Global Calculator

Annual Steel production per ambition level(1), by product
(M tons)



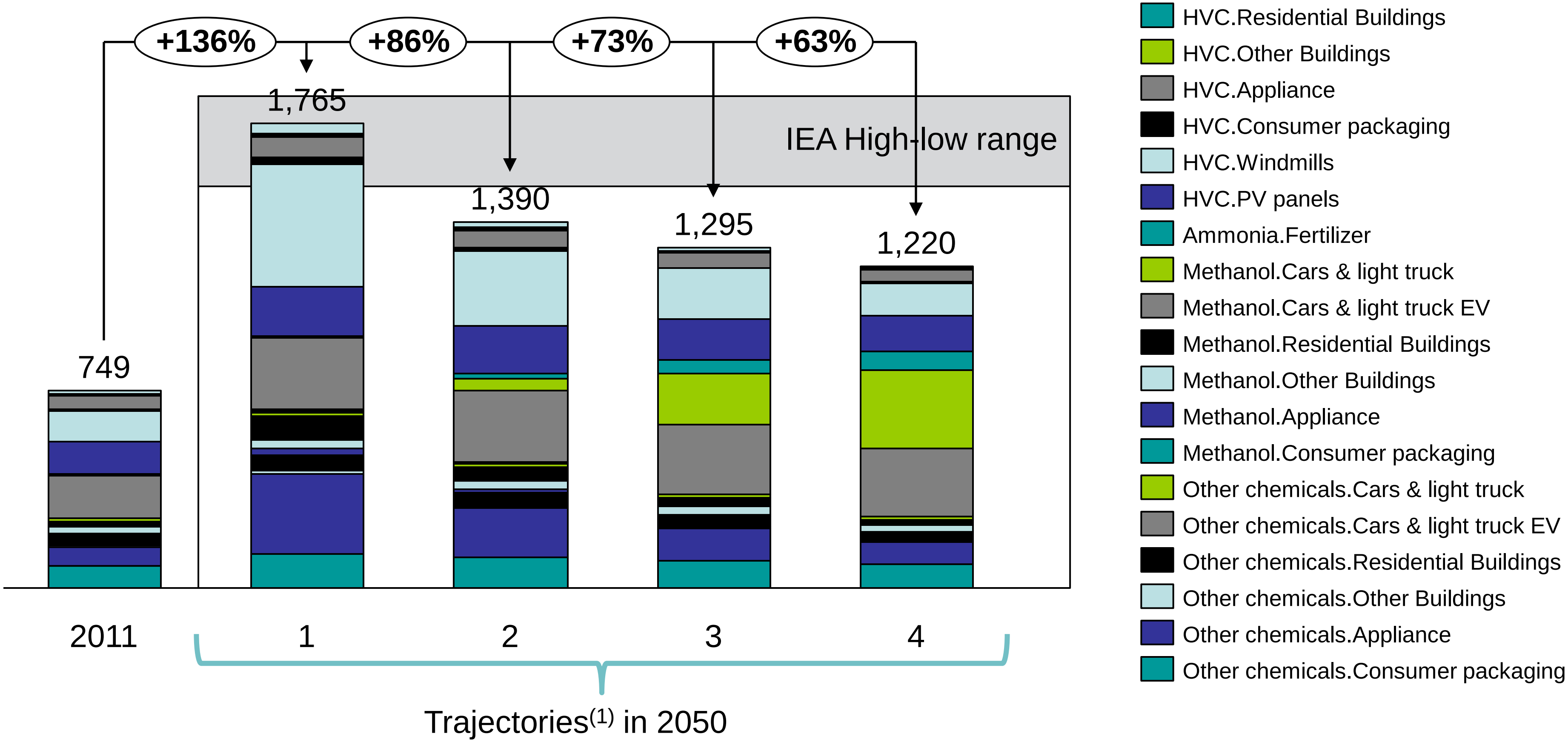
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Global Calculator

Chemicals

Materials demand growth in trajectories 1, 2, 3 & 4 (1)

Annual Chemical production per ambition level(1), by product
(M tons)



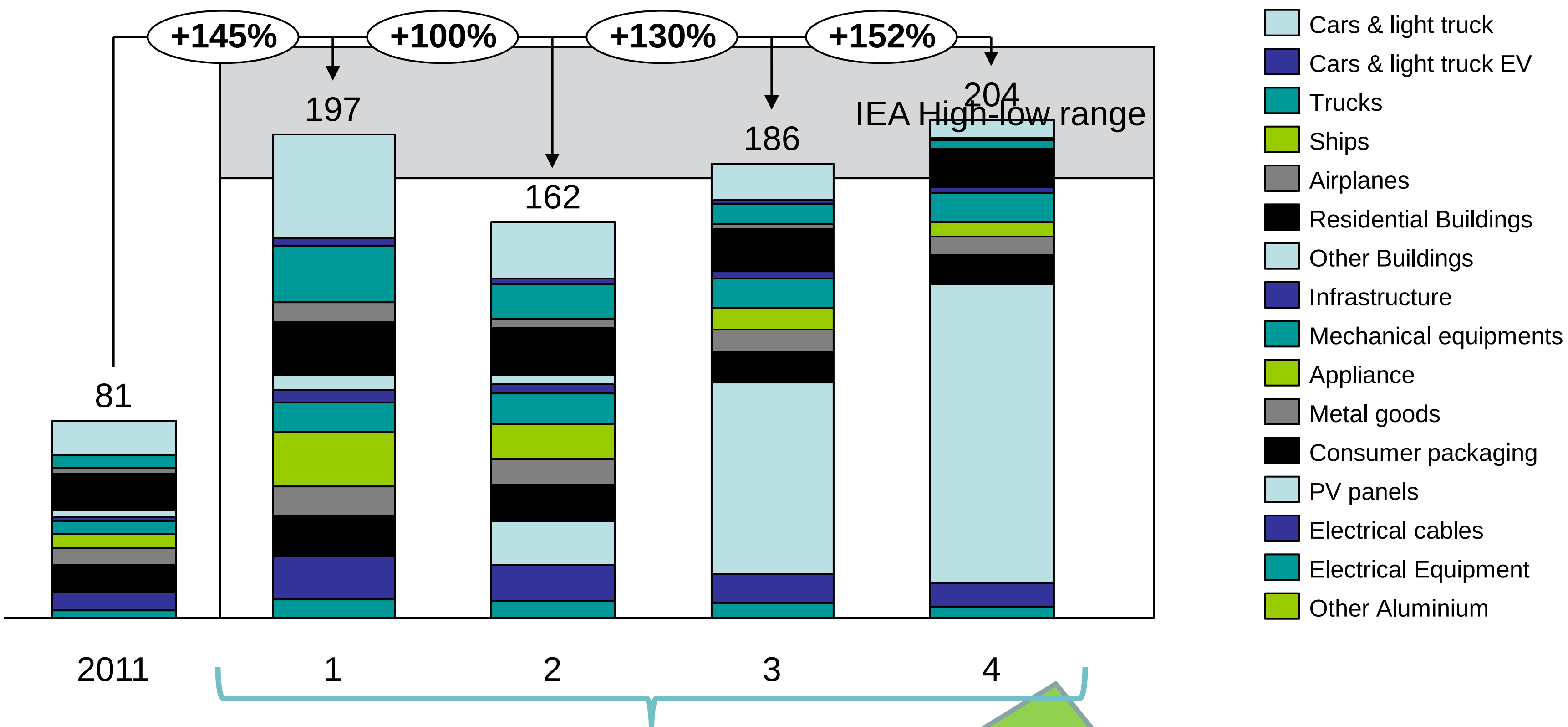
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Global Calculator

Aluminium

Materials demand growth in trajectories 1, 2, 3 & 4 [1]

Annual Aluminium production per ambition level[1], by product
(M tons)



Aluminium sector will gain from product switch

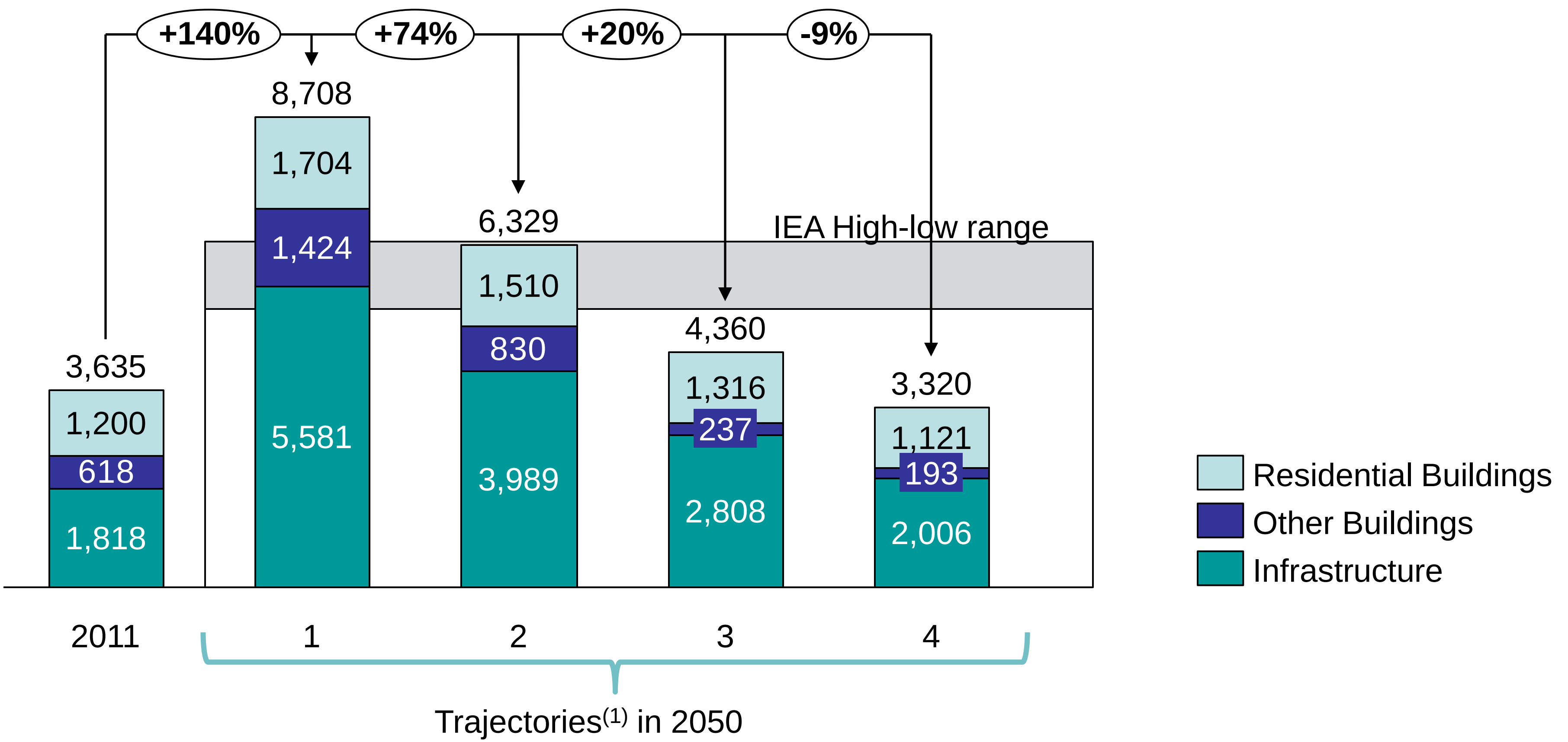
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Cement

Materials demand growth in trajectories 1, 2, 3 & 4 (1)

Global Calculator

Annual Cement production per ambition level(1), by product
(M tons)



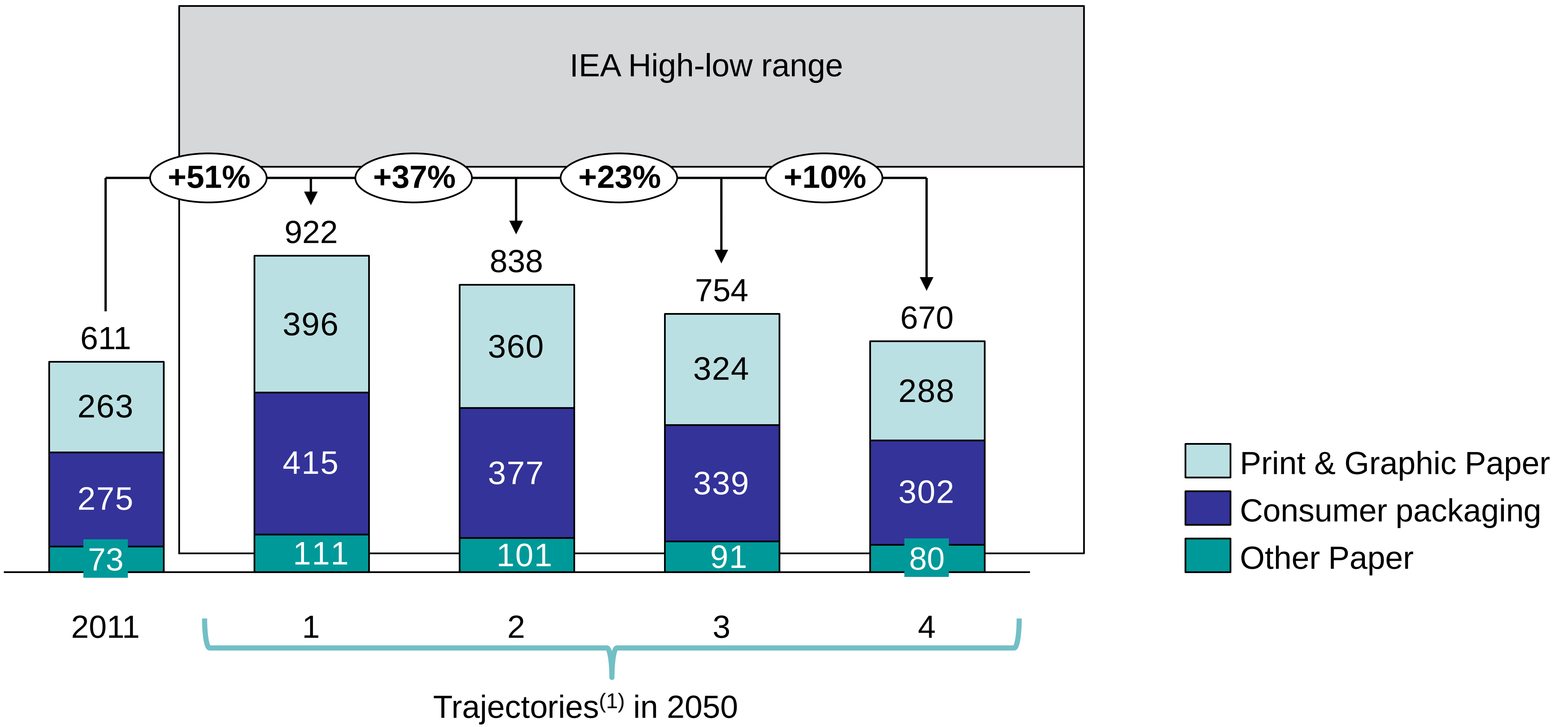
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Paper

Materials demand growth in trajectories 1, 2, 3 & 4 [(1)]

Global Calculator

Annual Paper production per ambition level[(1)], by product
(M tons)



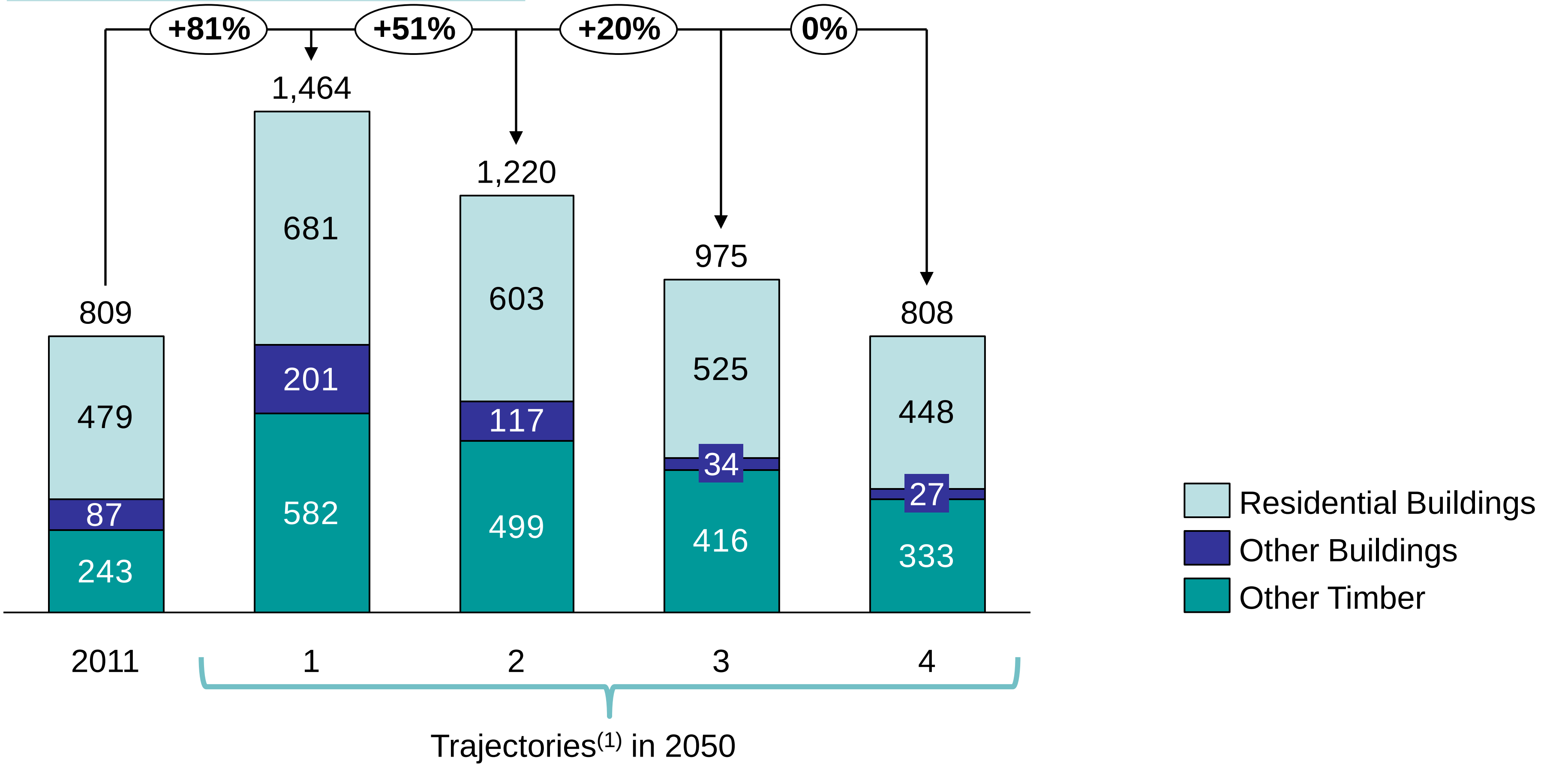
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Global Calculator

Timber

Materials demand growth in trajectories 1, 2, 3 & 4 (1)

Annual Timber production per ambition level(1), by product
(M tons)



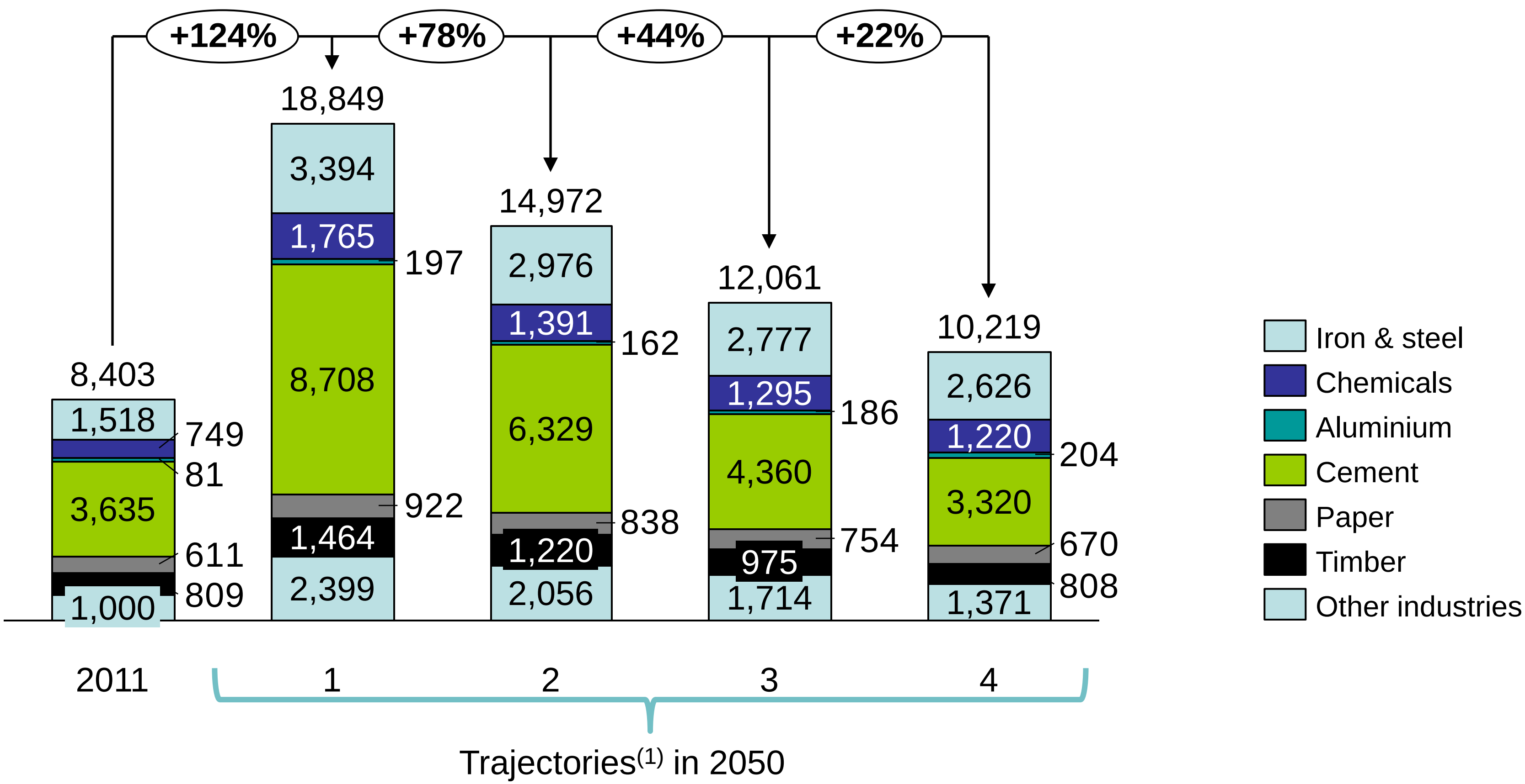
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Global Calculator

Total

Materials demand growth in trajectories 1, 2, 3 & 4 [1]

Annual Total production per ambition level[1], by product
(M tons)



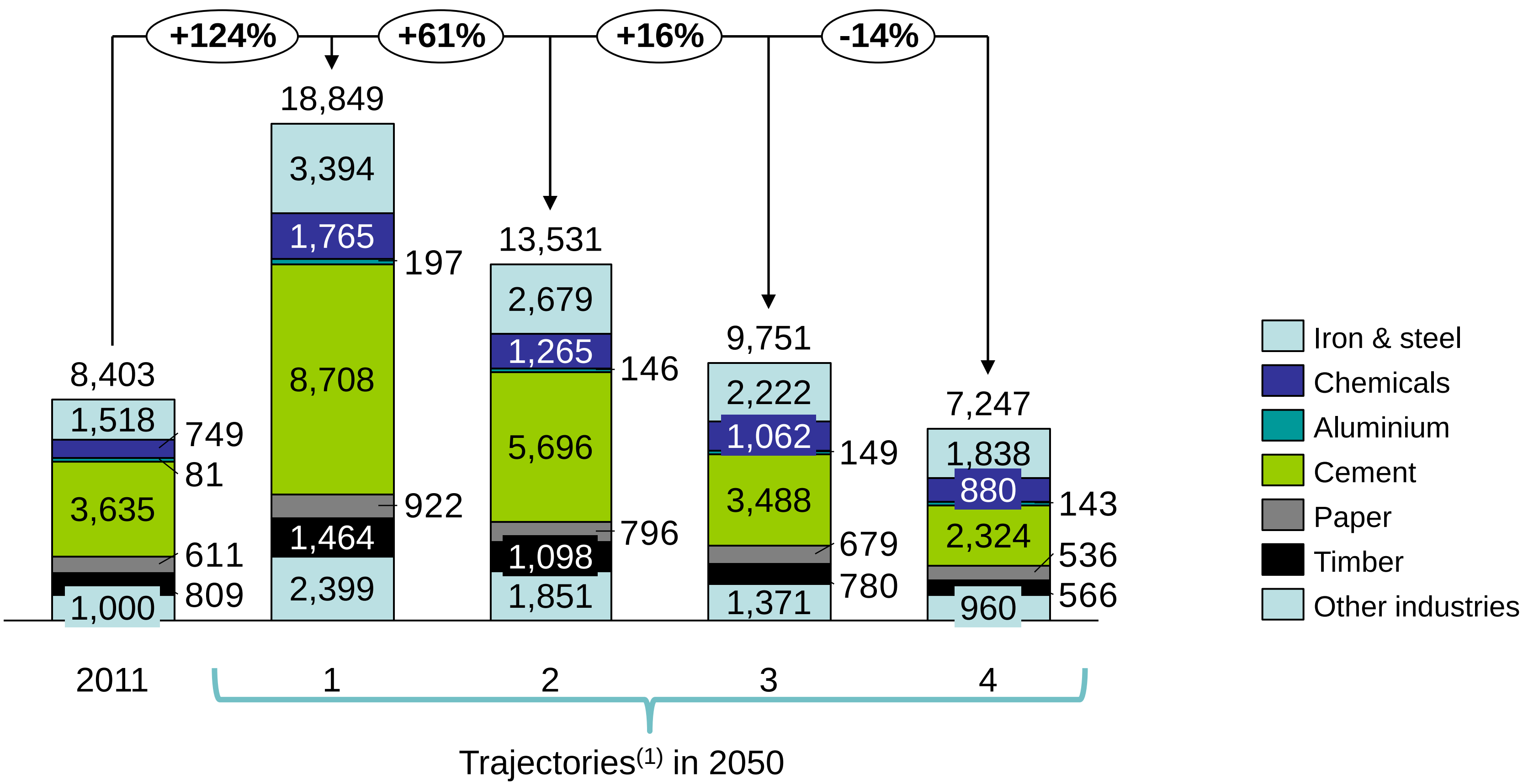
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Total

