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A Low-carbon roadmap for Belgium

Study realised for the FPS Health, Food Chain Safety and Environment

Industry sector – refineries document

This document is based on content development by the consultant team as well as expert workshops that were held on the 17-07-2012 and 21-09-2012

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vision on technology

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Content – Industry sector - refineries

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- **Summary and references**
- Context and historical trends
- Methodology
- Details of the ambition levels and costs per lever
- Resulting scenarios

Executive summary for the refineries sector

Construction of different future production trajectories

- 3 trajectories for production of refineries in Belgium have been defined, which include a range between **~-8% to at least ~-50% of 2010 production levels in 2050.**
  - A low carbon world scenario will have impact on the refinery sector.
  - At the moment: overcapacity world wide, no new builds in EU and US
  - Today Belgium refinery sector very competitive in terms of energy efficiency, directly linked to petrochemical sector in Antwerp, but high labour costs. Belgian refinery output is twice the Belgian demand.
  - **Trajectories 2 and 3 will be hard linked to the oil demand of the other sectors.**

Estimate of potential and cost for the GHG reduction opportunities

- **GHG reduction potential (assuming constant production) is high - (Levers 3 description)**
  - **Energy efficiency** can be improved and reduce emissions by 30%
  - Extra **CHP potential** is limited and can increase with 15% compared to the current level
  - **Process improvements** and new technology can be implemented from 2030 on and will improve energy efficiency by 15%
  - A 50% substitution of liquid fossil fuels by **natural gas** allows for an additional **11%** of emission reductions
  - **CCS** can be applied on the remaining emissions and will reduce for a further 85%.
- NOTE: While the future production of refineries is under pressure, the uncertainty on investments in reduction technologies increases. Building integrated scenario's, we will take this into account.

NOTE Except explicit mention, the reduction potential figures are mentioned at constant production, as reduction percentage versus 2010. Actions are applied in sequential order. Levers are of ambition 3 (except for CCS where level 2 is also detailed)

List of references

- www.gva.be, www.vandaag.be, www.petrolfed.be
- http://www.petrostrategies.org/Learning_Center/refining.htm
- Presentation from Total Fina Antwerp, TFA scheme
- Integrated Pollution Prevention and Control (IPPC), *Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries*, February 2003; http://eippcb.jrc.es/reference/BREF/ref_bref_0203.pdf
- Industrial Emissions Directive 2010/75/EU, *Best Available Techniques (BAT) Reference Document for the Refining of mineral oil and gas*, Draft 2 March 2012; http://eippcb.jrc.es/reference/BREF/REF_D2%20_032012.pdf
- http://www.petrostrategies.org/Learning_Center/refining.htm
- Concawe, *The potential for application of CO2 capture and storage in EU oil refineries*, report no. 7/11 Prepared for the CONCAWE Refinery Management Group by its Ad Hoc Group on Carbon Capture and Storage; October 2011
- IMJV data on thermal capacity
- www.petrolfed.be – jaarverslag 2001 – 2006 - 2011
- ATC PTIT Refining Trends for the future: a 2020 scenario, Axens IFP Group Technologies; http://www.authorstream.com/Presentation/Goldye-53781-ATC-PTIT-Refining-Trends-future-2020-Sce-Scenario-Agenda-Global-Demand-Refined-Products-Projected-2005-refini-Education-ppt-powerpoint/
- Europia, Annual report 2011
- Flanders Common Reporting Format v1.6
- Concawe, *EU refinery energy systems and efficiency*, report no. 3/12 Prepared for the CONCAWE Refinery Management Group by its Special Task Force RT/STF-1; http://solomononline.com/documents/Whitepapers/EII_AM_WWW.pdf
- Petroleum federation of India, FACTS SEP 2008; http://www.petrofed.org/
- EUROPIA Contribution to EU energy pathways to 2050 Roadmap, July 2011
- Benchmarkconvenant, www.benchmarking.be: jaarverslag 2010
- ECN, *Raffinaderijen naar 2030*, ECN-E--10-064, December 2010
- Platts newsfeed, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Oil/8279079
- VITO & Econotec, KEY ASSUMPTIONS FOR SUBSEQUENT CALCULATION OF MID AND LONG TERM GREENHOUSE GAS EMISSION SCENARIOS IN BELGIUM
- Ecolas, Evaluatie van het reductiepotentieel voor diverse polluentemissies naar het compartiment lucht in de sector van de petroleumraffinaderijen in Vlaanderen, i.o.v. Aminal, Augustus 2002
- E3M-lab, jrc-ipts, Ecofys, Sectoral Emission Reduction Potentials and Economic Costs for Climate Change (SERPEC-CC) - Industry & refineries sector, October 2009
- UCE, Icarus-4, Sectorstudy for refineries, September 2001

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Geographical distribution of production sites
Antwerp, hot spot in Belgium

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Destillation capacity (2011)

- Total Raffinaderij Antwerp (TRA): 18,2 Mton
- Esso Belgium: 16,2 Mton
- Petroplus Refining Antwerp → Antwerp Terminal and Processing Company (ATPC): only desulferisation of mid-destillates
- Petroplus Refining Antwerp bitumen → Antwerp Processing Company (ATC): 1,2 Mton
- BRC relaunch by Gunvor, Independent Belgian Refinery: 5,5 Mton

SOURCE: www.gva.be , www.vandaag.be, www.petrolfed.be

Details GHG for production sites (ETS registry)

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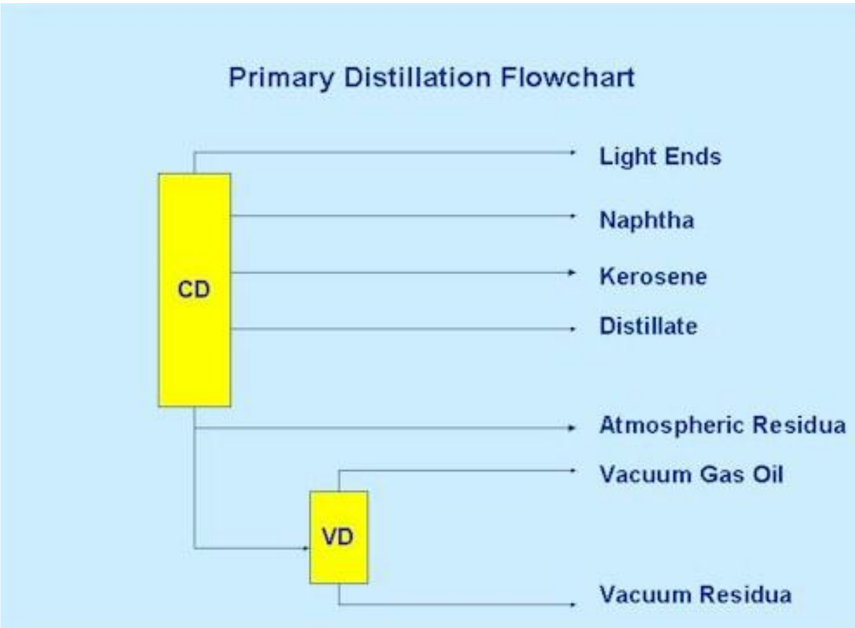
Excluding cracker NC3 for TRA, cracker is included in chemical sector
Including all CHP installations (autoproducers + CHP in co-operation with electricity sector)

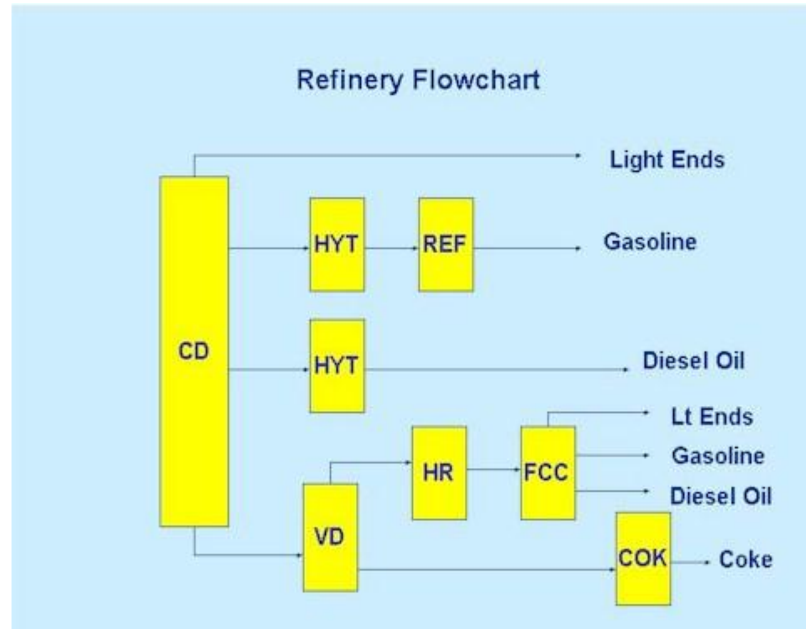
Production site	GHG emissions (kton CO2)		
	2010	2009	2008
Total Raffinaderij Antwerp	3098	3058	3191
Esso Belgium	1799	1839	1666
ATPC + ATC bitumen	55	93	93
Independent Belgian Refinery	522	526	525
Total	**5474**	**5516**	**5475**

SOURCE: ETS registry, Belgium, excluding NC3 cracker (data from TRA, 21/09/2012)

Technical detail refinery processes
Refinery complexity: from low to high

Flux of the process





CD: Atmospheric distillation, VD: Vacuum distillation, REF: reforming, FCC: fluid catalytic cracking,
COK: coking, HYT: hydrotreating, HR: hydrodesulferization

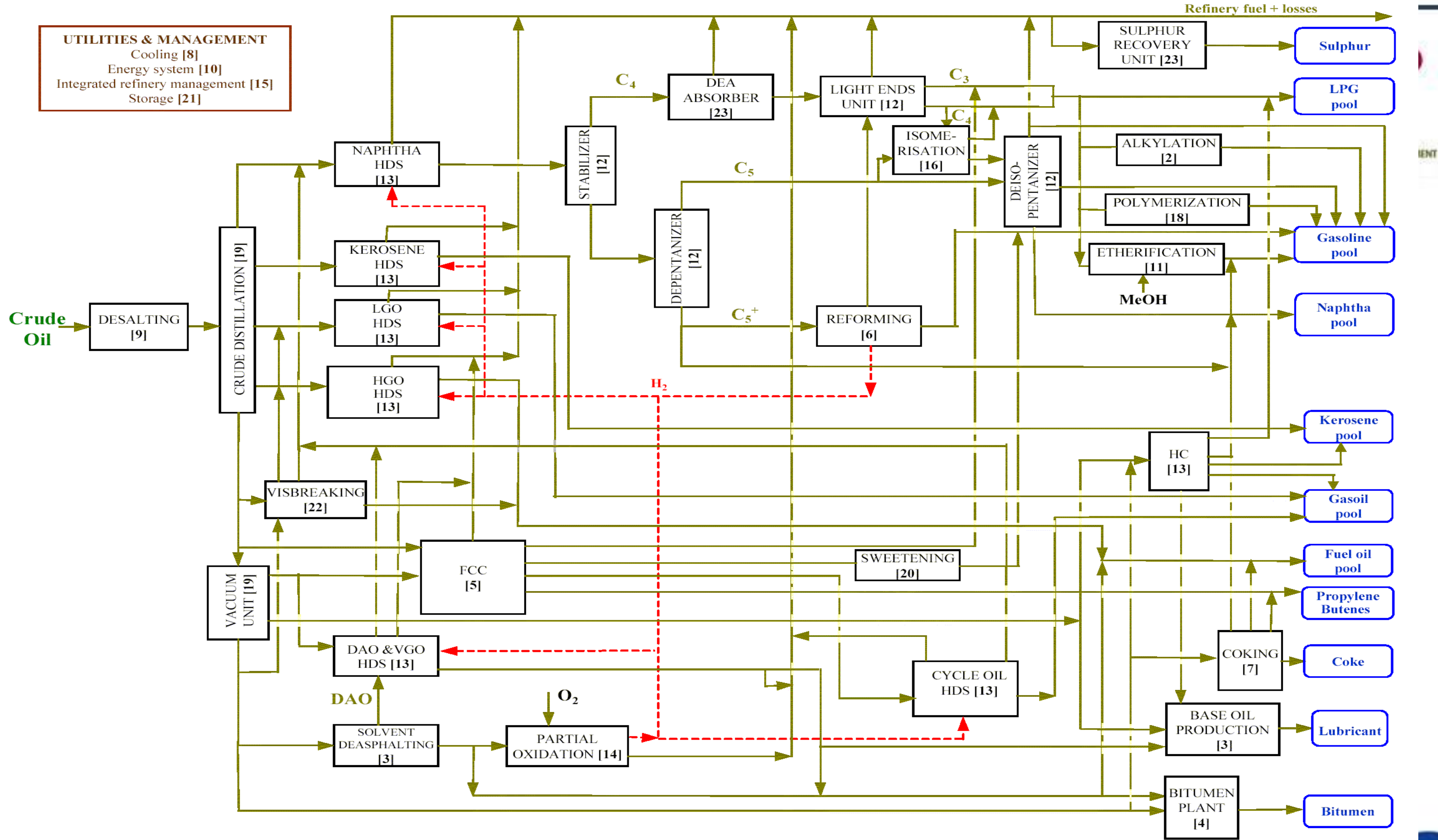
SOURCE: http://www.petrostrategies.org/Learning_Center/refining.htm

Nelson complexity index (2003) increased by 2010

The higher the index number, the greater the cost of the refinery and the higher the value of its products

- TRA:
  - medium complexity, 8.3
  - Second largest refinery complex in EU
- Esso:
  - Complexity not known
- AT(P)C:
  - Complexity not known
- IBR: 4.5

SOURCE: BREF mineral oil and gas refineries, http://eippcb.jrc.es/reference/BREF/ref_bref_0203.pdf
IBR: Petroplus Holdings AG, Company overview 2009

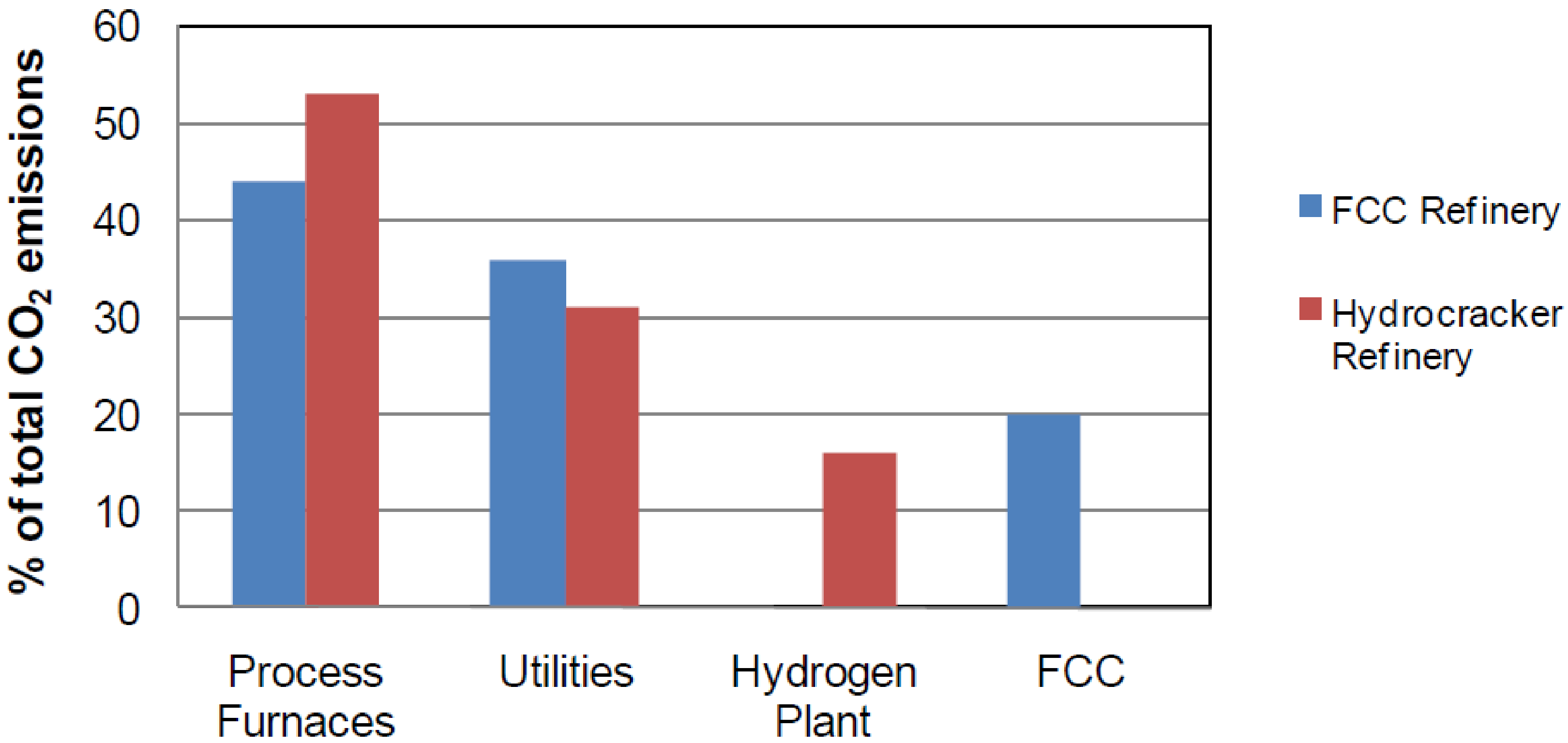


DAO: Deasphalted oil **DEA:** Diethylamine **FCC:** fluid catalytic cracker **HC:** Hydrocracking **HDS:** Hydro desulphurisation **HGO:** Heavy gas oil **LGO:** Light gas oil **VGO:** Vacuum gas oil

SOURCE: BREF mineral oil and gas refineries, http://eippcb.jrc.es/reference/BREF/ref_bref_0203.pdf

