Energy Disruption: New forces reshaping the downstream energy landscape

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- Costs and Technology
- Companies and Transactions

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- Midstream Oil and Natural Gas Liquids
- Refining and Marketing
- Company Strategies and Performance

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- Coal
- Power and Renewables
- Regional Gas, Power and Coal Markets

### ENERGY-WIDE PERSPECTIVES
- Long-Term Planning & Scenarios
- Climate Strategy
- Curated Content
- Integrated Energy Events & CERAWeek
Recent IHS studies have focused on short term and long term disruptive forces in the downstream industry

- Personal mobility – impact of technology, regulatory, and societal influences
- Commercial transport – same influences, different results
- IMO bunker fuel sulfur reduction – a major disruption is coming
Converging factors are driving disruption in mobility, transport, and energy consumption

- Disruptive technologies
- Climate policy and air quality
- Societal changes
Mobility services, driverless technology, and electric cars are adding new dimensions to the century-old personal car use model.

Selling oil-powered cars to consumers for personal use is challenged by new mobility services and powertrain options.
Disruptions to the trucking ecosystem—and diesel markets—are coming

Automation and electrification … the pace of change for cars and trucks

Note: ZEV = zero-emission vehicle.
Source: IHS Markit

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Over the next decade, up to 90% of light duty vehicle (LDV) sales will be subject to fuel economy standards.

Beyond 2020, a major increase in the number of markets supporting fuel economy regulations is expected.

Source: IHS Markit
Fuel economy and emissions standards for LDVs are increasing across the world

*US standards for 2025 are not yet finalized. Sources: National/regional regulatory agencies.

China: 74% increase from 2015 to 2025

Light duty vehicle fuel economy standards are increasing

<table>
<thead>
<tr>
<th>Country</th>
<th>2015-17 Standard</th>
<th>2020-21 Standard</th>
<th>2025*</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>40</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>European Union</td>
<td>40</td>
<td>60</td>
<td>60</td>
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<tr>
<td>India</td>
<td>40</td>
<td>60</td>
<td>60</td>
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<tr>
<td>United States</td>
<td>40</td>
<td>40</td>
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</tbody>
</table>
Anti-fossil fuel moves are gathering pace, with strong impact on new car sales, especially diesel

**Norway:** Plan to phase out new gasoline and diesel car sales by 2025 using tax incentives

**Sweden:** Seeking bans, beginning with older diesel cars in town centres from 2020

**Finland:** Mulling ban on sales of diesel cars by 2030

**Italy:** Rome seeking to ban diesel cars by 2024

**Ireland:** Considering 2030 ban on fossil fuel car sales, reducing diesel-gasoline tax differential

**UK:** Seeking ban on fossil fuel car sales by 2040; London ULEZ; mulling HGV ban in London. Scotland looking for fossil fuel car sales ban in 2032

**Netherlands:** Halt sales of new gasoline and diesel cars by 2030

**Belgium:** LEZ in Brussels, ban older diesels from 2018. Reduce fuel tax differential

**Germany:** Diesel bans begin in 2018 following court ruling. Stuttgart is the first to enforce ban on older diesels

**Austria:** Tentative target of 2025 for ban on fossil fuel cars

**Slovenia:** Ban on new fossil fuel car sales by 2030

**Denmark:** Copenhagen seeking ban on diesel cars by 2019

**France:** Ban sales of fossil fuel cars by 2040; Paris restricts older diesels, total ban by 2030. Diesel/gasoline tax levelling. Scrappage bonus

**Spain:** Madrid seeks to ban older diesels by 2025

**Greece:** Athens seeking ban diesel cars by 2025

**Scotland:** Looking for fossil fuel car sales ban in 2032
Electric vehicle technology is advancing – and China is leading the way

Globally, EVs accounted for 1.7% of global new LV sales and 0.2% of fleet (parc).