Materials demand growth in trajectories 1, 2, 3 & 4 (1)

Global Calculator

Annual Total production per ambition level(1), by product
(M tons)



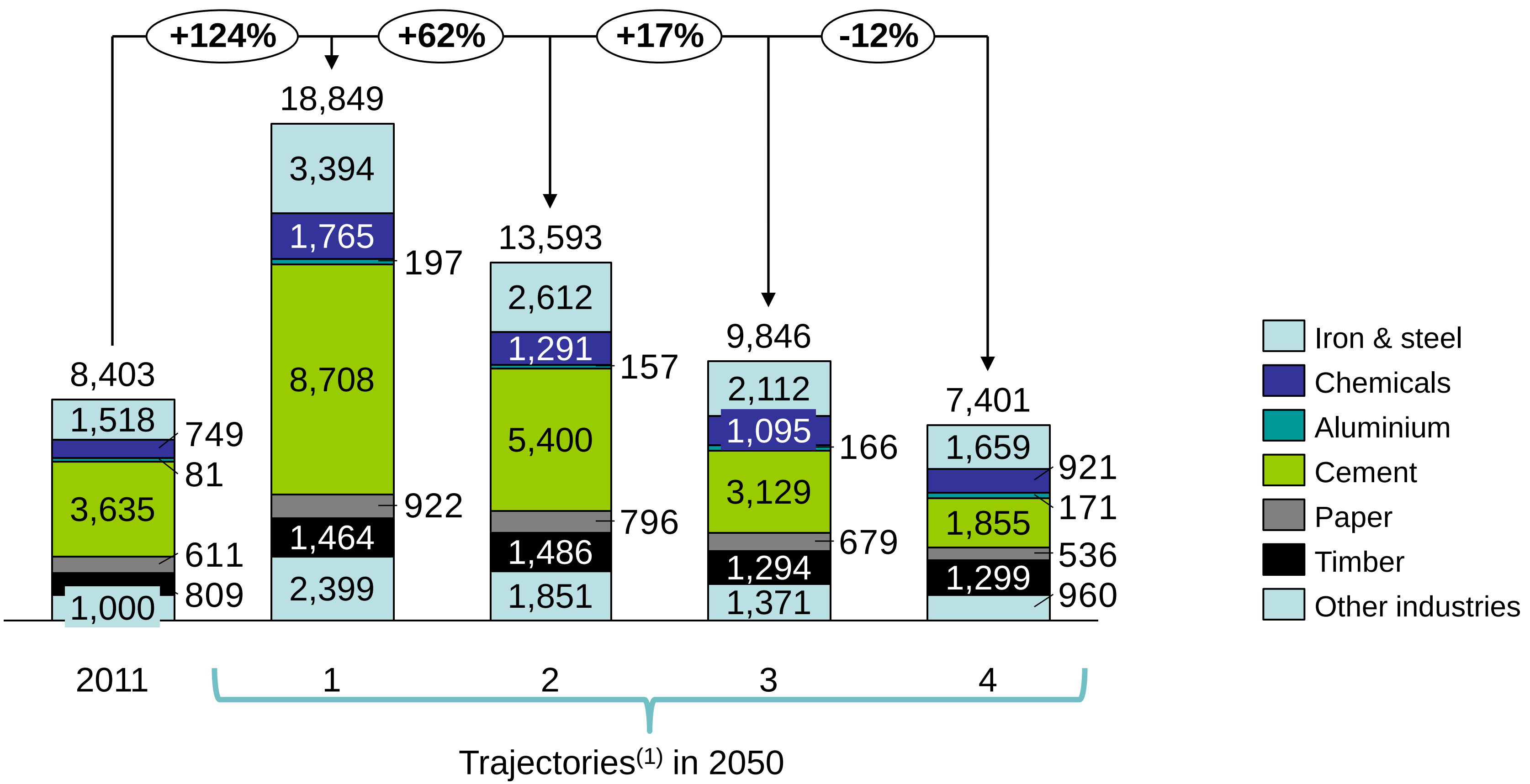
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Total

Materials demand growth in trajectories 1, 2, 3 & 4 [(1)]

Global Calculator

Annual Total production per ambition level[(1)], by product
(M tons)

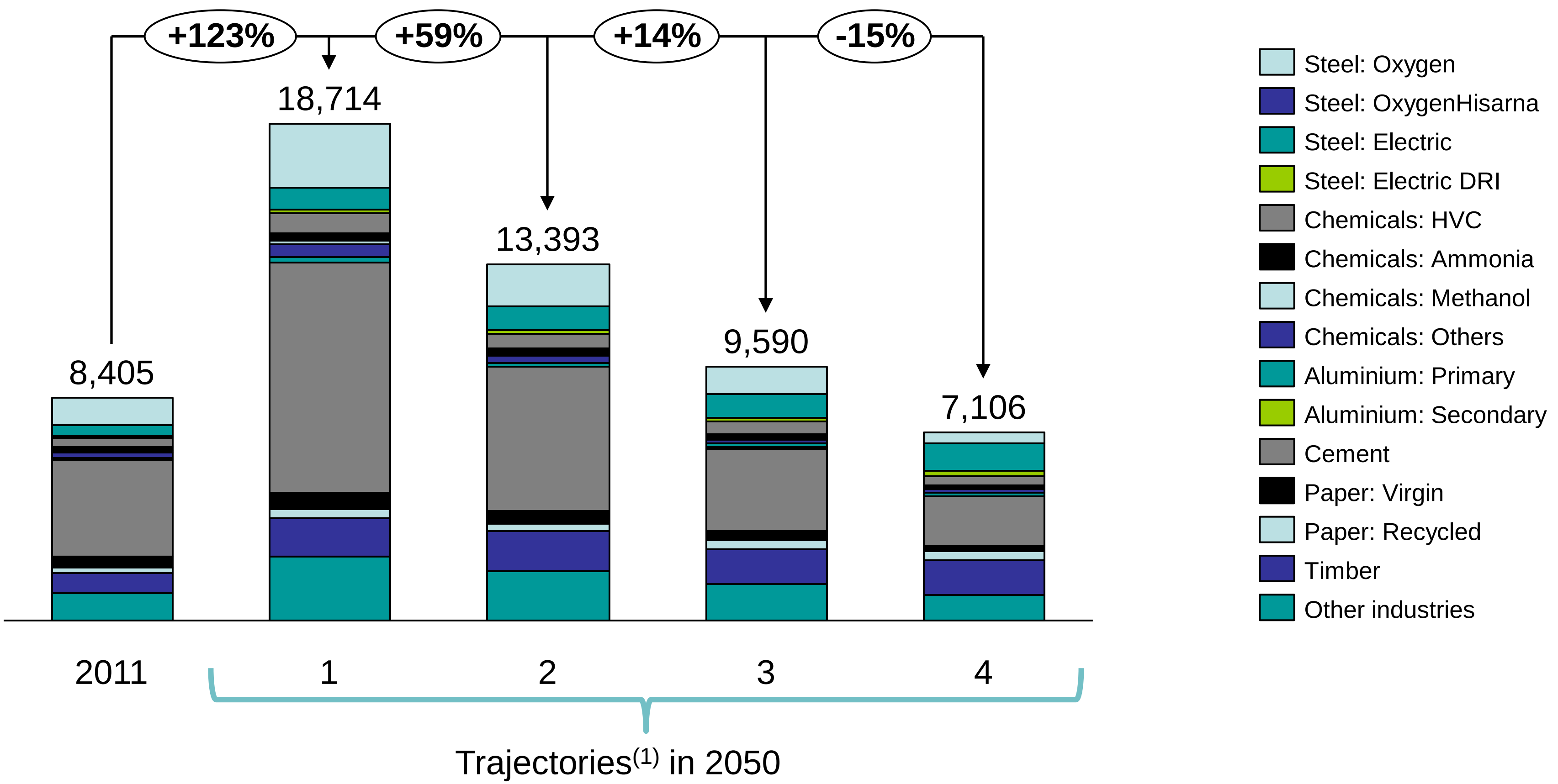


NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Total

Materials demand growth in trajectories 1, 2, 3 & 4 [(1)]

Annual Total production per ambition level[(1)], by product
(M tons)



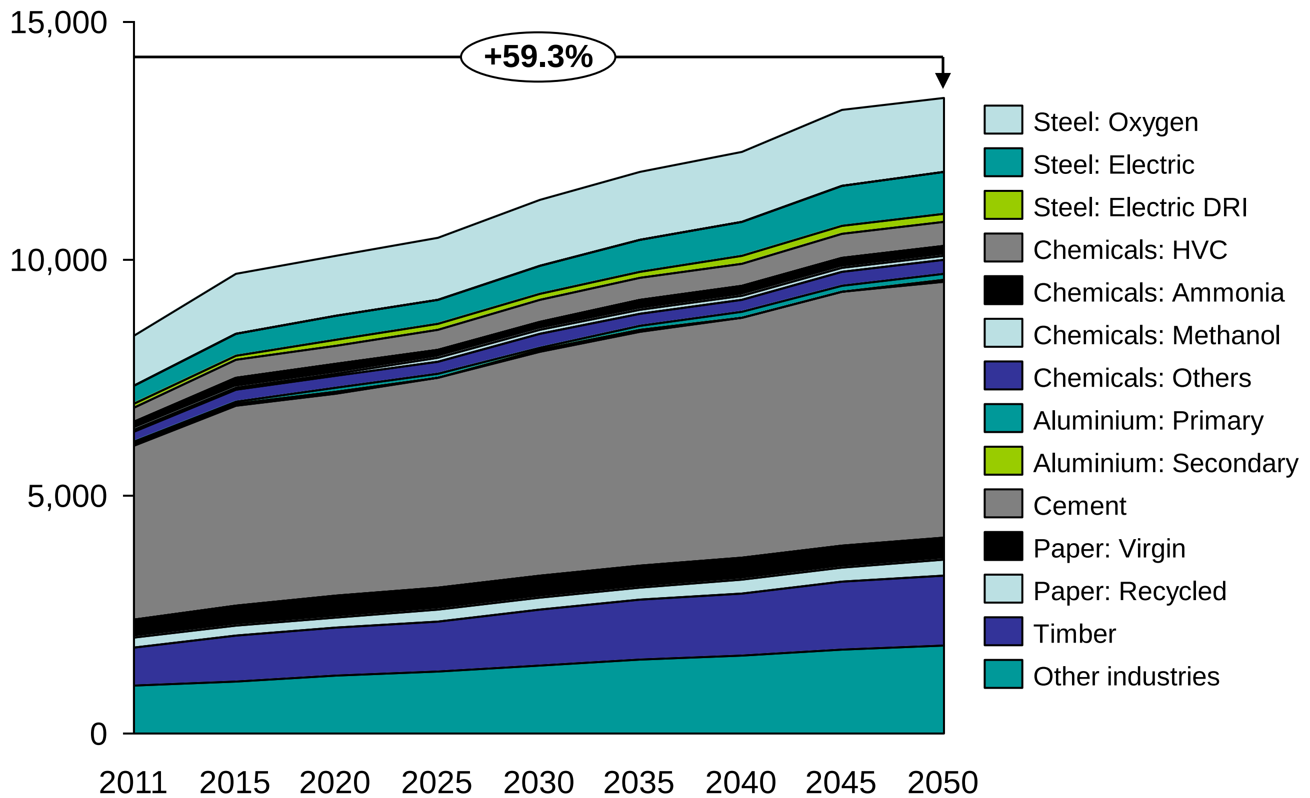
NOTE: (1) The population follows the average UN projection in all four trajectories
SOURCE: IEA ETP 2012, Global calculator model

Total industry

Materials demand growth with ambition 2 (1)

Global Calculator

Production evolution per industry with an ambition 2, (Mton)



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

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- Growth depending on ambition level
- **Discussion on Material switch**

Resulting GHG emissions

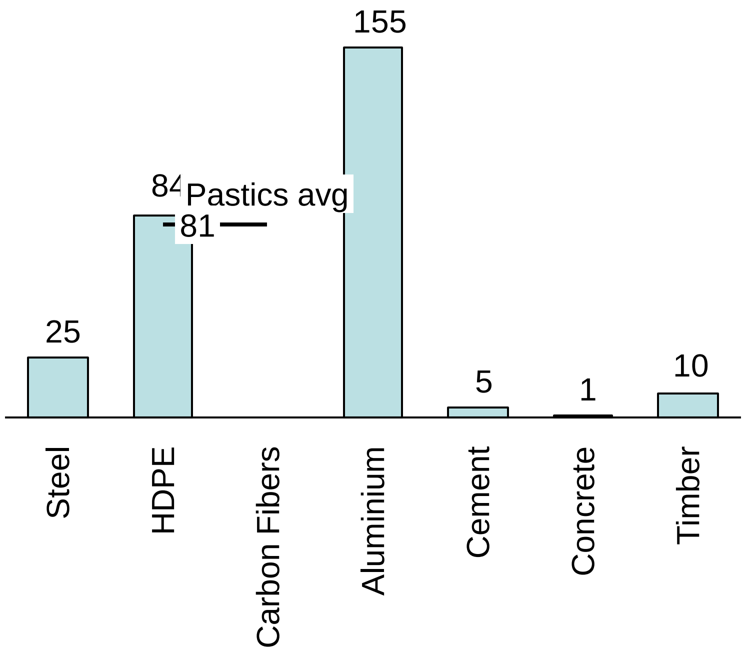
- Resulting emissions depending on ambition level
- Discussion on ambition levels across sectors
- Discussion on CCS

Aluminium assumptions summary

Each material has a different set of properties

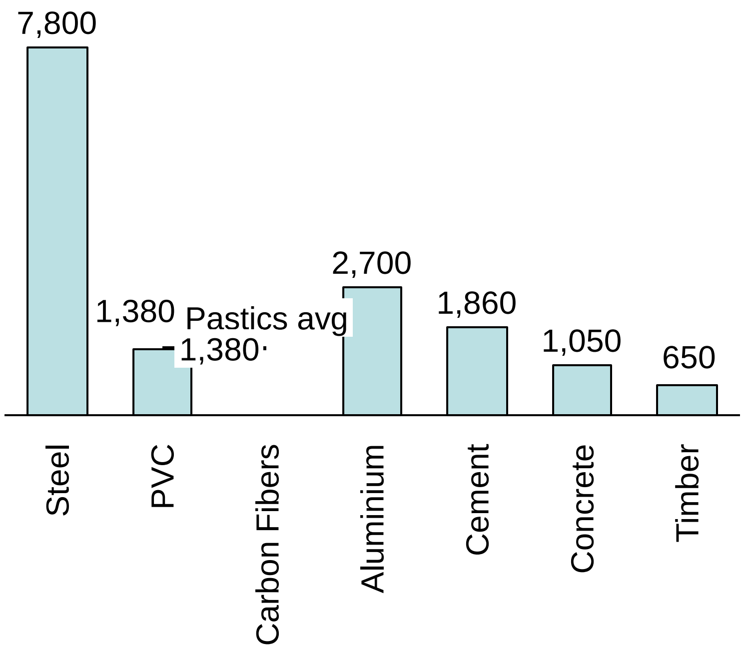
Global Calculator

Embodied Energy
(MJ/Kg)



- Embodied energy reflects the amount of energy needed to produce a kg of the material in the model before any effieicny lever is applied

Density
(Kg/m³)



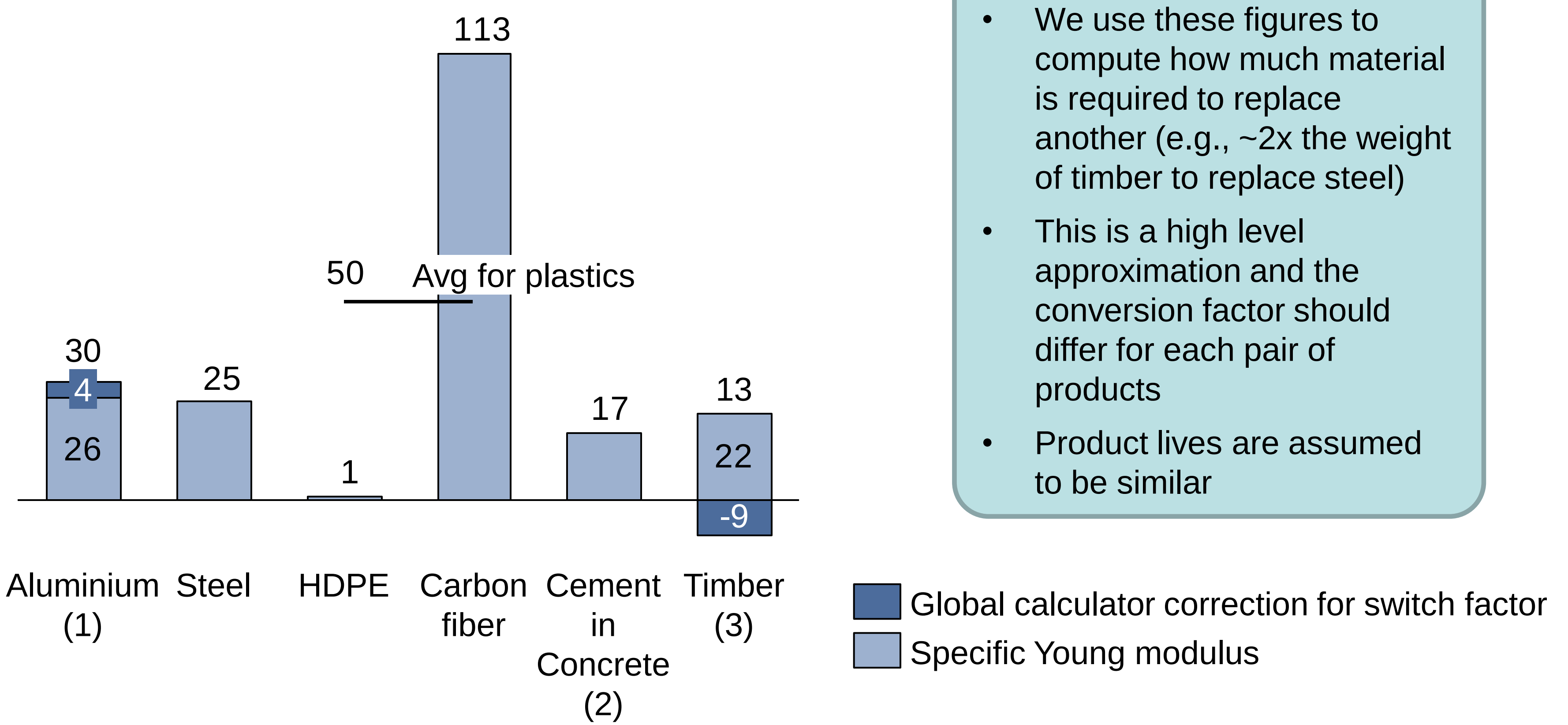
- Density reflects xxxx

SOURCE : Bath construction database

The specific Young modulus indicates how much of a material is required to replace another

Global Calculator

Specific Young modulus
(Young modulus in Gpa, divided by density)



Rationale

- We use these figures to compute how much material is required to replace another (e.g., ~2x the weight of timber to replace steel)
- This is a high level approximation and the conversion factor should differ for each pair of products
- Product lives are assumed to be similar

NOTE: (1) Tweaked to 20% more than steel, to represent the fact 20% less mass is typically required in transport applications
(2) Assuming 8% cement per ton concrete
(3) Assuming Pine, then removing 40% to account to material discontinuity safety factor
SOURCE : Wikipedia Specific modulus

To update

Global Calculator

Material switches in Transport

Groups	Products	Units	Composition per unit (tons, (vs 2011)) 2011	Ambition 1	Ambition 4
Transport	**Cars & light truck**	units	Steel: 1,150 ton Alu: 0,15 ton HVC: 0,1 ton Methane: 0,02 ton Other chem: 0,07ton	idem	**Replace** • 20% steel by aluminium • 20% steel by carbon fibres
	Trucks	units	Steel: 3,030 ton Alu: 1 ton HVC: 0,3 ton Methanol:0,06ton Other chem: 0,2ton	idem	**Replace** • 20% steel by aluminium • 20% steel by carbon fibres
	Ships	units	Steel: 0,462 ton	idem	Idem
	Rail	units	Steel: 6,875 ton	idem	Idem
	Airplanes	units	Alu: 63 ton	idem	**Replace** • 50% alu by carbon fiber (HVC)

To update

Material switches in Buildings

Global Calculator

Groups	Products	Units	Composition per unit (tons, (vs 2011)) 2011	Ambition 1	Ambition 4
Buildings	**Buildings (residential & others)**	m² (ground surface)	Steel: 0,202 ton Alu: 0,008 ton HVC: 0,02 ton Methanol: 0,004ton Other chem: 0,004 ton Cement:0,560 ton Bricks: not modelled Timber: 0,22 ton	idem	**Replace** • 20% steel by timber • 20% concrete by timber • 5% concrete by insulation materials (HVC)
	Infrastructure	m² (ground surface)	Steel: 0,187 ton Alu: 0,001 ton Cement0,450 ton	idem	**Replace** • 5% concrete by insulation materials (HVC)
	Mechanical equipment	tons	Steel: 0,750 ton Alu: 0,013 ton	idem	idem
	Appliance	Million tons	Steel: 0,17 ton Alu: 0,02 ton HVC: 0,43 ton Methanol: 0,08ton Other chem: 0,28ton	idem	idem

Reduce | Design | Switch | Recycle | Process | Fuel Switch | Energy efficiency | CCS

To update

Global Calculator

Material switches in Consumer goods and Energy

Groups	Products	Units	Composition per unit (tons, (vs 2011)) 2011	Ambition 1	Ambition 4
Consumer goods	Print & Graphic Paper	Million tons	Paper: 1 ton	idem	idem
	Metal goods	Million tons	Steel: 0,750 ton Alu: 0,03 ton	idem	idem
	Consumer packaging	Million tons	Steel: 0,021 ton Alu: 0,023 ton HVC: 0,240 ton Methanol: 0,04ton Other Chem: 0,157ton Paper: 0,516 ton	idem	idem
	Fertilizer	tons	Ammonia: 1 ton	idem	idem
Energy	Windmills	2MW Units	Steel: 350 tons HVC: 30 tons	idem	idem
	PV panels	m2	Steel: 2 kg Alu: 2 kg HVC: 5 ton	idem	idem
	Electrical equipment	tons	Steel: 0,750 ton Alu: 0,03 ton	idem	idem
	Electrical cables	Km	Alu: 0,3 ton	idem	idem
	Pipes	meter	Steel: 0,4 ton	idem	idem

- In packaging, both a tendency to more (e-shipping) and to less (more lightweight, tailored to needs) packaging
- Check expectations with EU packaging federation

Open questions

Global Calculator

Discussion topics on material switch

Trends	• Impact of urbanisation on the proportion of Steel/Cement in buildings
Intellectual capital	• Which working groups compare the applicability of materials • Which dimensions should be taken into account • Vedh has a working group • Others ?
Other dimensions to take into account	• All products could keep similar lifetimes • Timber is less uniform, so a safety margin needs to be included (current assumption of +40% requirements) • Fiber glass cannot be recycled and are harder to repair
Costs	• How to you suggest to account of the costs associated with each material? Use the embedded energy of each material?
Magnitude orders	• Overall substitution rate through the above is limited, even in level 4: • -11% steel, -1% aluminium, -16% cement

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- Growth depending on ambition level
- Discussion on Material switch

Resulting GHG emissions

- Resulting emissions depending on ambition level
- Discussion on ambition levels across sectors
- Discussion on CCS

Aluminium assumptions summary

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- Growth depending on ambition level
- Discussion on Material switch

Resulting GHG emissions

- **Resulting emissions depending on ambition level**
- Discussion on ambition levels across sectors
- Discussion on CCS

Aluminium assumptions summary

For the materials production, ~50 actions are being considered

Global Calculator

List of actions & levers assessed

Industry groups		Design	Switch	Recycle	Process improvements	Alternative fuels	Energy efficiency	CCS
Steel		• Product Design • High strength steel	• Switch to alu, fibres & timber	• Product recycling • % scrap based (for each various technologies exist)	• Carbon materials reduction • Portion of Classic BOF /Top gas recycling & Hisarna/ oxygen/EAF DRI/EAF scrap • Smelt reduction, Hydrogen, Electrolysis	• Coke to gas injection • Coal PCI to biomass	• Material efficiency • Energy efficiency (EE) • CHP	• CCS
Chemicals	All	• Product design		• Product recycling • Material recycling	• Process intensification • Catalyst optimization	• Oil to gas	• Clustering & integration	• CCS
	HVC		• Switch from steel, alu, cement	• Green chemistry	• Included in energy efficiency		• EE	• CCS
	Ammonia			• Fertilizers composition	• Included in energy efficiency		• EE	• CCS
	Methanol						• EE	• CCS
	Other			• Green chemistry	• Included in energy efficiency • Selective catalytic reduction	• Hydrogen production by electrolysis • Natural gas or biomass	• EE • Switch Mercury to membrane	• CCS
Aluminium		• Product design	• Switch to fibres	• Product recycling • Material recycling	• Included in energy efficiency	• Gas injection	• EE	• CCS
Cement		• Product design	• Switch to Timber & Plastics	• Composed/metallurgical cement	• Dry process	• Coal & oil to Waste & biomass	• EE • CHP /heat recovery	• CCS
Pulp & paper		• /	• /	• More recycled paper • Other cellulose sources • Bio-refineries	• Black liquor gasification • Drying innovation	• Coal & oil to gas • Coal & oil to biomass	• EE • CHP	• CCS
Timber		• Product design	• Switch from steel &cement	• /	• /	• /	• /	• /

