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EU Refining Study 2020-2030

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10th CONCAWE Symposium

25th-26th February 2013

The CONCAWE EU Refining LP Model

Study facilitated by RTSG (Refinery Technology Support Group)

LP model used, as for earlier refining studies

- Nine regions represent EU27 + Norway & Switzerland
  - Each region is represented by a composite refinery
  - Each composite refinery has combined capacities of all refineries & petrochemical units in the region
- The quality of the crude processed in the EU is represented by a mix of five model crudes reflecting the EU overall crude quality
- Product imports and exports allowed:
  - Diesel, heating oil and jet fuel imports
  - Gasoline exports
- Unit yields are crude-dependent in most cases
- The model is Mass, Energy, Carbon, Sulphur & Hydrogen balanced

Product quality assumptions

Product Qualities

BASE CASE 2008

Fuels Quality Directive (FQD)

2009: Sulphur-free road fuels (<10ppm S)
Diesel PAH content <8 wt%

Sulphur in Liquid Fuels Directive (SLFD):

Inland Waterway Gasoil 2011: ↘ from 1000 to 10ppm S

Marine Fuels 2010: global cap ↘ from 4.5 to 3.5% S

2010: SECA ↘ from 1.5 to 1.0% S

2015: SECA ↘ from 1.0 to 0.1% S

2020: global cap ↘ from 3.5 to 0.5% S

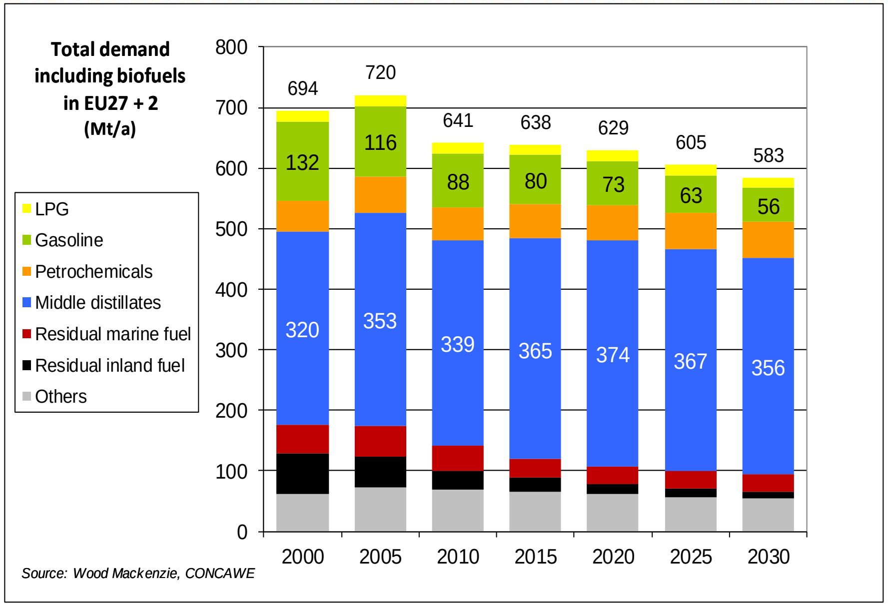
2020: Ferries ↘ from 1.5 to 0.5% S*

* The modelling assumed 0.1% S for ferries in 2020, a more severe reduction than that required by the SLFD

Demand assumptions including biofuels

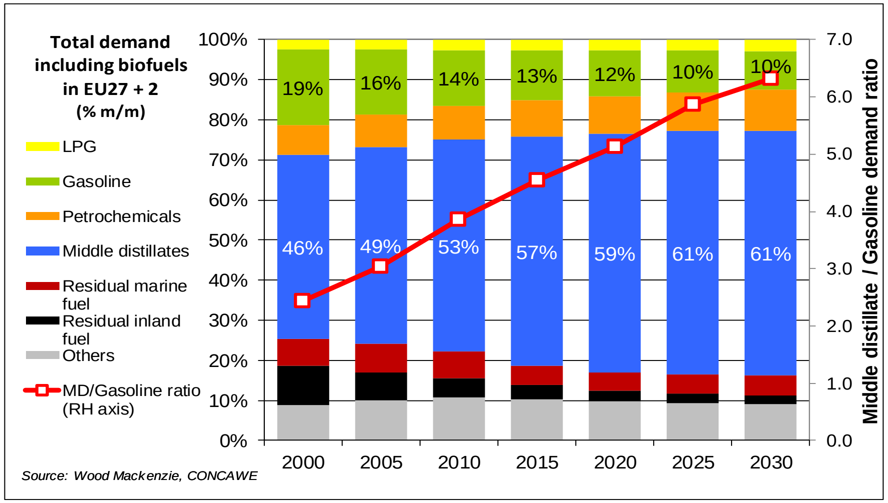
Demand (including biofuels):

- Declining total demand
- Erosion of demand for heavy fuels
- Growth of light products demand
- Increasing demand for jet fuel
- Demand for gasoline drops by 36% from 2010 to 2030



JEC "Fleet & Fuels" model:

- Source for road diesel and gasoline demand
- Evaluated scenarios for new vehicle fleet to meet the 2020/2030 target of 95/75 gCO2/km
- Share of gasoline in conventional car fleet declines from 63% in 2010 to 50% in 2030
- Growing share of alternative fuel vehicles:
  - 10% of car sales in 2020 (6% of fleet)
  - 15% of car sales in 2030 (12% of fleet)



concawe Refined Middle Distillate demand (2005 to 2030)

