Refining Operations

Potential supply of IMO low sulphur marine fuel from EU refineries

Global Outlook & Issues

EnSys Energy and Navigistics Consulting
Presented by Martin R. Tallett

12th Concawe Symposium

20-21 March 2017

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Topics

- EnSys & Navigistics in overview
- MARPOL Annex VI Global Sulphur Rule / MEPC70
- Recent assessments of Rule impacts
- Marine fuels 2020 key dimensions
- European refining outlook

Navigistics Consulting

Specialists in:

- Maritime Industry - issues in global and U.S. domestic shipping, markets, logistics, economics, energy efficiency, and regulations.
- Global marine fuel assessments (market, demand, efficiency, and emissions)
- North America marine/pipeline/terminal oil logistics
- Global and US domestic focus has brought wide range of clients including oil companies, tanker owners, financial institutions, governments, and industry associations.

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EnSys Energy

Specialists in:

- Strategic and regulatory issues in global refining, markets & logistics
- Refining economics and fuels assessments
- North America logistics
- Global focus has brought wide range of clients
- Global integrated modeling “WORLD”

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EnSys-Navigistics Studies

Extensive marine fuels projects experience:

- 2006/7/8 EPA, API/IPIECA, IMO:
  - Developed rigorous fleet & trade based marine fuels demand projections (Navigistics)
  - Evaluated alternative fuels compliance scenarios (WORLD)
  - Worked closely with Expert Group on inputs to Annex VI
  - Provided fuels supply analysis for USA ECA submission
- 2009 Major chemical company:
  - Developed rigorous assessment of marine fuels additives market
- 2014/15 SEMARNAT Mexico:
  - WORLD-based fuels supply analysis in support of Mexico ECA submission to IMO
- 2015: Initial studies on potential impacts of 0.5% sulfur global standard
- 2016: IPIECA, BIMCO, Concawe/Fuels Europe, Canadian Fuels, PAJ:
  - Updated Supplemental Fuel Availability study
  - Submitted to IMO July 2016 presented at MEPC70

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MARPOL Annex VI is not a typical fuel rule

- Refining sector has a long history of complying with fuels/emissions regulations but Annex VI Global Sulphur Rule is atypical:
- Inherent “regulatory uncertainties” make it difficult for ship-owners and refiners to invest
  - Implementation date 2020 vs 2025 - now settled
    - Little/no incentive for either party to pre-invest
    - Shipping sector in severe financial state and having to deal with ballast water rule (starts Sept 2017)
    - 2020-2025 “uncertainty” has limited scrubber investments to ECA compliance
      - To date only about 400 out of 50,000+ total ships have scrubbers, nearly all in ECA’s
  - Still three fuel compliance options
    - 0.5% refined fuel or 3.5% refined fuel + scrubber or alternative fuel (LNG, other)
  - Plus 0.5% fuel formulation options
    - Any refined fuel (within ISO 8217) as long as 0.5% sulphur
  - And geography of production and purchasing potentially variable
    - Marine fuels not a strategic product for all refineries
      - (hence the active blending / bunkering sector)

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Recent studies have highlighted major issues with ‘full on’ January 2020 compliance

- EnSys-Navigistics Supplemental Marine Fuel Study
  - Sponsored by:
    - IPIECA, Concawe/Fuels Europe, BIMCO, Canadian Fuels Association, Petroleum Association of Japan
  - but fully independent
- CE Delft Official IMO Study
- IEA latest medium term outlook
  - “Oil 2017”, Analysis and Forecasts to 2022
    - Published February 2017

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Scrubbers Cover only Fraction of 2020 Demand

- Detailed scrubber manufacturer survey plus penetration projection allowing for future manufacturing capacity
  - Led to close to projected 5,000 ships with scrubbers by end 2019, equals ~ 48 mtpa <20% of required global fuel by 2020
    - By comparison CE Delft 36 mtpa, Robin Meech 11 mtpa
    - IEA “Oil 2017” 2,000 ships with scrubbers by 2020
  - Means bulk (>80%) of High Sulphur (3.5%) HFO in 2020 will need to be “switched” to Low Sulphur (0.5%) compliant fuel
  - Although there is prospect of surge in scrubber demand starting 2020 leading to partial reversion after a few years to HS HFO demand
    - Potential deterrent to refining investment?