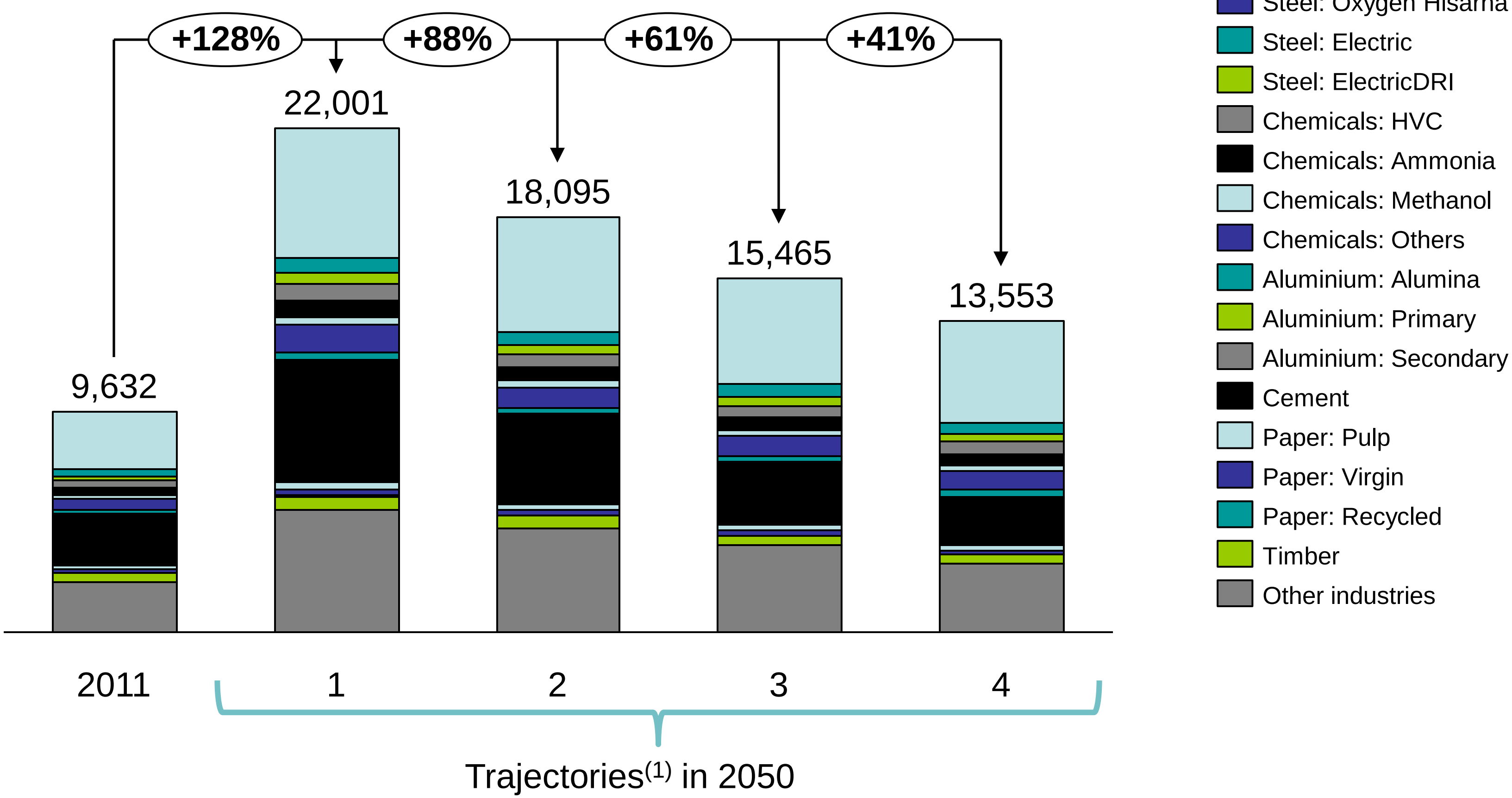
SOURCE: Climact

Total

GHG Emissions in trajectories 1, 2, 3 & 4

Global Calculator

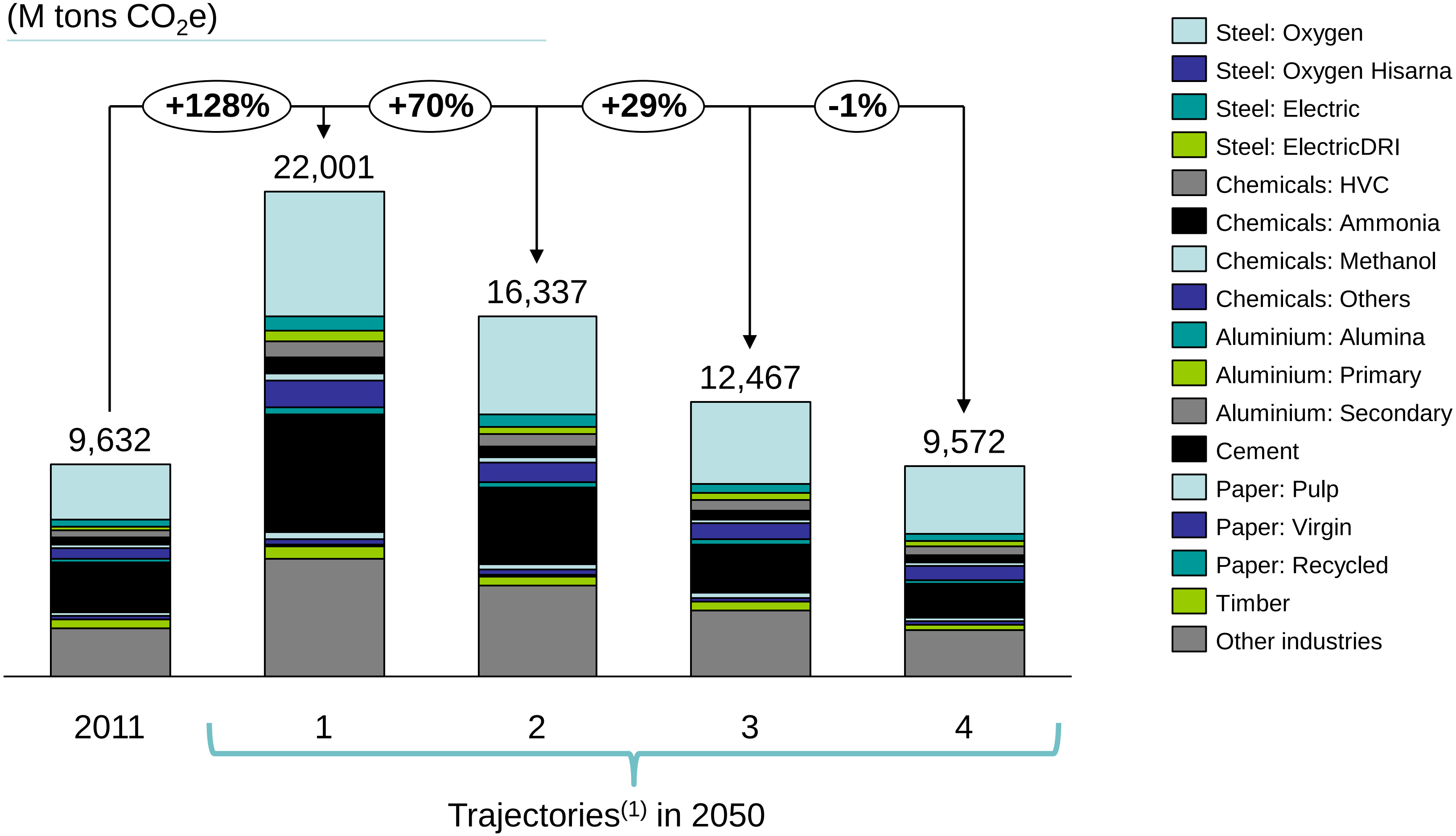
Total GHG emissions per year, by technology
(M tons CO_2e[2])



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

Total
GHG Emissions in trajectories 1, 2, 3 & 4

Total GHG emissions per year, by technology
(M tons CO_2e)



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

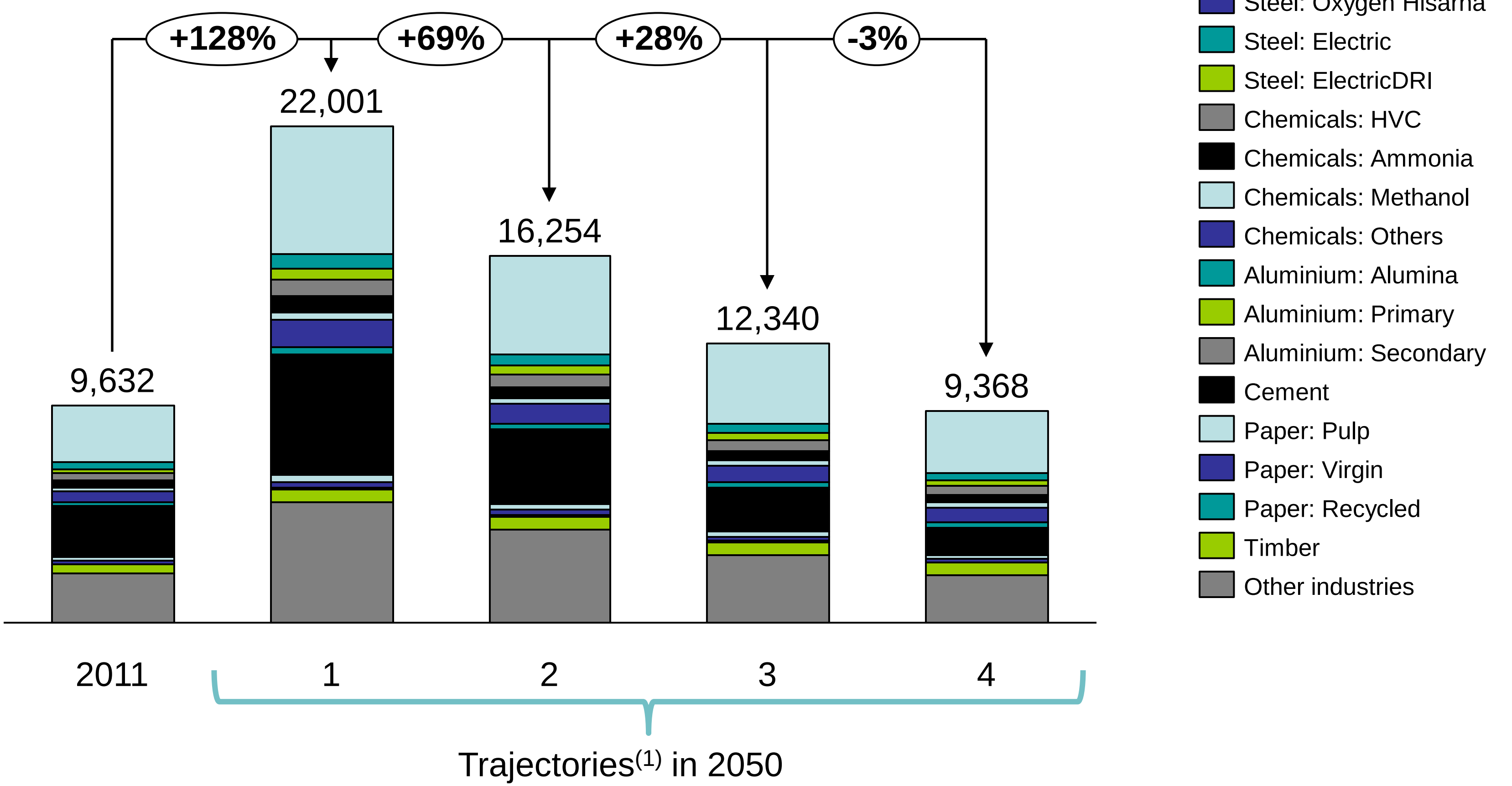
Total

GHG Emissions in trajectories 1, 2, 3 & 4

Global Calculator

Total GHG emissions per year, by technology

(M tons CO_2e)



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

(2)Assuming biomass emits, not including electricity related emissions

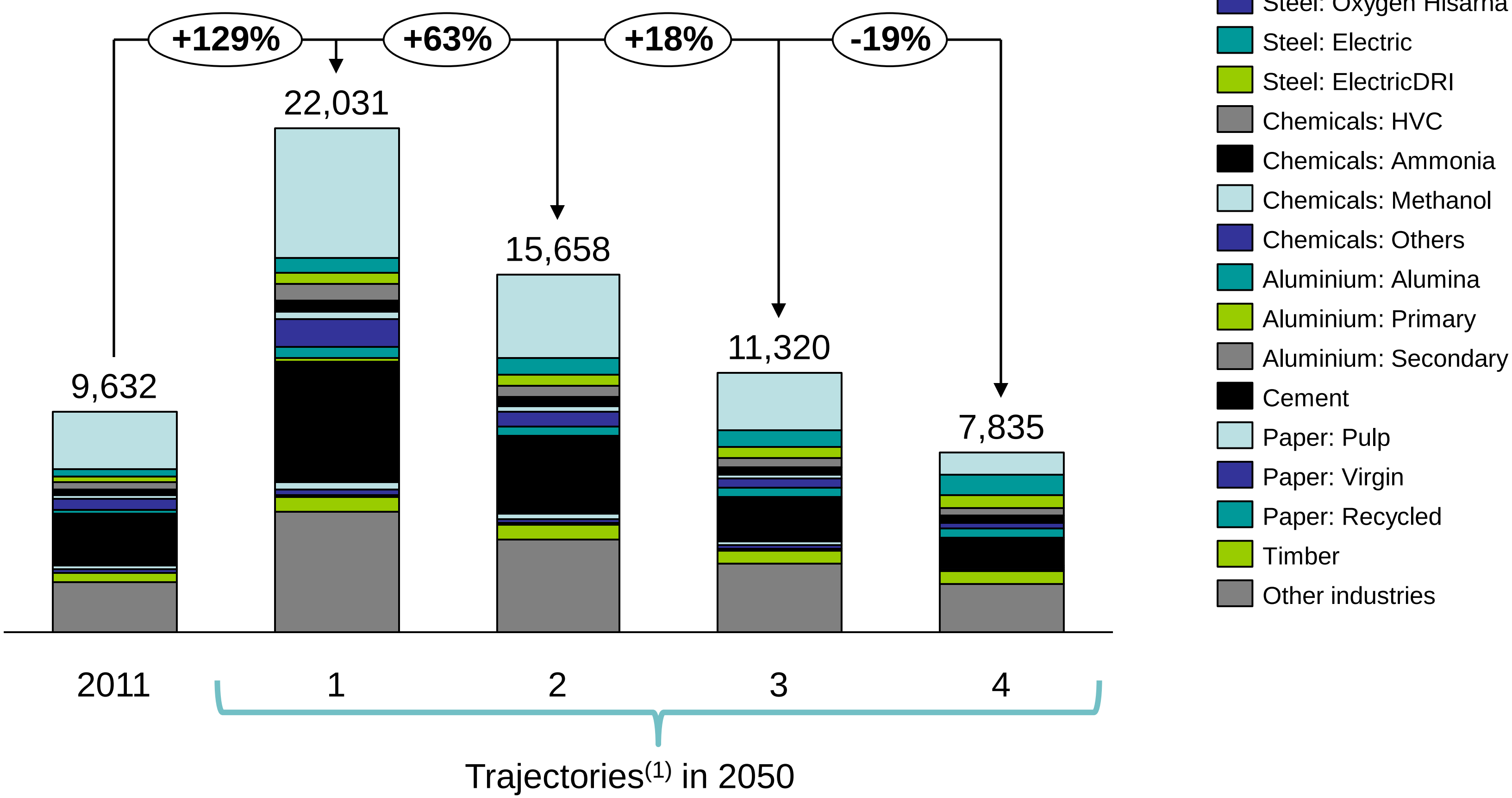
SOURCE: IEA ETP 2012, Global calculator model

Total

GHG Emissions in trajectories 1, 2, 3 & 4

Global Calculator

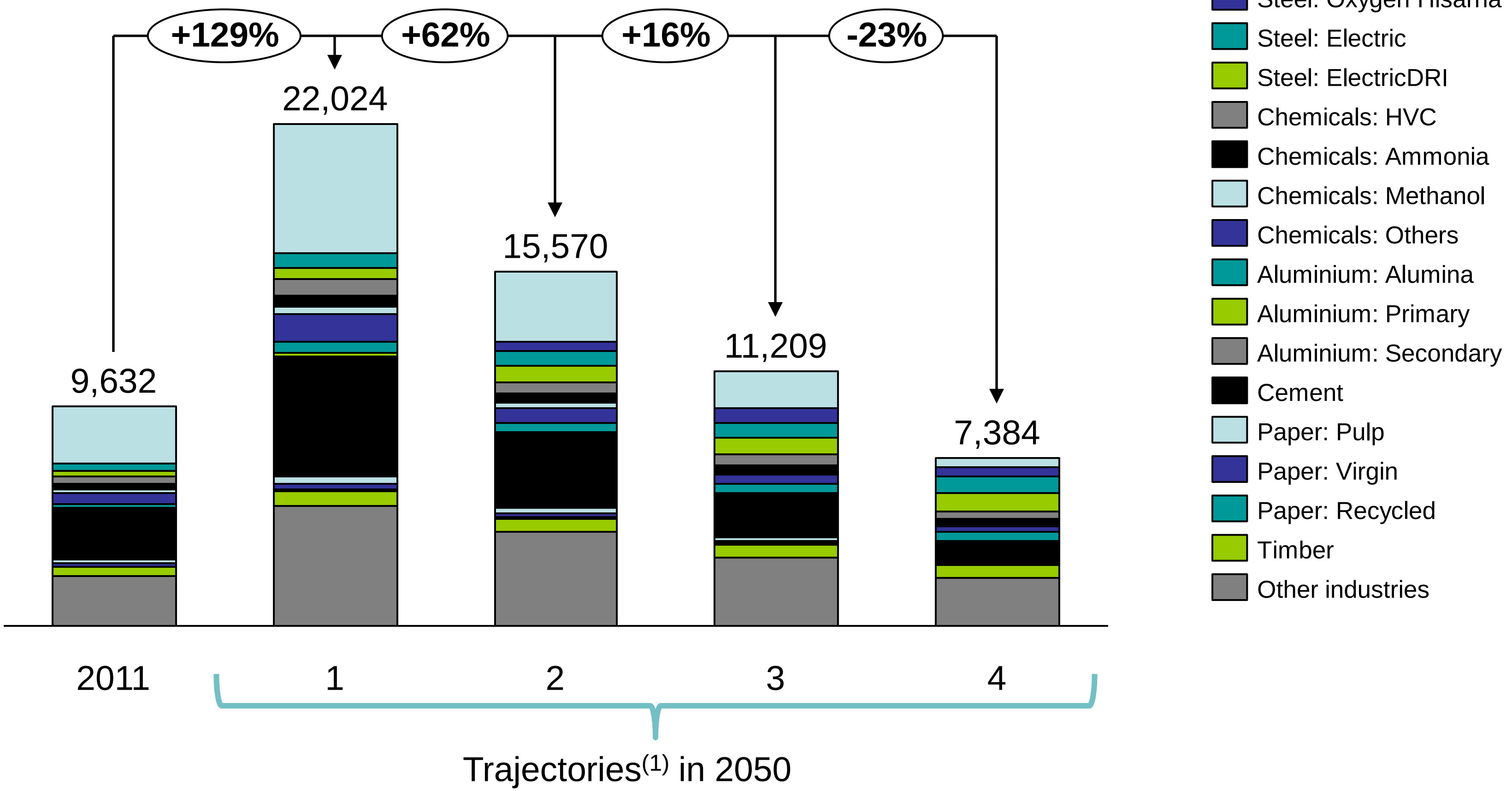
Total GHG emissions per year, by technology
(M tons CO_2e)



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

Total
GHG Emissions in trajectories 1, 2, 3 & 4

Total GHG emissions per year, by technology
(M tons CO_2e)



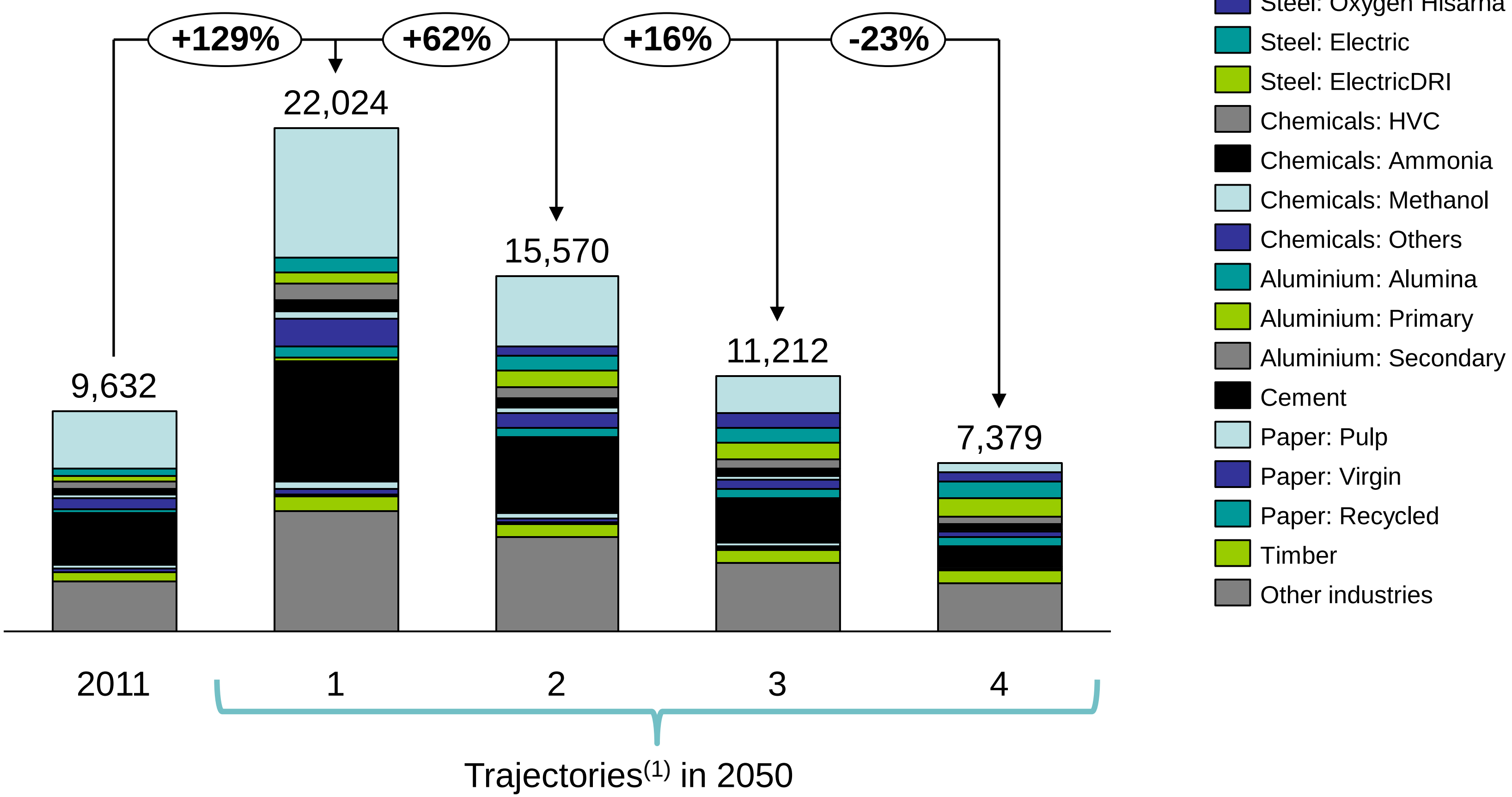
NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total

GHG Emissions in trajectories 1, 2, 3 & 4

Global Calculator

Total GHG emissions per year, by technology
(M tons CO_2e)



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

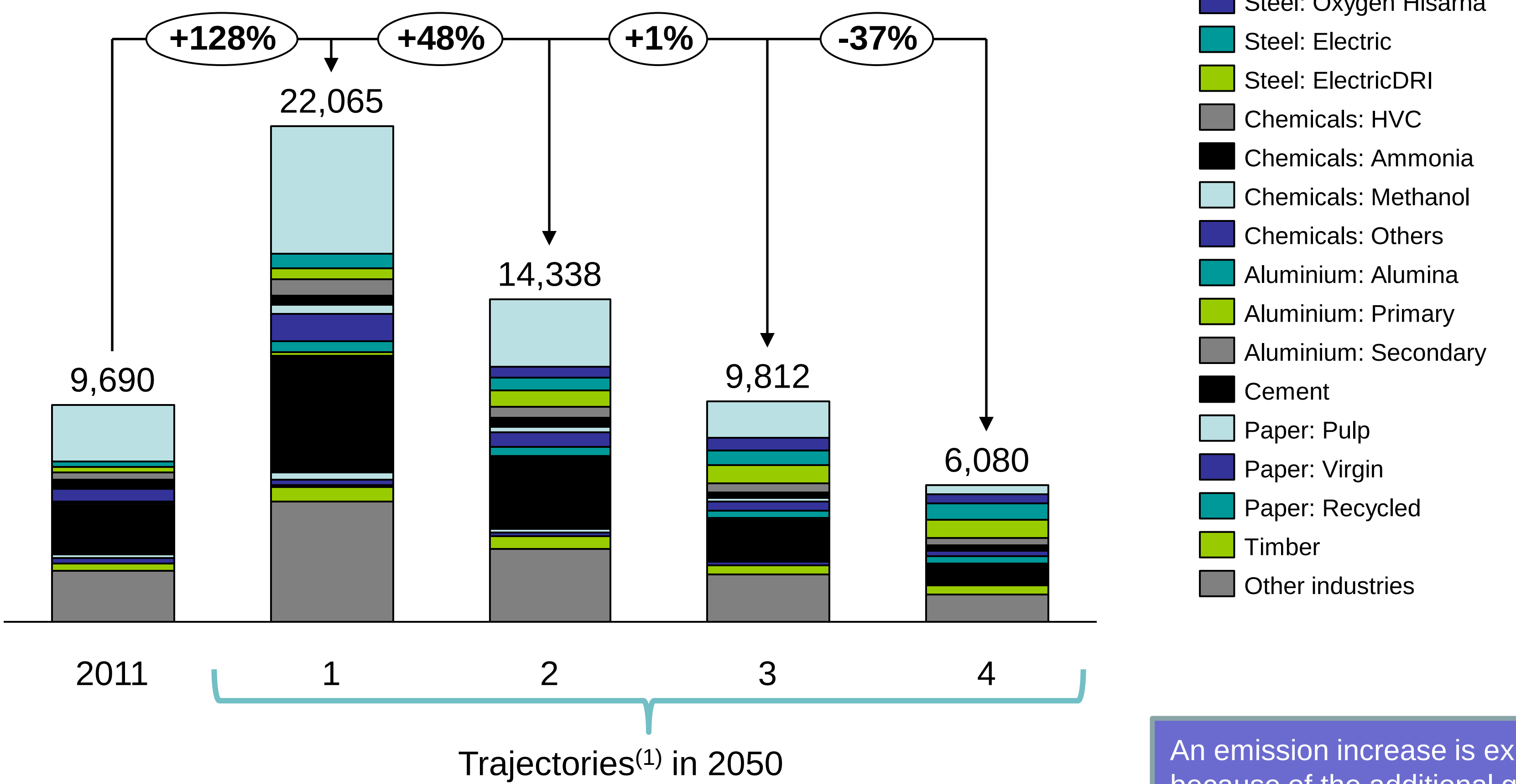
Biomass impact outweighs other fuel switches