Most important processes → energy use → emissions

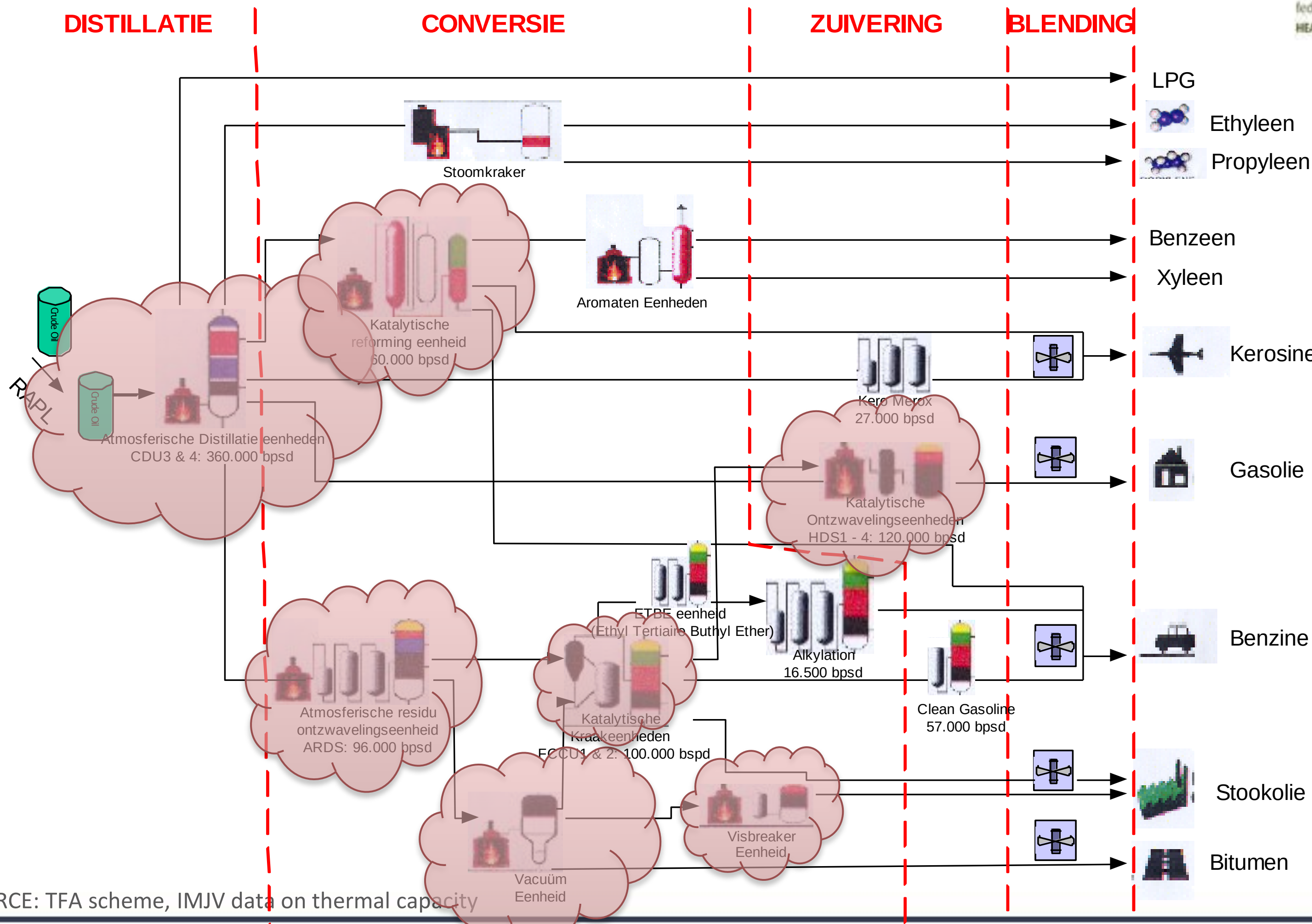
process furnaces and boilers, gas turbines, FCC regenerators, flare system and incinerators



SOURCE : www.concawe.be, the potential for application of CO2 capture and storage in EU oil refineries

Most important processes → energy use → emissions

process furnaces and boilers, gas turbines, FCC regenerators, flare system and incinerators



SOURCE: TFA scheme, IMJV data on thermal capacity

Belgian CO_2 emissions decreased by 7,55% since 1990, slightly below the 8% Kyoto 2010 objective

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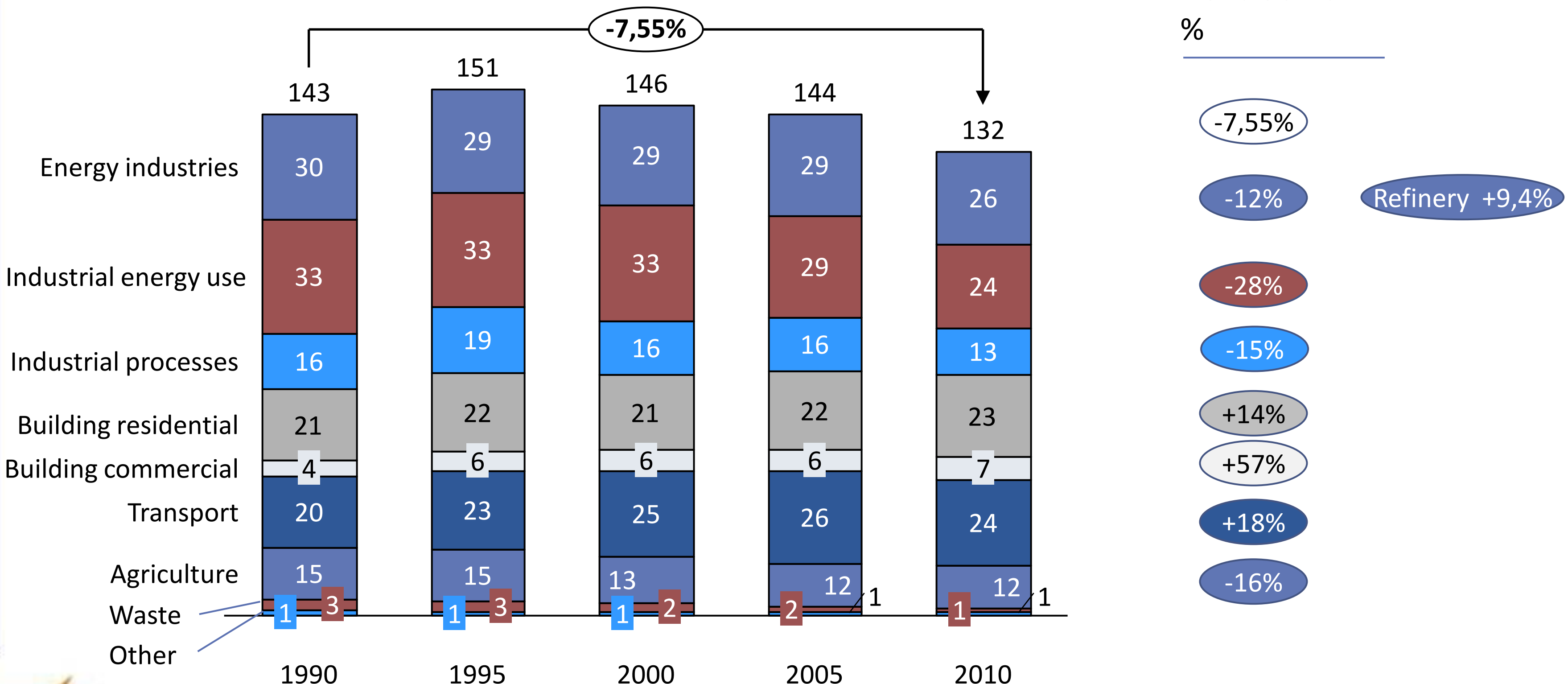
Belgium CO_2 emissions in the 2010 NIR CRF
($MtCO_2e$)



NOTE: Excluding LULUCF, international bunkers and biomass
SOURCE: NIR CRF v1.4

Refining capacity of refinery sector remained stable, applied destillation capacity decreased

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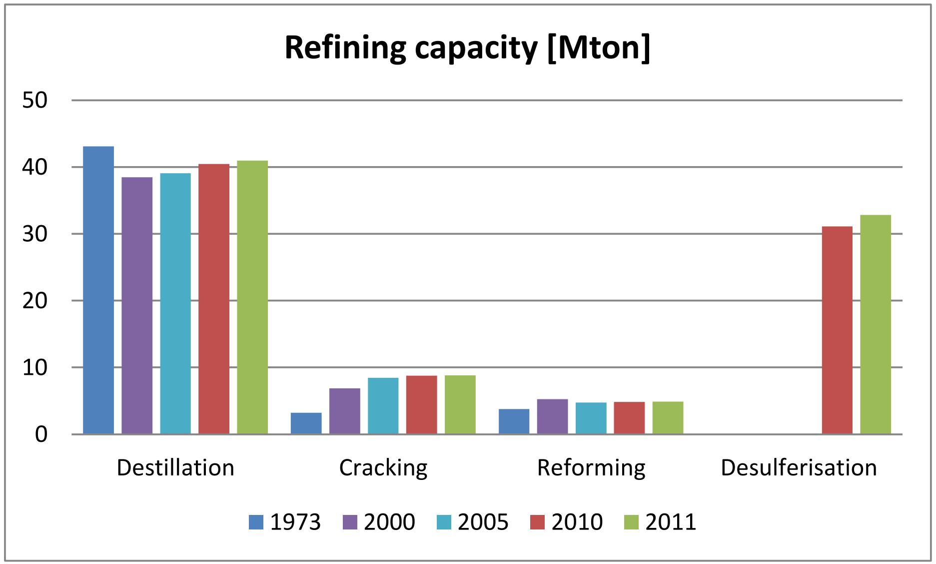
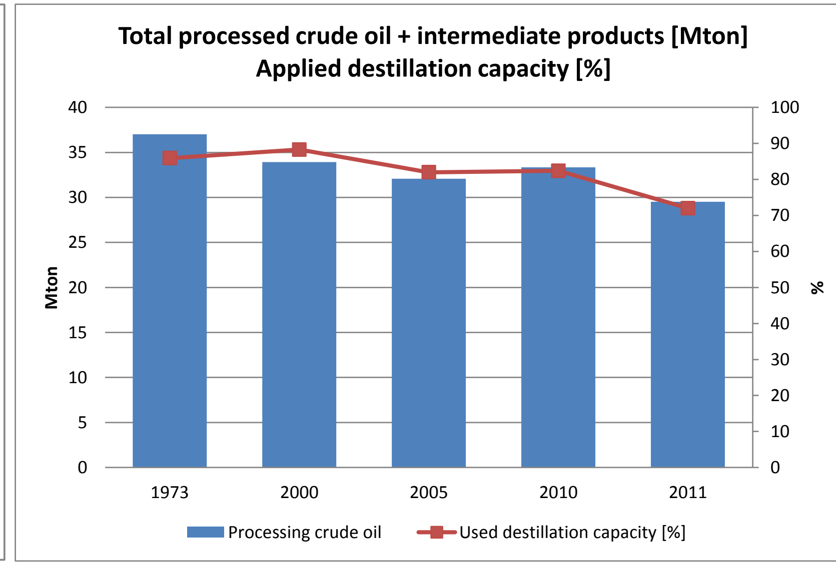
Destillation capacity remained stable from 1973-2010
Cracking capacity almost tripled
Applied destillation capacity decreased from 86 to 72%

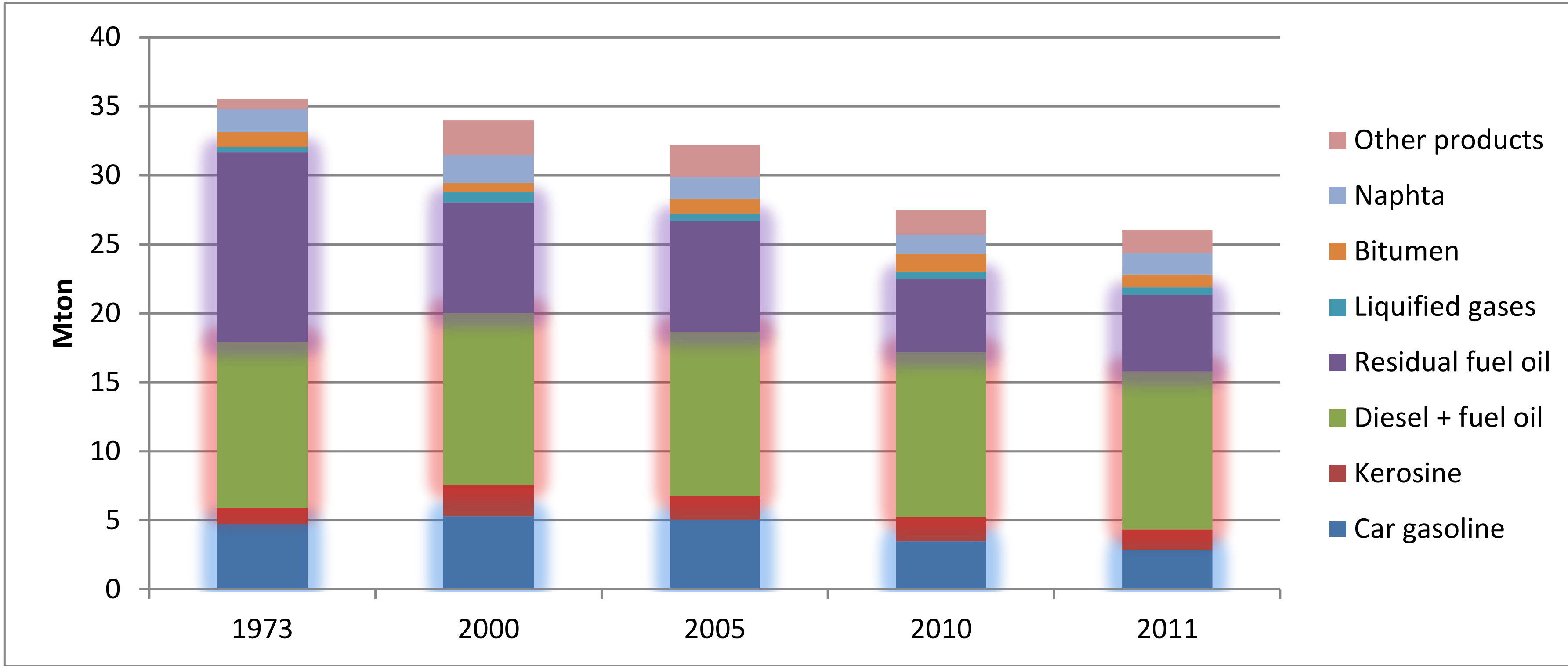




SOURCE : www.petrolfed.be – jaarverslag 2011

Belgium netto production decreased, Gasoline, residual oil ↓ - transport diesel ↑

Percentage 'diesel + fuel oil' increased from 34% in 1973 to 44% in 2010



SOURCE : www.petrolfed.be – jaarverslag 2001 – 2006 - 2011

Diesel to gasoline market ratio in EU-27 (1/3)

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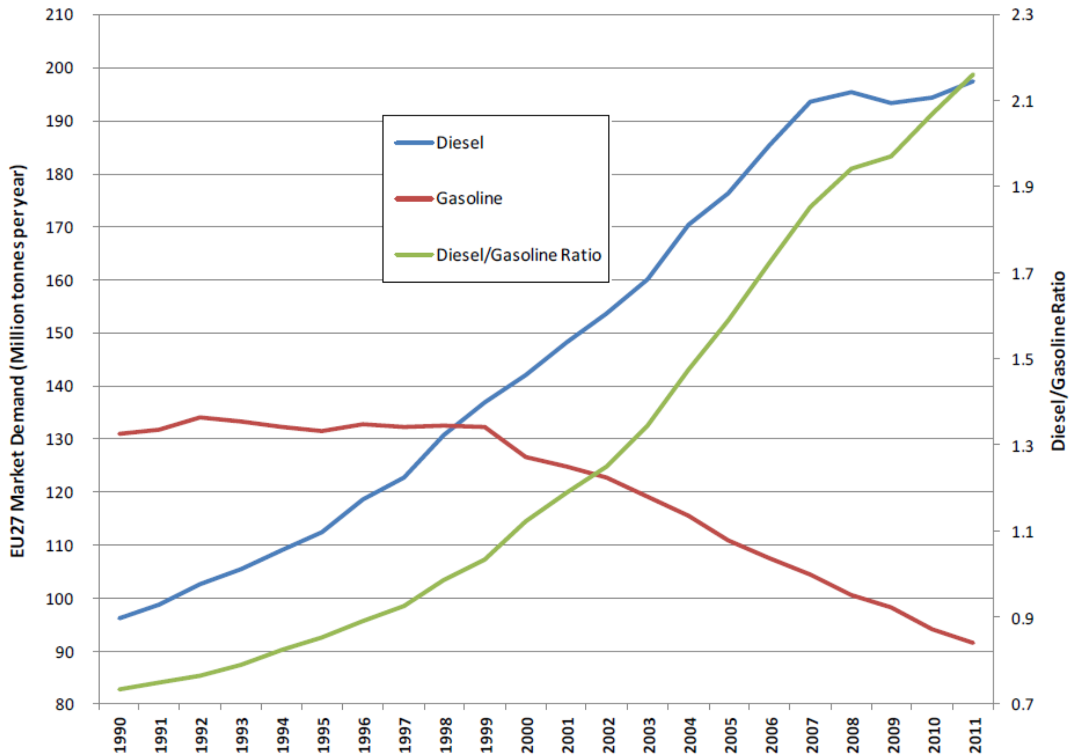
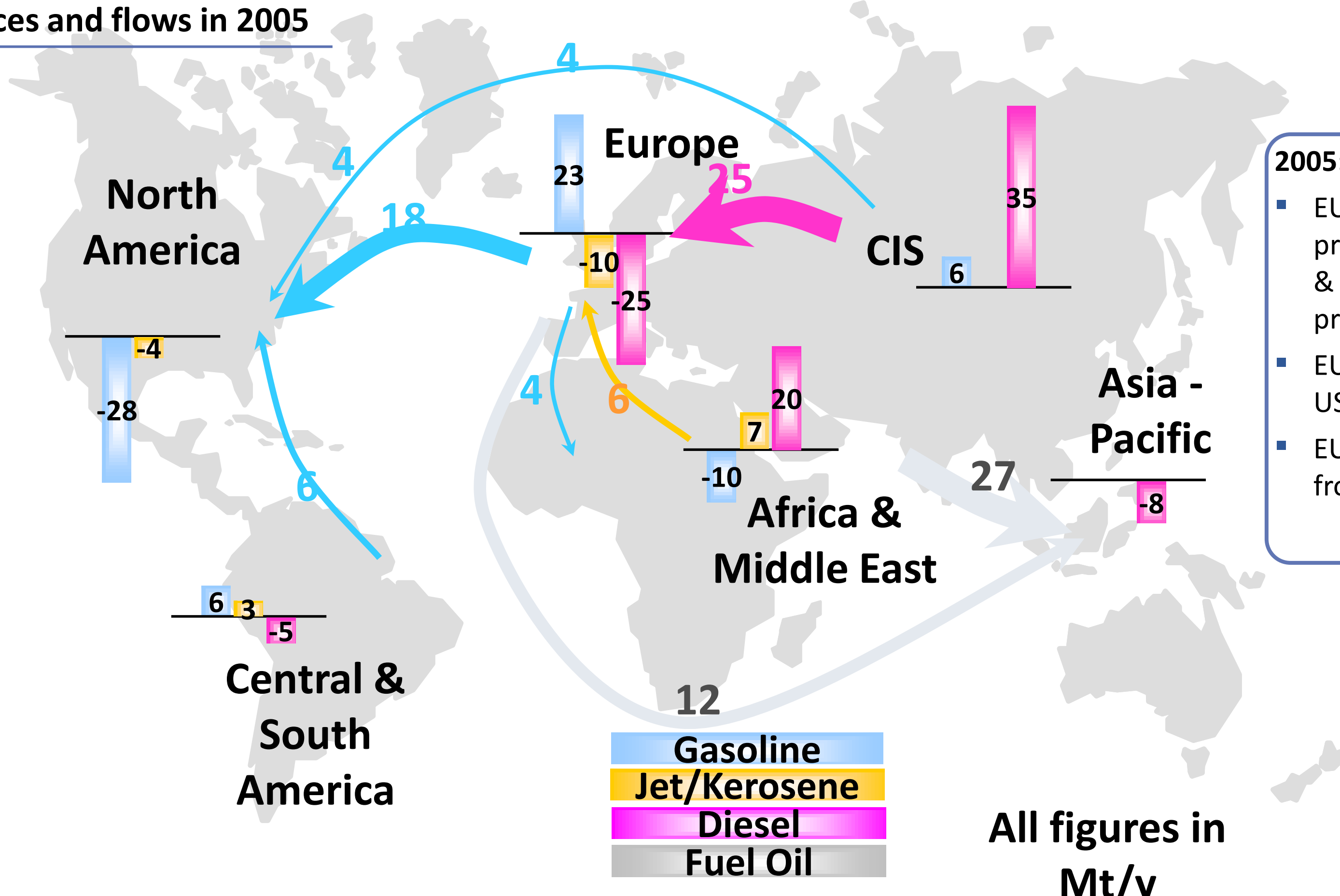
Diesel use increased dramatically in EU-27, gasoline use decreased