Leads to “switch volume” to 0.5% fuel close to 4 mb/d (200 mtpa) assuming full compliance

- Central case 3.8 +/- mb/d (195 mmtpa) switch to mainly distillate is a major shock to the system

- Equals:
  - 8-9 years of past growth in (inland) gasoil/diesel
  - 5 years’ growth 2015-2020 in total main light products
    - (gasoline + jet +kerosene + gasoil + diesel)
  - A 45% reduction in total residual fuel demand

- All in a few months (to achieve 100% compliance)

World Oil Refining Logistics Demand (WORLD) Model

- Highly detailed
  - 23 modelled regions & 35 refining groups
  - 30+ products, each with multiple specifications
  - 200+ crudes
  - Detailed non-crudes supply (NGL's, biofuels, CTL/GTL etc.)

WORLD 23 Region Breakdown

- **Detail needed to get realistic representation / avoid over optimisation**
- **Proven over nearly 30 years of use**

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WORLD simulations indicated global refining industry could (just) cope except for H2/SRU capacity – but impacts far-reaching

- Refining adjustments
  - Increased coker unit throughputs to upgrade residual streams
  - Vacuum unit throughputs increase producing more vacuum gasoil (VGO) and vacuum resid
  - Shifting Fluid Catalytic Cracking feedstock from VGO to residual feedstock
    - Can lead to increased refinery SO_2 emissions
    - Regulatory constraints – need for added abatement facilities
    - Potential equipment/metals constraints?
  - Increased severity on desulphurization/hydrocracking units
    - Decreases catalyst life – may not be sustainable
    - Substantial increases in H2, sulphur recovery plant throughput needed
  - 2 – 4.5% increase in global refining CO_2 emissions
    - 7-10% if emissions from petroleum coke included

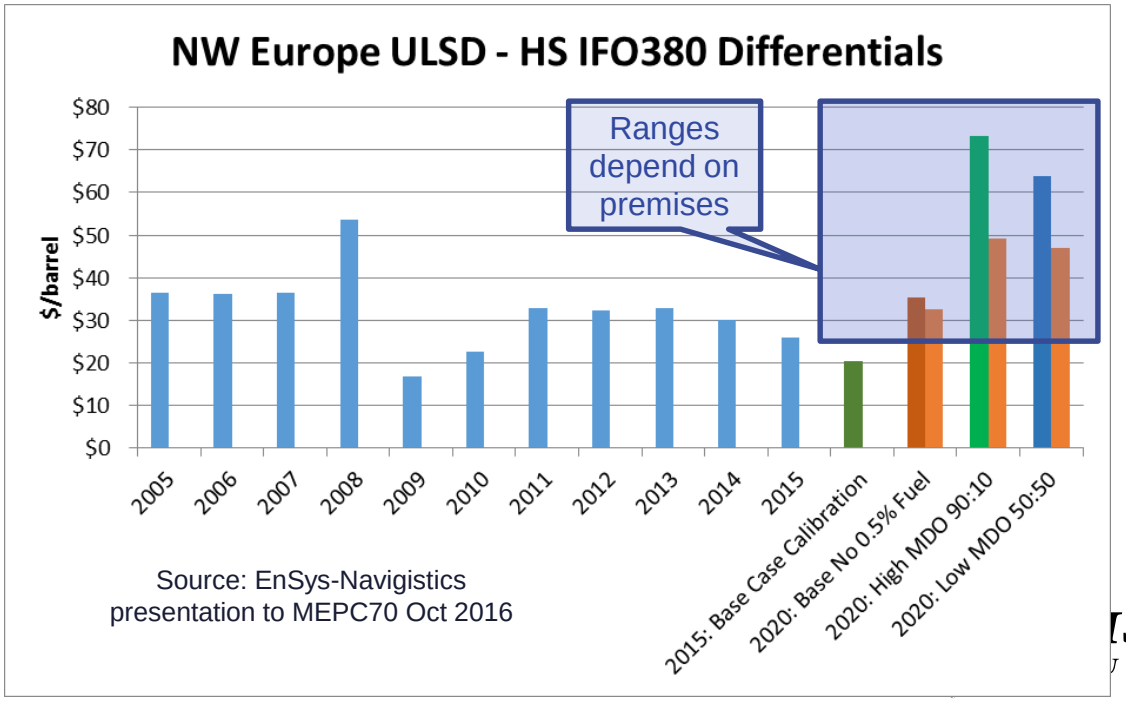
WORLD simulations indicated global refining industry could (just) cope except for H2/SRU capacity – but impacts far-reaching