Total

GHG Emissions in trajectories 1, 2, 3 & 4

Global Calculator

Total GHG emissions per year, by technology
(M tons CO_2e)



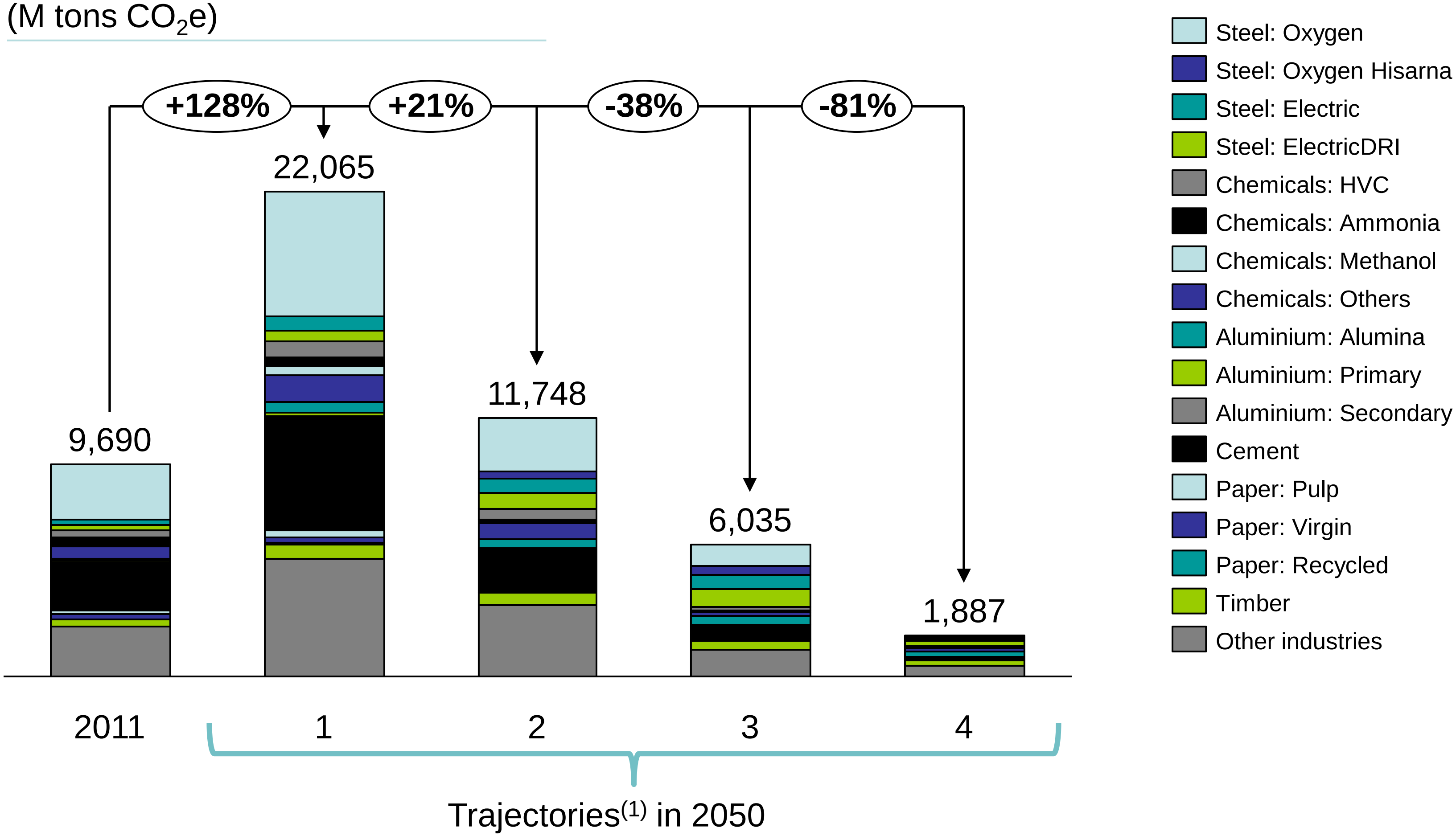
An emission increase is expected here because of the additional gas consumption in chemicals and paper for the CHPs (while electricity emissions are not accounted for in this slide)

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

Global Calculator

Total
GHG Emissions in trajectories 1, 2, 3 & 4

Total GHG emissions per year, by technology
(M tons CO_2e)



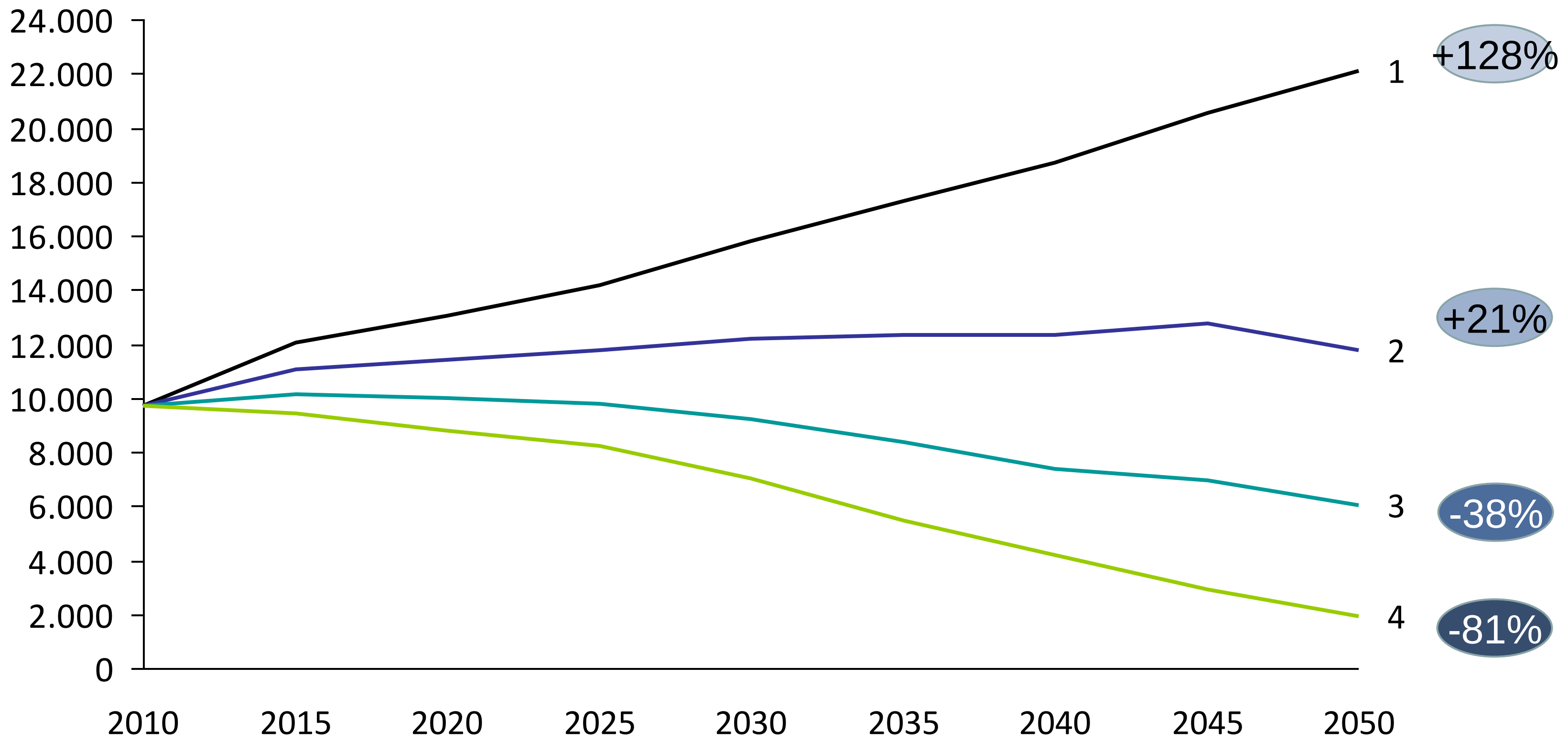
NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total

GHG Emissions evolutions in trajectories 1, 2, 3 & 4

Total GHG emissions for different lever ambition levels

(MtonCO_2e)



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

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- Growth depending on ambition level
- Discussion on Material switch

Resulting GHG emissions

- Resulting emissions depending on ambition level
- **Discussion on ambition levels across sectors**
- Discussion on CCS

Aluminium assumptions summary

Ambition 1
For the materials production, ~50 actions are being considered

Global Calculator

List of actions & levers assessed

Industry groups		Design	Switch	Recycle	Process improvements	Alternative fuels	Energy efficiency	CCS
Steel		• Product Design • High strength steel	• Switch to alu, fibres & timber	• EAF/Oxygen Mix	• Carbon materials reduction • Portion of Classic/Top gas recycling & Hisarna/ oxygen/EAF DRI/EAF scrap • Smelt reduction, Hydrogen, Electrolysis	• Coke to by gas injection • Coal PCI to biomass	• Energy efficiency (EE) • CHP	• CCS
Chemicals	All	• Product design			• Process intensification • Catalyst optimization	• Oil to gas	• Clustering & integration	• CCS
	HVC		• Switch from steel, alu, cement	• Green chemistry	• Included in energy efficiency	• Fuel switches	• EE	• CCS
	Ammonia			• Fertilizers composition	• Included in energy efficiency		• EE	• CCS
	Methanol							• CCS
	Other			• Green chemistry	• Included in energy efficiency • Selective catalytic reduction	• Hydrogen production by electrolysis • Natural gas or biomass	• EE • Switch Mercury to membrane	• CCS
Aluminium		• Product design	• Switch to fibres	• Increase proportion Recycled	• Included in energy efficiency	• Gas injection	• EE	• CCS
Cement		• Product design	• Switch to Timber & Plastics	• Composed/metallurgical cement • Design	• Dry process	• Coal & oil to Waste & biomass	• EE • CHP /heat recovery	• CCS
Pulp & paper		• /	• /	• More recycled paper • Other cellulose sources • Bio-refineries	• Black liquor gasification • Drying innovation	• Coal & oil to gas • Coal & oil to biomass	• EE • CHP	• CCS
Timber		• Product design	• Switch from steel &cement	• /	• /	• /	• /	• /

SOURCE: Climact

Total
GHG Emissions in trajectories 3

Global Calculator

Total emissions, along each step (by materials)
(M tons CO_2e, (% evolution vs 2011))

Material	2011	2050							
		Demand	Design	Switch	Recycling	Process	Fuel	EE	CCS
Steel	3.039	5558 (83%)	4447 (46%)	4227 (39%)	3690 (21%)	3718 (22%)	3715 (22%)	3642 (20%)	2842 (-6%)
Chemicals & petrochemicals	1.286	2223 (73%)	1824 (42%)	1880 (46%)	1315 (2%)	1275 (-1%)	1269 (-1%)	1225 (-5%)	466 (-64%)
Aluminium	150	347 (131%)	278 (85%)	311 (107%)	481 (220%)	470 (213%)	470 (213%)	449 (199%)	385 (156%)
Cement	2.206	2646 (20%)	2117 (-4%)	1899 (-14%)	1899 (-14%)	1844 (-16%)	1855 (-16%)	1746 (-21%)	633 (-71%)
Pulp & Paper	393	485 (23%)	436 (11%)	436 (11%)	349 (-11%)	316 (-20%)	316 (-19%)	238 (-39%)	86 (-78%)
Timber	348	419 (20%)	335 (-4%)	557 (60%)	557 (60%)	557 (60%)	557 (60%)	417 (20%)	417 (20%)
Other industries	2.210	3787 (71%)	3030 (37%)	3030 (37%)	3030 (37%)	3030 (37%)	3032 (37%)	2095 (-5%)	1205 (-45%)
Total	9.632	15465 (61%)	12466 (29%)	12339 (28%)	11320 (18%)	11210 (16%)	11214 (16%)	9812 (2%)	6034 (-37%)

Knowing the different sector characteristics, do these reductions seem balanced across sectors ?

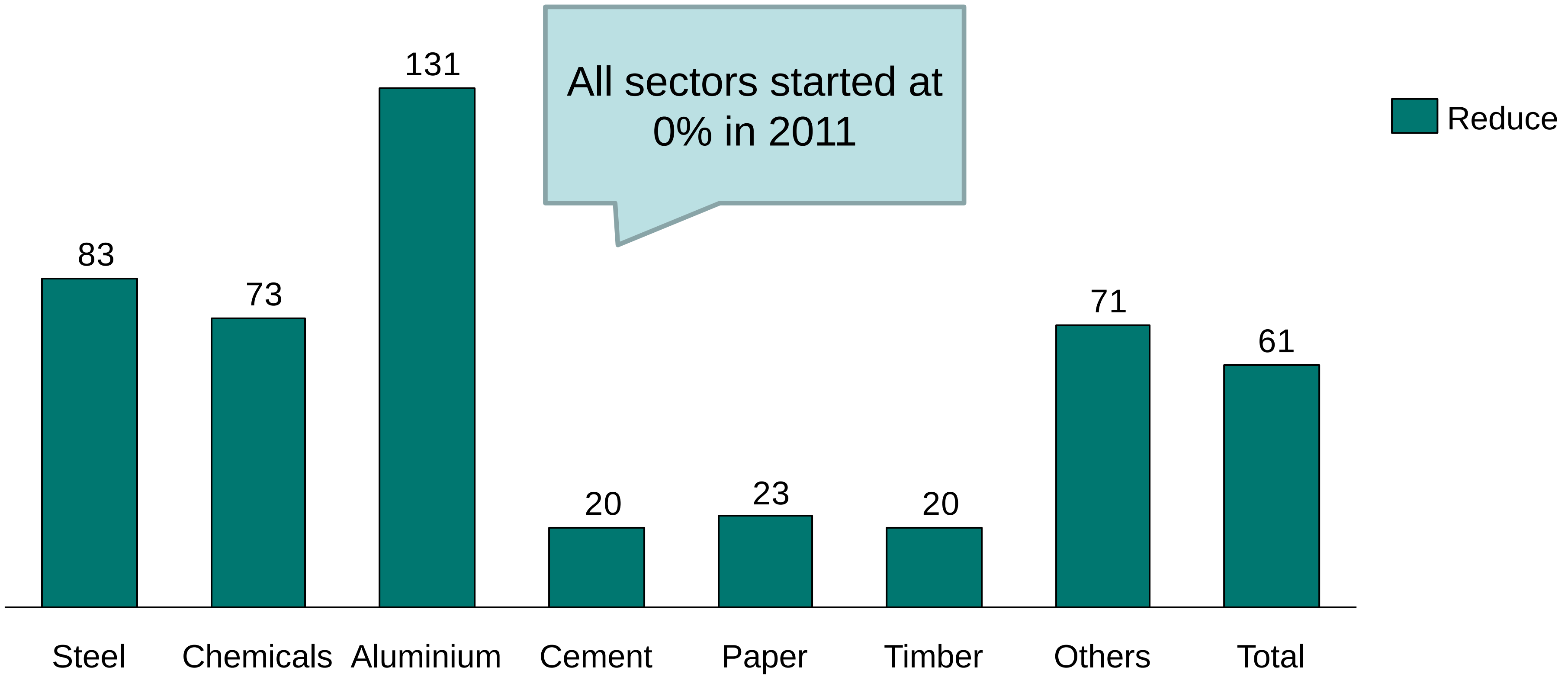
Let’s decompose this slide step by step

Total

GHG Emissions in trajectories 3[1]

Global Calculator

Change in GHG emissions[2] vs 2011 after this lever
(% vs 2011)

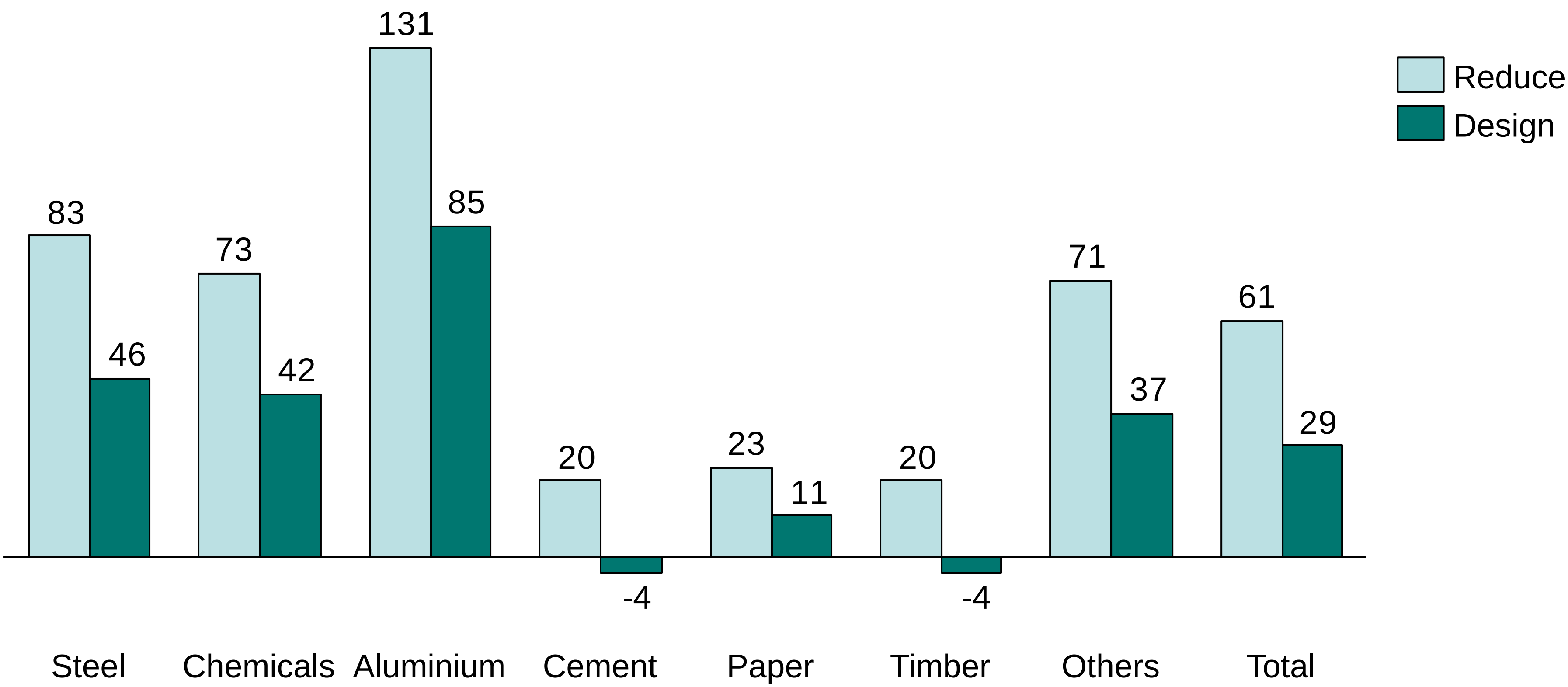


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total
GHG Emissions in trajectories 3(1)

Global Calculator

Change in GHG emissions(2) vs 2011 after this lever
(% vs 2011)



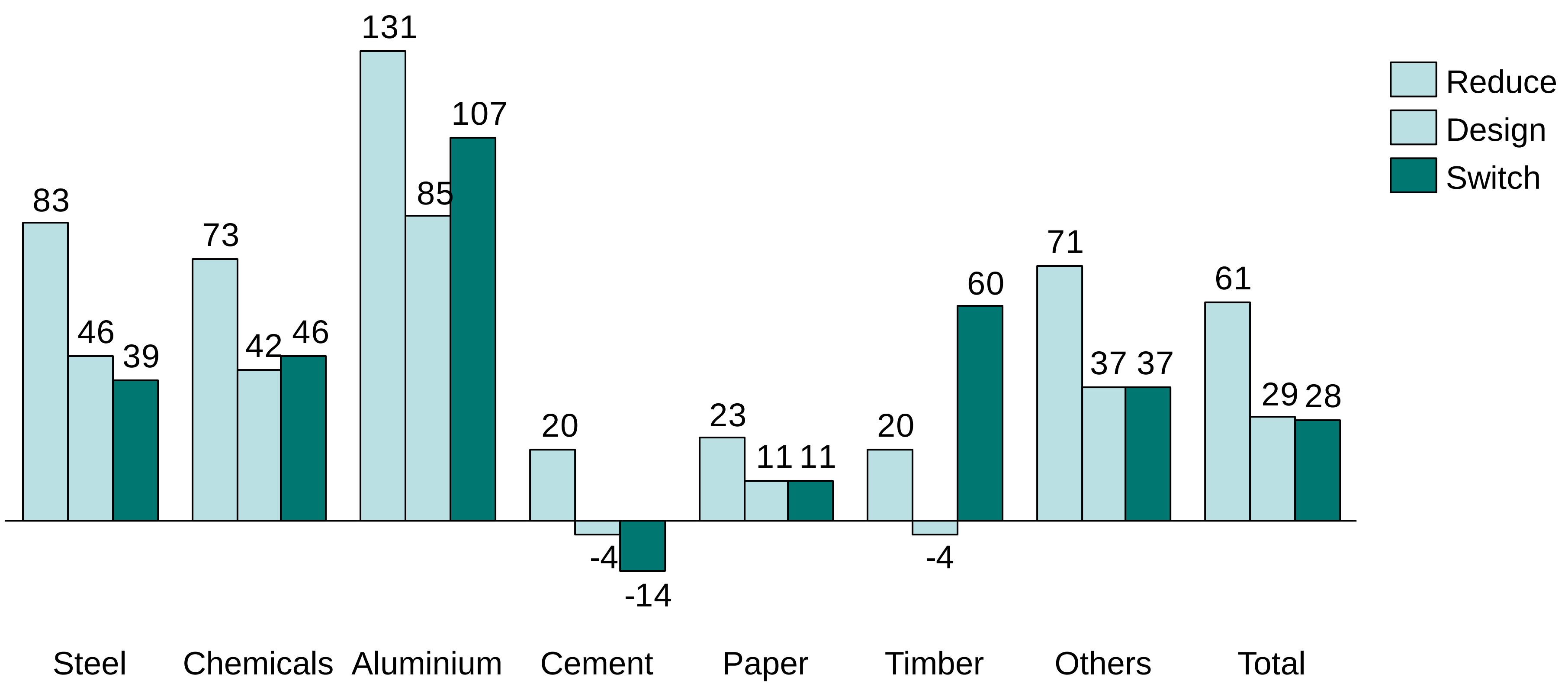
NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total

GHG Emissions in trajectories 3(1)

Global Calculator

Change in GHG emissions(2) vs 2011 after this lever
(% vs 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

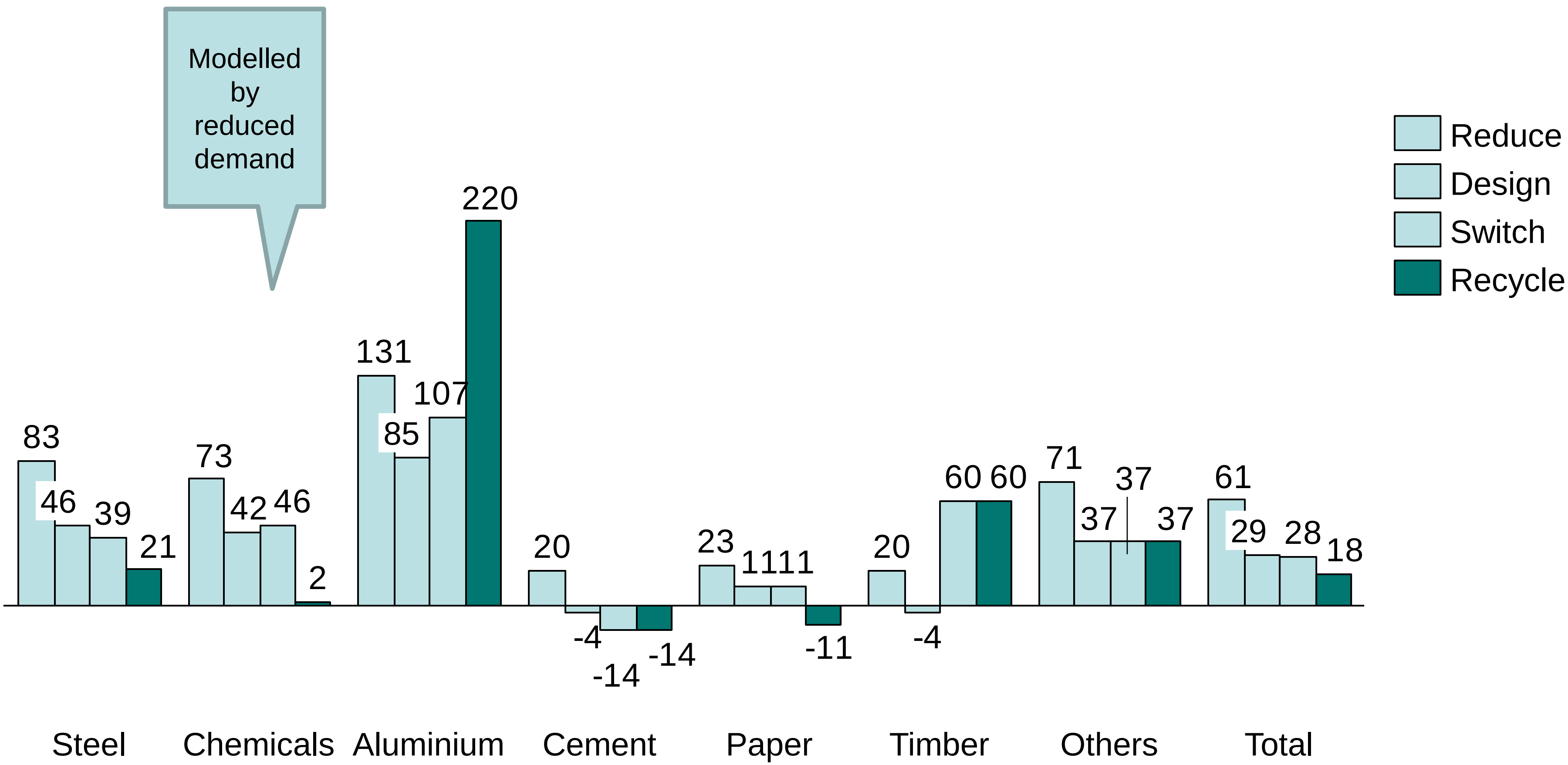
The fact carbon fibres emit more is currently not modelled

Total

GHG Emissions in trajectories 3[(1)]

Global Calculator

Change in GHG emissions[(2)] vs 2011 after this lever
(% vs 2011)