Refined MD demand excludes biofuels but includes distillates imports

Positive factors for refined distillates:

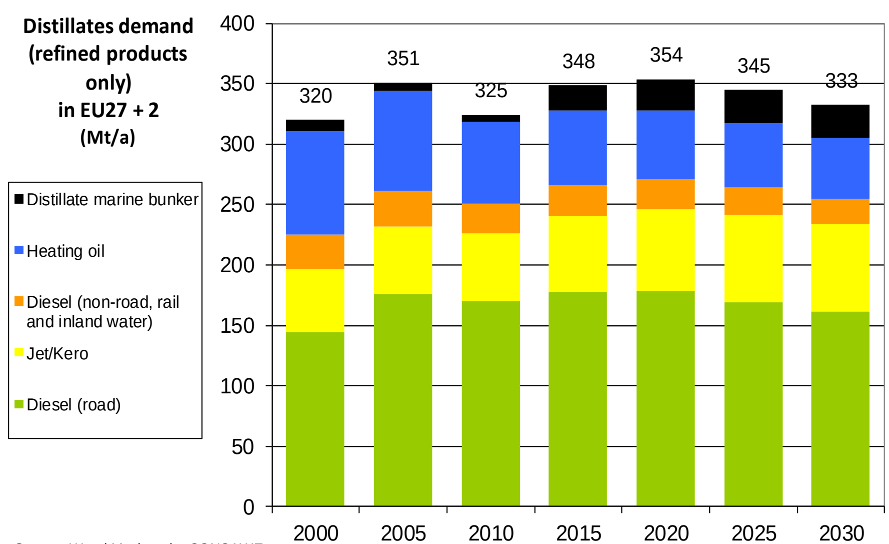
- Aviation fuel ↗ by 28%
- Distillate marine fuel ↗ by 280%

Negative factors for refined distillates:

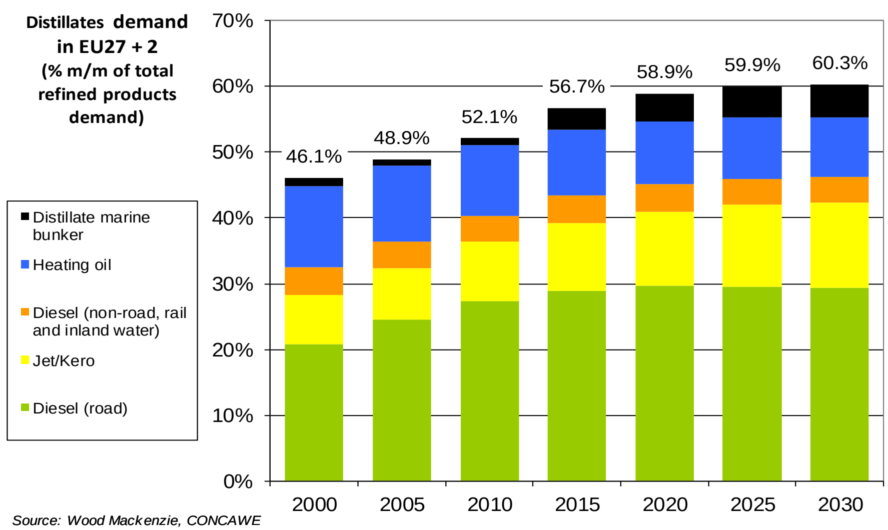
- Road diesel ↘ by 8%
- Non-road diesel ↘ by 27%
- Heating oil ↘ by 39%

The net effect from 2005 to 2030:

- Refined middle distillates demand ↘ by 11%
- Overall refined products demand ↘ by more than double this rate (23%)
- Share of distillates in total refined products demand ↗ from 49% to 60%