- Refining/trade adjustments
  - More crude oil required (+0.2 to 1.2 mb/d) – cokers & refinery fuel
    - USA main region picking up refinery throughput
  - 20% of export crude trade changes
    - Highest conversion regions take heavier, higher S crude slate
      - USA, Europe, Pacific Industrialised, China
    - Lower conversion regions go lighter lower S
      - Canada, Latin America, Africa, Middle East, Other Asia
  - Trade of non-crude supply, intermediates and finished products increases, with 30% changing trade routes
  - If additional needed SRU capacity not – or only partly – built, Global Fuel shortfall of around 25-32% or 50-60 million tpa (1-1.2 mb/d)

Refining and oil trade adaptation will take months/year not days/weeks

WORLD simulations point to very strained markets at/near 100% compliance

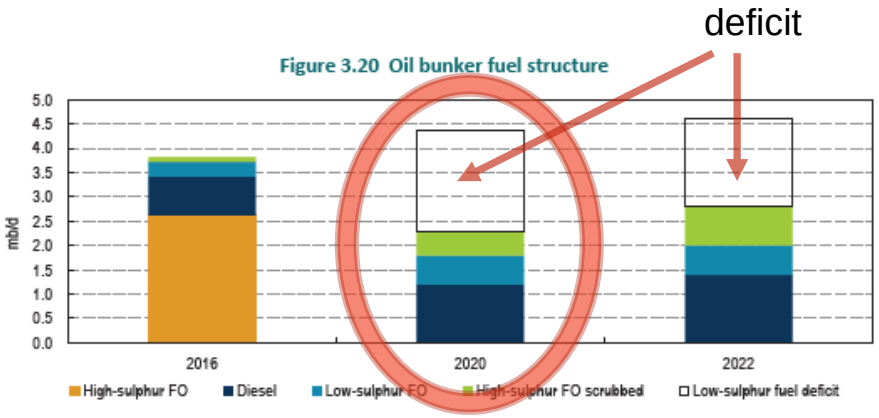
- Model results indicated short term reaction – first weeks/months – before market has had time to adapt
  - And assuming adequate H2 & SRU capacity available showed
- Major impacts across all products – not just marine
- And all regions



Source: EnSys-Navigistics presentation to MEPC70 Oct 2016

Other studies have reached similar conclusions

- CE Delft Official IMO study
  - Executive Summary indicated belief that refiners would invest – hence full compliance volumes could be supplied
  - But refinery modeling showed inadequate H2 & SRU capacity (Report Tables 92, 93) versus Oil & Gas Journal data
- IEA MTOMR "Oil 2017"
  - Have projected major challenges to refining industry in last 3 medium term reports
  - February 2017 outlook shows approx 50% 2020 LS fuel deficit ~ 2 mb/d



- 100% compliance looks an unrealistic target for 2020
- What is really going to happen?

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EnSys-Navigistics *Marine Fuels 2020 Service* Covers the Key Issues/Dimensions

- Build on prior work done
- Track developments, announcements
  - Refining, fuels, shipping, scrubbers, IMO, other
- Regularly update 2020 projections, assessments
- Steadily narrow the uncertainty
  - 2017 -> 2018 -> 2019 -> 2020
- Progressively add post-2020 focus

EnSys-Navigistics *Marine Fuels 2020 Service* Covers the Key Issues/Dimensions

- 1. Marine Fuel Demand
  - Key drivers:
    - Global economic growth
      - Jan 2017 IMF outlook ↑
    - International trade growth
      - Globalisation vs protectionism
    - Vessel speed-up due to lower fuel costs
    - Vessel efficiency developments (EEDI initiative)
    - LNG bunkering infrastructure, vessels
      - Activity & announcements but scale?
    - Scrubber orders
      - We should be starting to see increase soon if it is going to occur