SOURCE : www.concawe.be, EU refinery energy systems and efficiency

Diesel to gasoline market ratio in EU-27 (2/3)

Imbalances and flows in 2005



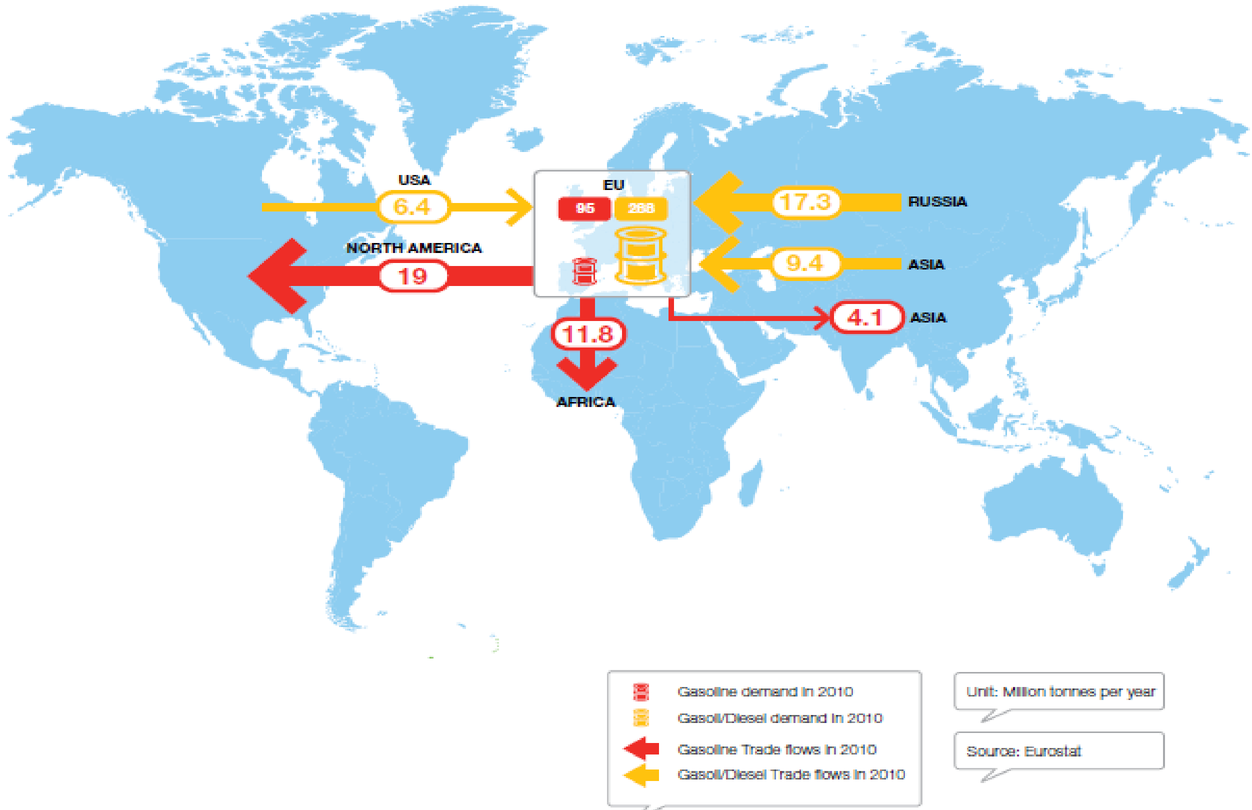
2005:

- EU: gasoline over-production, kerosene & diesel under-production
- EU export gasoline to USA
- EU import diesel from Russia, USA

SOURCE : ATC PTIT Refining Trends for the future a 2020, Axens IFP Group Technologies

Diesel to gasoline market ratio in EU-27 (3/3)

Major gasoline and diesel trade flows to and from EU → Asia new importer of EU gasoline



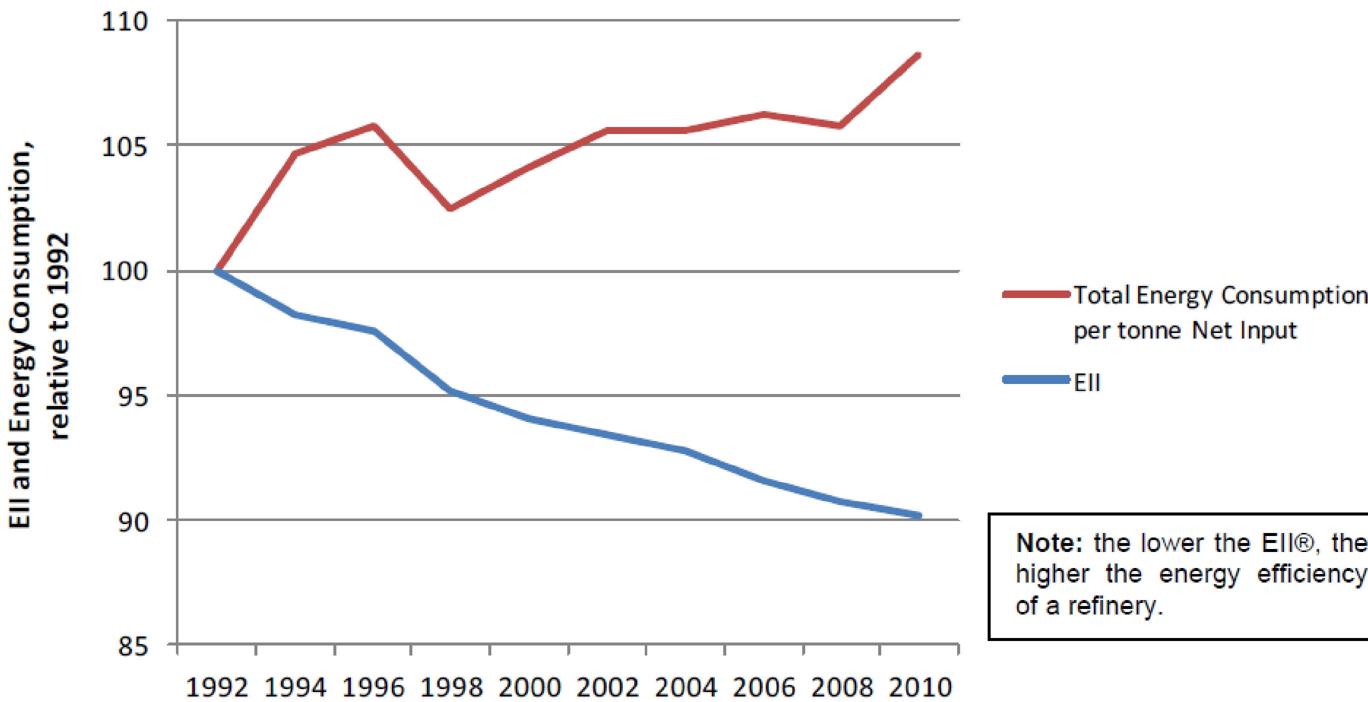
2010:

- EU: gasoline over-production, gasoil & diesel under-production
- EU export gasoline to USA & Asia
- EU import diesel from Russia, Asia, USA
- Gasoline from not EU ≠ gasoline from EU

SOURCE : Europia, Annual report 2011

EU-27 refineries energy use and energy efficiency

Energy use vs energy efficiency in refinery sector (1990-2010)
Higher energy consumption, but also higher efficiency because of more complex processes



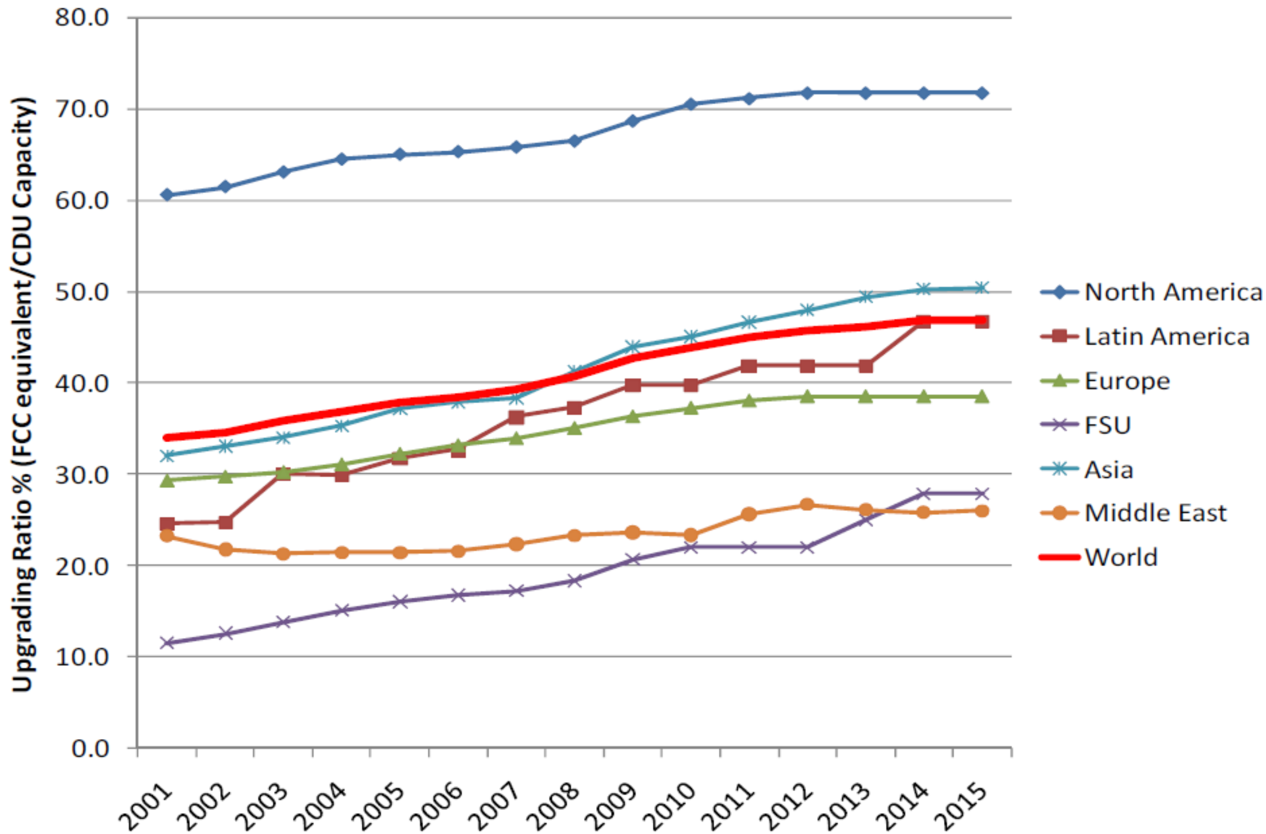
Note: the lower the EII®, the higher the energy efficiency of a refinery.

- EII: Energy intensity index developed by HSB Solomon Associates LLC
- EII is ratio of real energy use vs reference energy use
- Av. improvement:
  - industry: 0,8 %/y
  - refinery: 0,6 %/y
- Reference energy use is calculated per type of installation (AD, VD, desulf, reformer, …)

SOURCE : www.concawe.be, EU refinery energy systems and efficiency, http://solomononline.com/documents/Whitepapers/EII_AM_WWW.pdf

EU-27 refineries energy use and energy efficiency

Increase in upgrading ratio driving the market

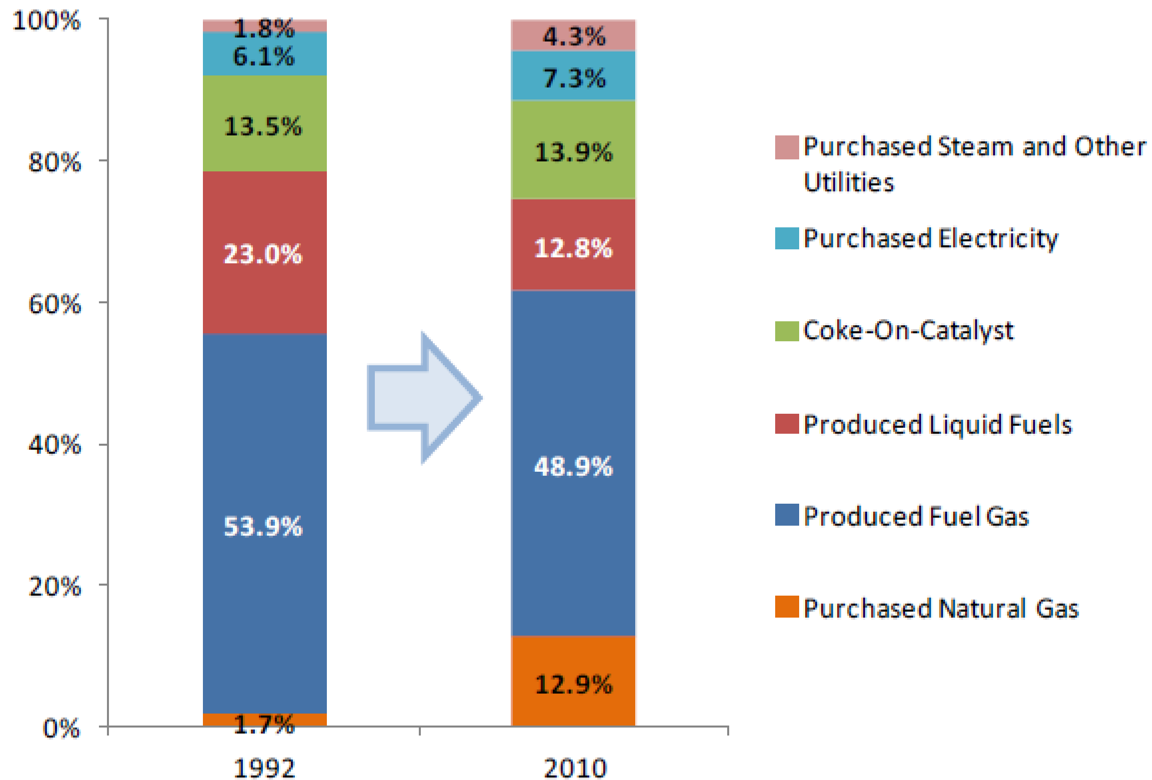


- Upgrading ratio: FCC equivalent / CDU capacity
- EU and USA → not increasing
- Asia → strong increase predicted

SOURCE: http://petrofed.winwinhosting.net, FACTS SEP 2008

EU-27 change in energy mix used in refineries

Switch from heavy fuels to natural gas

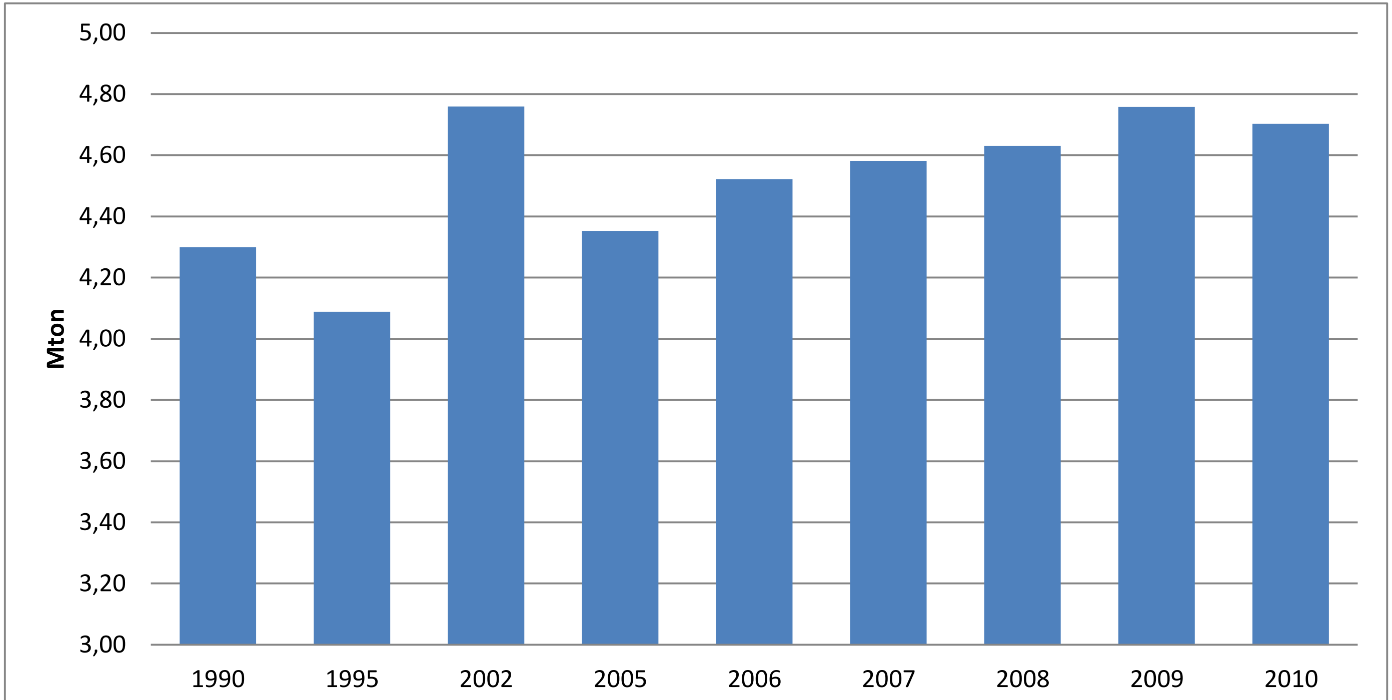


- Why is this shift happening:
  - Price
  - (because of GHG reductions) → small impact previous years
  - also air pollutant reductions
  - CHP implementation
  - Low-S fuel → sold
  - Others ?