Electric vehicles address emissions, climate, efficiency, and technology
Driverless technology has the potential to be most disruptive force of change in the automotive ecosystem

Illustrative diagram of driverless technology

- Improve road safety
- Lower the cost of mobility
- Increase access to mobility
- Liberate people from driving
- Increase sales & use of EVs
- Support stringent restrictions on car use
- Fewer cars needed due to higher utilization
- Less parking needs will impact urban design
- However, costs are high for the suite of technologies, but declining
Driverless technology will benefit from strong cost incentives, if hurdles can be overcome

### Cost of mobility by car for US market

<table>
<thead>
<tr>
<th></th>
<th>Dollar per mile traveled, Constant 2017 $US</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Personal owned car basis</strong></td>
<td></td>
</tr>
<tr>
<td>Today</td>
<td>Human driver (ICE) 0.59</td>
</tr>
<tr>
<td>2040</td>
<td>Human driver (ICE) 0.58 Human driver (EV) 0.48</td>
</tr>
<tr>
<td><strong>Mobility as a service basis</strong></td>
<td></td>
</tr>
<tr>
<td>Today</td>
<td>Human driver (ICE) 2.17 Driverless (HEV) 0.43</td>
</tr>
<tr>
<td>2040</td>
<td>Driverless (EV) 0.33</td>
</tr>
</tbody>
</table>

**Notes:** BEV = battery electric vehicle. Hybrid = gasoline/electric with internal combustion engine. ICE = internal combustion engine.

Source: IHS Markit
Different mobility channels will prefer different vehicles, and affect the structure of travel demand

### RTW regional powertrain sales mix by mobility channel, Rivalry 2040

<table>
<thead>
<tr>
<th>Share of LDV Sales</th>
<th>Total LDV, 2016</th>
<th>Total LDV, 2040</th>
<th>PNAC</th>
<th>PAC</th>
<th>MaaS</th>
</tr>
</thead>
<tbody>
<tr>
<td>100%</td>
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<td>80%</td>
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<td>0%</td>
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</tbody>
</table>

Notes: HEV: Hybrid electric vehicles, which include both mild and full conventional hybrids
PHEV: Plug-in electric vehicles
BEV: Pure battery electric vehicles
FCEV: Hydrogen fuel cell vehicles
Other: Include both compressed natural gas and LPG vehicles

### RTW regional total LDV miles traveled by mobility channel: Rivalry

<table>
<thead>
<tr>
<th>Billion miles per year</th>
<th>PAC</th>
<th>PNAC</th>
<th>MaaS</th>
<th>Total LDV</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
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<td>2010</td>
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<td>2020</td>
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<td>2030</td>
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<tr>
<td>2040</td>
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</tbody>
</table>

Source: IHS Markit

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Future sales led by hybrid and EV powertrains, but fleet turnover is slow

**RTW regional LDV sales by powertrain: Rivalry**

- Gasoline
- Diesel
- HEV
- PHEV
- BEV
- Other

**Note:** Other includes CNG and LPG vehicles. PHEV = plug-in hybrid electric vehicle.

**RTW regional LDV on road fleet by powertrain: Rivalry**

- Gasoline
- Diesel
- HEV
- PHEV
- BEV
- Other

**Note:** Other includes CNG and LPG vehicles. PHEV = plug-in hybrid electric vehicle.
Demand for trucking growing rapidly, but changes to this ecosystem are coming, too

Certainties
- Trucking remains a central element of the global logistics system
- There is significant scope for diesel engine fuel efficiency improvements
- The pace of change will be hampered by the inertia of a conservative and fragmented trucking industry

Uncertainties
- The role of policy and regulation in forcing change
- The disruptive impact of autonomous driving and other technologies
- The future role for alternative fuel powertrains, which today have fragmented offerings

Ton-kilometers: RTT markets, 2000–40

Ton-kilometers set to more than double to 2040

Source: IHS Markit

RTT = Reinventing the Truck study that includes these four markets that account for about 40% of global medium/heavy duty diesel demand

© 2018 IHS Markit
Driverless trucks have the potential to fundamentally alter the cost structure of the industry

Autonomous = Level 4 and Level 5

Increasing automation

- L5: Full automation
- L4: High automation
- L3: Conditional automation
- L2: Partial automation
- L1: Driver assistance
- L0: No automation

Source: Based on Society of Automotive Engineers levels of automation (SAE J3016) © 2018 IHS Markit

TCO breakdown: Europe MDV Rivalry, 2020

- TCO $396
- Fuel $53
- Maintenance $26
- Resale value $(20)
- Driver $180
- Taxes $20
- Vehicle capex $71

Note: Assumes six-year vehicle life with 220,000 km driven. For a general application MDV purchased in 2020, all values are net present values assuming a 6% discount rate. Source: IHS Markit © 2018 IHS Markit
Higher HDV fuel efficiency is feasible and many countries are targeting improvements

What technologies could contribute to improvements in diesel fuel economy?