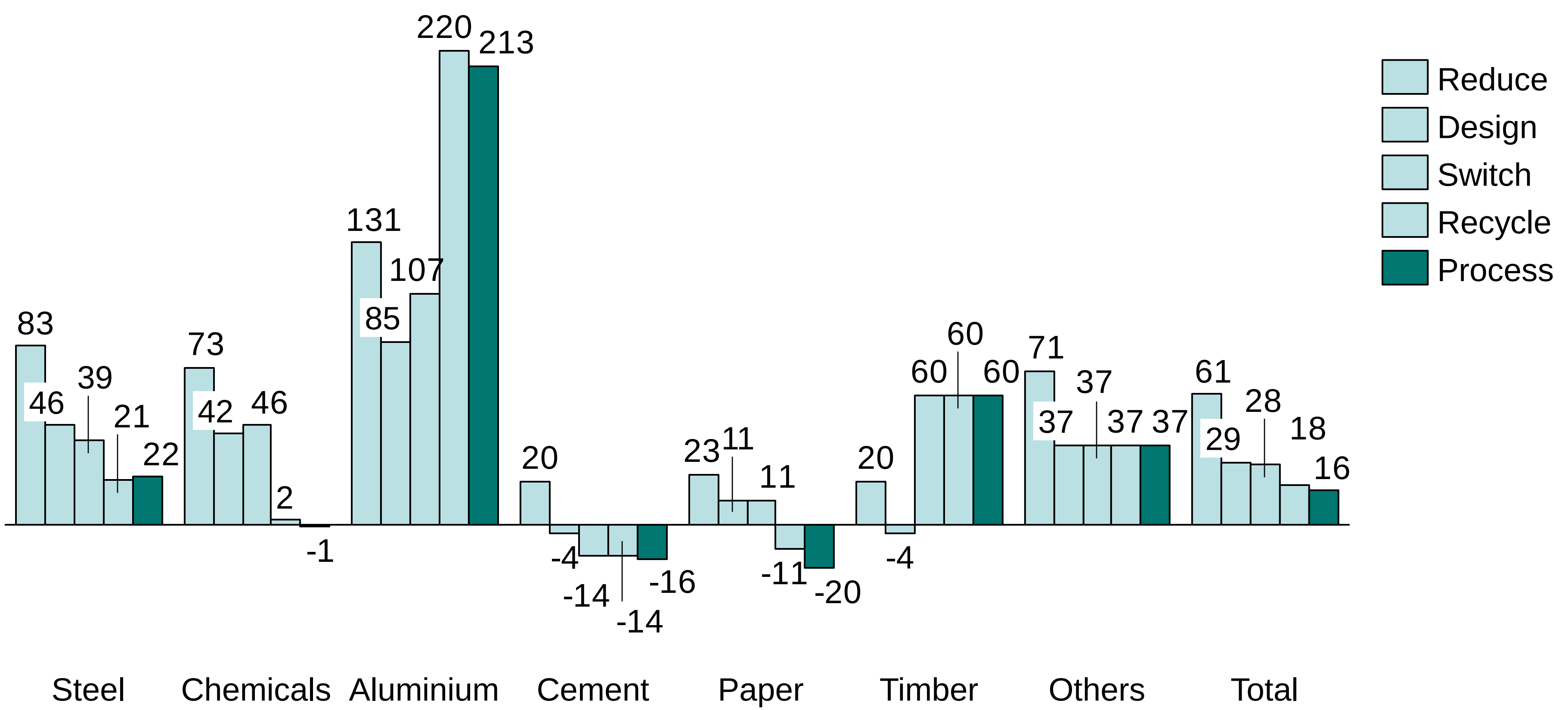


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total
GHG Emissions in trajectories 3(1)

Global Calculator

Change in GHG emissions(2) vs 2011 after this lever
(% vs 2011)

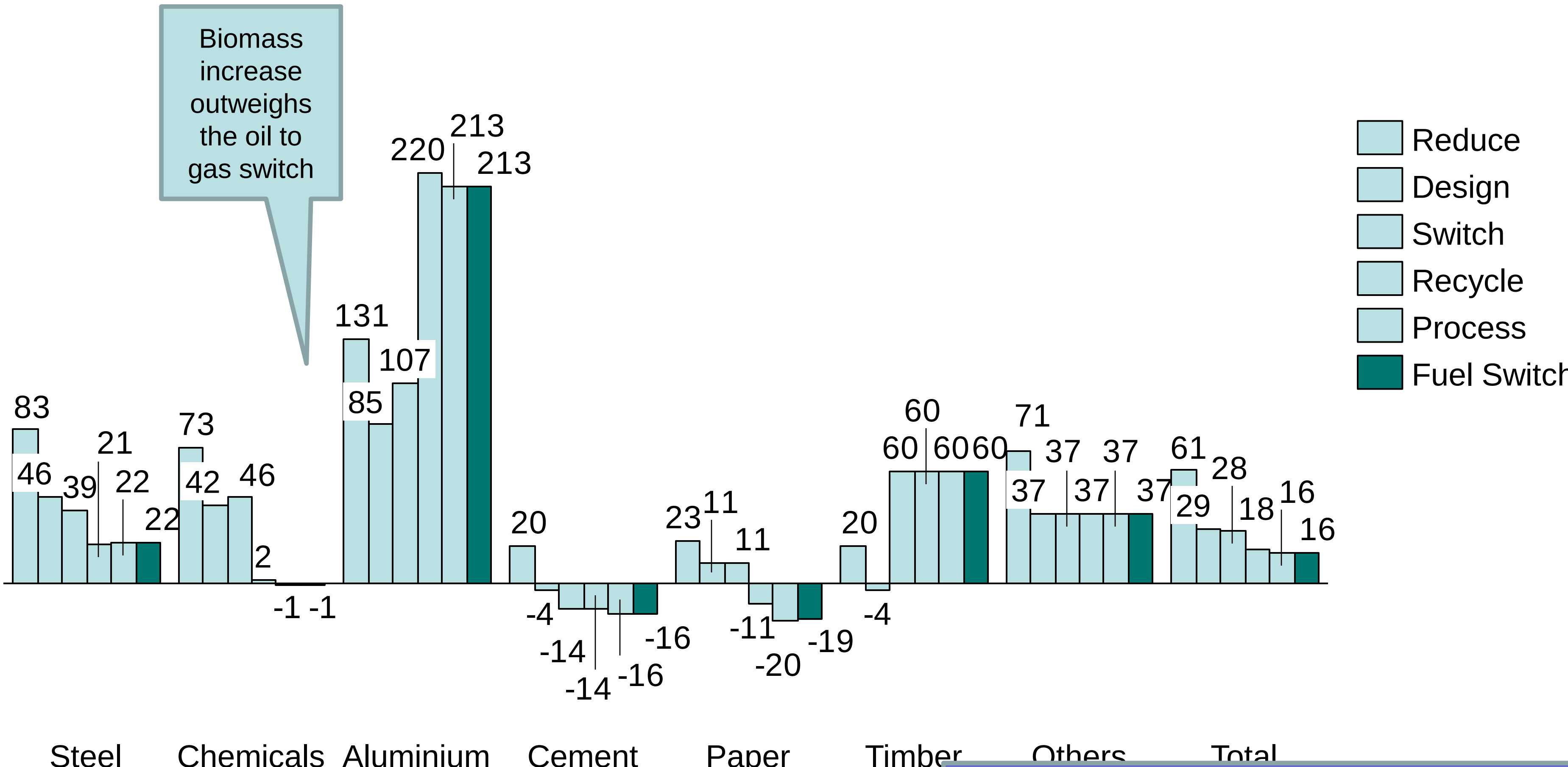


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total
GHG Emissions in trajectories 3(1)

Global Calculator

Change in GHG emissions(2) vs 2011 after this lever
(% vs 2011)



Biomass is modelled as fossil hydrocarbons at this stage, it is then removed at the end

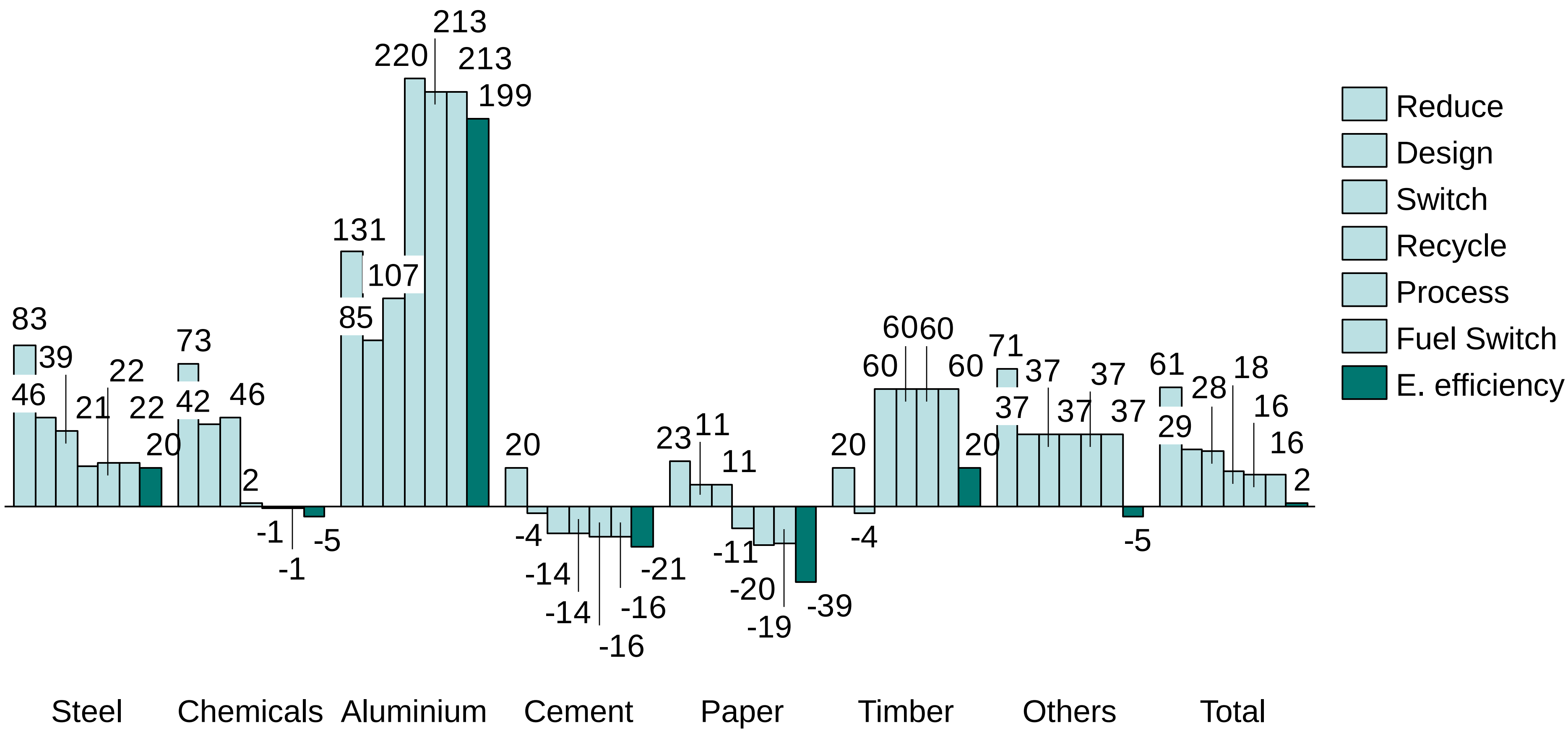
NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions

SOURCE: IEA ETP 2012, Global calculator model

Total
GHG Emissions in trajectories 3(1)

Global Calculator

Change in GHG emissions(2) vs 2011 after this lever
(% vs 2011)

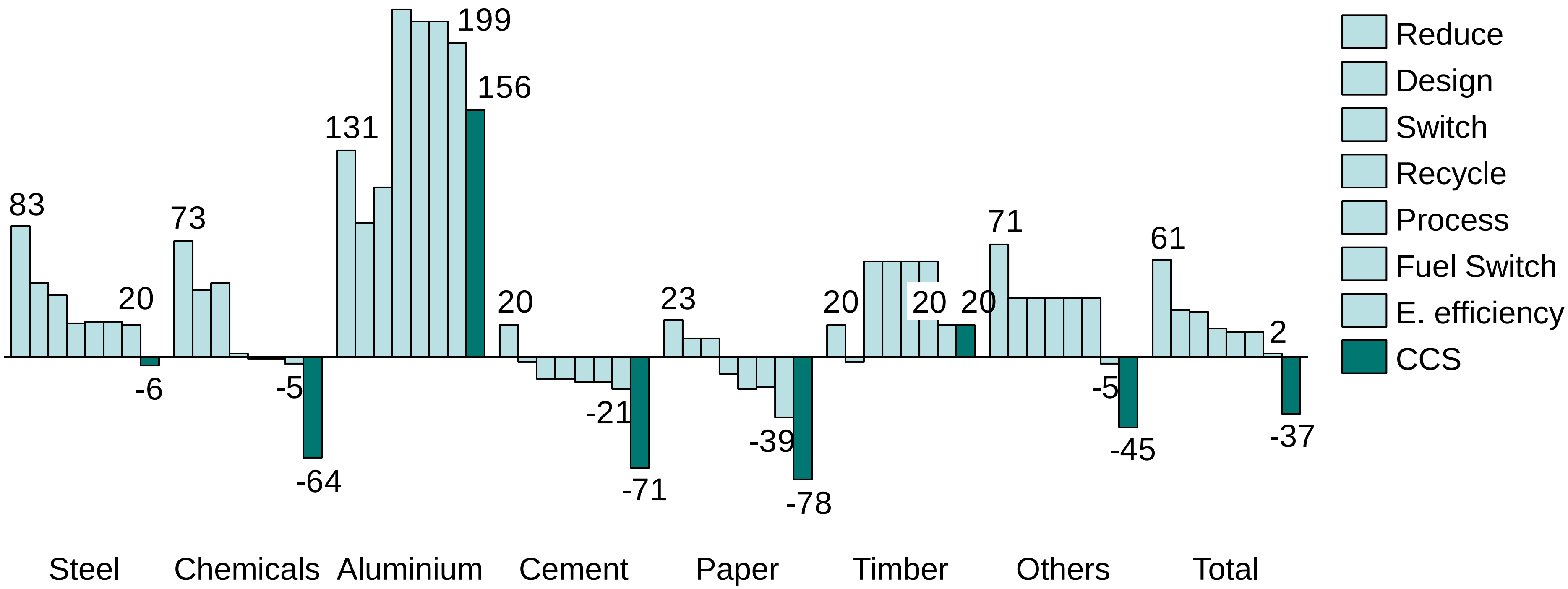


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Total
GHG Emissions in trajectories 3[1]

Global Calculator

Change in GHG emissions[2] vs 2011 after this lever
(% vs 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

Total

GHG Emissions in trajectories 3

Total emissions, along each step (by technology)
(M tons CO_2e, (% evolution vs 2011))

BACKUP

Material	Technology	2011	2050							
			Demand	Design	Switch	Recycling	Process	Fuel	EE	CCS
Steel	Oxygen	2.529	4626 (83%)	3701 (46%)	3518 (39%)	2477 (-2%)	1674 (-34%)	1670 (-34%)	1598 (-37%)	1022 (-60%)
	Oxygen Hisarna	-	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Electric	300	548 (83%)	438 (46%)	417 (39%)	714 (138%)	625 (109%)	625 (109%)	625 (109%)	625 (109%)
	Electric DRI	210	384 (83%)	307 (46%)	292 (39%)	499 (138%)	794 (278%)	794 (278%)	794 (278%)	794 (278%)
Chemicals & petrochemicals	HVC	324	559 (73%)	459 (42%)	473 (46%)	441 (36%)	420 (30%)	413 (28%)	396 (22%)	198 (-39%)
	Ammonia	286	495 (73%)	406 (42%)	419 (46%)	318 (11%)	318 (11%)	319 (11%)	296 (3%)	44 (-84%)
	Methanol	158	273 (73%)	224 (42%)	231 (46%)	130 (-18%)	130 (-18%)	130 (-18%)	121 (-23%)	18 (-89%)
	Others	518	895 (73%)	735 (42%)	757 (46%)	426 (-18%)	406 (-22%)	406 (-22%)	412 (-21%)	206 (-60%)
Aluminium	Alumina	106	245 (131%)	196 (85%)	219 (107%)	365 (245%)	365 (245%)	365 (245%)	349 (229%)	349 (229%)
	Primary	30	70 (131%)	56 (85%)	62 (107%)	104 (245%)	95 (214%)	95 (214%)	91 (200%)	33 (9%)
	Secondary	14	33 (131%)	26 (85%)	29 (107%)	11 (-20%)	10 (-27%)	10 (-27%)	10 (-31%)	4 (-75%)
Cement	Cement	2.206	2646 (20%)	2117 (-4%)	1899 (-14%)	1899 (-14%)	1844 (-16%)	1855 (-16%)	1746 (-21%)	633 (-71%)
Pulp & Paper	Pulp	194	240 (23%)	216 (11%)	216 (11%)	163 (-16%)	148 (-24%)	148 (-24%)	109 (-44%)	40 (-80%)
	Virgin	176	217 (23%)	195 (11%)	195 (11%)	148 (-16%)	134 (-24%)	134 (-24%)	101 (-42%)	37 (-79%)
	Recycled	23	28 (23%)	26 (11%)	26 (11%)	38 (63%)	34 (49%)	34 (49%)	27 (19%)	10 (-57%)
Timber	Timber	348	419 (20%)	335 (-4%)	557 (60%)	557 (60%)	557 (60%)	557 (60%)	417 (20%)	417 (20%)
Other industries	Other industries	2.210	3787 (71%)	3030 (37%)	3030 (37%)	3030 (37%)	3030 (37%)	3032 (37%)	2095 (-5%)	1205 (-45%)
Total	Total	9.632	15465 (61%)	12466 (29%)	12339 (28%)	11320 (18%)	11210 (16%)	11214 (16%)	9812 (2%)	6034 (-37%)

Knowing the different sector characteristics, do these reductions seem balanced across sectors ?

Agenda

Global Calculator

Introduction to the global calculator

2011 overview of energy and material demand

2050 growth of materials and emissions

Materials growth

- Growth depending on ambition level
- Discussion on Material switch

Resulting GHG emissions

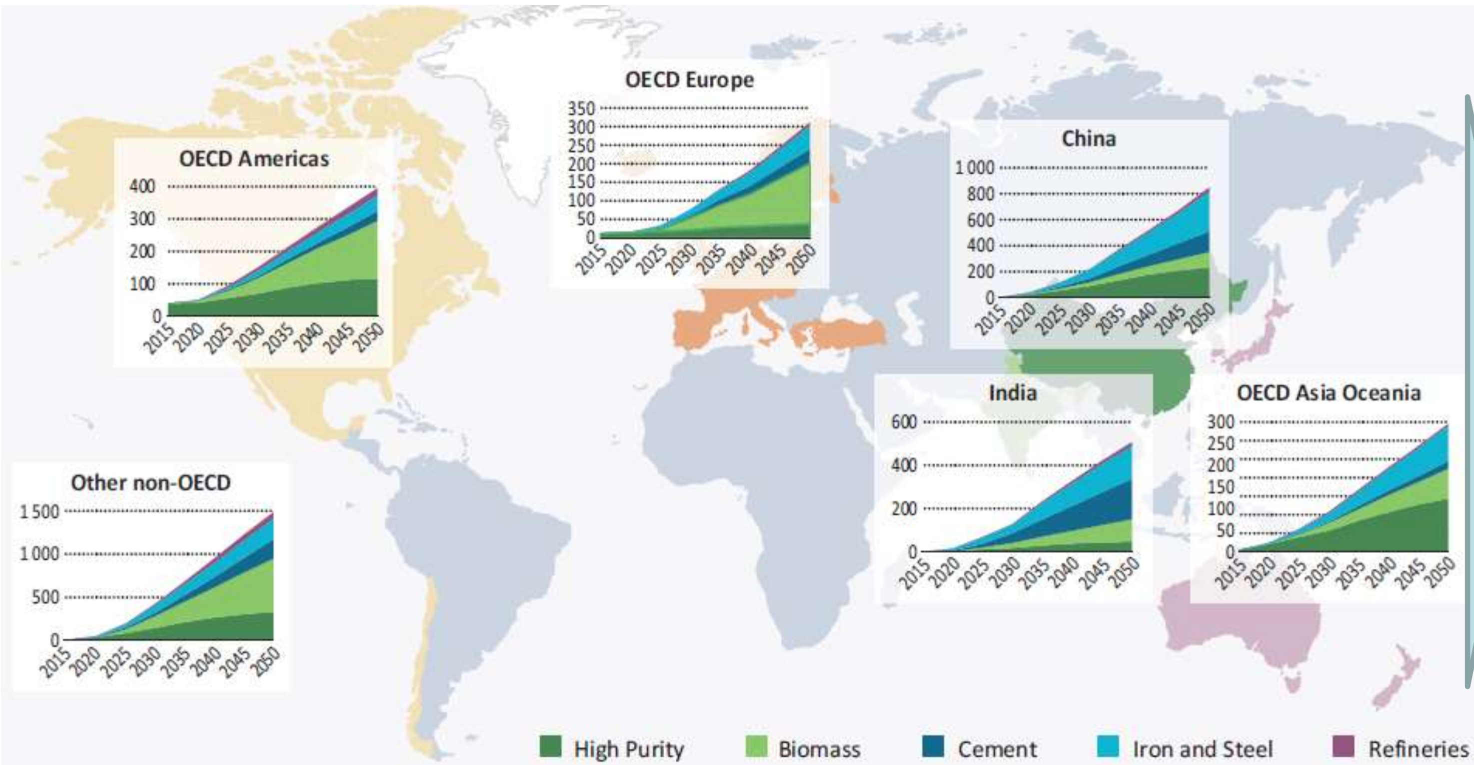
- Resulting emissions depending on ambition level
- Discussion on ambition levels across sectors
- **Discussion on CCS**

Aluminium assumptions summary

Carbon Capture & Storage

Projections by region

Capture rate
($MtCO_2$/year)



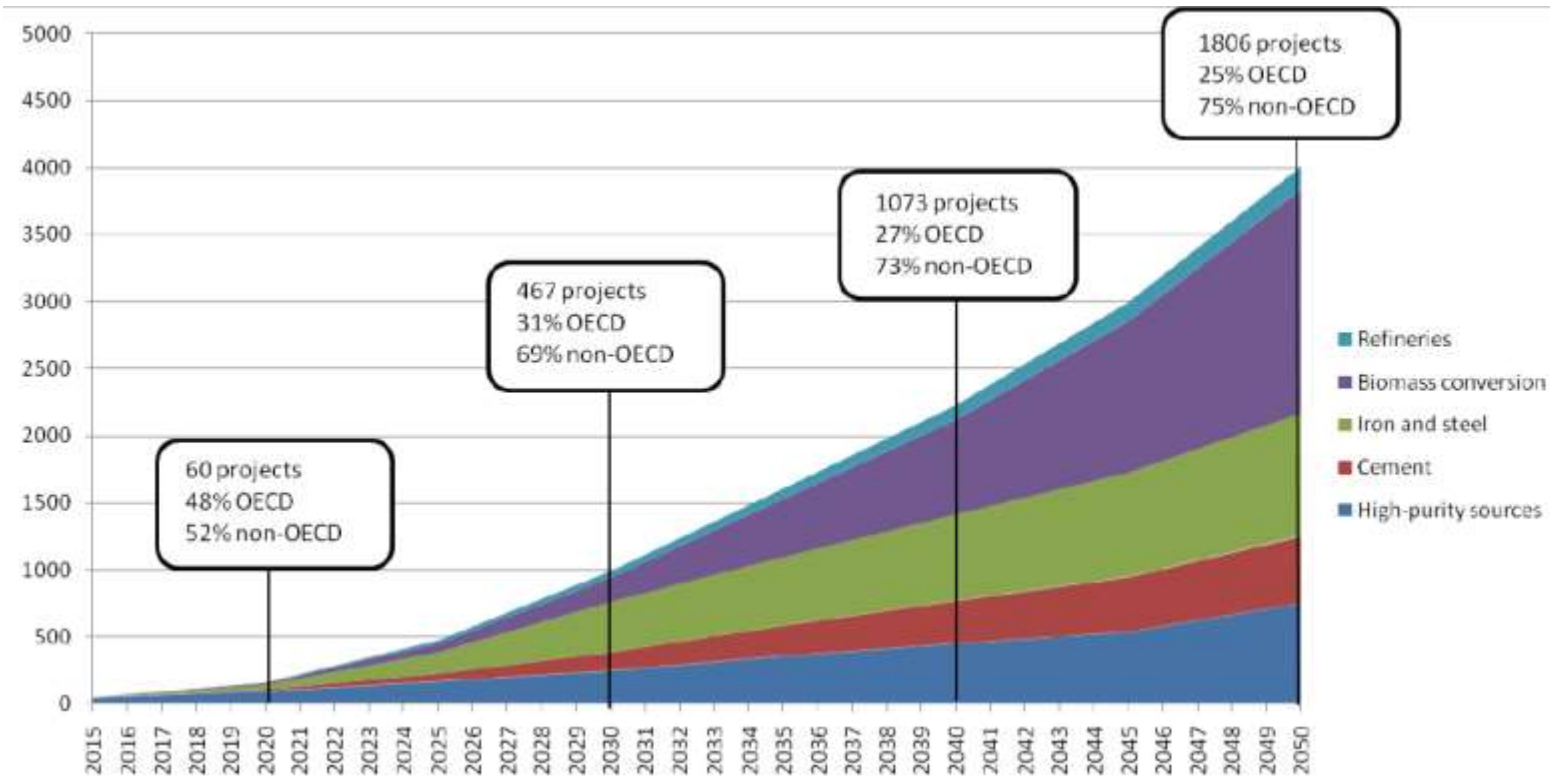
Blue scenario leads to a 4 Gt reduction in 2050, while total additional costs add up to 3 trillion USD by 2050

SOURCE: IEA ETP 2012, IEA UNIDO 2011

Carbon Capture & Storage
Blue roadmap goes from 60 projects in 2020 to 1800 in 2050