Source: Wood Mackenzie, CONCAWE



Source: Wood Mackenzie, CONCAWE

Feedstock and product trade assumptions

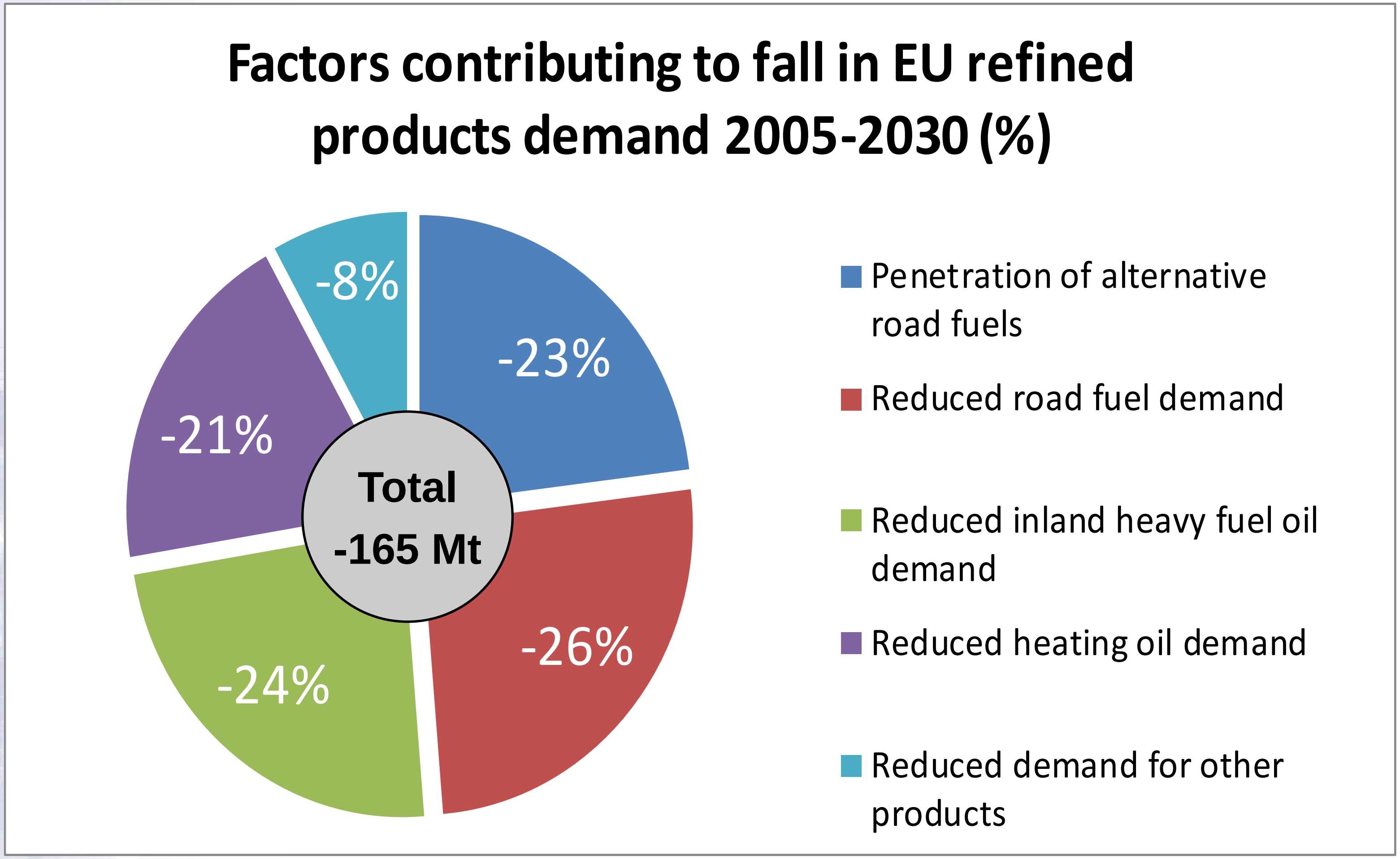
EU Crude supply (based on Wood Mackenzie data)

- Sources of supply for Europe will change
  - Declining light, sweet North Sea crude production
  - Replaced by other regions such as West Africa and Caspian basin
- Average quality of the EU crude slate not significantly affected

Imports/Exports (based on IEA data for 2008)

- 35 Mt/a imports of middle distillates
  - 10 Mt/a diesel, 10 Mt/a heating oil, 15 Mt/a of jet fuel.
- 43 Mt/a exports of gasoline
  - 22 Mt/a of the gasoline exports for the USA.

The evolution EU refined products demand



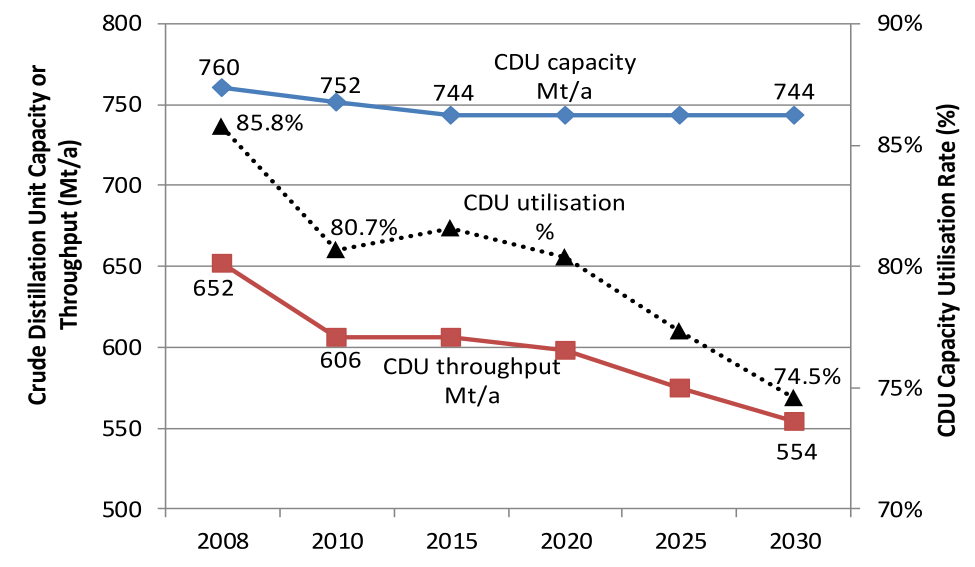
Note: Refined products demand excludes biofuels and gasoline exports but includes distillates imports