EnSys-Navigistics *Marine Fuels 2020 Service* Covers the Key Issues/Dimensions

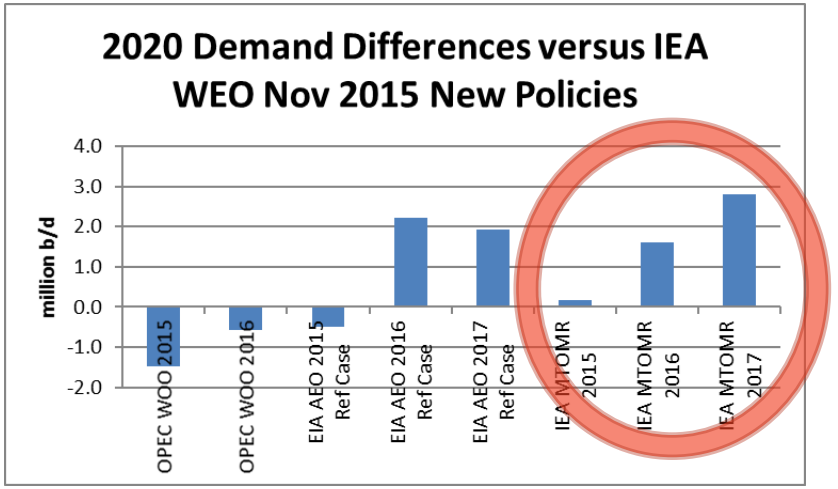
- 2. Enforcement, Compliance, Non-Compliance
  - Key factors:
    - Legal non-compliance – IMO mechanism
    - Illegal non-compliance - fuel savings vs penalties
    - Flag state vs port-state enforcement
    - Regional differences
      - Europe, USA/Canada, developing countries
      - High level of compliance versus emerging push-back
    - IMO requested “PPR” sub-committee to address implementation
      - Implementation plan not likely until 2019

EnSys-Navigistics *Marine Fuels 2020 Service* Covers the Key Issues/Dimensions

- 3. Fuel Formulations, Compatibility, Port Supply
  - Key factors:
    - Potential for different 0.5% sulphur fuel types
      - Distillate (DMA/DMB ULSD?) vs IFO grades vs hybrid VGO type fuels
    - Acceptability
      - Timescale for new fuels testing and acceptance hence volume
    - Compatibility
      - Potential for incompatibilities
    - Flash point issue
      - Marine 60°C versus on-road diesel 52°C
    - Issue of supply by port
      - Will ports have to carry multiple grades to satisfy ships reluctant to switch grade?
      - Implications for supply by port, bunker lifting patterns, supply costs

EnSys-Navigistics *Marine Fuels 2020 Service* Covers the Key Issues/Dimensions

- 4. Global Total Liquids Supply & Demand
  - Key factors:
    - Crude quality
    - Total global demand
      - Recent outlooks project increased 2020 demand
      - IEA "Oil 2017" MTOMR 101.7 mb/d 2020 versus 98.9 mb/d used for 2016 EnSys-Navigistics Supplemental Study
    - Demand mix and quality
      - Demand growth is predominantly light products (gasoline, jet, diesel, petchem)
      - Progress toward LS / ULS gasoline/diesel standards



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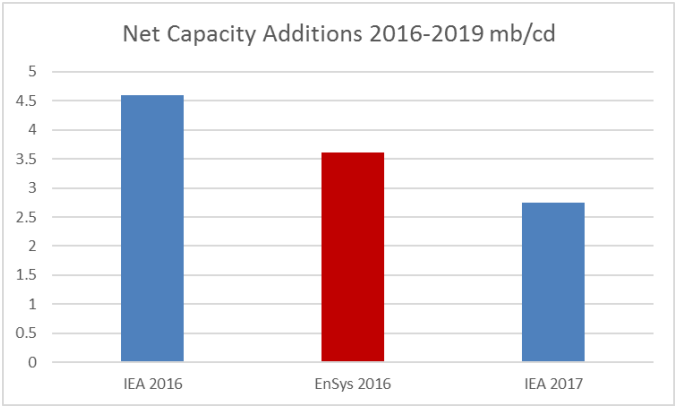