Global Calculator

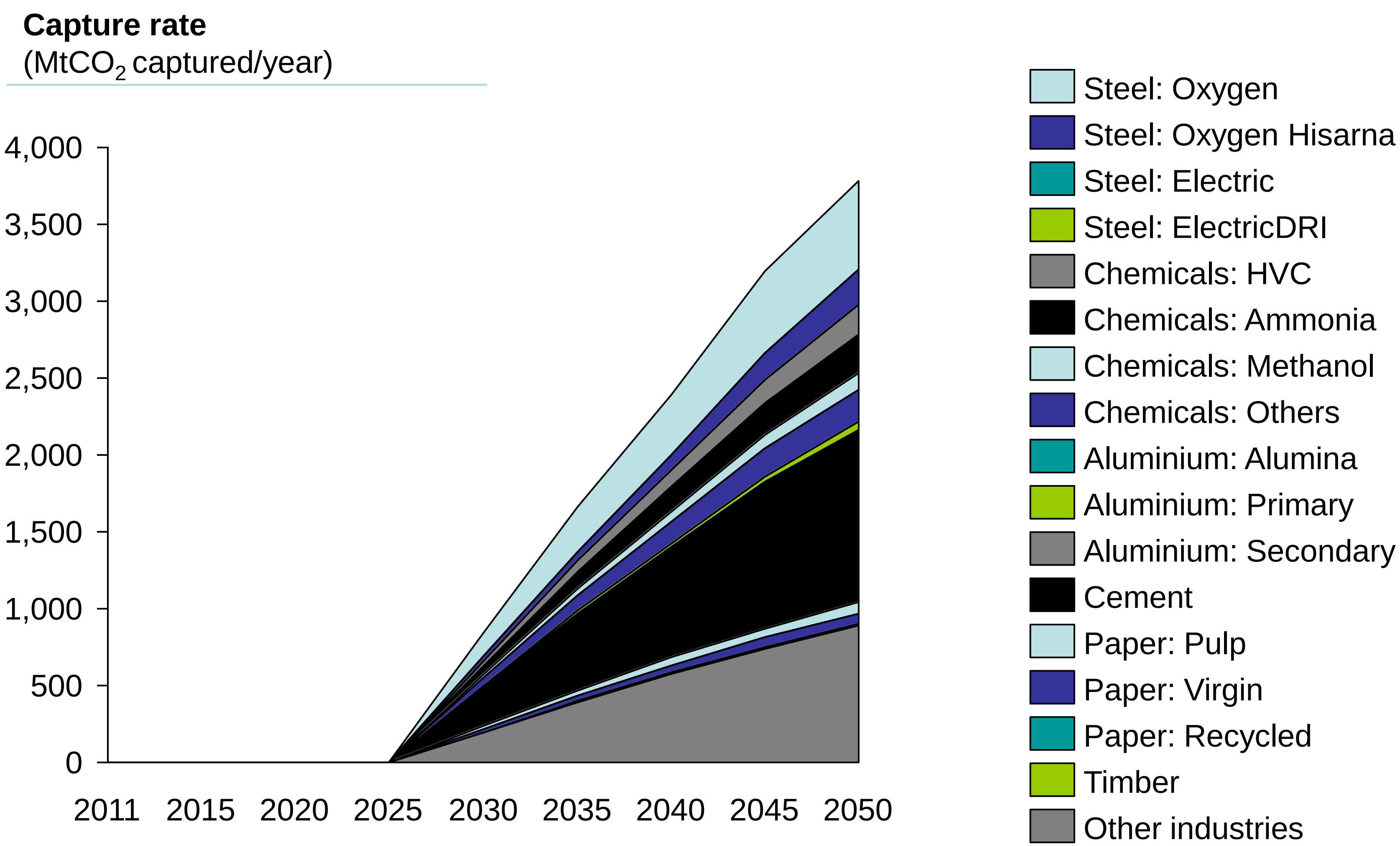
Capture rate
($MtCO_2$ captured/year)



Carbon Capture & Storage

Industry ambition 3 leads to a similar capture rate

Global Calculator



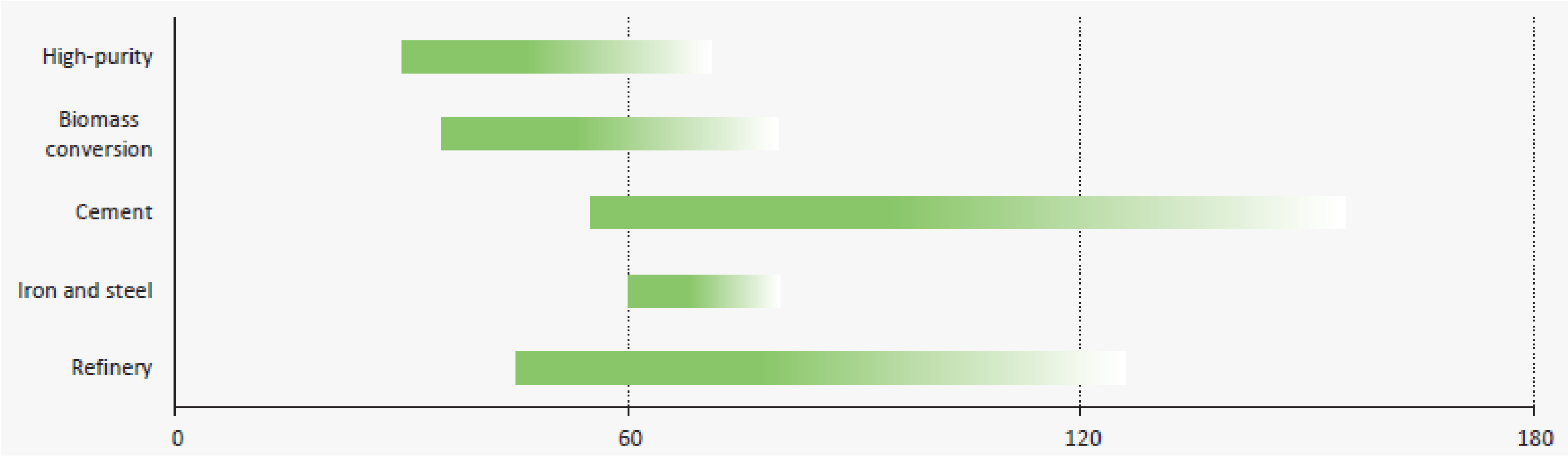
NOTE: Biomass is considered as fossil fuel & electricity emissions are not counted in this view

SOURCE: Global Calculator model,

Carbon Capture & Storage

Cost per industry

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
What this would imply per sector

Global Calculator

Sector implications for a blue scenario equivalent

Iron & Steel	• Improve the economics of capture techniques in the iron & steel sector • Equip 75% of new production with CCS by 2030 in OECD (50% in non OECD)
Chemicals (High Purity)	• Compile inventory of opportunities & assess costs • Perform demonstration projects involving hydrogen, ammonia & ethylene processes
Aluminium	• Assumed similar to steel (relatively)
Cement	• Improve the economics of capture techniques under flue gas conditions which are typical for the cement sector • Perform full scale plant between 2015 & 2020
Paper	• Assumed similar to Biomass sector objectives (relatively) • R&D on biomass gaseification processes • Realise full scale plants by 2020
Timber	• Assumed similar to paper

SOURCE: IEA UNIDO 2011

Global Calculator

Backup

Aluminium assumptions summary

Global Calculator

Lever	Ambitions			
	1	2	3	4
Design	0%	-10%	-20%	-30%
Switch to Aluminium from steel	0%	0,5%	1%	2%
Switch to plastics from aluminium (planes)	not modeled	not modeled	not modeled	not modeled
Recycling(% of total)	+10%	+15%	+20%	+25%
Process improvements (as EE)	0%	-5%	-10%	-20%
Fuel switches (coal to biomass in primary alu	0%	2%	3%	5%
CHP	0%	0%	0%	0%
Energy efficiency (additional)	0%	-3%	-5%	-10%
CCS(emissions captured)	0%	43%	64%	85%

NOTE: Because it is used in long term products (alumium locked in buildings & cables) aluminium recyclability rates are expected to decrease

SOURCE: Global Calculator consultations, WorldAluminium

NOTE
- Check 2011 recycled rates:
  - 30% (world aluminium)
  - 52% (current source)

Global Calculator

Backup

Industry specific water falls

Existing studies

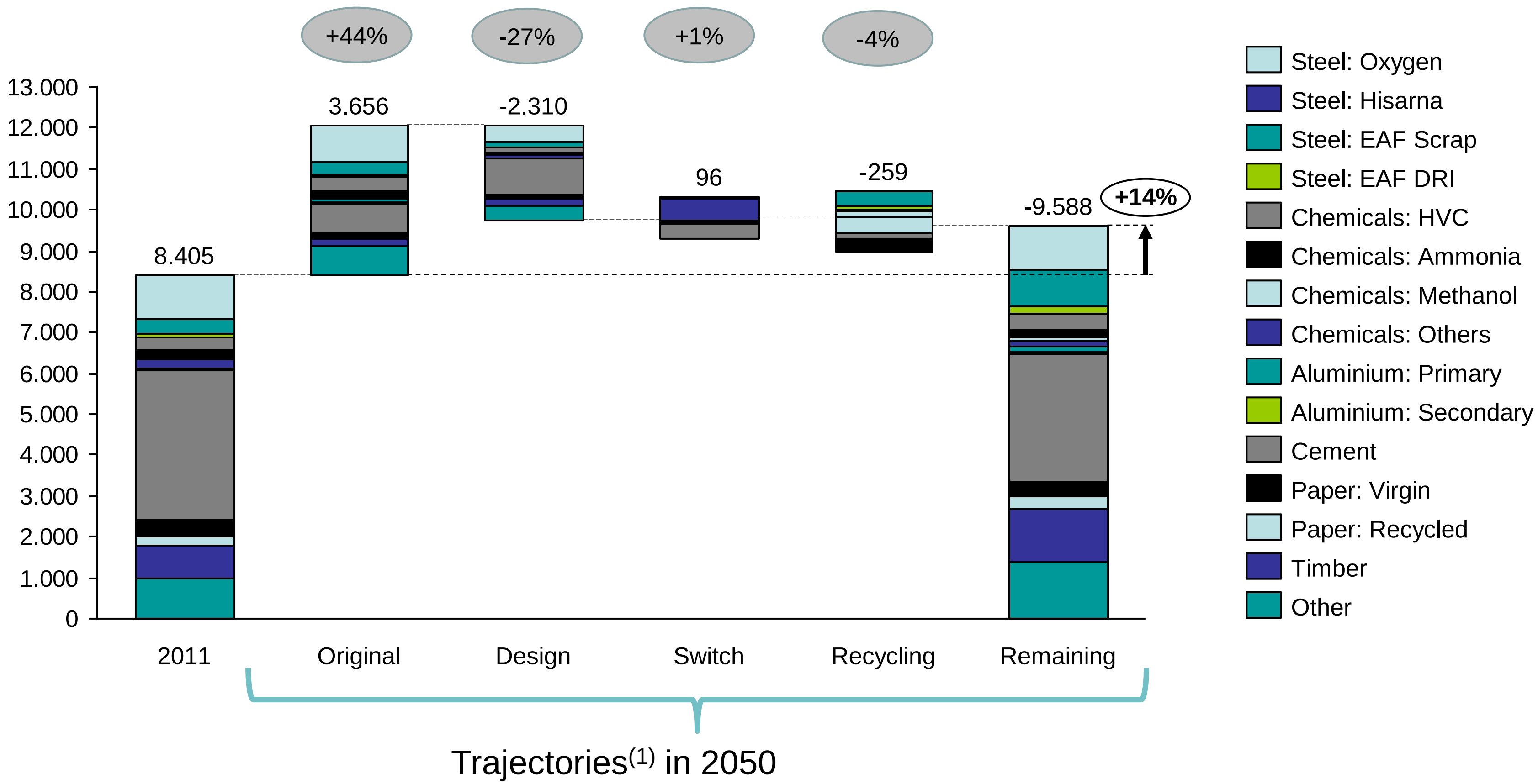
Industry overview

Reduction potential

Details for ambition level 3 (then detailed per industry)

Global Calculator

Total 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

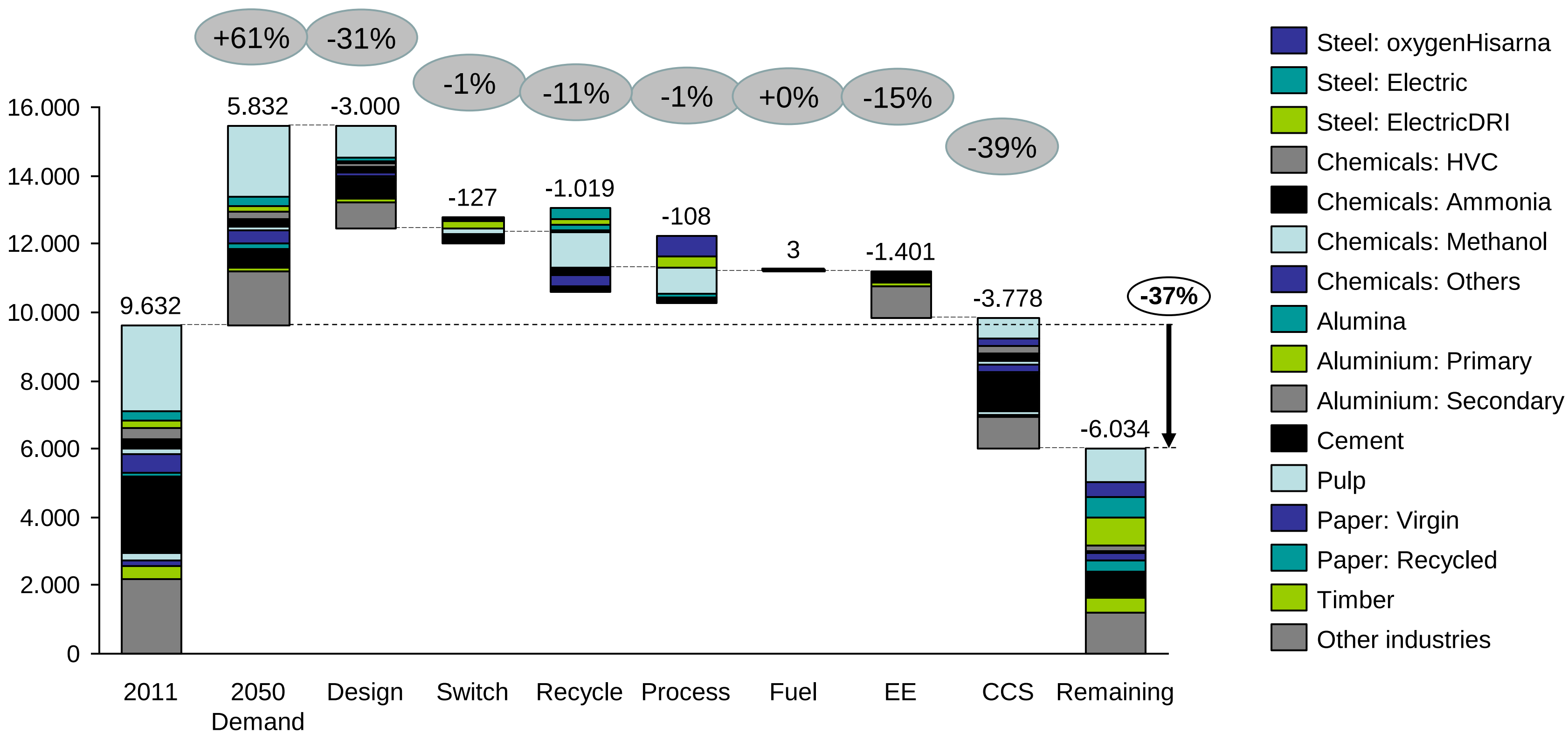
SOURCE: IEA ETP 2012, Global calculator model

Reduction potential

Details for ambition level 3 [(1)] (then detailed per industry)

Global Calculator

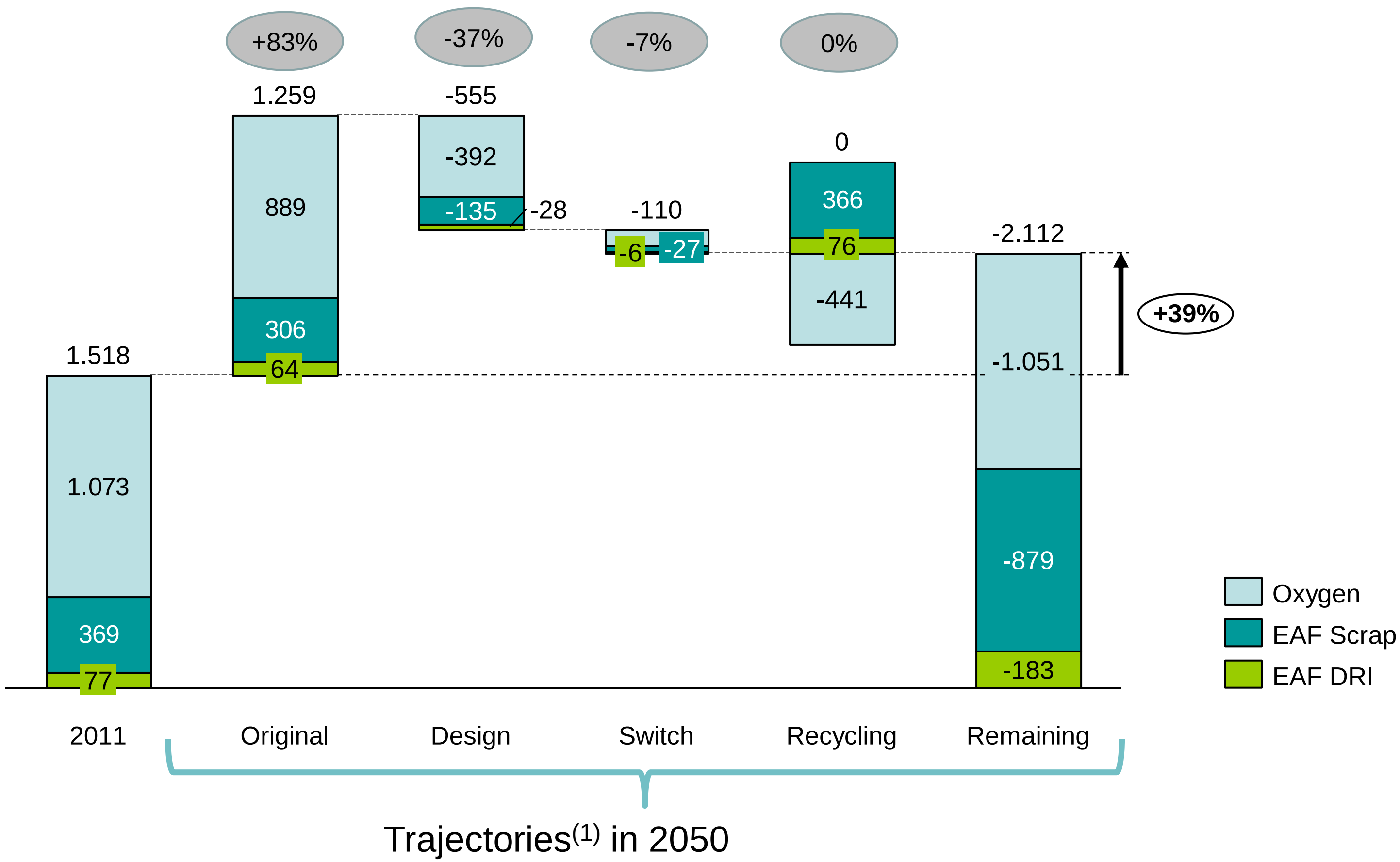
Total GHG emissions in 2050, for ambition level 3[(1,2)], using different levers[(3)]
($MtCO_2e$, % of 2010)



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

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

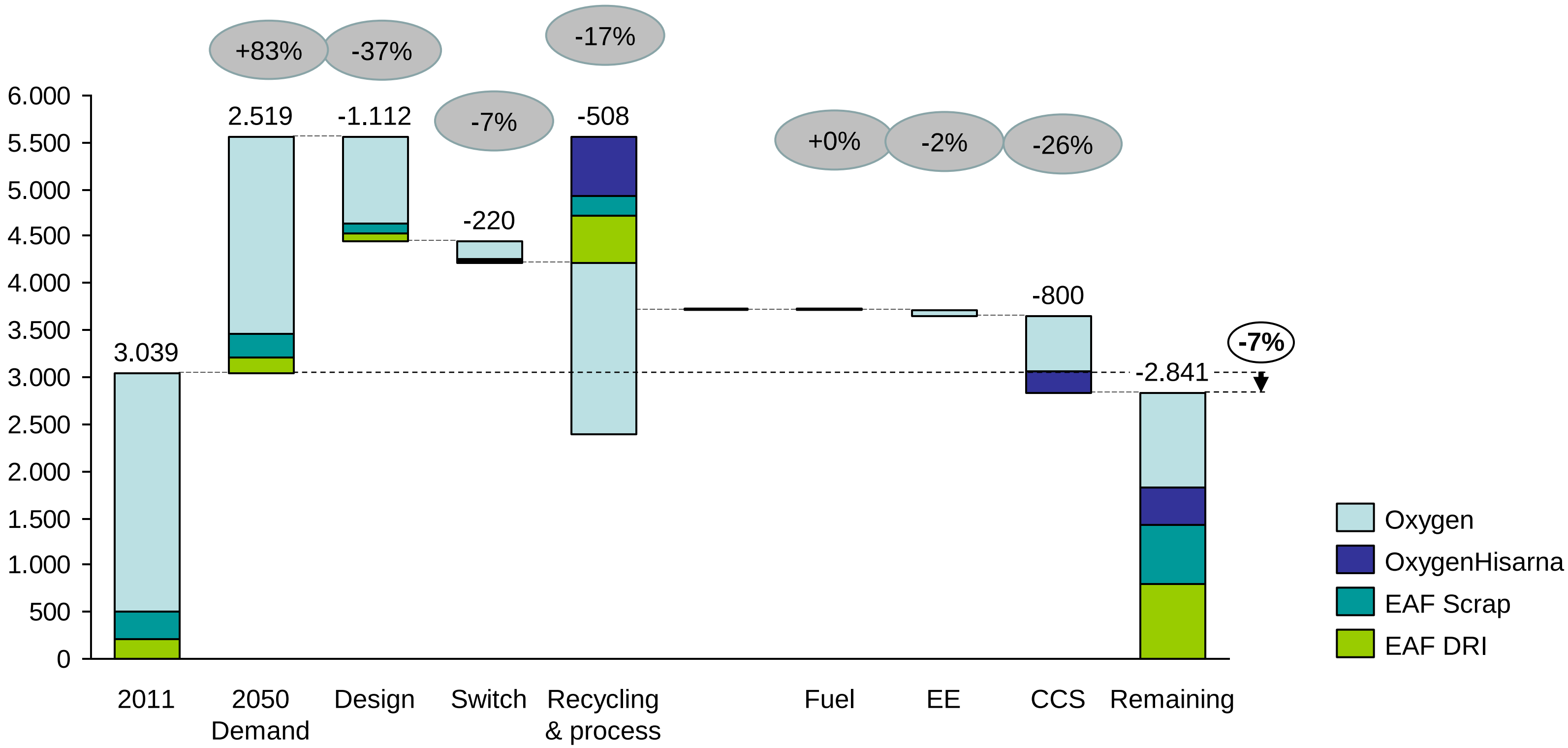


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3 (1)

Global Calculator

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



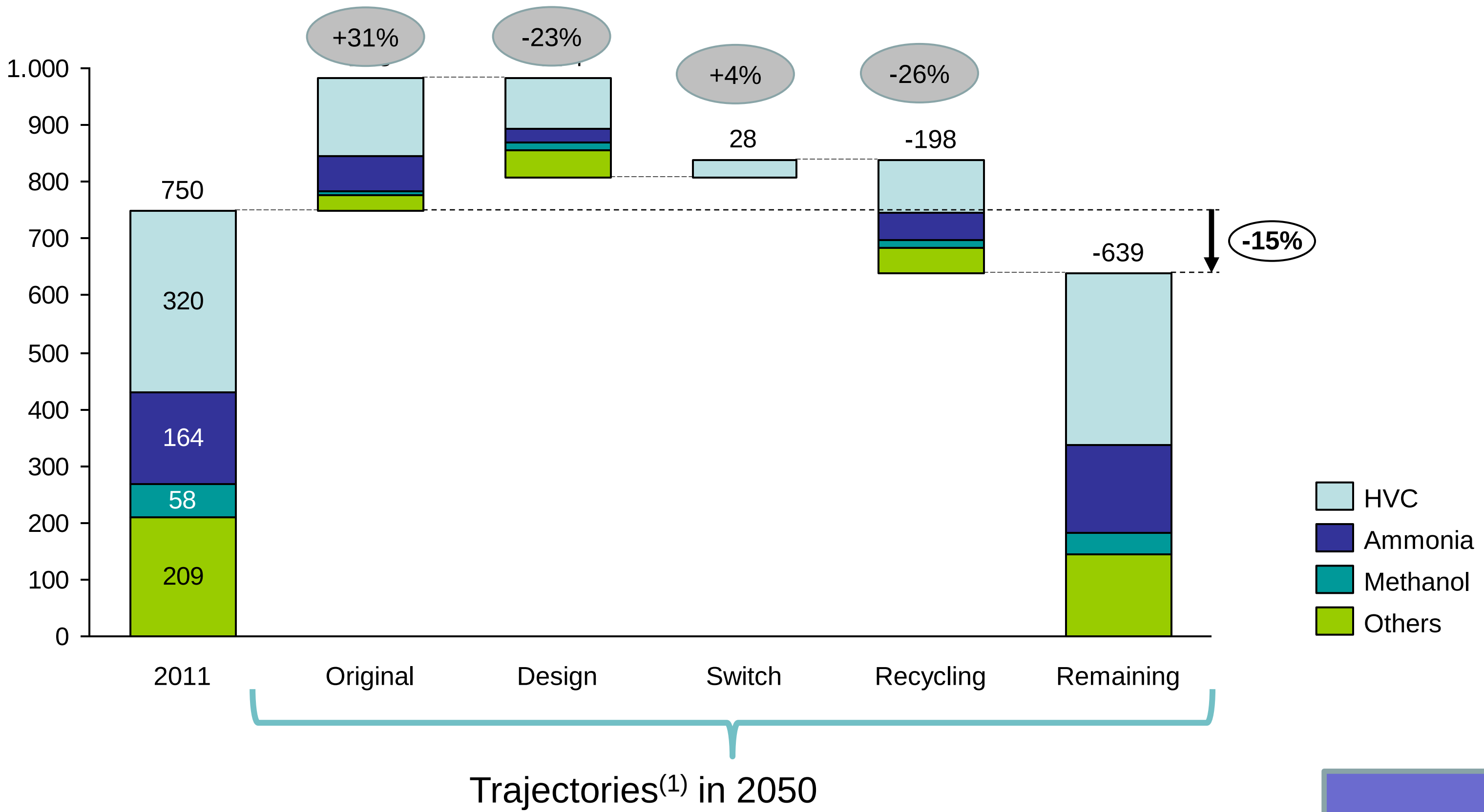
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions are calculated vs the 2010 baseline
SOURCE: IEA ETP 2012, Global calculator model