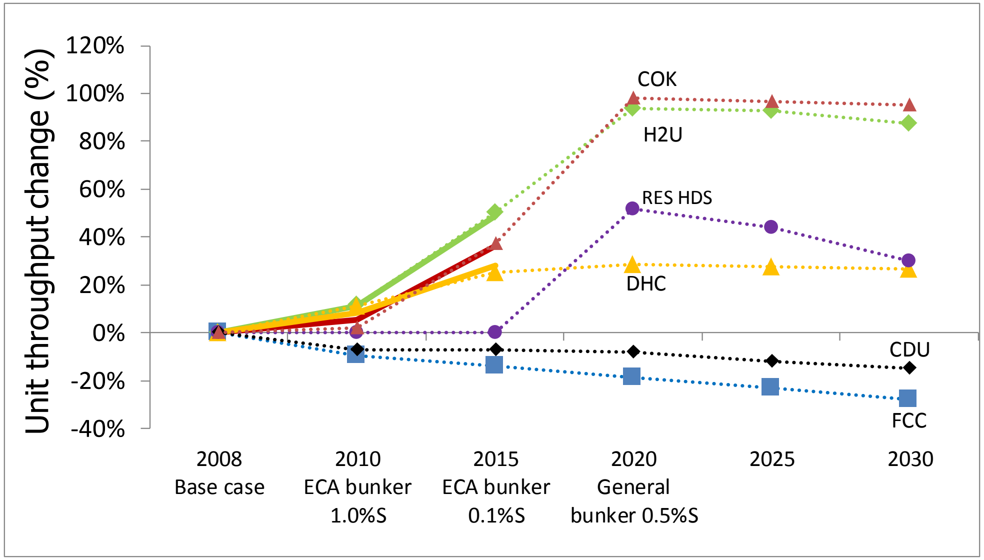
Source: Wood Mackenzie, CONCAWE

Study results: Unit throughput trends

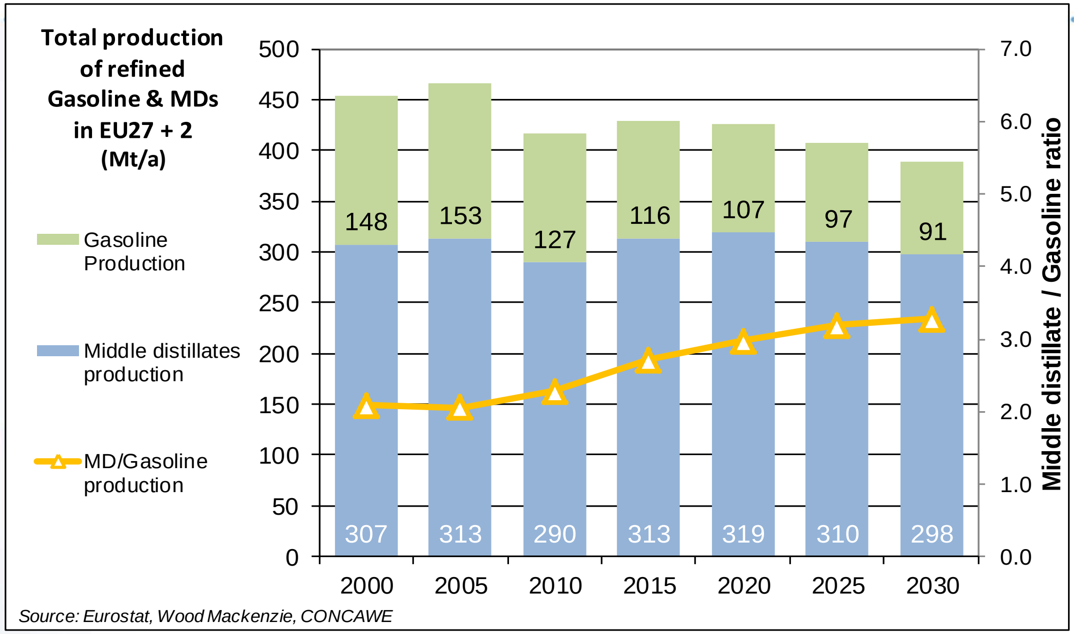
Process unit capacity utilisation

- Declining demand for refined products results in a substantial drop in throughput
  - 710 Mt of crude oil and feedstocks processed in 2008, falling to 600 Mt in 2030
  - Equivalent to the combined capacity of the 6 largest EU refineries (or the 30 smallest)
- CDU utilisation rate falls sharply from 86% in 2008 to 75% in 2030
- Contrasting trends for other process units
  - Severe under-utilisation of Crude Distillation units (CDU), Reforming (REF) and Fluid Catalytic Cracking (FCC) units.
  - Big increases in throughput of conversion units: Distillate Hydrocracking (DHC), Coking (COK), Residue Desulphurisation (RES HDS) and Hydrogen production (H2U)
  - These throughput increases far exceed the current or projected unit capacities
  - Major capacity adaptations would be needed to meet future demand and quality requirements