- 5. Refining Capacity / Availability
  - Key factors:
    - Additions and closures
      - Net additions 2016 – 2019
        - EnSys Summer 2016 3.61 mb/cd
        - IEA have lowered outlook
          - 2016 4.60 mb/cd now 2.74 mb/cd
          - (1.86) mb/cd versus last year but upgrading/HDS reductions much smaller (0.25)/(0.1) mb/cd
          - IEA have also cut 2020 ACU additions (0.7) mb/cd so 2016-2020 >(2.5) mb/cd
        - EnSys Summer 2017 outlook under development
    - Effective availability / maximum utilisations
      - Sustainable levels over several months
        - Continuation or reversal of recent divergent trends?
          - Africa, parts of Latin America ⬇ versus USA, Europe ⬆

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EnSys-Navigistics *Marine Fuels 2020 Service* Covers the Key Issues/Dimensions

- 6. Supply/demand balance / Market impacts
  - Key factors:
    - Initial – several weeks/months
      - *Initially demand/supply inelastic, refinery operations and trade change*
        - Impacts on supply costs / differentials, inventories important
    - Short term – several months/year
      - *Then price elasticities / adjustments kick in*
        - Potential impacts on land fuels demands
        - Potential for expanded HS HFO outlets
          - Power / industrial boiler?
          - Storage (contango)?
        - Crude supply impacts in economically sensitive regions?
          - E.g. US LTO versus Western Canada oil sands / heavy grades
    - Longer term – 2021 plus
      - *Supply/demand move towards a new 'equilibrium'*
      - Scrubber surge or flop?
        - Scale of scrubber take up?
        - Reversion toward more HS HFO demand?
        - Deterrent to or incentive for refinery investments?

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Potential Implications for European Refining

Basis EnSys-Navigistics 2016 Supplemental Study

- Base outlook is for flat to declining refining activity by 2020
  - 2020 refining throughput slightly below 2015 at 13.2 mb/d
- Global Fuel
  - Has little impact on total throughput but
  - Heavier higher sulphur crude slate
    - ~ - 0.8°API, + 0.1% S
  - Maximizes conversion, desulphurization
    - 2016 results showed extra H2 needed at +460 million SCFD (~ +10%), sulphur recovery at +2,600 short tons/day (~ + 14%)
    - These projections highlight the likelihood of shortfall
  - Naphtha/gasoline/jet/resid yields⬇distillate yields ⬆
    - N.b. EnSys' assumption was marine distillate = DMB
  - Distillate imports & resid exports go up
    - Even given the upgrading projects currently under way

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Potential Implications for European Refining

- Wide range of impacts from Global Rule
  - As everywhere - winners and losers
    - High conversion / distillate oriented versus simpler / high HS HFO yield
    - Implications for additional closures

Summary

- Global Sulphur Rule represents major challenges to refining worldwide
  - A lot of “moving parts”
  - Uncertainties will remain to and through 2020
  - But developments/dimensions can be tracked and evaluated
  - Entering a critical period – reaction to MEPC70, orders?
  - Some form of progressive implementation / compliance likely
    - Market strains likely – impacting all products not just marine
    - How IMO (PPR) handles implementation an important factor impacting how orderly or disorderly
  - Europe rigorous enforcement – some other regions?
  - European refineries substantially and variably impacted

Thank you!