SOURCE : www.concawe.be, EU refinery energy systems and efficiency

Belgium: GHG emissions have increased slightly since 1990

GHG emissions in refinery sector (1990-2010)
($MtonCO_2e$)

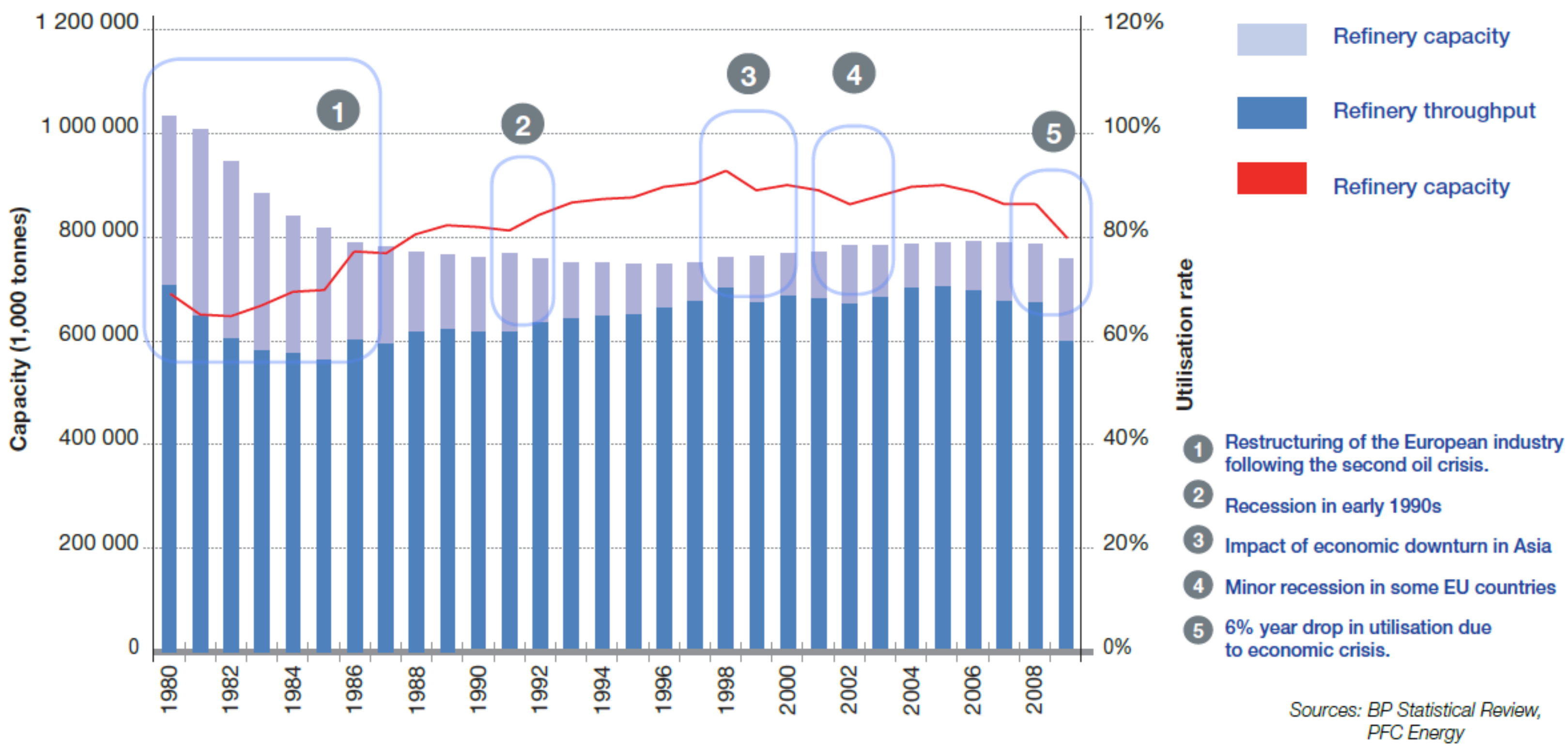


- All GHG emissions covered by ETS
- Despite decrease in processed crude oil → GHG emissions increase
  - Increased demand for diesel, lower S-content
  - Intermediate products (high S-content)
  - Percentage diesel/total destilled
  - Change in crude oil mix

SOURCE: FLA CRF v1.6

EU-27 refining capacity: prospects (1/5)

Impact of external shocks (1980-2009)



SOURCE: Europia, Roadmap 2030-2050

EU-27 refining capacity: prospects (2/5)

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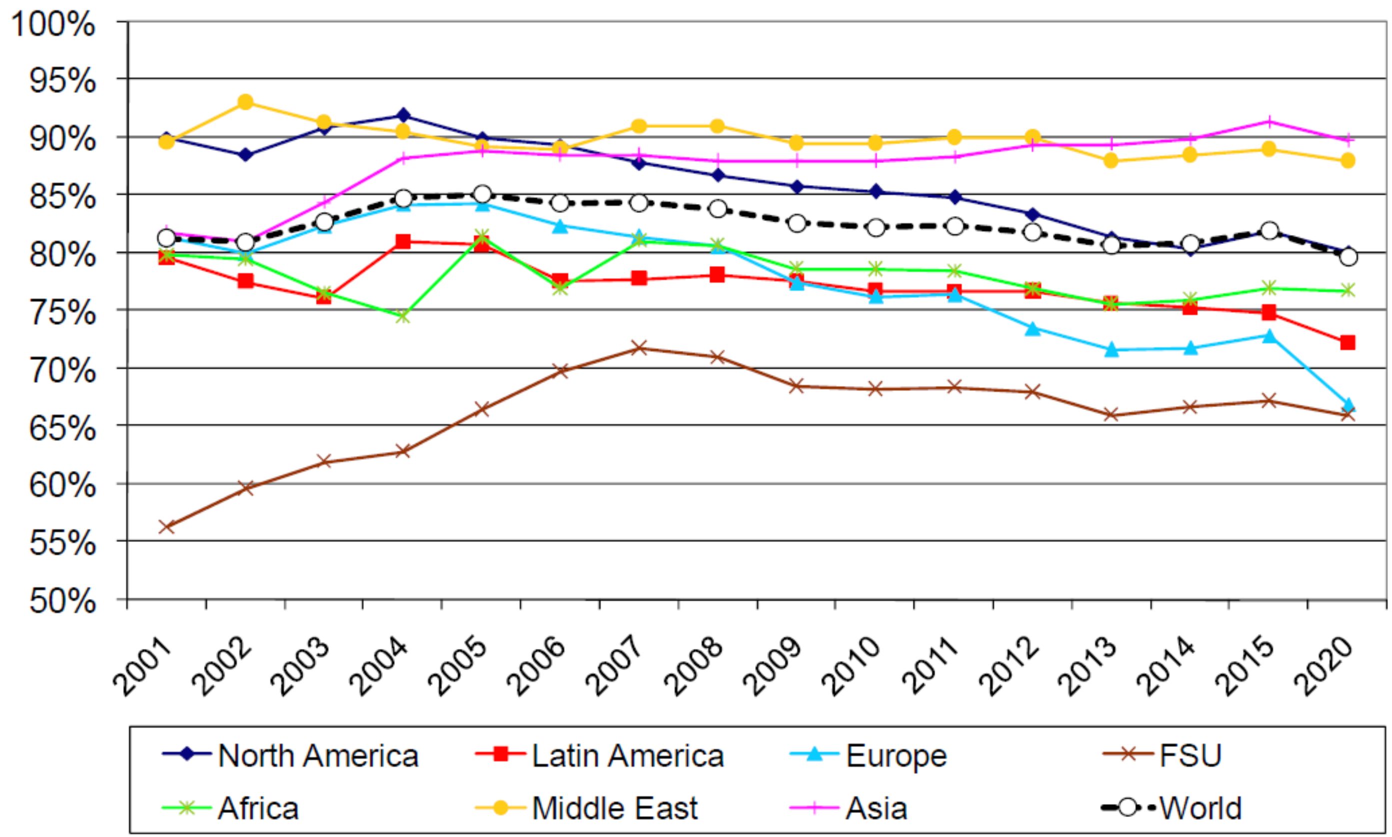
World refinery utilization rates



SOURCE: http://petrofed.winwinhosting.net, FACTS SEP 2008

EU-27 refining capacity: prospects (3/5)

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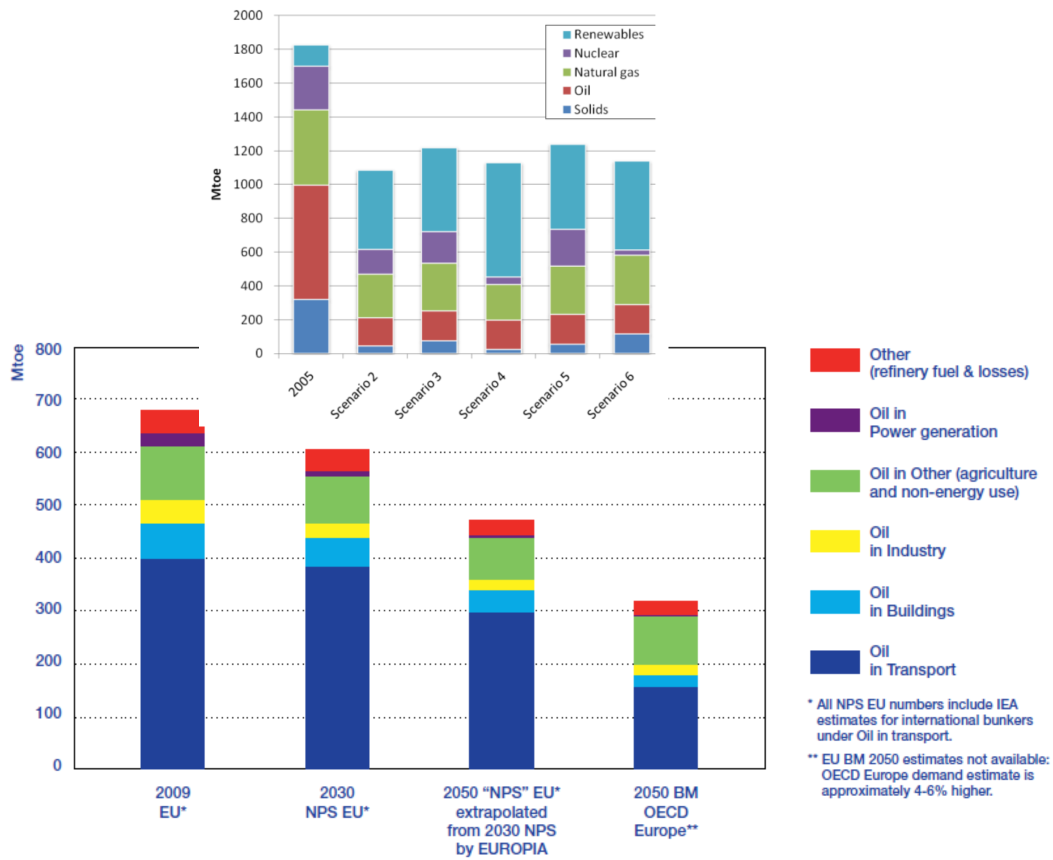
By 2030 oil demand could decline by 11% and by 30% in 2050 versus 2009



- From EU Roadmap 2050:
- Oil is likely to remain in the energy mix in 2050 for long-distance passenger and freight transport in all scenario's
- Refinery sector will remain in EU, but sector must be able to adapt capacity levels to economic realities

SOURCE: EU Roadmap 2050 Energy (upper), Europia, Roadmap 2030-2050 (lower)

EU-27 refining capacity: prospects (4/5)

Policy scenarios deriving from the Competitive Low carbon Roadmap literally shape the end of the refining business as we know it today.

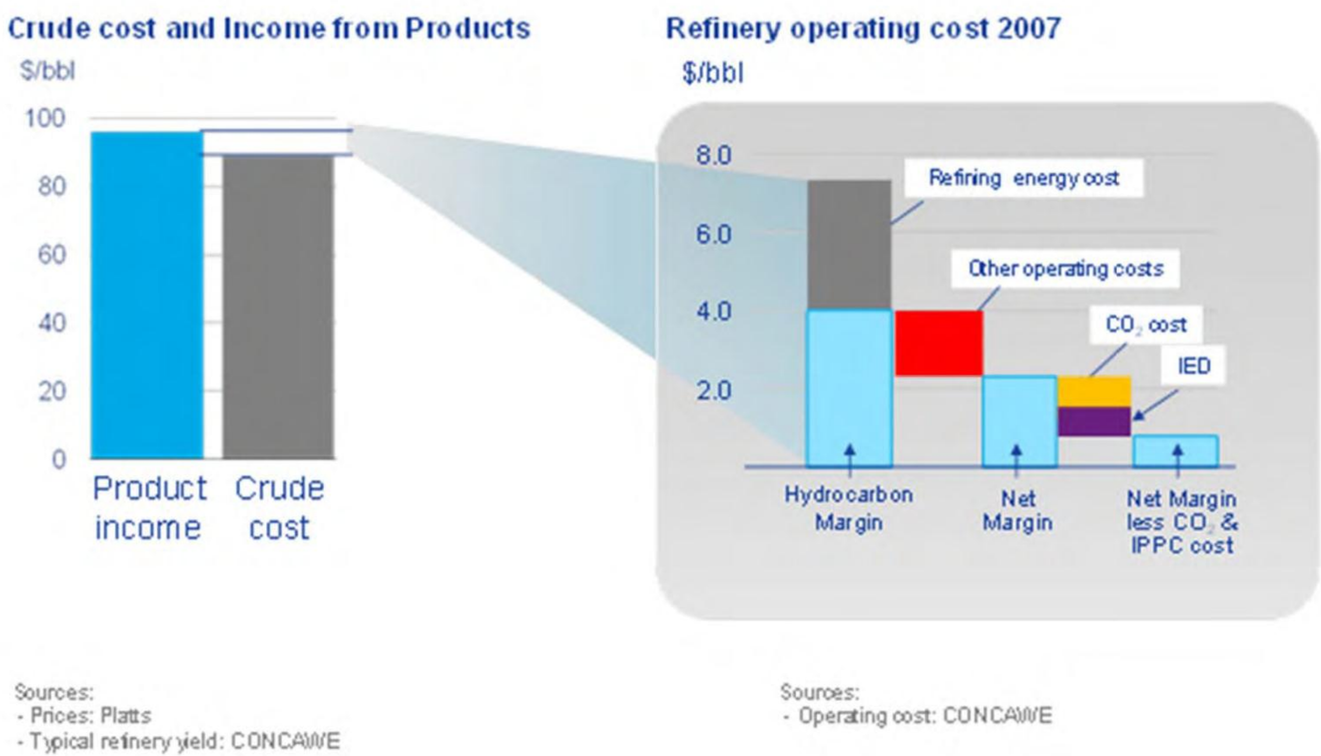
EU refining capacity will need to adapt to EU demand decrease

GHG compared to 1990	2005	2030	2050
Total	-7%	-40 to -0.44%	-79 to -82%
Sectors			
Power (CO2)	-7%	-54 to -68%	-93 to -99%
Industry (CO2)	-20%	-34 to -40%	-83 to -87%
Transport (incl. CO2 avation, excl. Maritime)	30%	20 to -9%	-54 to -67%
Residential and serices (CO2)	-12%	-37 to -53%	-88 to -91%
Agriculture (non-CO2)	-20%	-36 to -37%	-42 to -49%
Other non-CO2 emissions	-30%	-72 to -73%	-70 to -78%

SOURCE: Europia, Roadmap 2030-2050

EU-27 refining capacity: prospects (5/5)

EU legislation impacts directly EU refining costs and margins compared to other regions



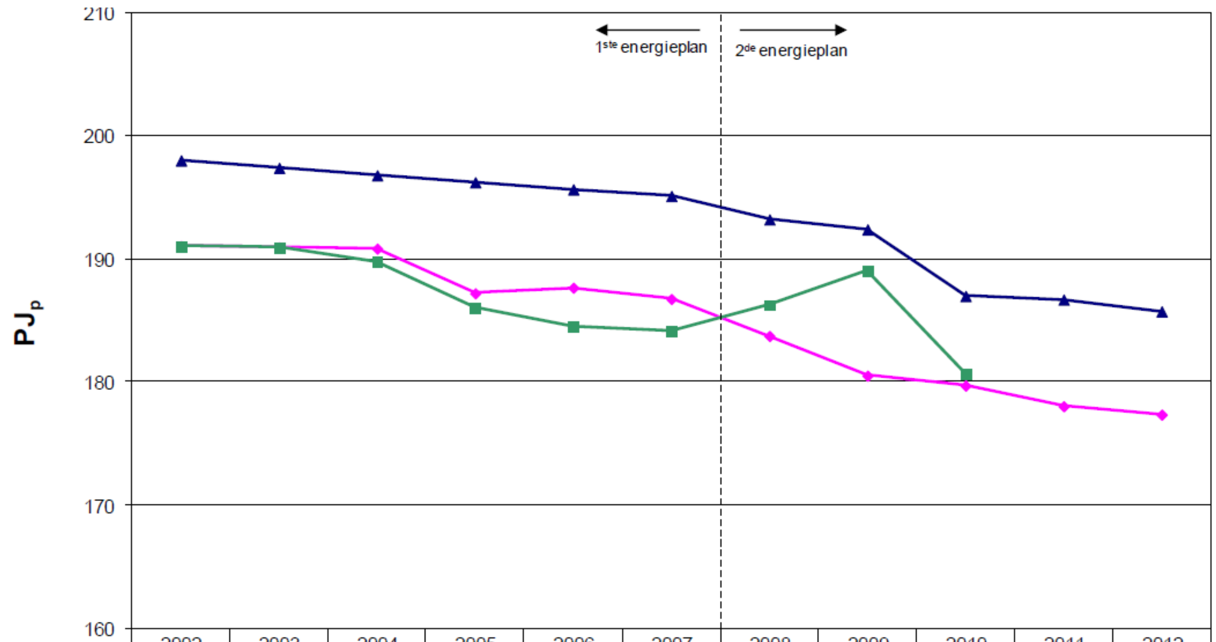
- Force capacity reduction
- EU competetive disadvantage, poor investment outlook
- Threat for industrial value chain → petrochemicals?
- Labour cost BE very high compared to neighbouring countries
- IED: Industrial Emissions Directive, IPPC BAT