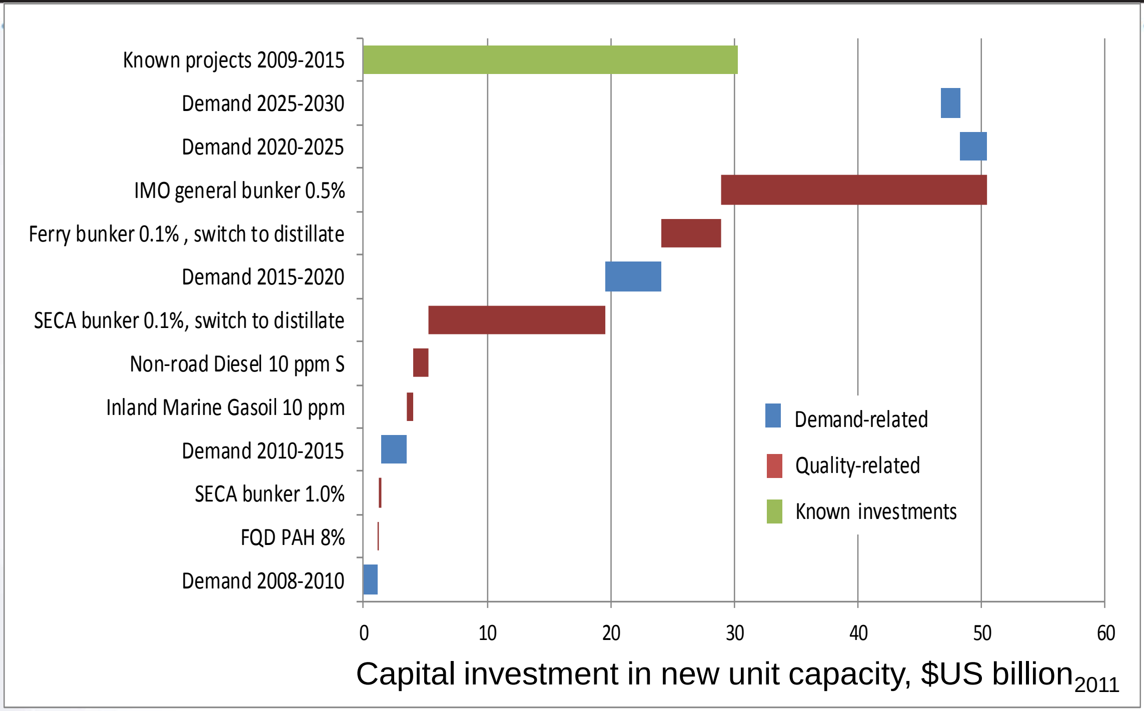
Study results: Gasoline & Distillate production



Note: Refined products production excludes biofuels but includes gasoline exports

- Steady increase of the middle distillate (MD) to gasoline (G) production ratio
- Mostly due to the fall in gasoline demand, as MD demand remains fairly constant
- Upward trend in MD/G production ratio is not as steep as the MD/G demand ratio
- Relatively modest shift in MD/G production ratio results from optimistic assumptions:
  - EU distillate imports and gasoline exports remain constant through to 2030
  - A secure supply exists for middle distillate imports
  - Gasoline export markets are able to absorb such high volumes, allowing EU refineries to maintain a relatively high level of gasoline production
- Real picture could be worse, requiring bigger cutbacks in gasoline production and more investment in new plant capacity for distillate production

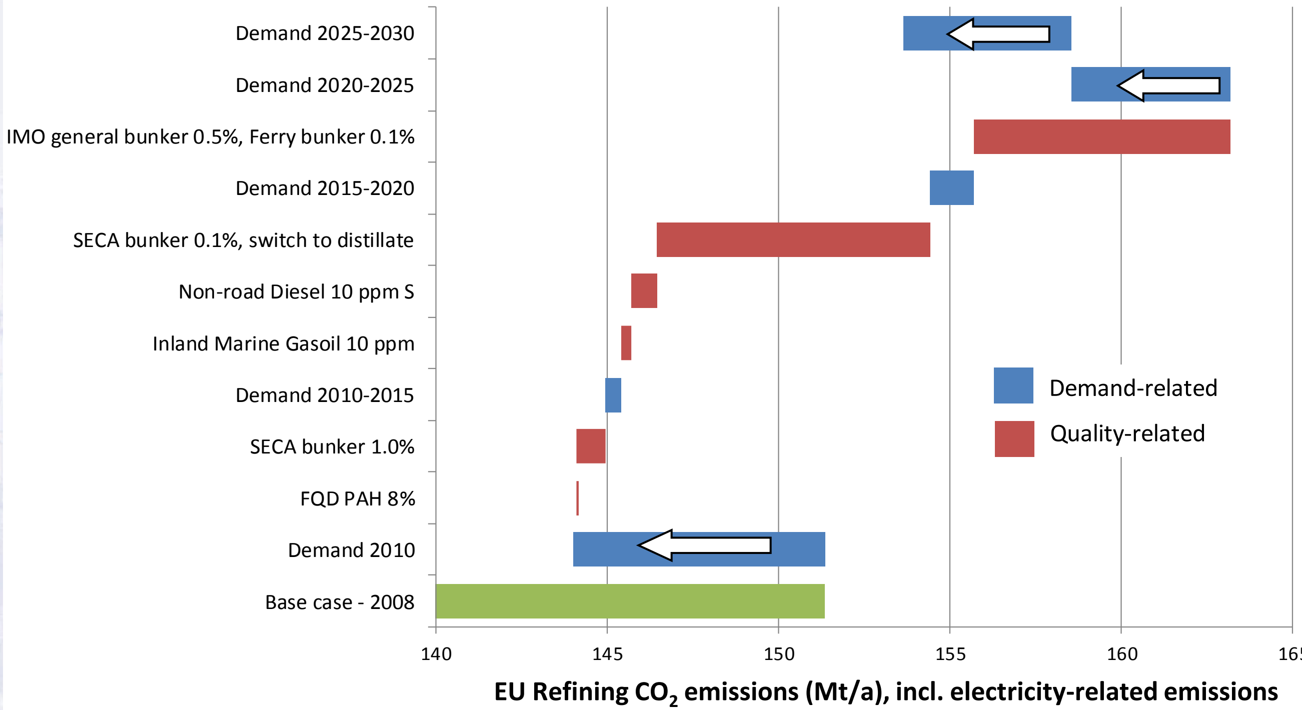
Study results: Investment in new unit capacity