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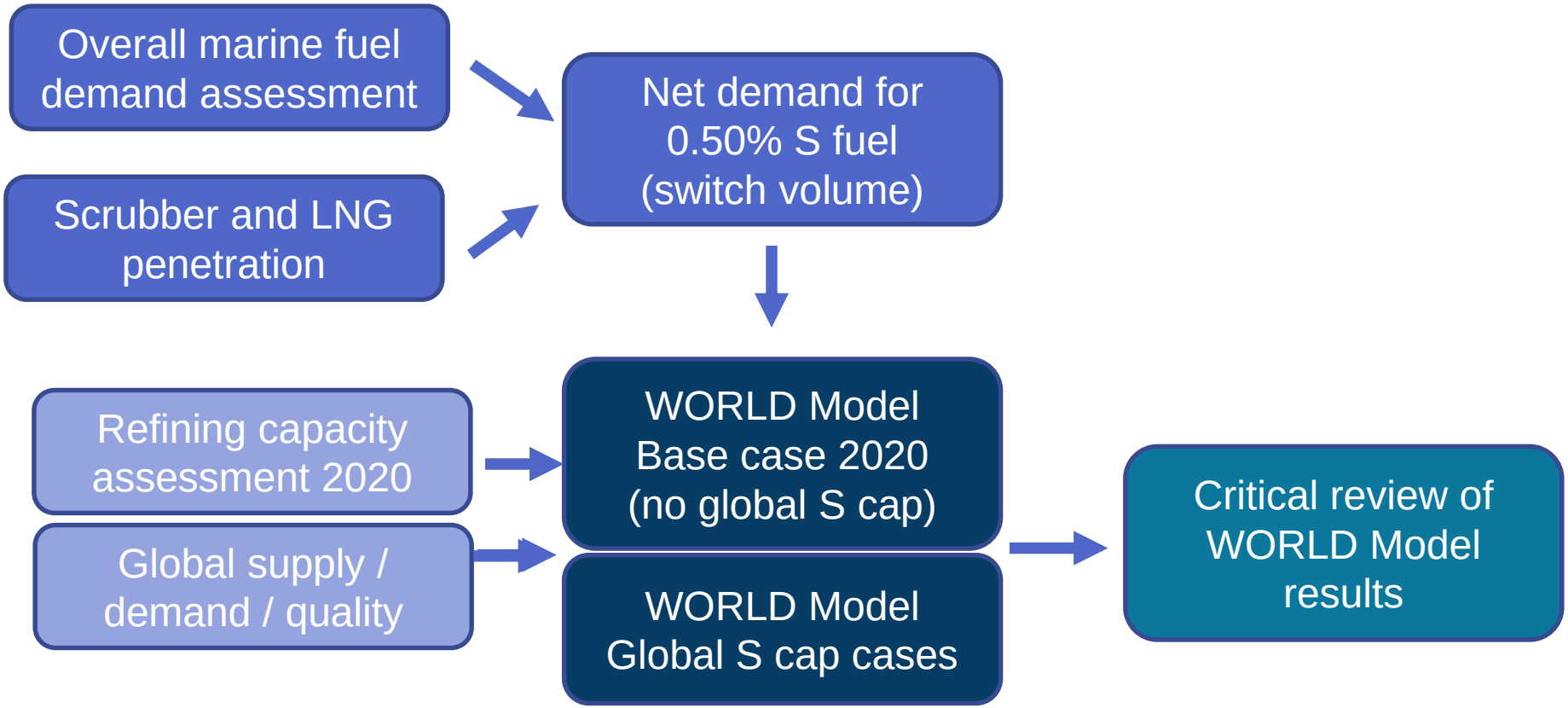
Extras