SOURCE: Europia, Roadmap 2030-2050

Belgian refining capacity: prospects (1/3)

Benchmark convenant (Steel + refineries) → taking into account complexity

Evolution primairy energy use of the refineries and steel companies at constant production level 2010



	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Wereldtop	198,0	197,4	196,8	196,2	195,7	195,1	193,2	192,4	187,0	186,7	185,7
Bedrijven volgens Plan	191,1	191,0	190,9	187,2	187,7	186,8	183,7	180,5	179,7	178,0	177,4
Bedrijven volg. Monitoring	191,1	191,0	189,8	186,1	184,6	184,2	186,3	189,0	180,7		

SOURCE: Benchmarkconvenant, www.benchmarking.be: jaarverslag 2010

Belgian refining capacity: prospects (2/3)

Trends apparent at world, EU and Belgian level

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World

- Global refining capacity surplus set to reach 6 million b/d by 2016
- 'Capacity creep' by debottlenecking and improvement in equipment reliablility → higher capacity
- Utilization rate is decreasing
- USA no new capacity for decades, decrease in operating refineries
- Challenges:
  - Crude oil sourcing, security
  - Crude oils become heavier
  - Margin improvement
  - Environmental issues

EU

- Competitiveness under pressure
  - Net margin decreasing
  - Overcapacity
  - Energy prices rise: gas prices
  - Costs of environmental regulation rise
  - Capacity increase in Asia
- Market asks for more diesel, less S content (liquid fuels in total) → higher energy use, more complex refineries
- Western Europe: shortage diesel, too much gasoline production. Gasoline export more difficult → ethanol additive
- from 1995 to 2007: -22 refineries BUT average crude capacity per refinery increased by 16%

Belgium

- Complexity of refineries increased
- Net margin decreasing since 2008
- Labour costs very high:
  - FR vs BE: - 39 %
  - NL vs BE: - 31 %
- Today Be refinery sector very competitive in terms of energy efficiency
- Directly linked with petrochemical activities in 'Port of Antwerp'
- Survival of the fittest = the most complex, efficient refineries ? Refineries that can adapt ?
- Production Be = 2x own use in Be

SOURCE: ECN: Raffinaderijen naar 2030, http://www.platts.com/RSSFeedDetailedNews/RSSFeed/Oil/8279079, www.petrolfed.be (o.a. Nieuwsbrief N°3 2011), VITO & Econotec: KEY ASSUMPTIONS FOR SUBSEQUENT CALCULATION OF MID AND LONG TERM GREENHOUSE GAS EMISSION SCENARIOS IN BELGIUM; Europia: STUDY ON OIL REFINING AND OIL MARKETS (Pervin & Gertz, Inc.)

Belgian refining capacity: prospects (3/3)

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New markets on the long term

- Flexi refinery: handle wide range of crude oils, from high naphtenic acid to high S levels
- Product mix improvement:
  - shift to mere production of feedstock for petrochemical sector →capacity decrease necessary?
  - Next era: strong integration with biorefining
- Bio-refinery future
  - Co-process feedstocks of bio-origin, production of second generation biofuels
  - Bio-substitutes for petroleum derivates, green chemistry, biofuels, bioplastics
  - Can refineries be adapted to bio-refineries?
    - Large-scale production of biofuels from algae
    - Alcohol production from ligno cellulosic material
    - Pyrolysis of biomass and gasification of biomass, pet-residue and coke
  - Location Belgium for bio-refining → not ideal ?
    - Biomass availability limited
    - Import by bulk transport more difficult than crude oil
- Can refineries reinvent themselves ?

SOURCE: VITO and http://petrofed.winwinhosting.net

Content – Industry sector - refineries

- Summary and references
- Context and historical trends
- **Methodology**
- Details of the ambition levels and costs per lever
- Resulting scenarios

Industry is one of the various sectors studied in the process of constructing the low carbon scenarios

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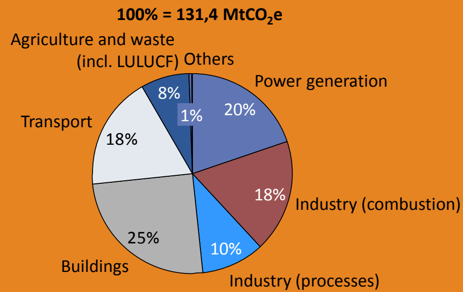
Focus of the consultations

1 Bottom up study by sector of feasible GHG reductions

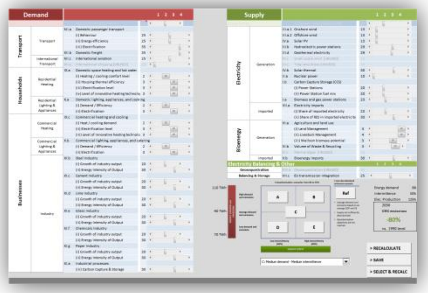


2 Test each sector with external experts

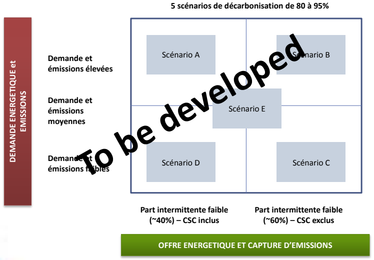
Consultations by sector with external experts

Discussions with international experts

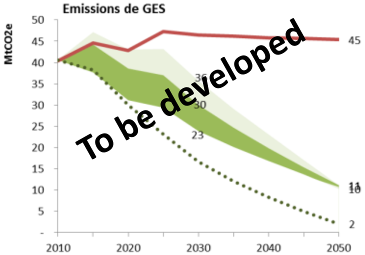
3 Adapt the DECC model to Belgian data and improve it



4 Define and model various scenarios



5 Detail key implications for these scenarios

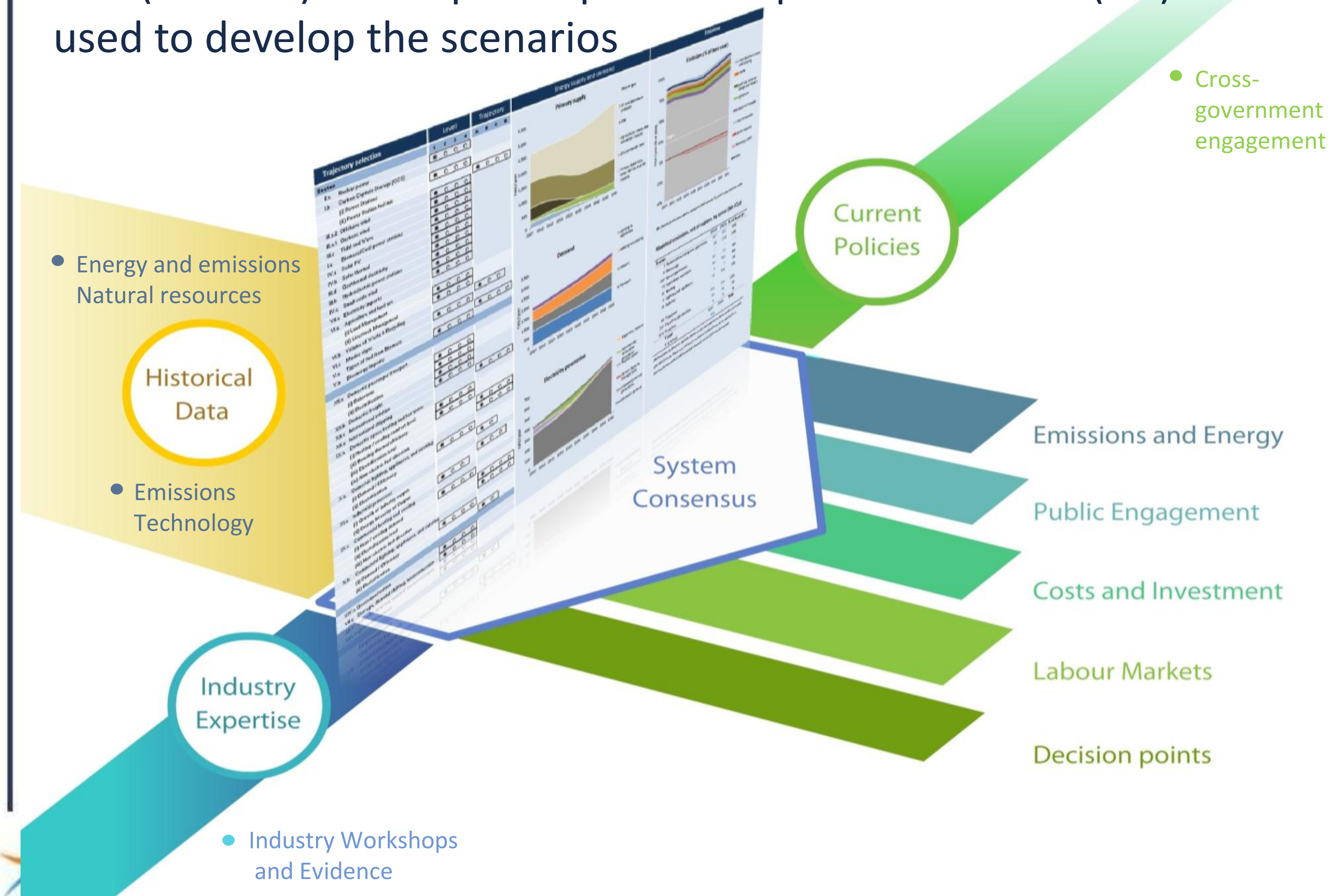


6 Review conclusions with the steering and high level consultation committees

- Federal administration
- Industry
- Civil organizations
- Academics
- …

Note: Orange = covered by this workshop

The Open-source Prospective Energy and Emissions Roadmap Analysis tool (OPE²RA) developed in partnership with the DECC (UK) will be used to develop the scenarios



OPE²RA balances demand and supply based on fixed input parameters as well as modifiable levers

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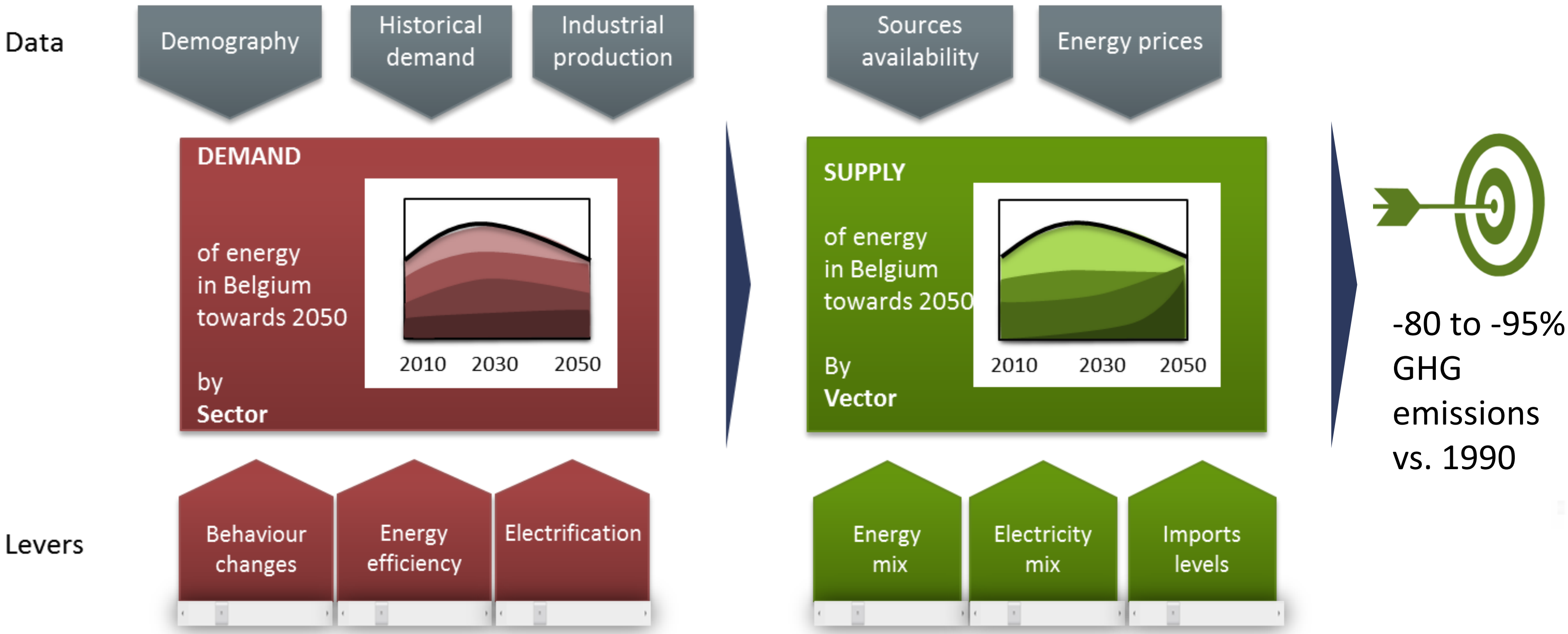

Industrial sectors modelled

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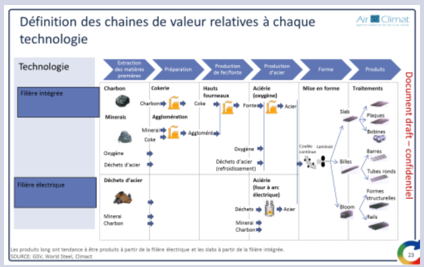
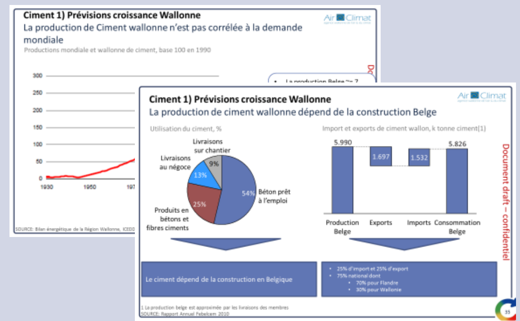
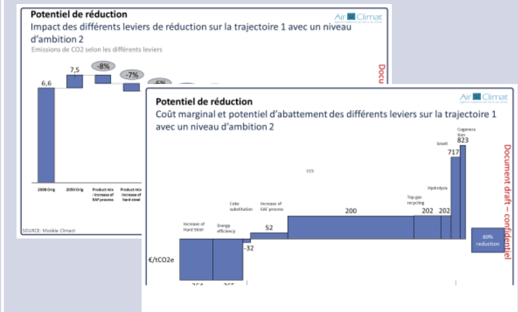
Sector	Consultation
Refineries	Belgian Petroleum Federation
Iron & Steel	Steel Federation
Chemicals	Essenscia
Paper	Cobelpa
Food	Fevia
Bricks & Ceramics	Bricks Federation
Non-ferrous metals	Agoria
Cement	*Low Carbon Wallonia Roadmap*
Lime	*Low Carbon Wallonia Roadmap*
Glass	*Low Carbon Wallonia Roadmap*

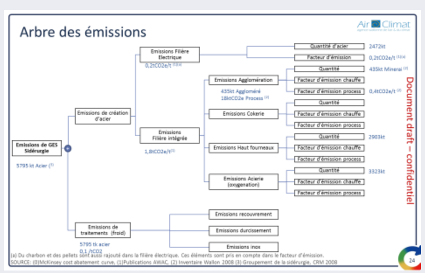
A detailed analysis is performed for each industrial sector

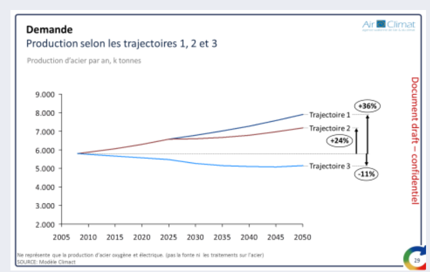
	Understanding the industry	Modelling demand trajectories	Modelling trajectories with intensity levels + CCS
Analyses	Definition of the value chain	Analyses of growth and competitivity	Potential of CO_2 reduction incl. costs
Results	Modelling the emissions tree	Demand trajectories	Trajectories with different intensity levels + CCS

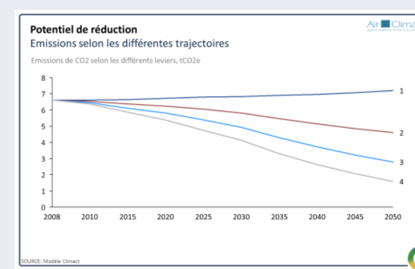












Levers are applied in a sequential manner on an indepth modeling

Chemical industry example

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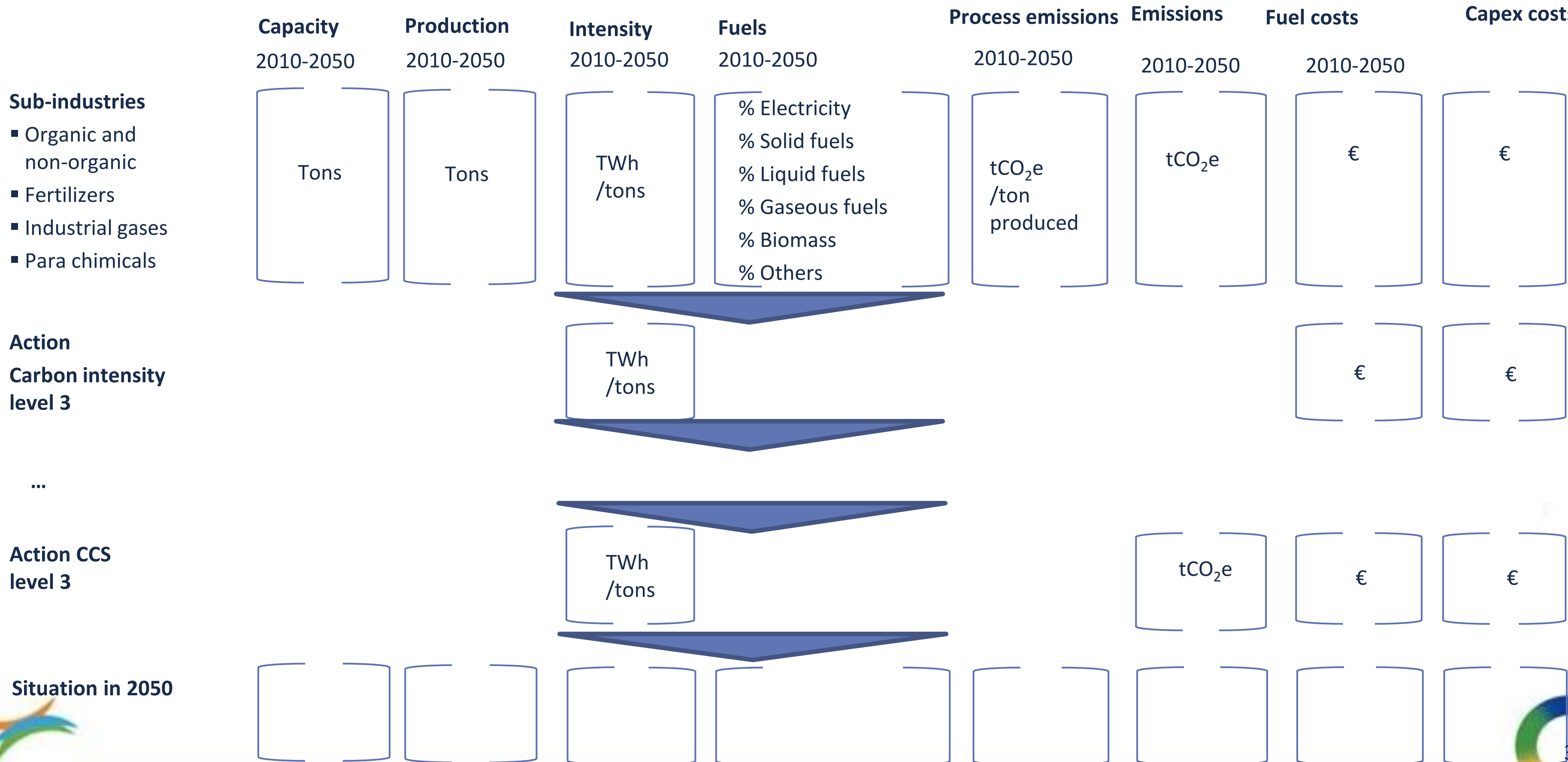
Modeling logic for the chemical industry