- About **$30 billion**$_{2011}$ being spent in announced refining capacity projects in 2009-2015
  - A major contribution to meeting future requirements
- But….. the announced projects are not sufficient to meet the marine fuel sulphur reduction to 0.5% in 2020
- Additional capacities needed, on top of the $30 billion known projects:
  - 13 Mt/a in Coking units
  - 3 Mt/a in Residue HDS units
  - 6 Mt/a in Distillate HDS units
  - 0.9 Mt/a in Hydrogen production units

Raises overall investment requirement to **$51 billion**$_{2011}$ in 2009-2020 period

Study results: Increased CO2 emissions



Note: Refinery energy efficiency is assumed to remain unchanged

- Increase in CO_2 emissions due to more intensive processing:
  - Higher throughput in CO_2-intensive units (hydrocracking, desulphurisation, coking)
  - Increased production of hydrogen for cracking and desulphurisation reactions
- Refinery CO_2 emissions per tonne throughput reach 255 kg/t in 2030 (214 kg/t in 2008)
- Hydrogen production contributes 22% of refinery CO_2 by 2020 (12% in 2008)
- Refinery CO_2 emissions increase by 12 Mt from 2008 to 2020

Sensitivity cases

Sensitivities around 2020 base assumptions:

- Refined road diesel to gasoline (D/G) demand ratio
- On-board scrubbers to meet IMO emissions reductions
- Gasoline octane qualities
- Jet fuel sulphur reduction
- Road diesel poly-aromatics reduction
- Heating oil sulphur reduction
- Inland heavy fuel oil sulphur reduction
- Reduced gasoline exports

Sensitivities around 2030 base assumptions:

- High biofuels
- Refinery energy efficiency improvement

Alternative base case:

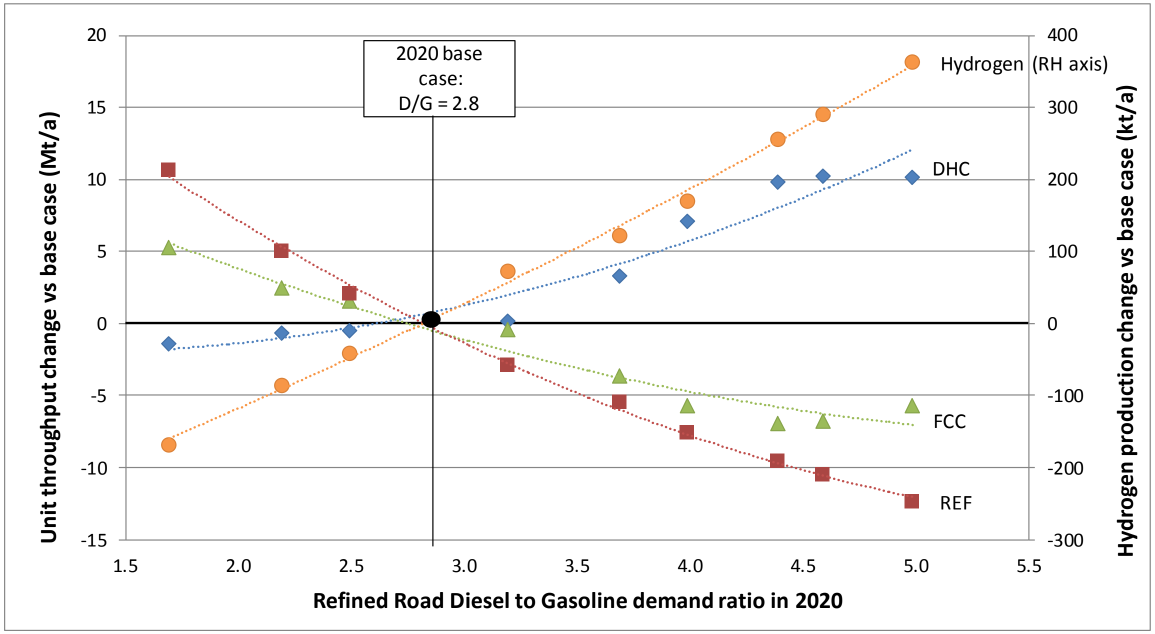
- Limited refining investment in 2020

Sensitivity 1: Refined road diesel to gasoline (D/G) ratio

Assumptions:

The share of diesel cars in 2020 new car sales was varied between 10% and 90% (vs. 50% in base case)