EnSys WORLD Applications

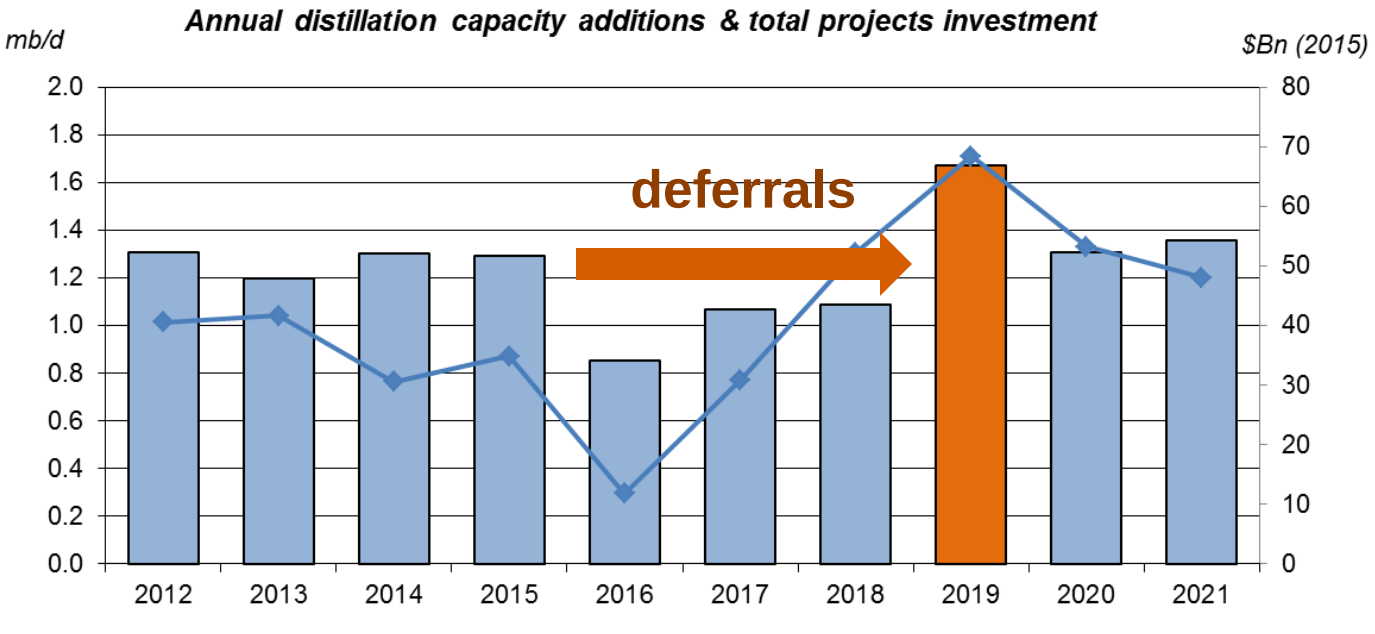
- **Recent major studies include:**
- 1987–2017: Department of Energy Office of Strategic Petroleum Reserve
  - Several analyses of real and hypothetical market disruptions
  - Impacts on refining, markets and product supply costs of different SPR draw rates and crude quality mixes; current analysis impacts of new supply/export developments
- 2000-2017: OPEC World Oil Outlook Downstream Section
  - Reference and sensitivity global outlooks to 2040
- 2008: World Bank, African Refiners Association
  - Refining and product supply cost impacts of introducing more advanced (AFRI) gasoline and diesel sulfur standards in sub-Saharan Africa
- 2009: American Petroleum Institute
  - US and global refining and market impacts of the then proposed Waxman-Markey climate bill
- 2011-2013: Departments of State and Energy
  - 2 analyses of Keystone XL and other pipeline and rail logistics scenarios and their refining, crude flows and market economic impacts
- 2014: American Petroleum Institute
  - Impacts of allowing US crude oil exports
- 2015: European Commission
  - Impacts on European refining and imports/exports of different levels of future mandated biofuels in gasoline/diesel *(Fuels Quality Directive 98/70/EC)*

EnSys- Navigistics Methodology



Crude price drop has impacted timing of refining investments

- Deferral of planned refinery additions to 2019 adds a further concern
  - EnSys' 2016 assessment showed crude price had drop deferred many capacity additions into 2019
  - Any further slippage/cancellations will place 2020 capacity at risk (with limited chance to offset)



WORLD simulations indicated global refining industry could (just) cope except for H2/SRU capacity – but impacts far-reaching

- IMO Rule involves a massive sulphur reduction (at 100% compliance) in a short period

	Sulphur reduction to meet ULS standards ppm	Timescale in years	Stages?
Gasoline / petrol	100 – 1000	10 - 20	yes
Diesel	1000 – 10000	10 – 20	yes
Annex VI	20000 - 30000	months	no

- Raises required sulphur removal by ~15,000 short tons/d

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WORLD simulations indicated global refining industry could (just) cope except for H2/SRU capacity – but impacts far-reaching

- Key Issue: H2 and sulphur recovery load
  - Four mechanisms projected as needed

Sulphur reduction/recovery mechanisms from WORLD Model results (EnSys/Navigistics Mid Switch High MDO Case)	**St/d – all numbers rounded**	**% of Total**
Sulphur into **petcoke** (increased coking unit throughputs)	4,500	30%
Sulphur into increased **FCC stack gas SOx**	250	< 2%
Sulphur recovered via **increased t/p's on existing 2020 sulphur recovery units** (close to 4% utilizn increase worldwide average)	5,400	36%
Sulphur recovered from **needed 2020 sulphur recovery unit capacity additions beyond projects** (nameplate capacity approx. +9,500 st/d)	4,850	32%
Total incremental sulphur	15,000	100%

  - If additional needed SRU capacity not – or only partly – built, Global Fuel shortfall of around 25-32% or 50-60 million tpa (1-1.2 mb/d)

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