1. Trailer aerodynamics
   - Side skirts
   - Boat Trails

2. Driveline
   - Axle efficiency
   - Transmission efficiency
   - Integrated transmission
   - Downspeeding
   - Direct Drive
   - Predictive cruise control

3. Tractor aerodynamics
   - Roof deflectors or fairing
   - Side fenders
   - Aerodynamic mirrors
   - Turning vanes

4. Engine
   - Friction reduction
   - Auxiliary electrification
   - Combustion optimization
   - Aftertreatment improvements
   - Waste heat recovery

5. Tires
   - Automatic inflation system
   - Low-rolling resistance tires

Diesel engine example:

- Downsizing from 15L engine to 11L-13L is becoming the norm in class-8
- Large improvements in turbocharging technology allow for similar performance at a smaller size
- A 1MPG (6MPG to 7MPG) increase at 100,000 miles/yr = ~$7.5k/yr fuel savings
  - Such savings challenge EV in trucking, at least for the same light-duty model
- Injection pressures have also increased to 1600/1800 BAR – 2500 BAR in the future

Source: IHS Markit © 2018 IHS Markit
Fuel economy standards—not EV penetration—have the biggest impact on LDV gasoline and diesel demand

Global LDV gasoline and diesel demand: Rivalry

Oil demand assuming constant fuel economy and no EVs

Rivalry demand with no EVs

Decrease due to higher fuel economy

Decrease due to EVs

Notes: This is an illustrative example of how much gasoline EVs displace versus improving fuel economy. “Rivalry without EVs” is calculated by assuming all global electric miles are instead driven by gasoline HEVs. “Rivalry without EVs and constant fuel economy” assumes that all global LDV miles are traveled by vehicles with a constant 25 miles per gallon (mpg) fuel economy from 2020 to 2040.

Source: IHS Markit

© 2018 IHS Markit
Efficiency gains and fuel substitution curb long-term commercial trucking diesel demand in our base (Rivalry) scenario

Diesel and gasoline demand from MHCV—RTT markets

Source: IHS Markit

Peak in 2025 (+4% versus 2018)
(4)% versus peak
(8)% versus 2018
As these efficiency gains and substitution slow demand growth, global refined products demand peaks in the 2030s

World demand growth by region: Total refined products

Source: IHS Markit
IMO 2020 bunker specification change—the biggest planned disruption to oil markets ever?

The International Maritime Organization (IMO) agreed in October 2016 to reduce bunker fuel sulfur from 3.5% to 0.5% as of January 2020.

The impact will be disruptive and uncertain, because:

1. The simultaneous global nature of the change
2. With less than one year until the change, refinery investment and ship scrubber installation appears insufficient
3. Legislative clarity on the change is still required as the largest area of uncertainty is compliance
4. IHS Markit still expects the most likely outcome to be an excess of residue in 2020 having to find a home in power generation

- IHS has studied impacts since 2009, with urgency accelerating since the 2016 decision
- Most oil market observers and the futures markets now anticipate significant disruption
  - Key questions are how much disruption and how long will it last?
Global shipping will need to comply with the new fuel quality rules

Four pathways

- **Switch to compliant low-sulfur bunker fuel**
- **Install exhaust gas cleaning systems, aka scrubbers**
- **Switch to liquefied natural gas**
- **Non-compliance, sanctioned or otherwise (Not a true pathway)**
At less than 12 months from one of the most disruptive changes for refining and shipping, a lot of work still needs to be done.