Reduction potential

Details for ambition level 3

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

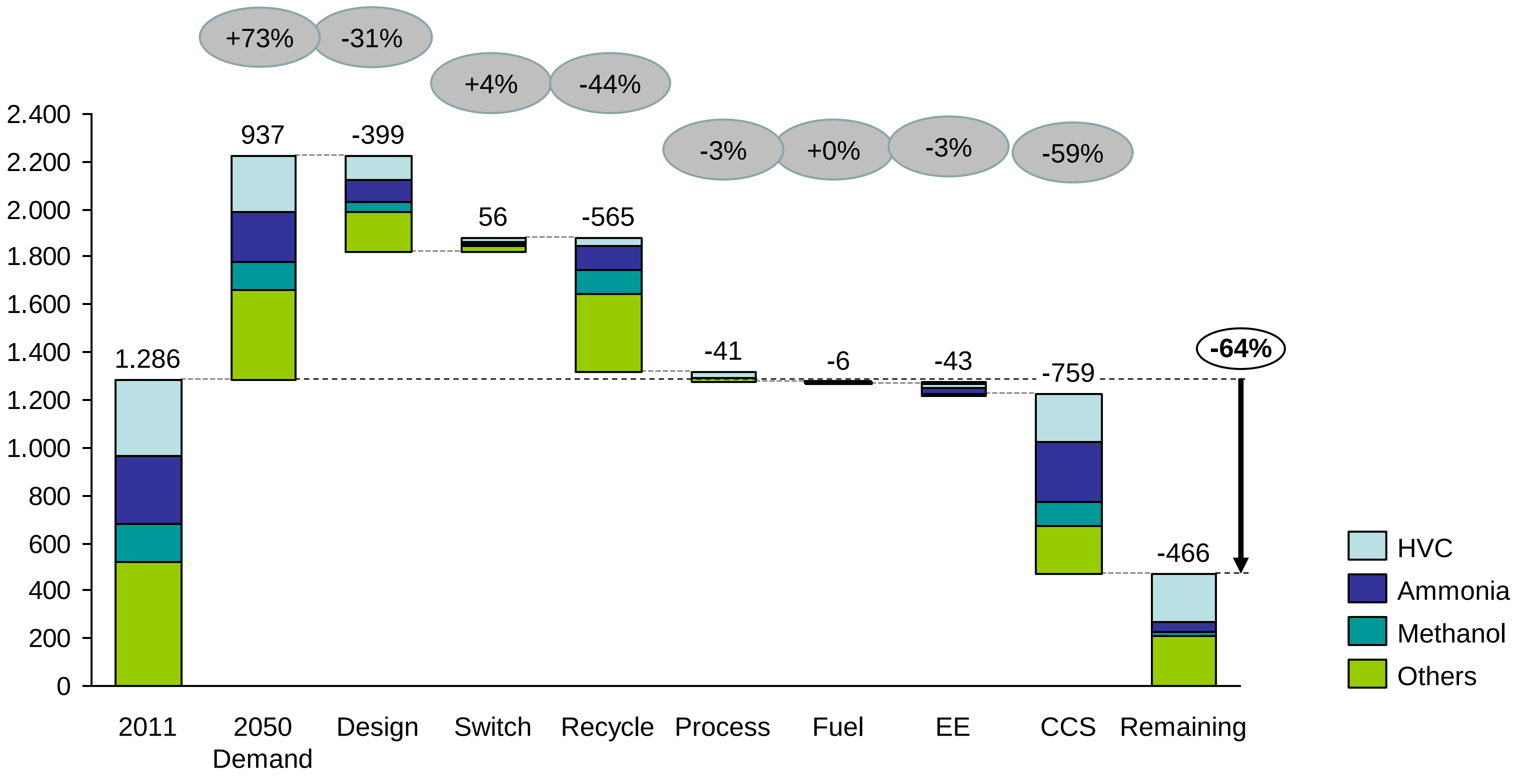
SOURCE: IEA ETP 2012, Global calculator model

Young modulus applied to chemicals is very high leading to low material increase

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)



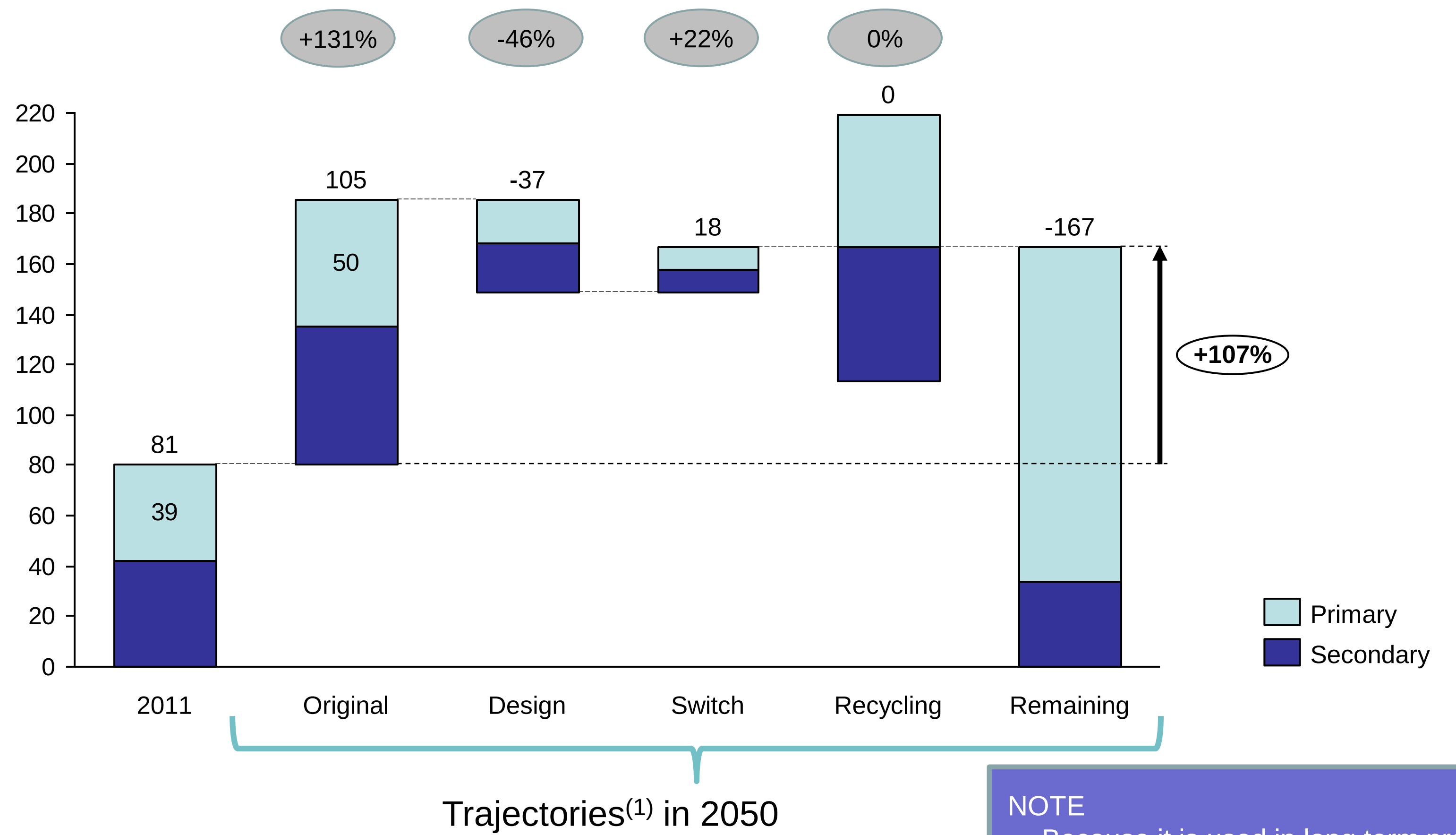
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions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

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3

Global Calculator

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



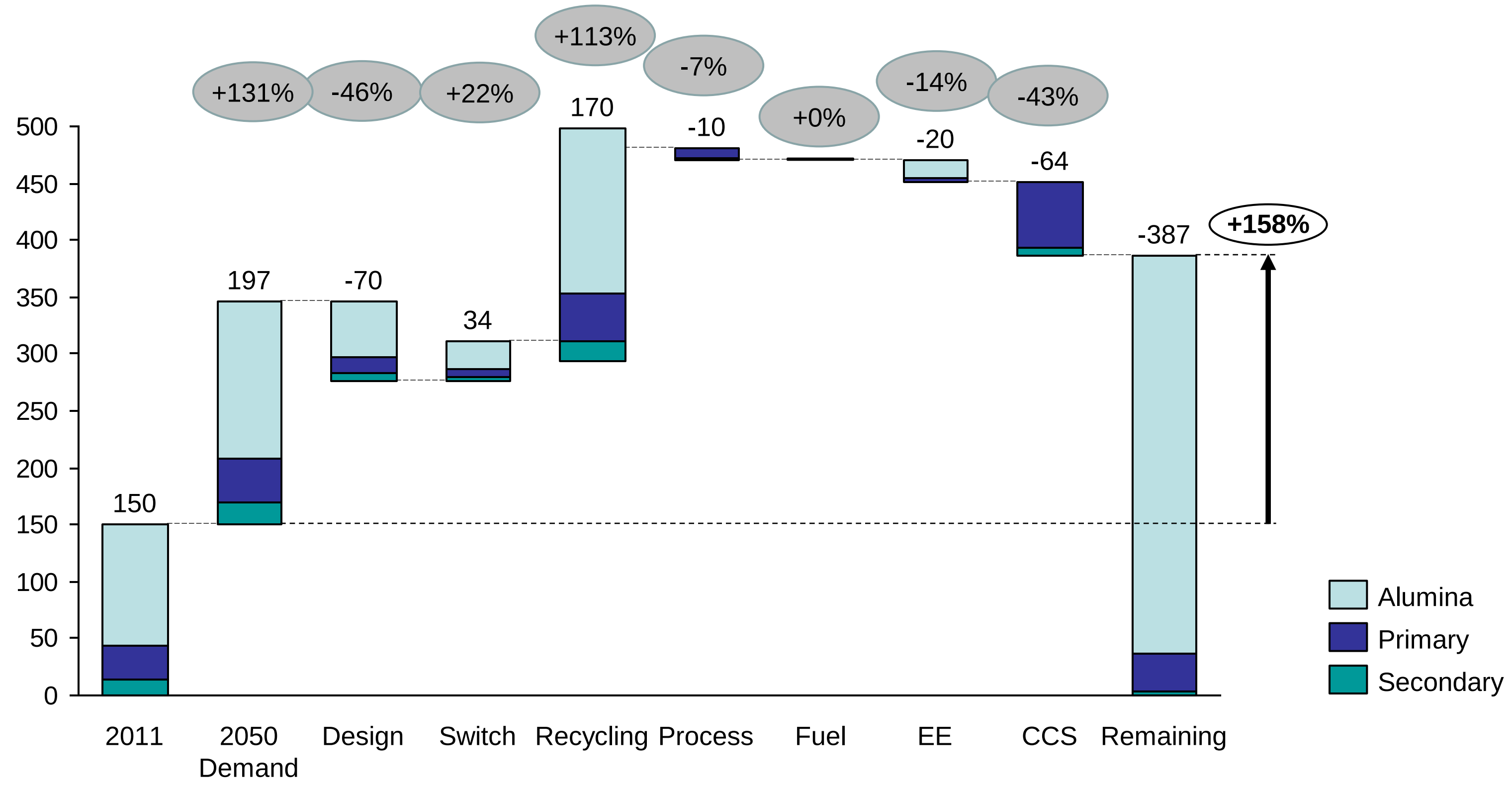
NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

NOTE
- Because it is used in long term products (alumium locked in buildings & cables) aluminium recyclability rates are expected to decrease
- Current 30%, Ambition 1: 10%, 2:15% 3: 20%, 4:25%

Reduction potential
Details for ambition level 3 (1)

Global Calculator

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



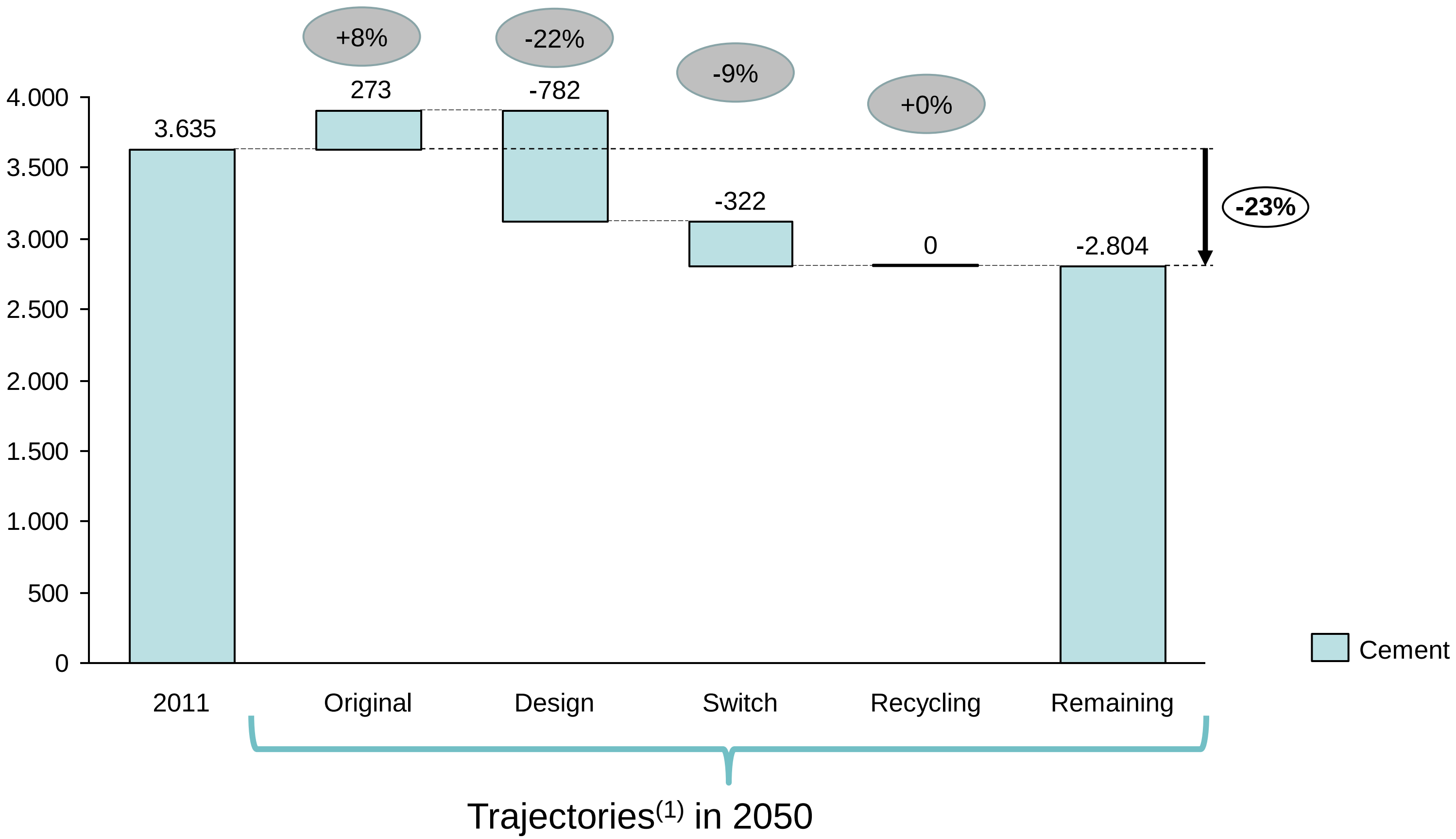
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions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

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3

Global Calculator

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

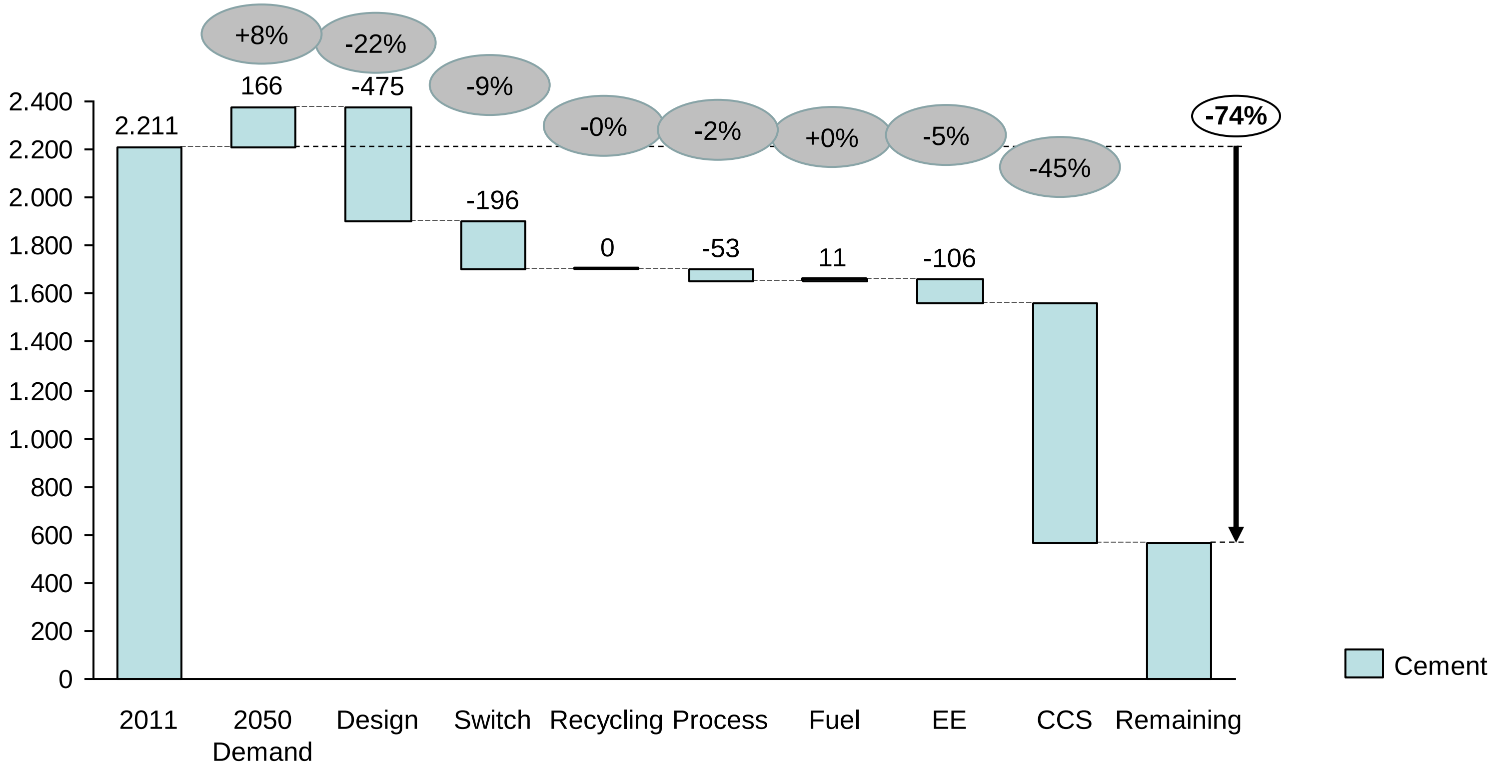


NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3 (1)

Global Calculator

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



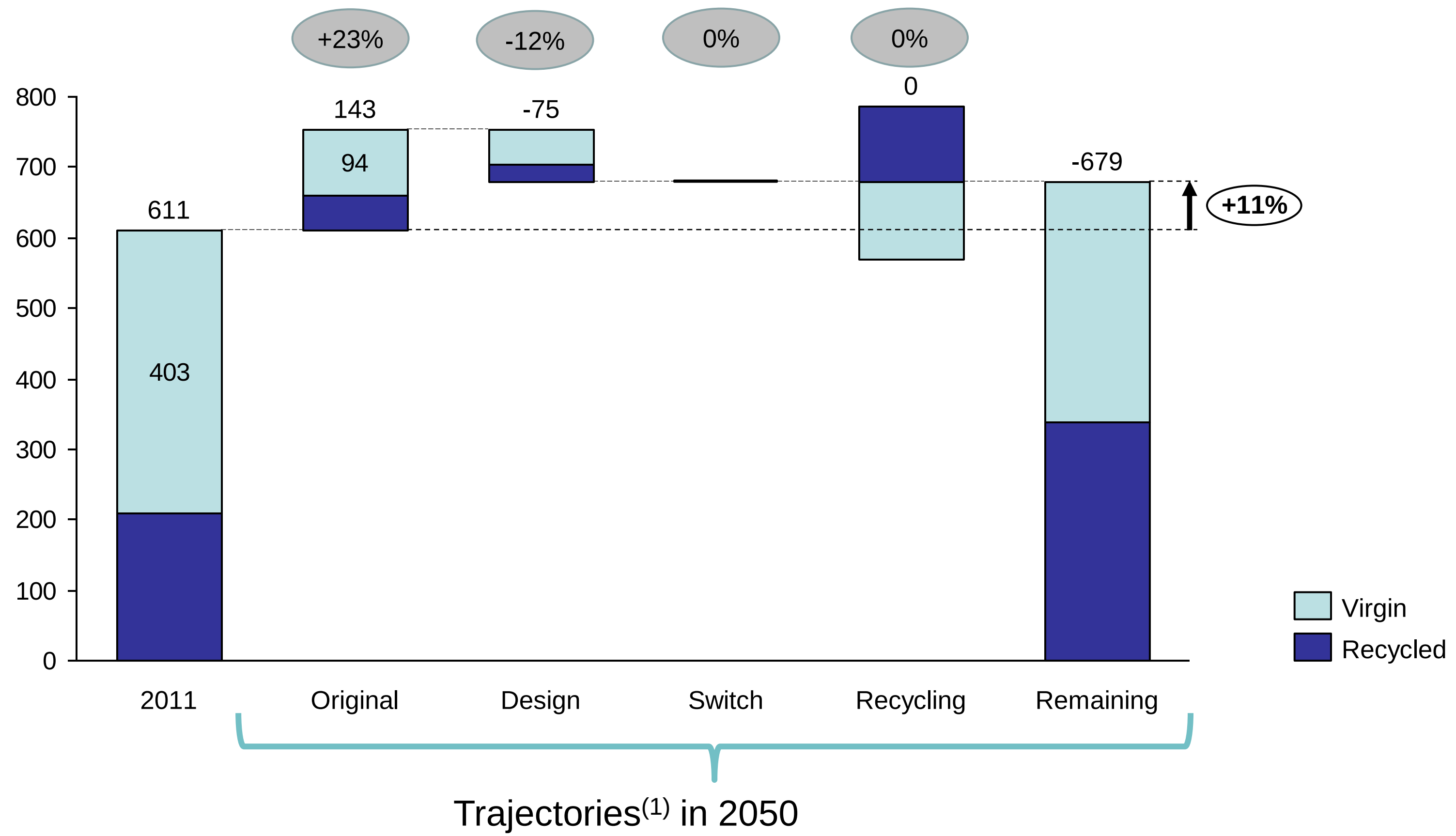
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions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

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3

Global Calculator

Paper 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

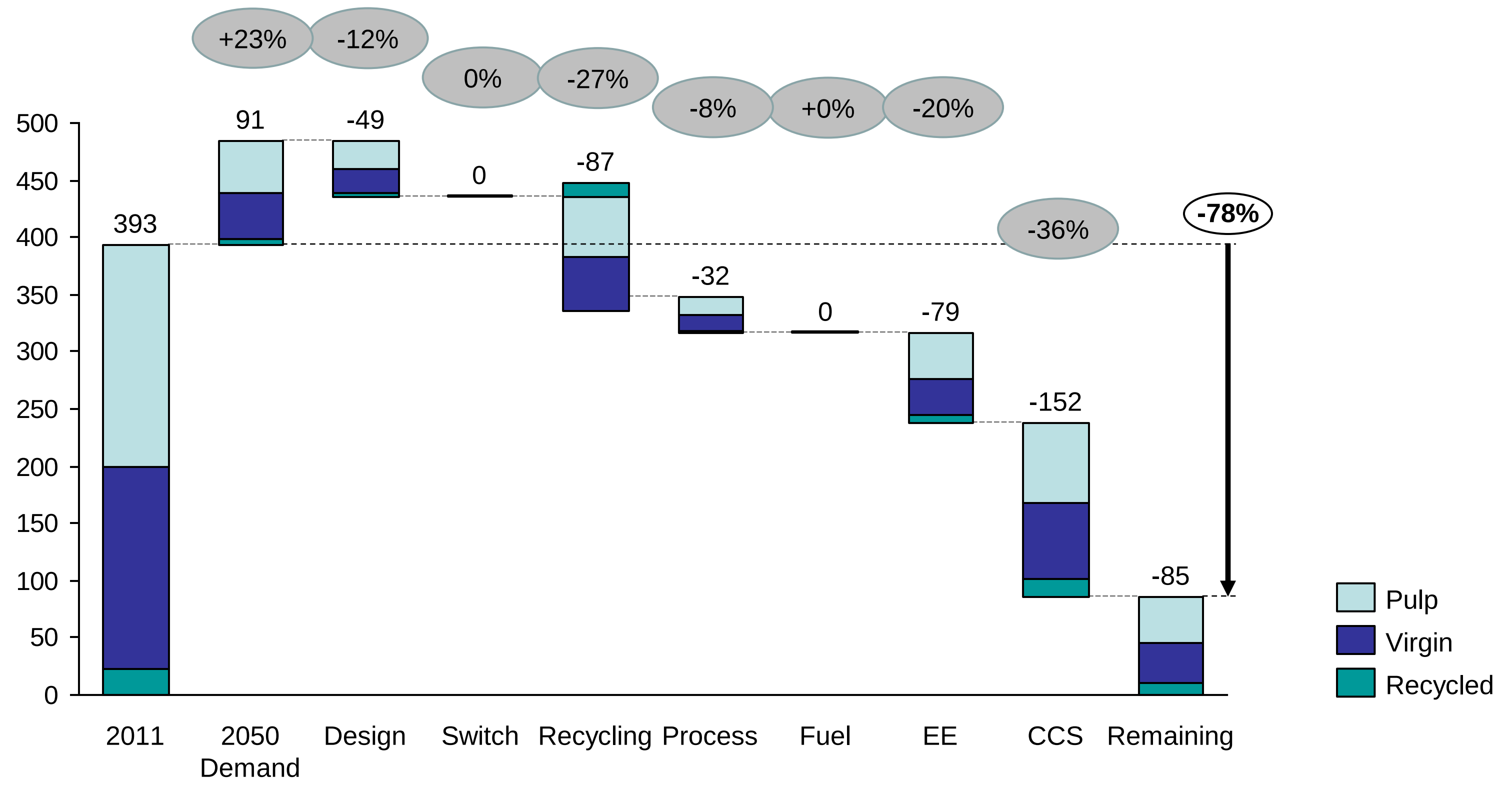
Reduction potential

Details for ambition level 3 (1)