4 ambition levels are defined for each lever

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation) • No additional decarbonisation efforts/policies • What will become a « Reference scenario »	• **Moderate effort** easily reached according to most experts • Equivalent to the development of recent programs for some sectors	• **Significant effort** requiring cultural change and/or important financial investments • Significant technology progress	• **Maximum effort** to reach results close to technical and physical constraints • Close to what's considered reachable by the most optimistic observer

One of the key objectives of the consultation is to support the estimation of these levels based on existing expertise

Content – Industry sector – refineries

- Summary and references
- Context and historical trends
- Methodology
- **Details of the ambition levels and costs per lever**
- Resulting scenarios

Growth prospects Belgium (1/2)

3 trajectories influencing energy demand will be modelled compared to reference

Possible growth scenarios
European population: 1%

Linked to demand prospects in other sectors. Belgian refineries exporters of gasoline.

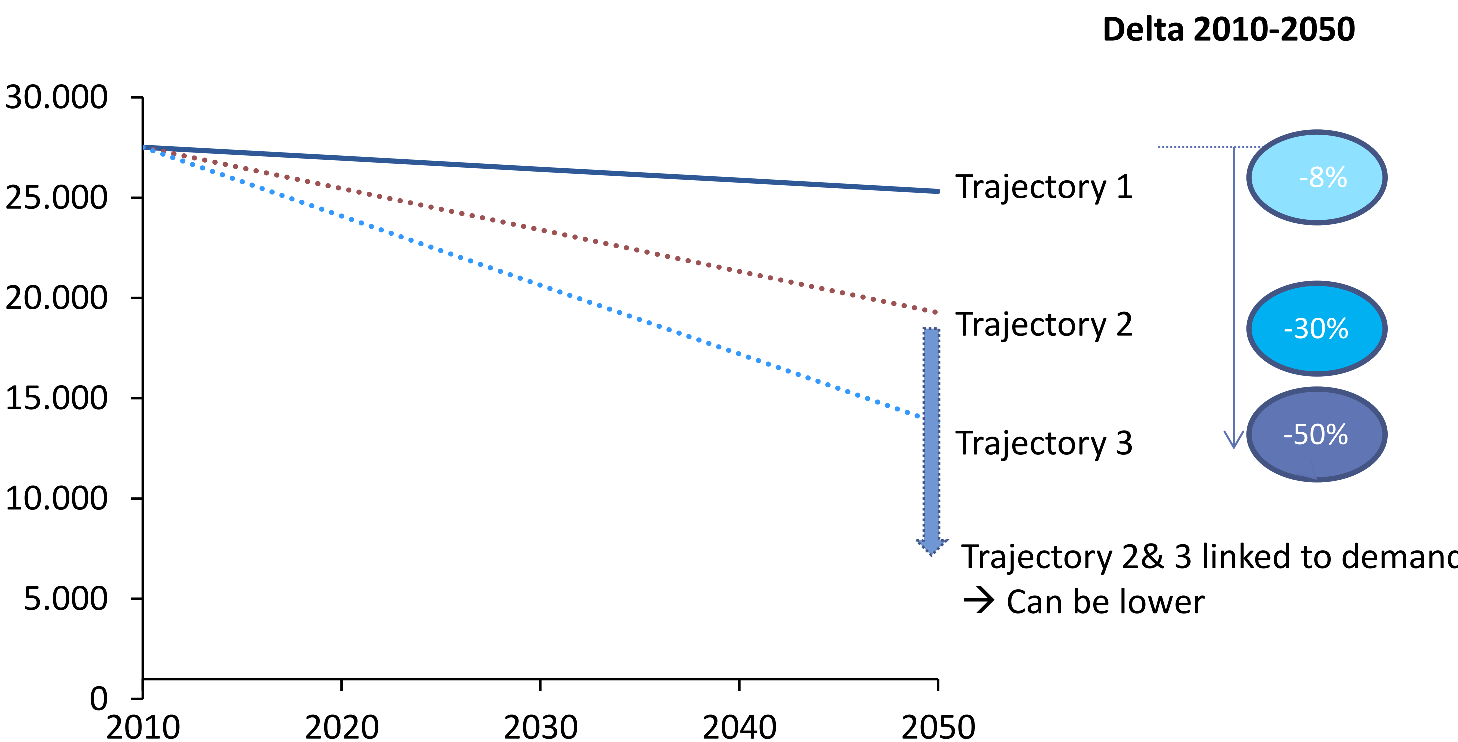
Background: low-carbon world, not only EU or Be

	Refineries
Trajectory 1	• Reference trajectory from study 100% RE in Belgium, only taking into account 202020 goals of EU climate-energy package • CAGR -8% in 2050
Trajectory 2	• Trajectory linked to outcome fuel demand other sectors when at same trajectory level 2 • At least: CAGR -30% in 2050 cf. Europia Roadmap 2050
Trajectory 3	• Trajectory linked to outcome fuel demand other sectors when at same trajectory level 3 • At least: CAGR -50% in 2050

Growth prospects Belgium (2/2)

Production according to trajectories 1, 2 et 3

Production of total final products, ktons



- Trajectories 2 & 3 for refinery sector will be linked with trajectories for other sectors (esp. Transport, industry)
- Background: low-carbon world, not only EU or Be.

Reduction potential

Reduction levers are additional and applied in the following order

Methodology

Product mix

- Augmenting the proportion of product which require less CO_2 for production → opposite movement is going on

Use sweeter crude mixes

Biorefineries

[Beyond scope] Sustainability of biomass

Energy efficiency

- Reduce mechanical and thermal losses
- Recuperate thermal energy (CHP)

Energy efficiency

CHP

BAT application

Process improvements

- Modification of processes

Advanced distillation

Advanced catalysts

Thermal cracking

Flare gas recovery

Fuel switching

- Towards fuels which emit less CO_2

Fuel vs. gas

Fossil fuels vs. biomass

End of pipe

- Carbon capture and storage

CCS

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Energy efficiency (1/5)

Reduce thermal losses

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- How to reduce thermal losses:
  - Heat recovery from product streams, particularly from distillation columns
  - Boiler water and feed preheating using waste heat
  - Installation of additional levels of refrigeration

- Total reduction potential of efficiency measures = 20-50% (SERPECCC study), payback period generally less than 2 years, but
- Complexity and high level of process integration → implementation difficult, mostly integrated during turnaround or planned shutdown of a unit.

- Sector: gradual renewal of units is common practice
- BPF: “Belgian refineries are in top 10 of most efficient refineries”

SOURCE: SERPECCC study

Energy efficiency (2/5)
Reduce thermal losses

- In detail: what measures can be implemented:
  - Process control and energy monitoring: use of plant-wide energy optimization model to optimize the flows of intermediates, hydrogen, steam, fuel and electricity use, integrated with an energy monitoring system.
    Efficiency gains: 2-8% → Belgium 4%
    Cost: -89 €/ton CO_2
  - Process integration or pinch technology: find optimum site-wide utility levels by integrating heating and cooling demands of various processes
    Efficiency gains: 20-30%, economically feasible: 10-15% → Belgium 12%
    Cost: -69 €/ton CO_2
  - Steam generation and distribution : steam production correctly dimensioned, steam trap maintenance
    Efficiency gains: Belgium 2%
    Cost: -84 €/ton CO_2

SOURCE: SERPECCC study

Energy efficiency (3/5)

Reduce thermal losses

- In detail: what measures can be implemented:
    - Efficient drive systems: electric motors (pumps, compressors, fans, …) represent 80% of electricity use →look at entire motor system, matching speed and load, correct sizing, upgrading

      Efficiency gains: Belgium 16%

      Cost: -84 €/ton CO_2
    - Power recovery FCC: recover energy from elevated pressure

      Efficiency gains: Belgium 0%

      Cost: -63 €/ton CO_2

SOURCE: SERPECCC study

Energy efficiency (4/5)

Reduce thermal losses → benchmark convenant: 0,75 %/y

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation) • AV efficiency impr. 0,25 %/y 2010-2050 • **10% efficiency improvement**	• **Moderate effort** easily reached according to most experts • Excluding electricity use • AV efficiency impr. 0,5 %/y 2010-2050 • **18% efficiency improvement**	• **Significant effort** requiring cultural change and/or important financial investments • Including electricity use • AV efficiency impr. 0,9 %/y 2010-2050 • **30% efficiency improvement**	• **Maximum effort** to reach results close to technical and physical constraints • Maximum process integration • AV efficiency impr. 1,7 %/y 2010-2050 • **50% efficiency improvement**

- Note: Building integrated scenario's we will take into account that due to demand decrease, the refinery industry will be less inclined to make energy improvement investments

SOURCE: SERPECCC study

Energy efficiency (5/5)

CHP potential, cost 22 €/ton CO_2

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **0% extra implementation of CHP**	• **10% extra implementation of CHP**	• **15% extra implementation of CHP**	• **20% extra implementation of CHP**

- Note: Building integrated scenario's we will take into account that due to demand decrease, there is less potential for CHP

SOURCE: VITO

Process improvements (1/4)

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- In detail: what measures can be implemented:
  - CDU: Theoretically 3 MJ/bbl needed for crude destillation = 3% of conventional proces that uses 105 MJ/bbl →major savings possible
    - Advanced distillation: e.g. Progressive Crude Distillation: redesigning the crude preheater and the distillation column → especially suited for new construction or large crude distillation expansion projects

    Reduction energy use : Belgium 7% (19-30% reduction in CDU)

    Cost: -65 €/ton CO_2
    - Dividing wall destillation: 30% reduction energy use CDU
    - Fractionating, thermical and mechanical integration destillation columns

    Reduction energy use: to 37 MJ/bbl or 65% reduction in CDU

    Cost: 800 $\$_{2005}$/bbl
    - Thermal cracking processes (available > 2020): switch from destillation to cracking → no double counting with 'advanced destillation' !

    Reduction energy use : 15% compared to total use

SOURCE: SERPECCC study, ECN Raffinaderijen naar 2030 (Haddad & Manley, 2008)

Process improvements (2/4)

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•In detail: what measures can be implemented:

- FCC: uses vacuum destillates (vacuum gasoil) as input → LPG, gasoline, olefines as output
  - Under pressure, because of overproduction of ligth fractions in EU.
  - Advanced catalysts for Fluid Catalytic Cracker

  Reduction energy use : 2%

- Flare gas recovery: installing recovery compressors and collection and storage tanks combined with new ignition systems

  Reduction energy use: Belgium 2%

  Cost: -83 €/ton CO_2

SOURCE: SERPECCC study, ECN Raffinaderijen naar 2030

Process improvements (3/4)

- In detail: what measures can be implemented:

  - Fouling mitigation of heat exchangers
    Reduction energy use : 2%
  - Advanced catalysts for hydroprocessing
    Reduction energy use : 2%
  - Biodesulpherisation as alternative to hydrodesulpherisation: lower temperature, atmospheric pressure
    Reduction energy use : unknown

SOURCE: Icarus-4 refineries

Process improvements (4/4)

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **Not applied**	• **Not applied**	• **Applied starting from 2030, 15% reduction energy use**	• **Applied starting from 2020, 23% reduction energy use**

SOURCE: SERPECCC, Icarus-4

Fuel switching : Switch to gas

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Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **0% extra switch to gas > 2010**	• **25% extra switch to gas > 2010**	• **50% extra switch to gas > 2010**	• **Up to 100% switch to gas**

SOURCE: VITO

Fuel switching : Switch to biomass

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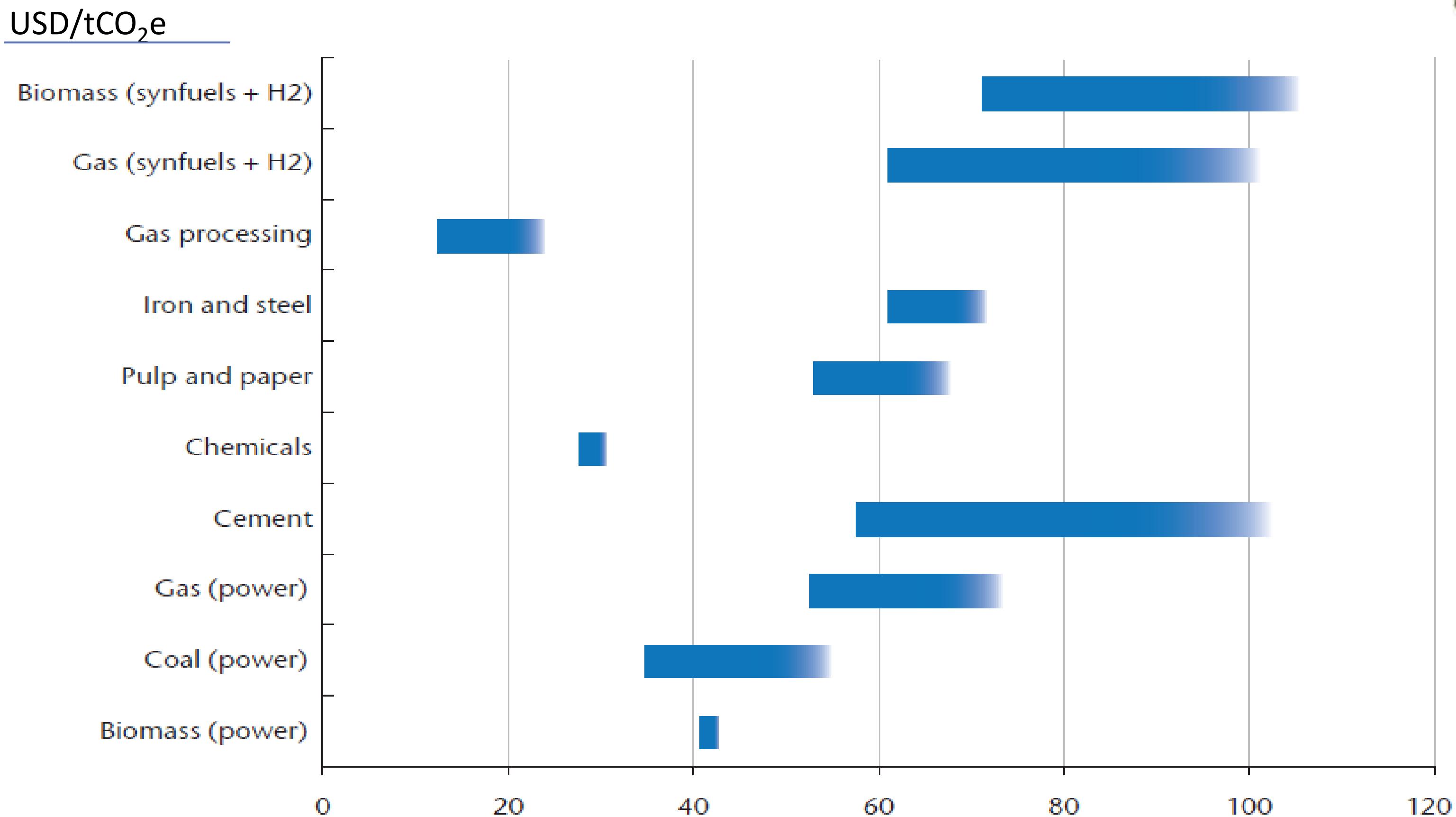
Level 1	Level 2	Level 3	Level 4
• **Minimum effort** (following current regulation)	• **Moderate effort** easily reached according to most experts	• **Significant effort** requiring cultural change and/or important financial investments	• **Maximum effort** to reach results close to technical and physical constraints
• **No biomass**	• **No biomass**	• **No biomass**	• **No biomass**

SOURCE: VITO

Reduction potential: CCS (1/4)

Industrial costs



SOURCE: IEA

Reduction potential: CCS (2/4)