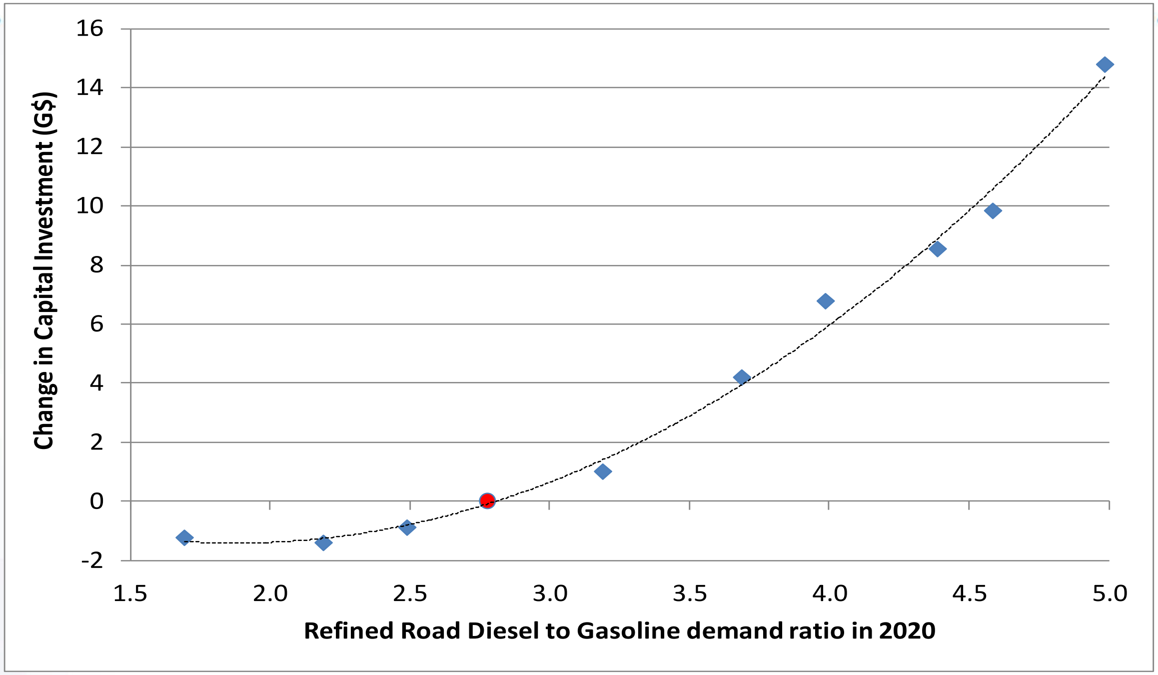
- Resulting Diesel/Gasoline demand ratio varies between 1.7 and 5.0
- Road fuel energy demand kept constant
- Target of 95gCO_2/km always met



Results:

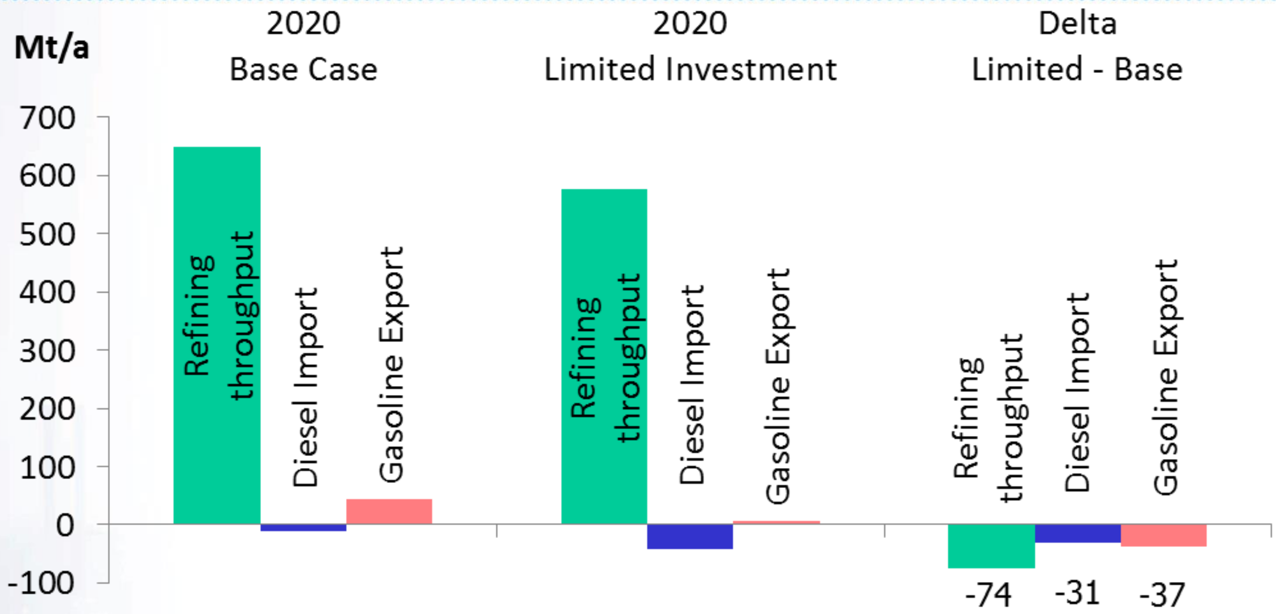
- Raising diesel production requires increased DHC (Distillate Hydrocracker) throughput and additional hydrogen
- Lowering gasoline production requires reduced throughput in FCC (Fluid Catalytic Cracker) and REF (Catalytic Reforming) units.
- FCC unit operation is modified to maximise the yield of distillate components