- **Fuel availability study**
  - Jul-2016

- **MEPC 70**
  - Oct-2016
  - Decision to impose a 0.50 wt% sulphur cap on marine bunkers from 1 January 2020

- **PPR 4**
  - Jan-2017
  - High sulphur fuel oil carriage ban proposed

- **MEPC 71**
  - Jul-2017
  - Proposed ship implementation plan but no consensus on guidance to PSC about enforcement and nonavailability

- **MEPC 72**
  - Apr-2018
  - High sulphur fuel oil carriage ban agreed
  - CO₂ emissions reduction targets agreed for 2030 and 2050

- **PPR 5**
  - Jan-2018
  - Final approval of the high sulphur fuel oil carriage ban

- **MEPC 73**
  - Oct-2018
  - No new specification
  - New fuels within ISO8217 Guidance about type of fuel blends expected from 2020

- **MEPC 74**
  - Spring 2019
  - High sulphur fuel oil carriage ban effective 1 March 2020

- **PPR Intersessional meeting**
  - Jul-2018
  - ISO quality guidance 0.50% sulfur cap Carriage ban

Key:
- MEPC: Marine Environmental Protection Committee
- PPR: Subcommittee for Pollution Prevention & Response
- ISO: International Standards Organisation
- Today
Interest in onboard scrubbing accelerated strongly in 2018

- IHS Markit records accelerating uptake of exhaust gas cleaning systems with 1,750 vessels with scrubbers fitted or on order as of year-end 2018, an increase of ~1,300 ships compared to March 2018
- In summer and autumn 2018, several large shipping companies announced significant scrubber fitting programs, and some carriers that were initially skeptical have since changed their tone
- Regardless, we still expect scrubber levels to be significantly below the expectation when the IMO change timing was set
- We expect most scrubbers to be open loop - often hybrid-ready - with only a minority of scrubbers closed loop or hybrid from the onset
- Time-charter premiums have been quoted for tankers and dry bulk vessels fitted with scrubbers, as charterers can compensate these through bunker fuel savings
- The new long-term shipping GHG emission reductions targets (50% by 2050) further confuse the decision for the shipping industry
Scrubber installations are focused on the highest fuel-consuming segments

Over 80% of the fleet fitted/to be fitted with scrubbers comes from the high consuming sectors, Tanker (26%), Bulk Carrier (33%), Cruise ships (9%) and Container Ships (14%)

Aside from cruise ships, the other three sectors have seen a large rush to install scrubbers

The confirmed scrubber population of new builds is around 6% of the total order book, however it is assume that this percentage will rise as more installations are confirmed in due course

Some major shipyards are offering retrofits to their in-house designs, which can be undertaken before the ship’s scheduled completion
With ‘IMO 2020’ deadline fast approaching, action is accelerating

**Refiners are focused on low-capital actions**

- Limited investment in conversion capacity under way – XOM Antwerp, Shell Pernis, a few more
- Optimize capacity of existing processing units
- Crude slate optimization
- Change bunker fuel blending recipe

**Clarity is emerging on enforcement**

- High sulfur fuel carriage ban
- Enhanced port state enforcement powers
- Harmonizing fuel non-availability reporting
- Implementing fuel oil data system
- Possible loss of insurance cover
IMO bunker fuel rules will create a spike in marine gasoil (diesel) demand…real issue for oil markets is disposal of heavy residual

Global bunker fuel demand

- Gasoil demand increases by 1 million b/d or more
- Gasoil Bunker
- High Sulfur Residual Bunker
- VLSFO Bunker
- LNG Bunker

1. Hybrid fuels
2. Very Low Sulfur blends

- 1. Scrubber uptake
- 2. More hybrid fuels
- 3. Gasoil market share falls to 20% by 2030
Oil product futures markets are continuing to demonstrate an increasingly significant ‘IMO 2020’ impact but less than the IHS Markit outlook.
The “IMO Scramble”: compliance and scrubber uptake are the two key uncertainties

- High Sulfur Fuel Oil (HSFO) will be sharply discounted to penetrate power markets
- New 0.5% sulfur bunker will approach marine diesel price
- Increased demand will drive up light product prices (gasoline and diesel/kerosene)
- Scrubbers eventually take care of HSFO surplus – but it will take time

- Recent study used Monte Carlo and scenario analysis to assess range of uncertainty – significant disruption is the most likely outcome
Energy disruption will come from many directions

Technology and innovation changing product demand patterns

Policy and societal forces are reshaping markets

Technology, mobility and IMO will have short and long term impacts