CCS potential is based on size of installations

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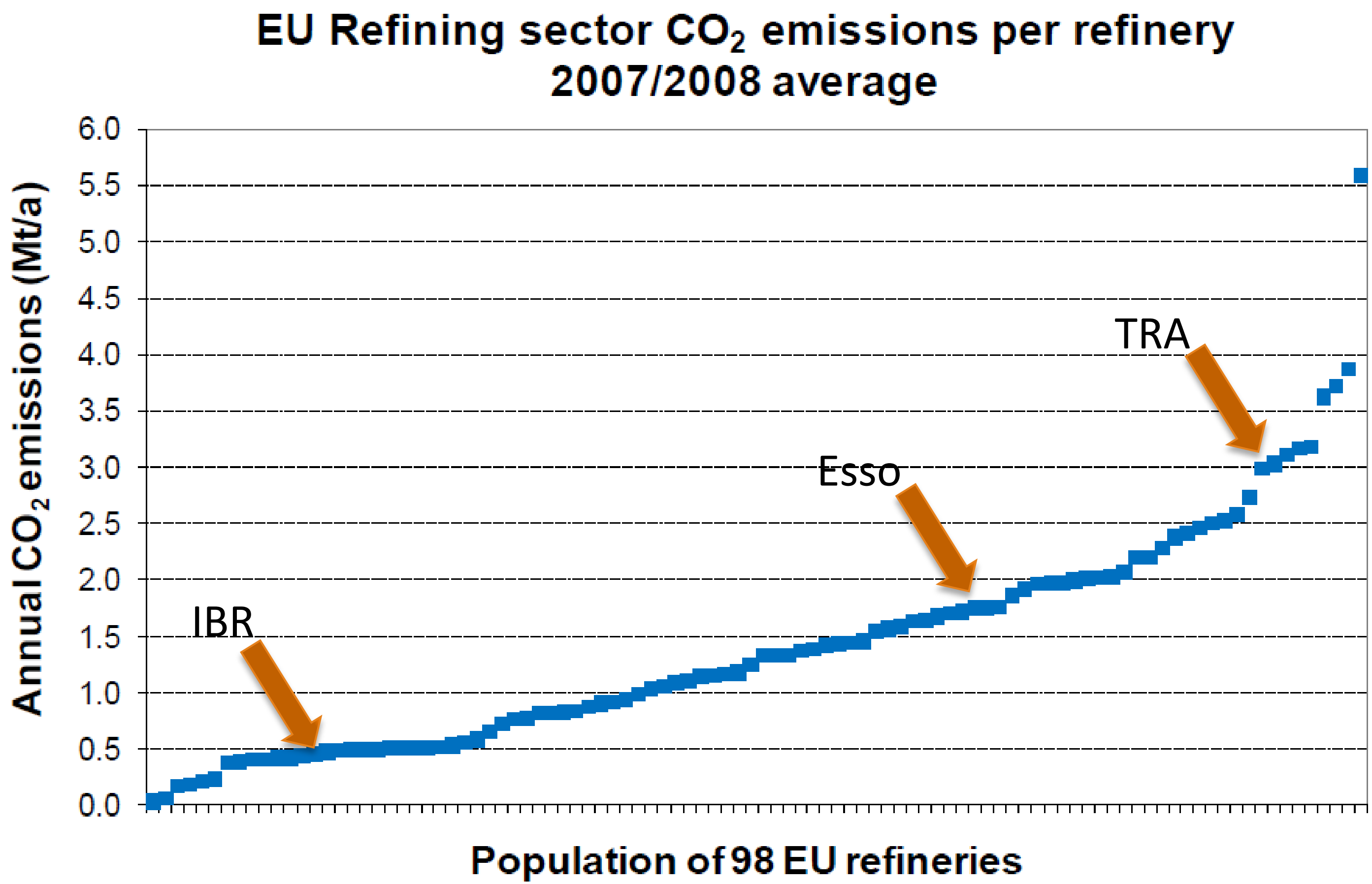
Industry	ton CO2eq by production site category			Total	Level 1	Level 2	Level 3	Level 4
	<0,3 M	0,3-1 M	>1 M					
Iron & steel	1.291.469	787.034	4.386.583	6.465.086	0%	68%	80%	85%
Non ferrous metals	310.098	-	-	310.098	0%	0%	0%	85%
Chemical	1.777.925	1.185.959	3.088.691	6.052.575	0%	51%	71%	85%
Refineries	**54.765**	**521.974**	**5.784.870**	**6.361.609**	**0%**	**85%**	**85%**	**85%**
Lime	363.771	1.517.514	1.240.023	3.121.308	0%	40%	85%	85%
Glass	457.924	601.861	-	1.059.785	0%	0%	57%	85%
Cement	155.095	695.438	3.998.520	4.849.053	0%	82%	85%	85%
Food	981.850	-	-	981.850	0%	0%	0%	85%
Pulp & paper	768.785	-	-	768.785	0%	0%	0%	85%
Bricks & ceramics	567.888	-	-	567.888	0%	0%	0%	85%
Total	6.729.570	5.309.780	18.498.687	30.538.037	0%	59%	73%	85%
Coverage level 1								
Coverage level 2								
Coverage level 3								
Coverage level 4								

SOURCE: ETS registry (Belgium), analyse VITO&Climact

Reduction potential: CCS (3/4)

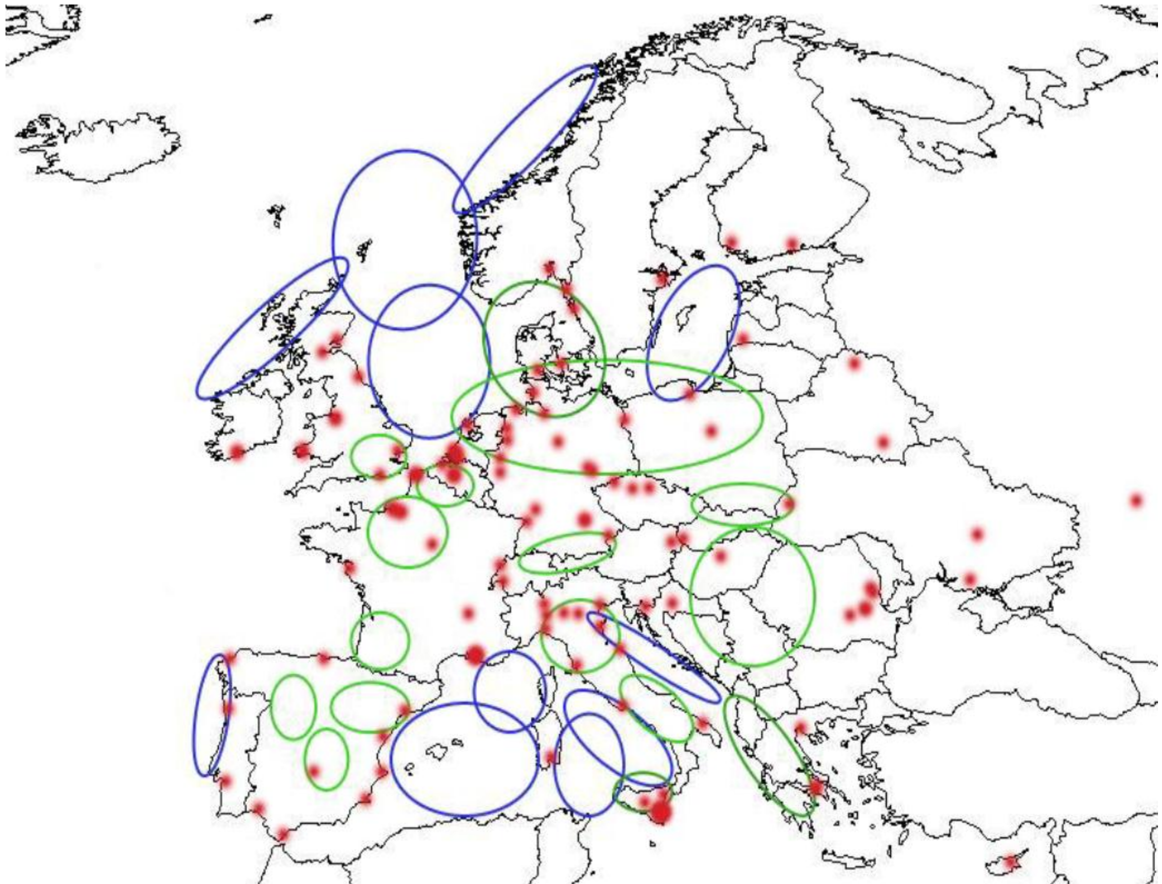
CCS potential is based on size of installations



SOURCE : www.concawe.be, the potential for application of CO2 capture and storage in EU oil refineries

Reduction potential: CCS (4/4)

Location of EU refineries and potential CO_2 storage areas



- Red dots: refineries
- Blue areas: offshore storage
- Green areas: onshore storage

SOURCE : www.concawe.be, the potential for application of CO2 capture and storage in EU oil refineries

Reduction potential:

Maximum reduction potential for different levers, horizon 2050

Refinery sector

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Type of lever	Improvement	Reduction potential (negative numbers) or implementation (positive numbers) (2050) in %				Cost	Description
		1	2	3	4		
Product mix	Change in crude oil mix	N/A	N/A	N/A	N/A	/	
Energy efficiency	Energy efficiency measures	-10%	-18%	-30%	-50%	-89 to -63 €/ton CO_2	
	CHP	0%	+10%	+15%	+20%	22 €/ton CO_2	
Process improvement	Process improvements from 2020 or 2030	NA	NA	-15%	-23%	-84 to 200 €/ton CO_2	
Alternative combustibles	Switch fuel towards gas	0%	25%	50%	100%	Cost of fuels	
	Switch fossil fuels towards biomass	NA	NA	NA	NA	/	
End of pipe	CCS	0%	85%	85%	85%	45 €/tCO_2	

Carbon price evolution

EU Roadmap 2050

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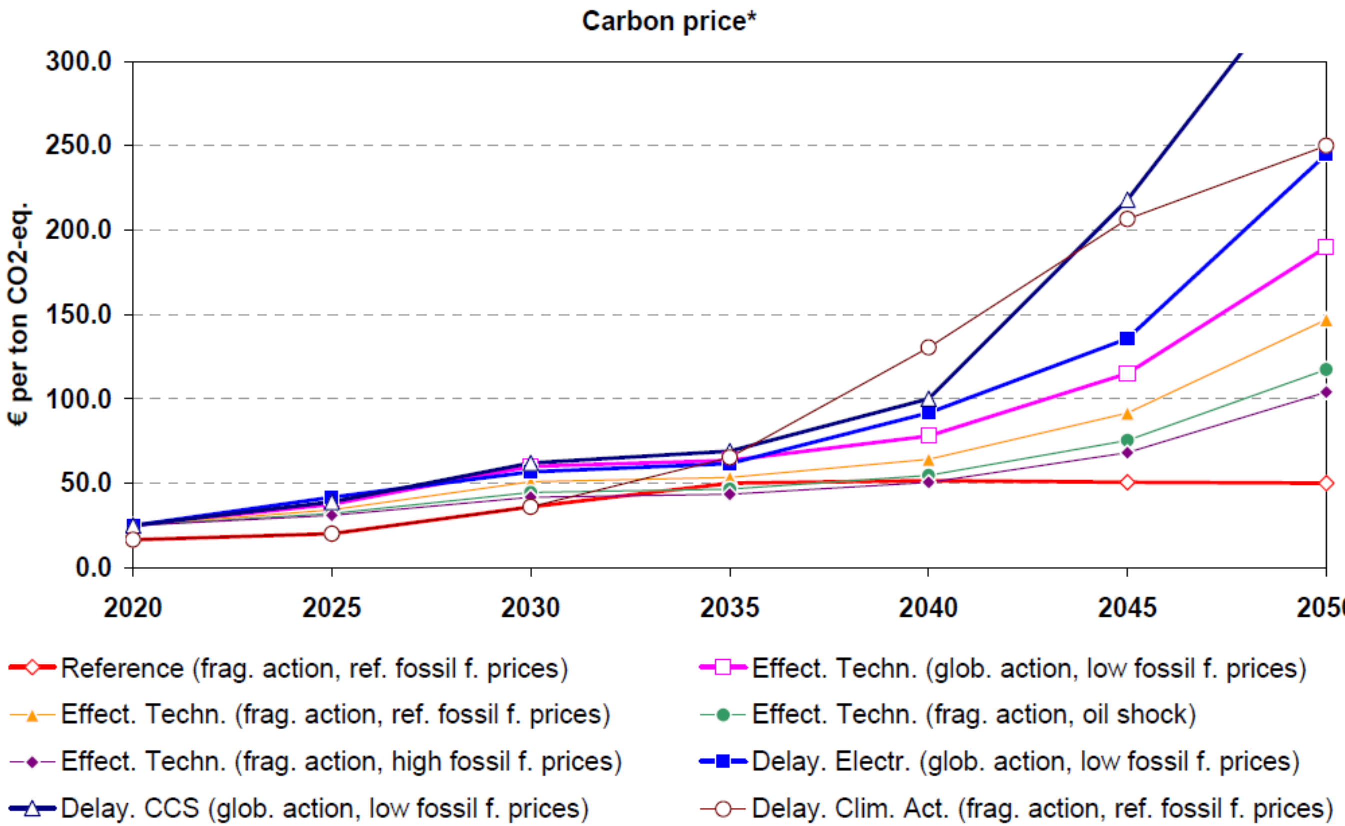

*For reference only ETS carbon price is represented

SOURCE: Impact assessment: A Roadmap for moving to a competitive low carbon economy in 2050

Content – Industry sector - refineries

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- Summary and references
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- Details of the ambition levels and costs per lever
- **Resulting scenarios**

Resulting scenario's

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- Sector calls for "evidence-based assessment" of the conclusions.
- In the report we will emphasize the global context in which we work:
  - *security of supply*
  - *global competition*
  - *energy efficiency*
  - *diesel/gasoline imbalance*

Reduction potential

Emissions according to different trajectories

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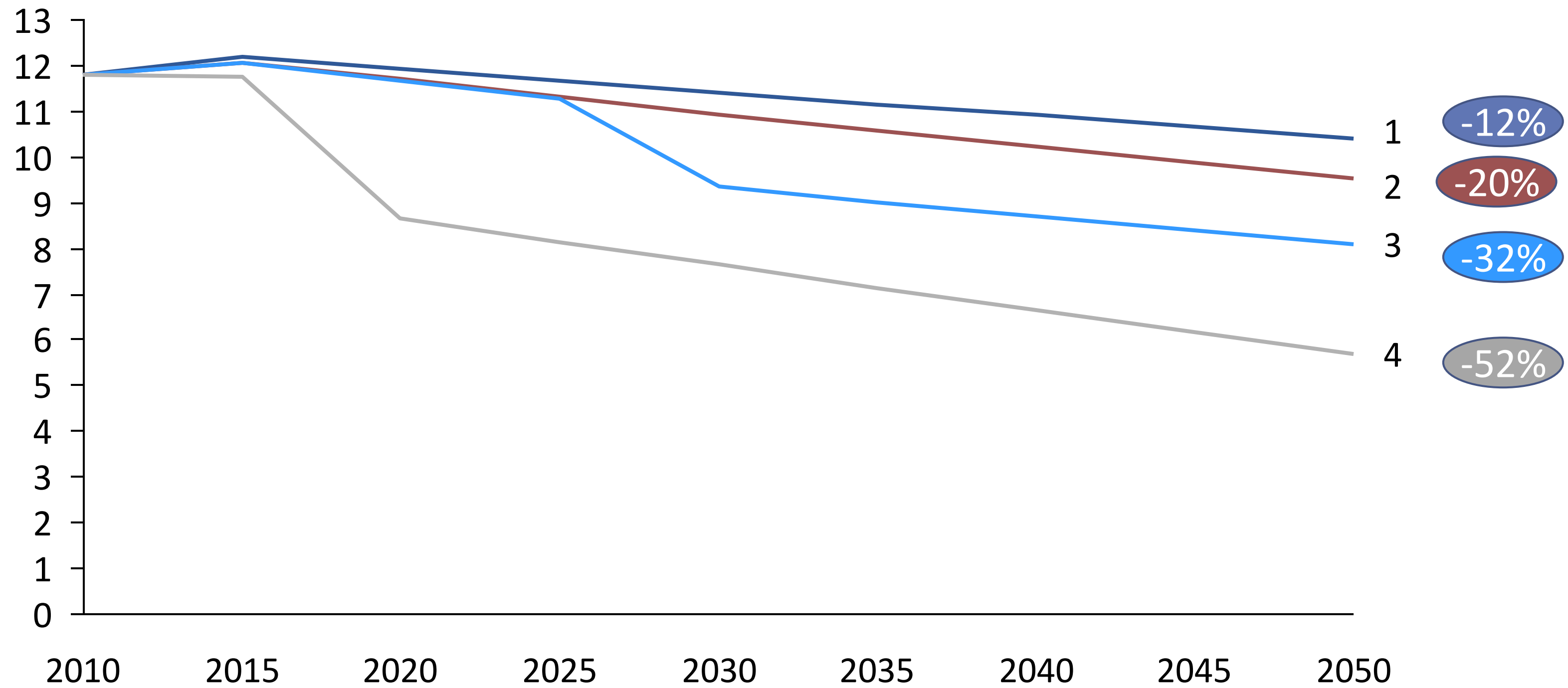
Trajectory 1 (CAGR -8% in 2050), GHG emissions for different ambition levels excl. CCS
($MtonCO_2e$)

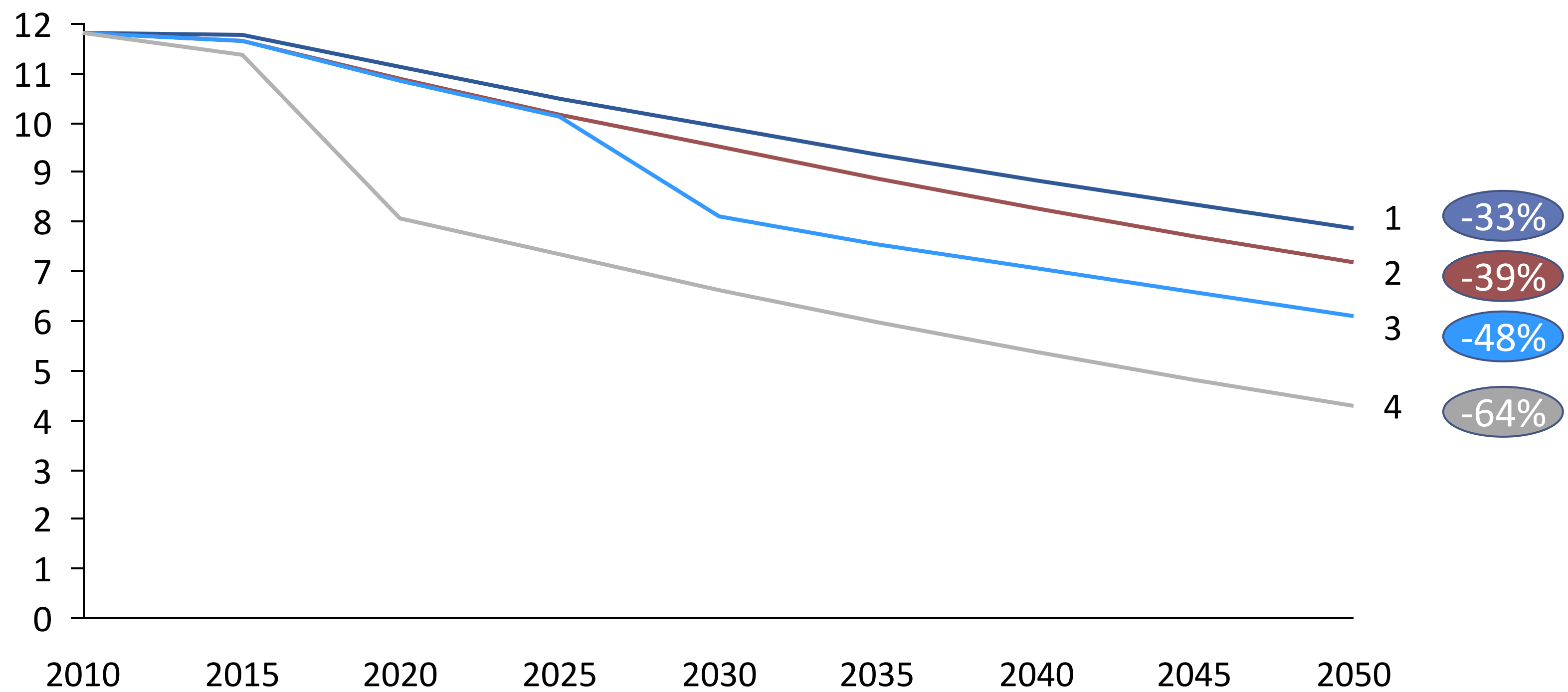


SOURCE: OPE²RA model

Reduction potential

Emissions according to different trajectories

Trajectory 2 (CAGR -30% in 2050), GHG emissions for different ambition levels excl. CCS
($MtonCO_2e$)