Sensitivity 1: Refined road diesel to gasoline (D/G) ratio



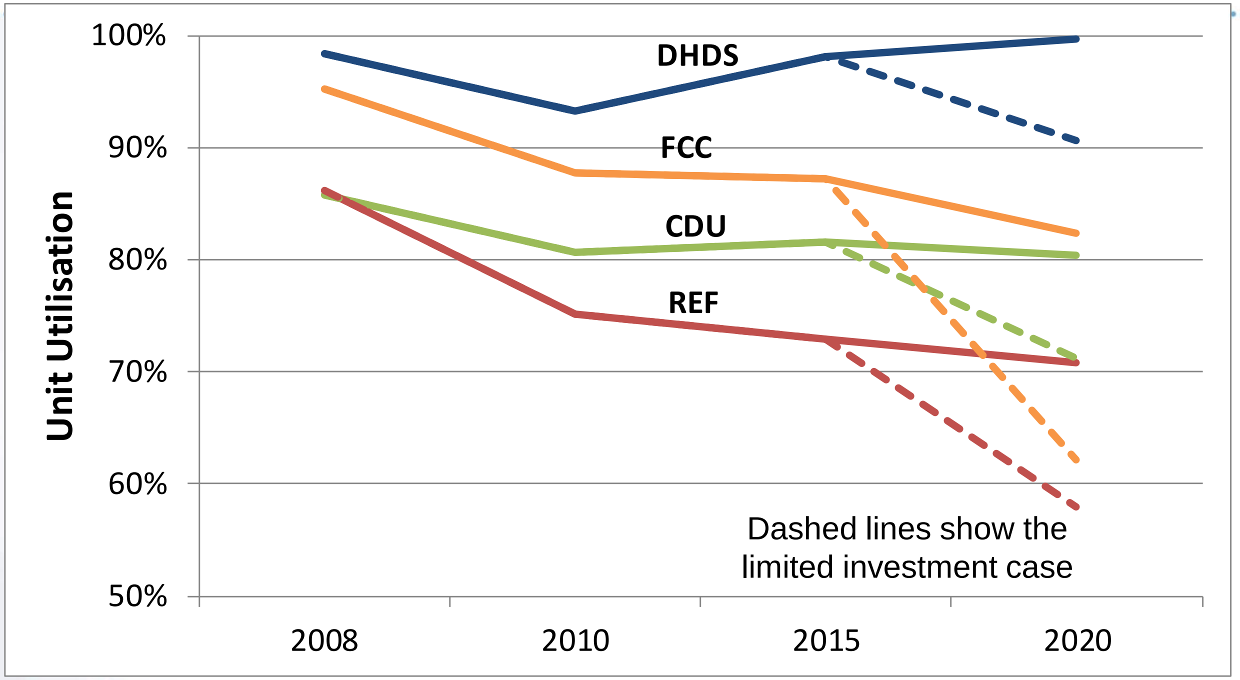
- The maximum D/G case requires almost $15 billion more investment than the $51 billion in the 2020 base case
  - Mostly made up of additional DHC (Distillate Hydrocracker), HDS (Hydrodesulphurisation) and H2U (hydrogen unit) capacity
- The minimum D/G cases reduce investment by up to $1.4 billion compared to the 2020 base case, mainly through reduced hydrogen unit investments
  - DHC investments cannot be reduced below the 2020 base case level because this level corresponds to the already committed investments in the 2009-2015 period

Alternative case: Limited Investment in 2020 (1)



- **What would happen in 2020 if there are no additional investments beyond the known 2009-2015 projects, all other things remaining equal?**
- Available processing capacity unable to remove enough sulphur to meet the 0.5% limit in marine fuels
- No export market for high sulphur Heavy Fuel Oil
- Refining throughput cut back by 11% (74 Mt) to reduce total sulphur entering the system
- Product imports/exports must adapt to satisfy demand and quality requirements
  - Diesel imports: ↗ by 310% (31 Mt)
  - Gasoline exports: ↘ by 86% (37 Mt)

Alternative case: Limited Investment in 2020 (2)



- CDU throughput reduction and import/export adjustments affect other units:
  - Reduced utilisation rates in REF (Reforming) and DHDS (Distillate Hydrodesulphurisation) units due to reduced CDU production of naphtha and gasoil
  - FCC utilisation rate is doubly impacted by:
    - Reduced feed availability from CDU
    - Feed switch to DHC (Distillate Hydrocracking) to maximise diesel production and minimise the import of diesel
- This scenario would present severe challenges for the EU refining industry

Conclusions

- The announced projects from 2009 to 2015 are a major contribution to meeting future refined product requirements
  - Committed capital expenditure estimated at \$30 billion$_{2011}$ (€21 billion$_{2011}$)
- Additional capital expenditure of \$21 billion$_{2011}$ (€15 billion$_{2011}$) would be required to meet the 0.5% sulphur limit on marine fuels by 2020
- The long-term demand in refined products will continue to decline
  - Refiners could have difficulty justifying the additional expenditure
  - Without additional capital expenditures the 2020 market demand would need to be satisfied by substantial increases in diesel imports and a further reduction in refinery utilisation rates
- CO_2 emissions from EU refining are expected to increase by 2020
- Declining demand post-2020 will reduce refining CO_2 emissions to a level in 2030 that is, at best, close to that of 2010

Thank you for your attention!