Global Calculator

Paper GHG emissions in 2050, for ambition level 3(1,2), using different levers(3)

($MtCO_2e$, % of 2010)



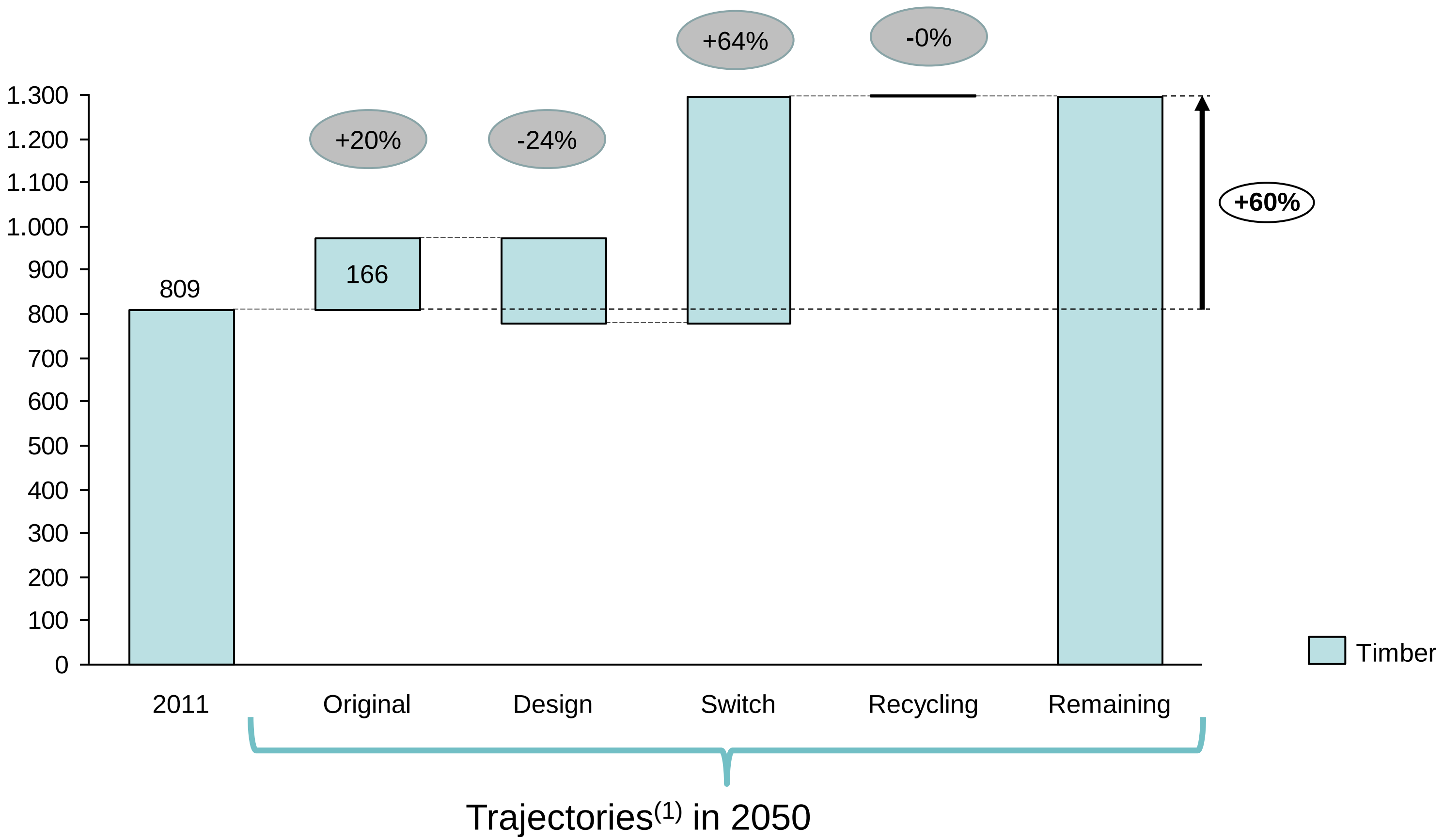
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions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

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3

Global Calculator

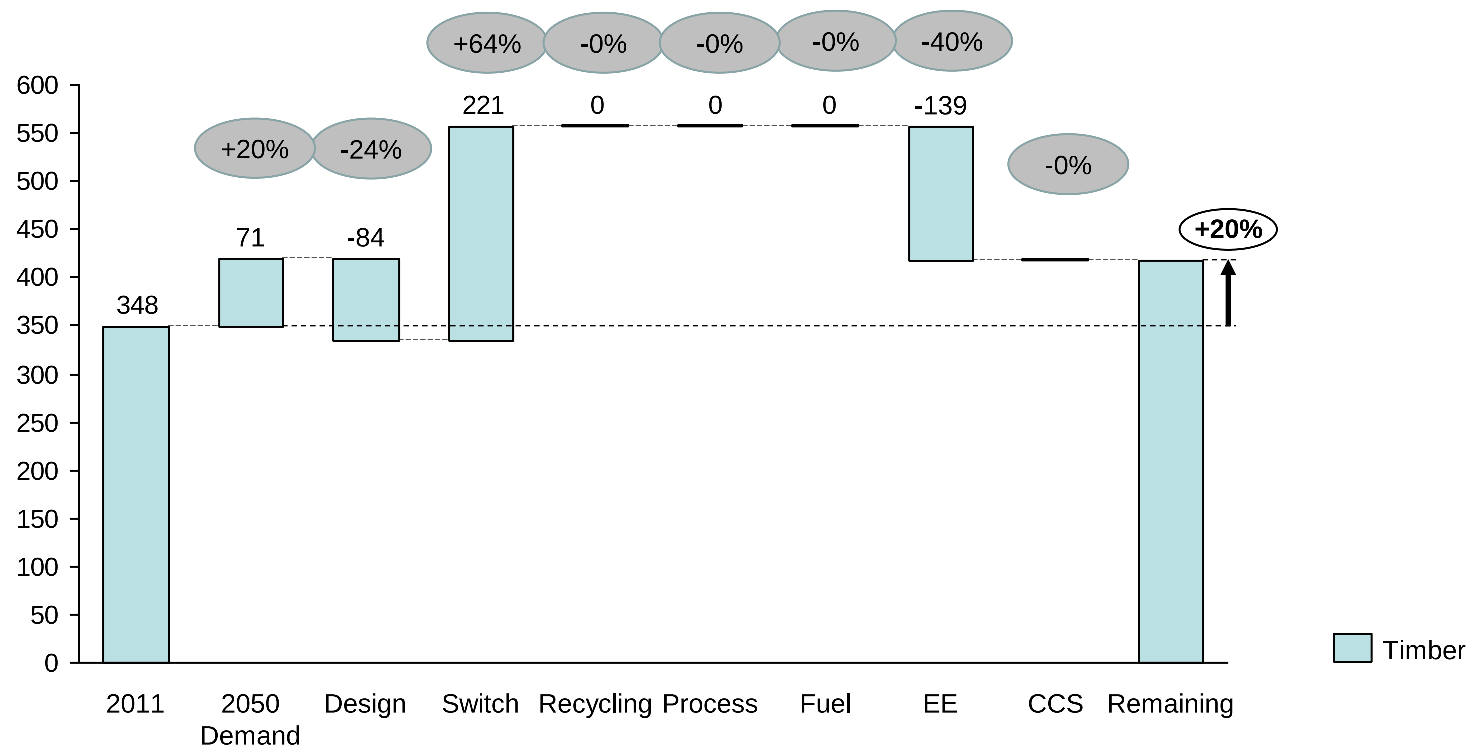
Timber production for ambition level 3
(M tons, % of 2011)



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
Details for ambition level 3 (1)

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



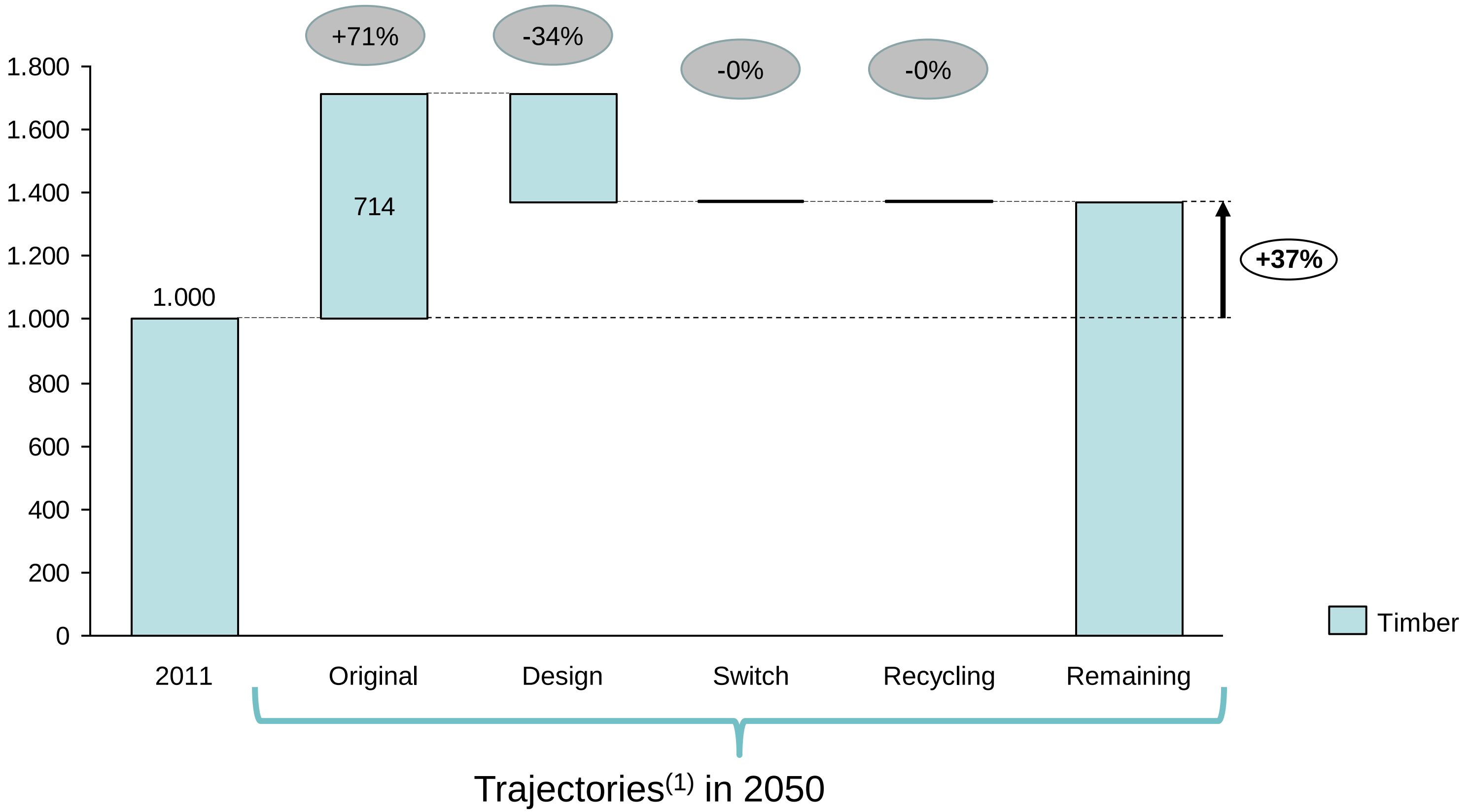
NOTES: (1) The population follows the average UN projection in all four trajectories
(2) Excluding biomass related reductions & electricity related emissions
(3) Other sectors are impacted by these transitions (e.g. additional emissions are created in the aluminium and plastics sectors)
Percentage reductions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

SOURCE: IEA ETP 2012, Global calculator model

Reduction potential
Details for ambition level 3

Global Calculator

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



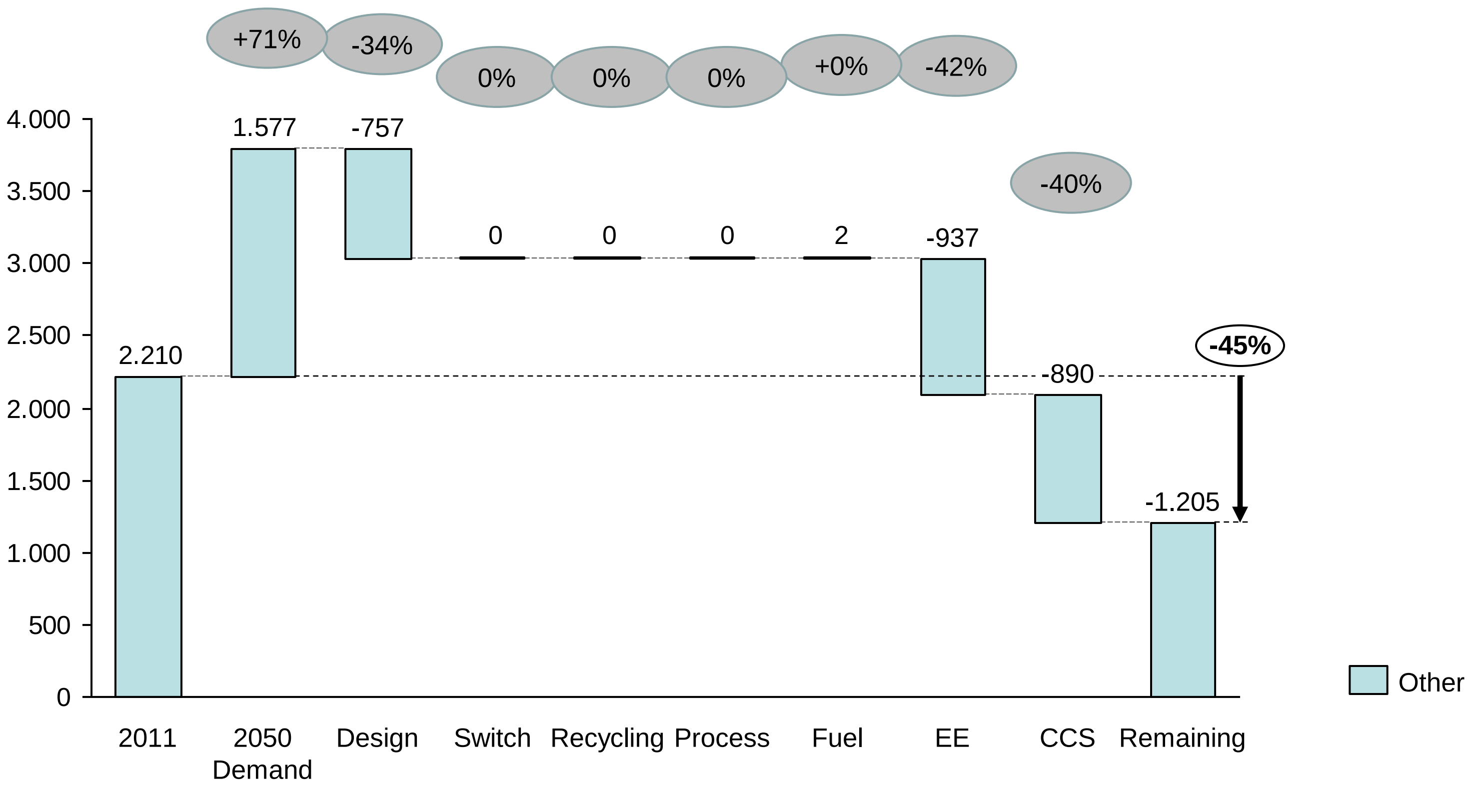
NOTE: (1) The population follows the average UN projection in all four trajectories
(2)Assuming biomass emits, not including electricity related emissions
SOURCE: IEA ETP 2012, Global calculator model

Production of other materials is normalized to 1000 in 2011

Reduction potential
Details for ambition level 3 (1)

Global Calculator

Other 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

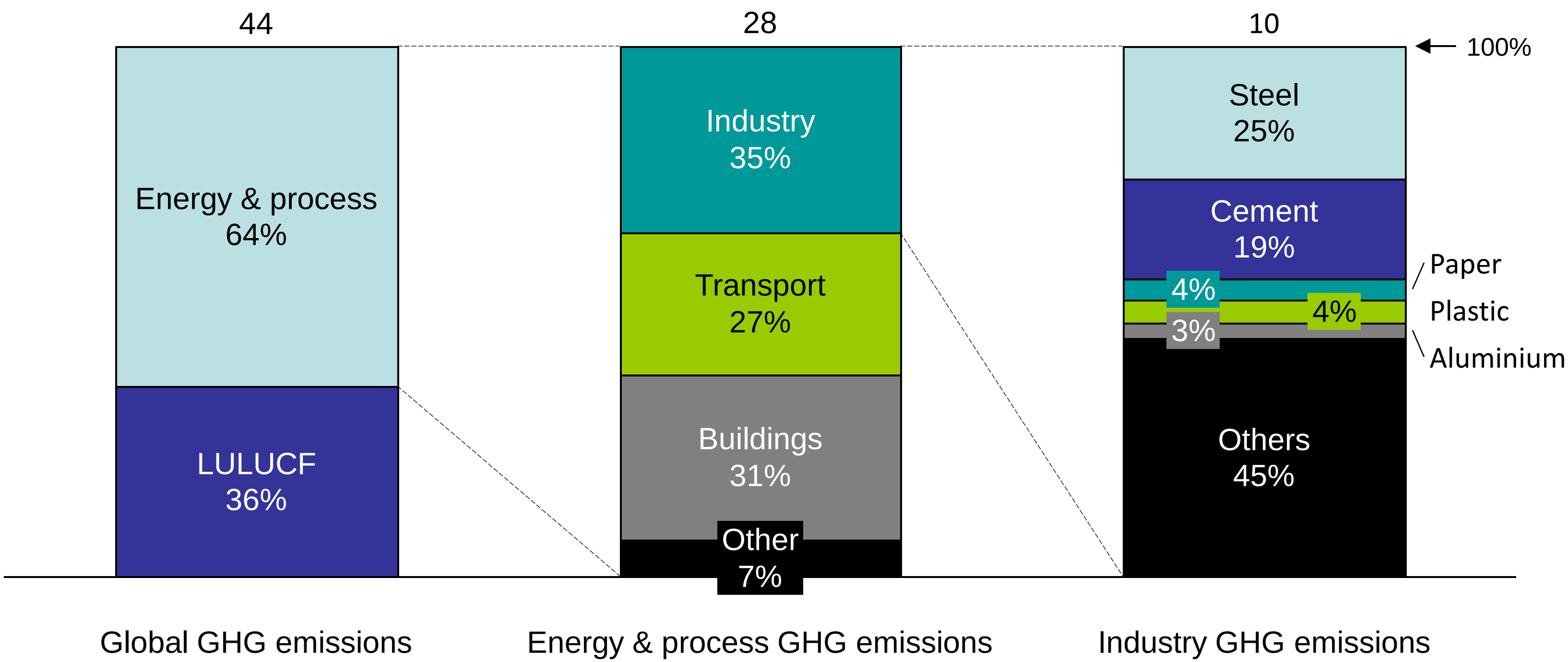
Backup

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



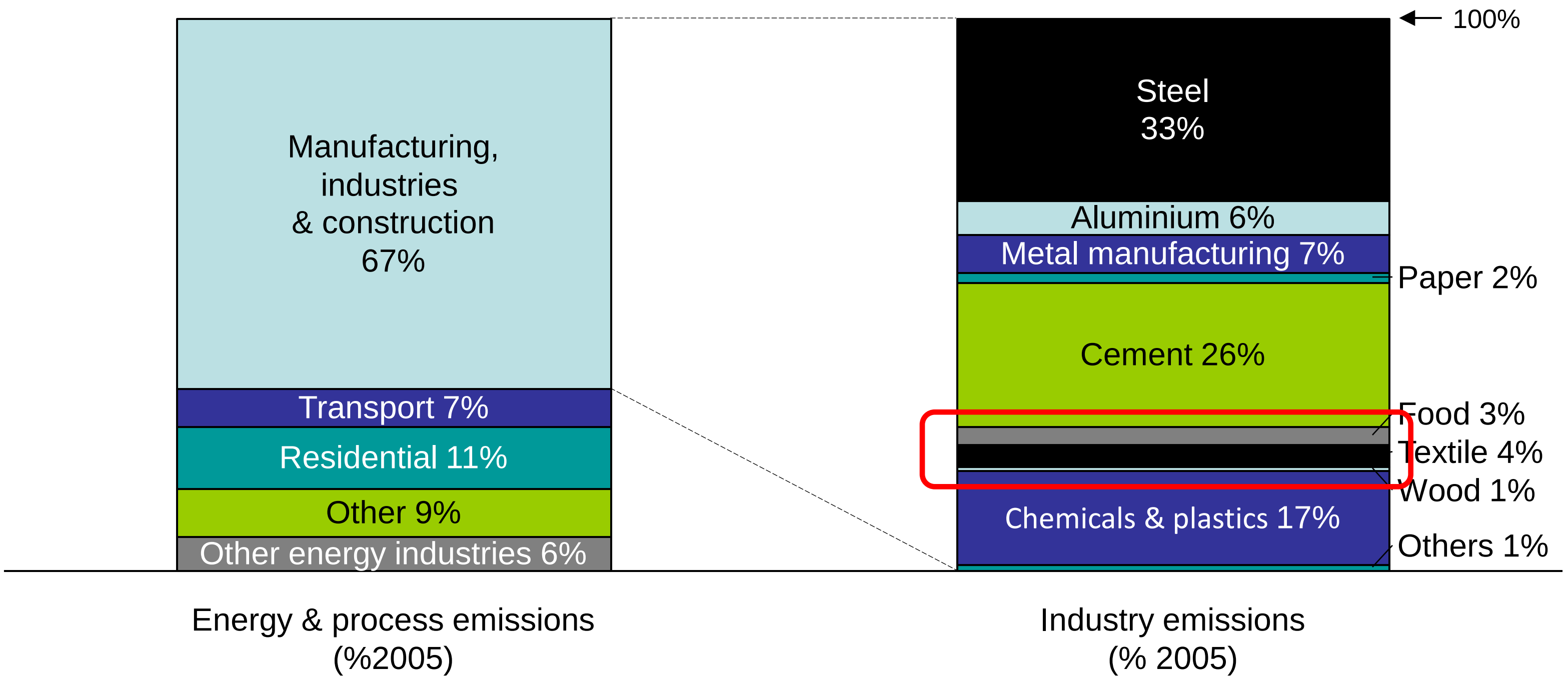
SOURCE: IEA 2008 on year 2005 through with both eyes open

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

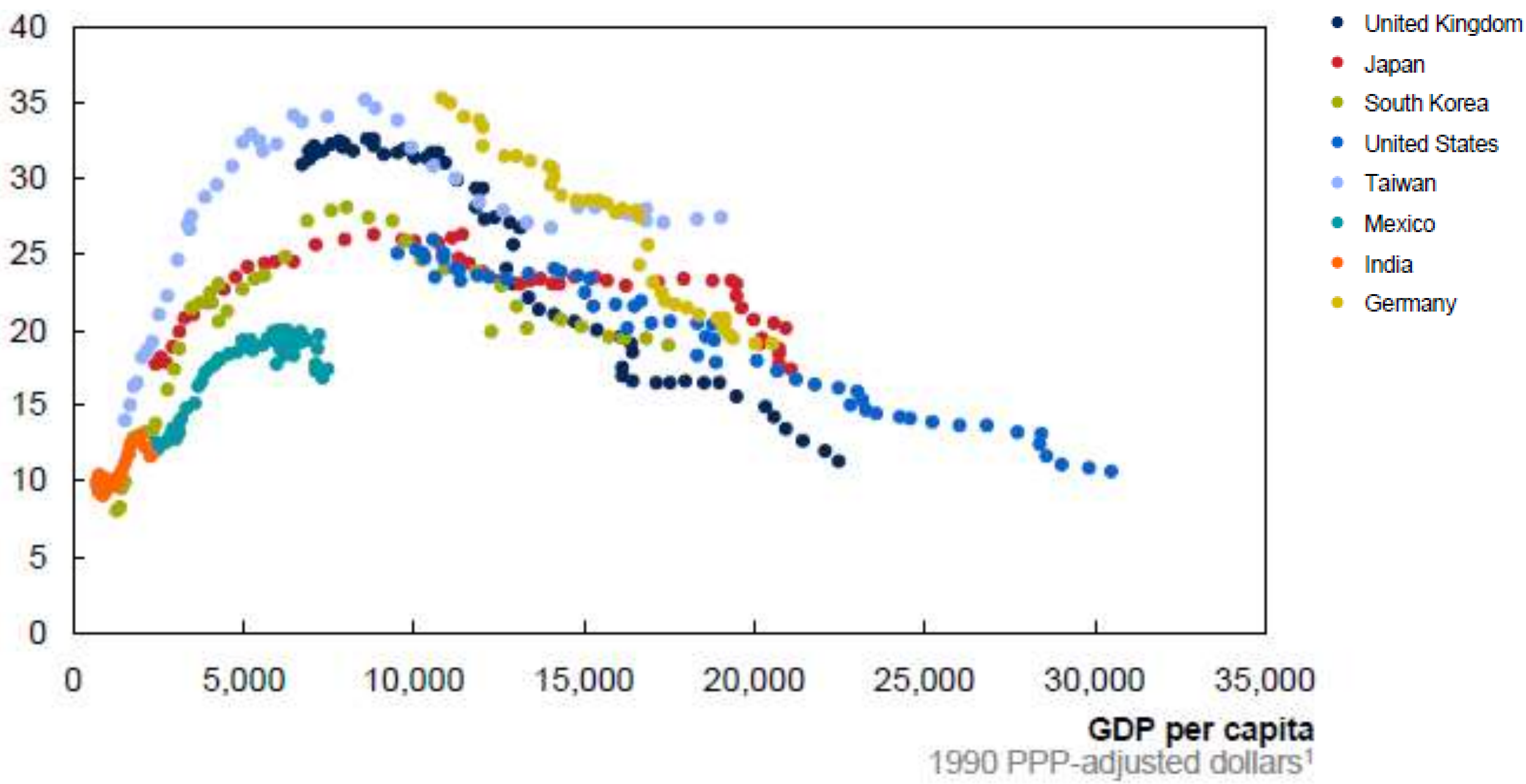
Top 15 manufacturers by share of global nominal manufacturing gross value added

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

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