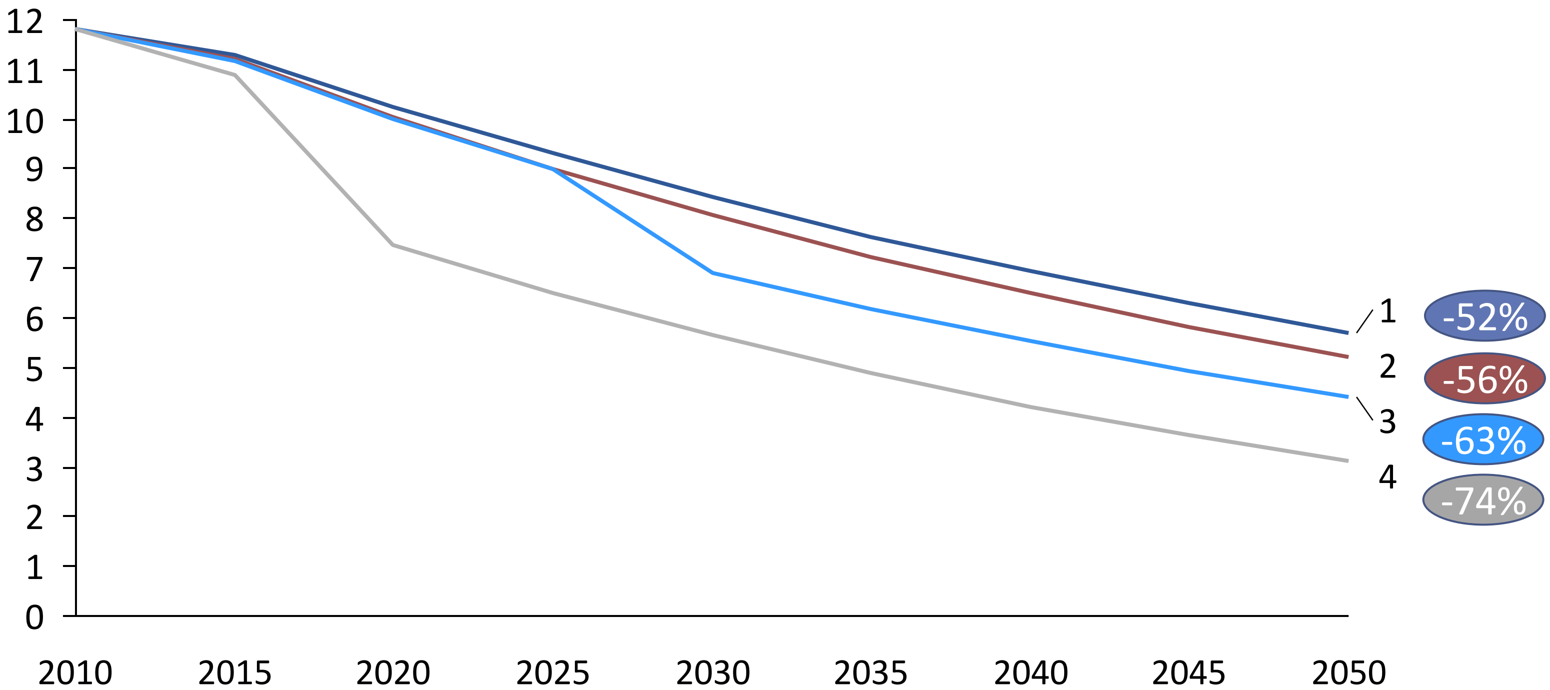


SOURCE: OPE²RA model

Reduction potential

Emissions according to different trajectories

Trajectory 3 (CAGR -50% in 2050), GHG emissions for different ambition levels excl. CCS
(MtonCO_2e)



SOURCE: OPE²RA model

Reduction potential

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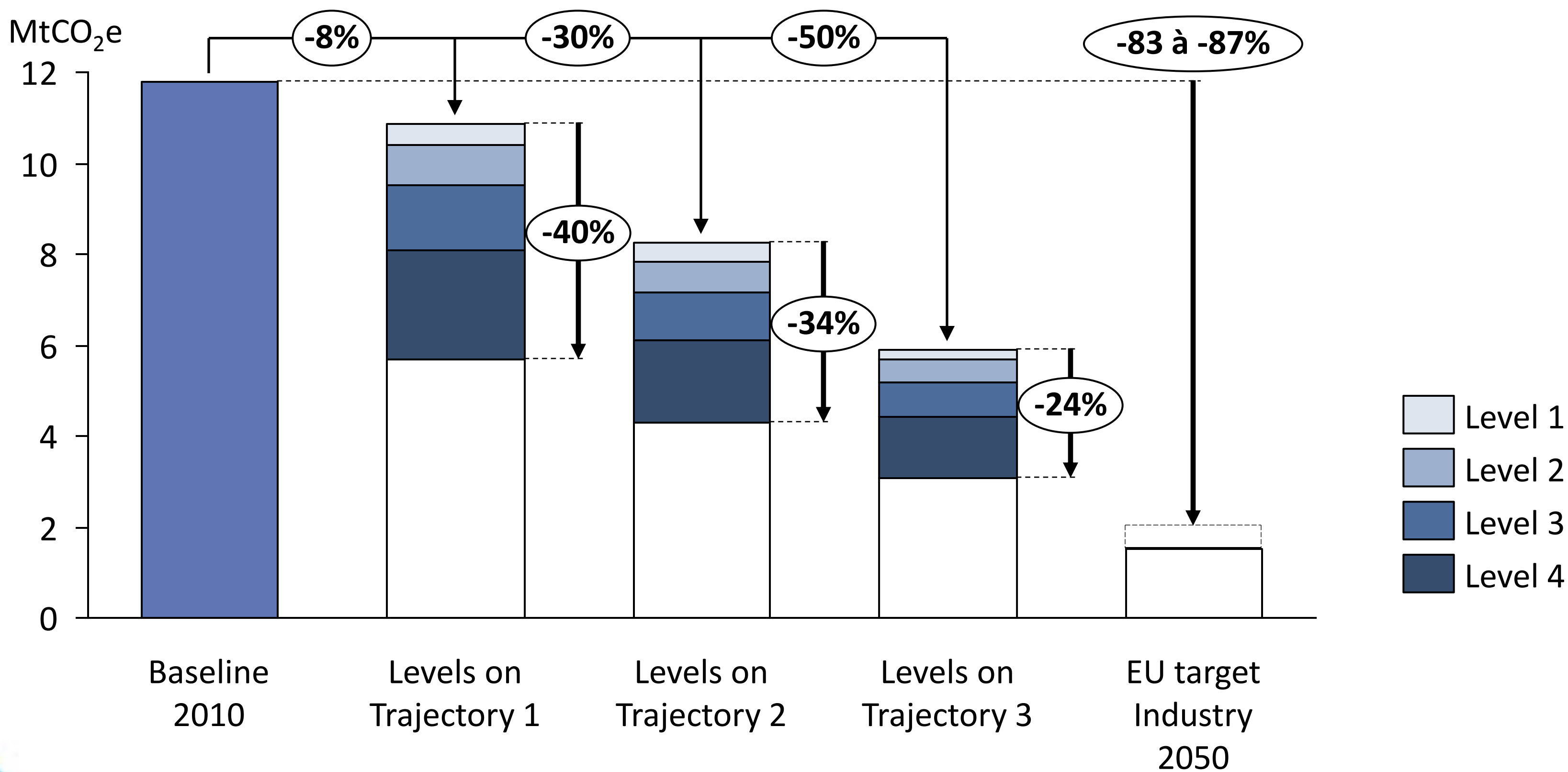
GHG emissions for different trajectories and ambition levels
($MtonCO_2e$ and % change (% of 2010 level))



SOURCE: OPE²RA model

Reduction potential

Details for trajectory 2 with ambition level 2, incl. CCS

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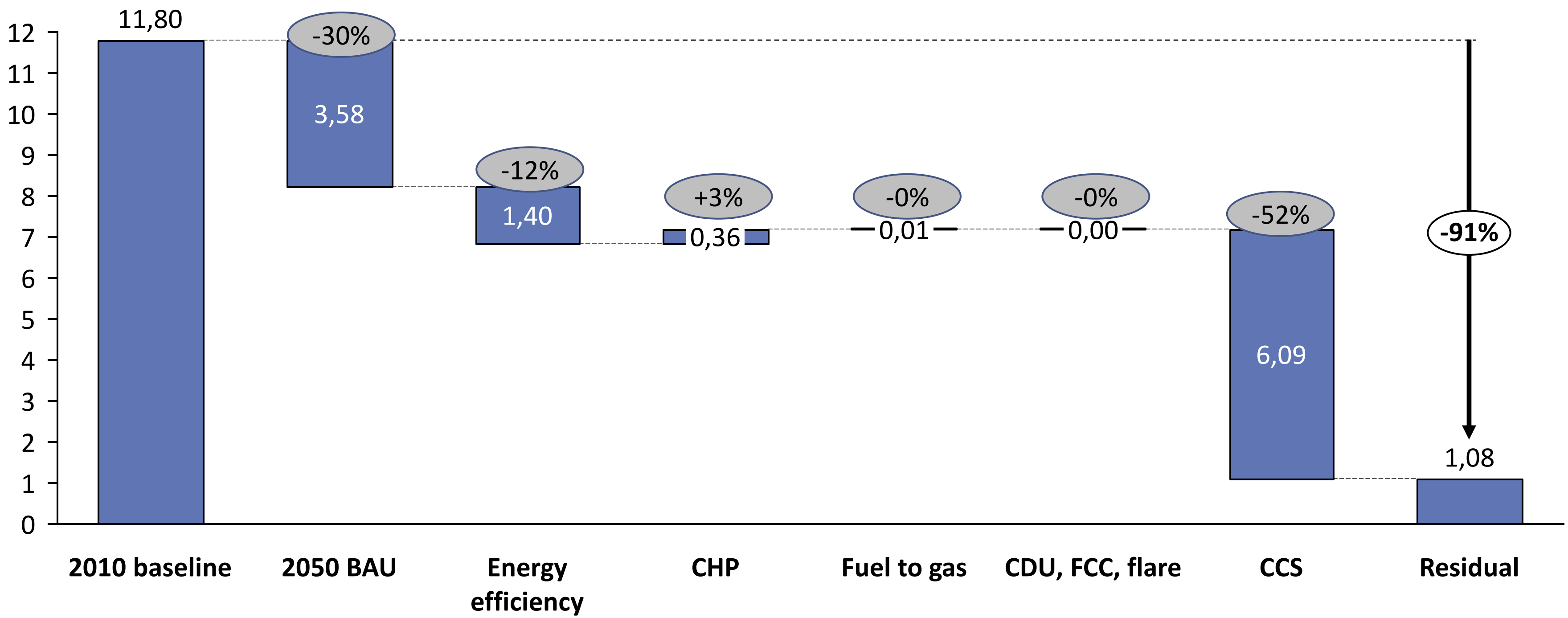
GHG emissions in 2050 using different levers
(% of 2010)



NOTE: Percentage reductions are calculated vs the 2010 baseline
SOURCE: OPE²RA model

Reduction potential

Details for trajectory 2 with ambition level 4, incl. CCS

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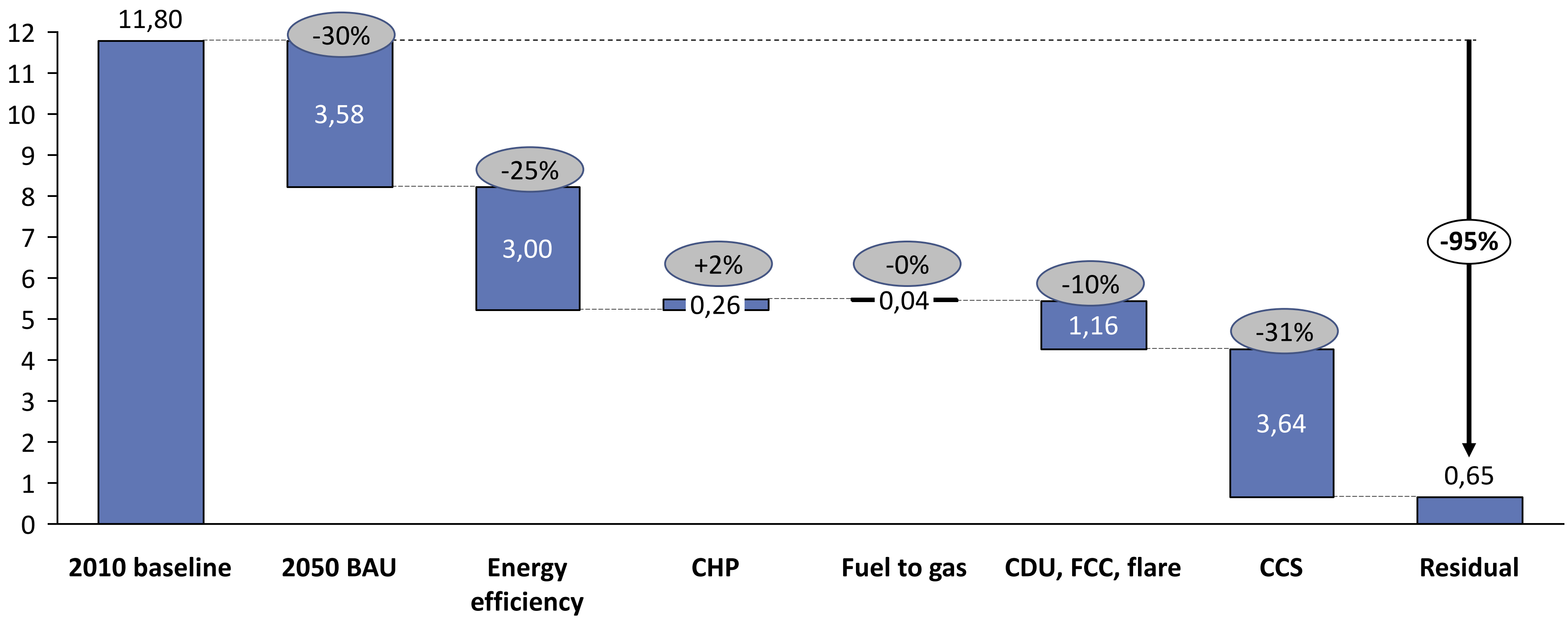
GHG emissions in 2050 using different levers
(% of 2010)



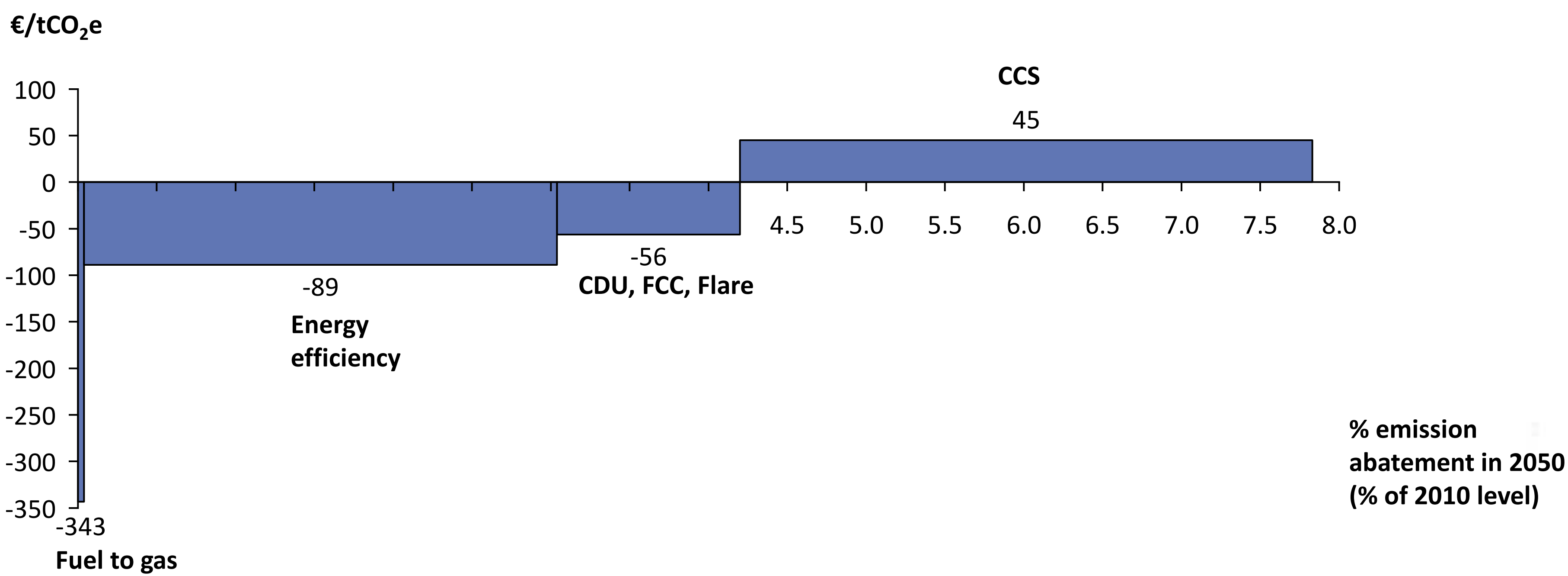
NOTE: Percentage reductions are calculated vs the 2010 baseline
SOURCE: OPE²RA model

Cost

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

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

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



NOTE: Hypothesis of cost neutral energy efficiency measures

SOURCE: OPE²RA model

Thank you.

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