Presentation to Analysts / Investors
Johnson Matthey and the Evolving Powertrain

4th February 2016
Cautionary Statement

This presentation contains forward looking statements that are subject to risk factors associated with, amongst other things, the economic and business circumstances occurring from time to time in the countries and sectors in which Johnson Matthey operates. It is believed that the expectations reflected in these statements are reasonable but they may be affected by a wide range of variables which could cause actual results to differ materially from those currently anticipated.
Introduction and Strategy Update

Robert MacLeod
Chief Executive
## Programme

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<th>Time</th>
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<td>Introduction and Strategy Update</td>
<td>Robert MacLeod</td>
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<td>13.50</td>
<td>Capturing Value from Powertrain Evolution</td>
<td>Nick Garner and John Walker</td>
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<td>15.00</td>
<td>Automotive Emission Control Regulations and Technology Trends</td>
<td>Chris Morgan and Andy Walker</td>
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<td>Creating Value from Market Opportunities in Battery Technologies</td>
<td>Martin Green</td>
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<td>Science and Technology – Delivering Sustainable Solutions to Customers</td>
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<td>Summary and Final Q&amp;A</td>
<td>Robert MacLeod</td>
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<td>Drinks Reception and Dinner</td>
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Purpose of the Day

**Update**
on progress in delivering group strategy

**Explain**
how global drivers are influencing future powertrain developments and creating market opportunities

**Detail**
how high technology solutions in both emission control and electrification will play a role

**Highlight**
how Johnson Matthey is positioned to create superior value from these opportunities
Update on Current Trading

- Sales* up 3%; operating profit lower
- Action to reduce costs by £30m p.a. well underway
- Strong growth in ECT
- Difficult trading conditions persist in PT and PMP
- Good progress in FC and NB

Outlook for FY in line with current market expectations

*2014/15 and 2015/16 adjusted to exclude contribution of Gold and Silver Refining and Research Chemicals businesses which were sold in 2014/15.
Difficult Macroeconomic Climate

**Oil price**
- 40% fall in last 12 months

**China**
- Lower GDP growth forecast
- Sufficient chemical capacity
- Review of coal strategy

**Pgm prices**
- Pt and Pd down 30% and 35% since last year
- Lowest Pt prices since end 2008

Investment delays in chemical industry

Delays and reduced market for coal to SNG

Lower pgm refining volumes, reduced profitability

Current macro climate expected to limit group’s short term growth opportunities
Long term strategy robust
Good Progress in Strategy Delivery

C³

- Customer focus
- Create value

- Growth from new business
- Collaborate to leverage our expertise
- The best of big and small

- Invest in people, products and technology
- Build on our core strengths
- Operational excellence and sustainability
- The Johnson Matthey culture
Good Progress in Strategy Delivery

**Invest in people, products and technology**
- Invest ~5% p.a. of sales in R&D
- Expect capex at ~1.5x depreciation

**Build on our core strengths**
- Disposal of two non-core businesses
- Medium term organic growth opportunities remain

**Growth from new businesses**
- Good progress in establishing Battery Technologies and ACT businesses
Good Progress in Strategy Delivery

Operational excellence and sustainability
- Increased focus on health and safety
- Business systems upgrade on track

Customer focus
- Leverage more from value add and total JM offering
- Facilitate entry into new markets

Create value
- Special dividend 150p per share
- ROIC target of 20% remains
- Growth opportunities from evolving powertrain
Sustainability Drivers Provide Superior Growth for JM

**Global Drivers**

- **Population Growth**
  - Provide opportunities across all businesses
  - JM well positioned in emerging markets

- **Urbanisation**
  - Energy security remains a major driver for PT’s technologies
  - Recycling pgms is a strategic service

- **Increasing Wealth**
  - Continued tightening of emissions legislation as air quality and focus on emissions remain a priority
  - Electrification of powertrain creates additional opportunities

- **Natural Resource Constraints**
  - Ongoing pressure on healthcare costs drives increased use of generics
  - Enzymatic catalysis / more sustainable chemistry in pharma industry

- **Environmental Factors**
  - Climate Change Regulation

- **Ageing Population**
Global Drivers Continue to Provide Opportunities for Powertrain Technology

- Increased demand for mobility, focus on emissions
  - Population Growth
  - Urbanisation
  - Increasing Wealth
- Environmental Factors
  - Climate Change
  - Regulation
- Health & Nutrition
  - Ageing Population
- Improved fuel efficiency, alternative fuels, sustainable energy generation
- Natural Resource Constraints

Tighter emission regulations, low CO₂, zero emissions
Focus on air quality to improve public health
Imperative for Improved Air Quality Supports Growth

Legislation continues to tighten at pace
- Regulated pollutants and CO₂ in focus
- ICE remains main powertrain technology for next decade; increased hybridisation
- Increased opportunity for JM from diversified powertrain

**ECT**
Increased demand for complex catalysts and hence more value over next decade
- JM a leading technology provider

**Battery Technologies**
Growing market for battery materials expected to expand
- JM player in current market
- Investing to capture value as market evolves

**Medium term targets remain**

**JM roadmap on track**
Driving Success in Evolving Powertrain Market

Chemistry and applications know how at heart of powertrain technology solutions

Chemistry...

...and its application

Cutting edge chemistry for emission control and battery technologies

JM differentiator – understanding how it can be used

That enables us to build multi million pound product businesses

Specialist technology expertise

Integration into apps

Manufacture at scale

Testing
The JM Advantage in Powertrain Solutions

- Strong expertise in translating metal chemistry solutions into auto applications
- Ability to scale up
- Efficient manufacturing
- Well positioned in supply chain
- Deep relationships with OEMs
- Strong reputation
- Understand future needs

JM well placed to capture value from evolving powertrain
Key Takeaways

- **JM remains well placed for sustained long term growth**
- **Robust strategy and strong market drivers**
- **Evolution of the powertrain requires high technology solutions**
Capturing Value From Powertrain Evolution

Nick Garner
Division Director, New Businesses and Corporate Development

John Walker
Executive Director, Emission Control Technologies
Overview

Explain
how tightening legislation and electrification offer strong growth opportunities for JM

Outline
how JM’s gasoline and diesel emission control technologies will continue to play an important role in a more diversified powertrain

Highlight
how JM is well placed to benefit further from the expanding market for battery technologies
JM – Well Placed to Meet Future Powertrain Needs

- Global leader in emission control
- Major lithium iron phosphate (LFP) supplier for automotive applications
  - Supplying / awarded 15 automotive platforms
- Extensive operations across the globe
  - 18 manufacturing sites and 11 technology centres
- ~5,000 employees; ~13% in R&D
- Ongoing investment in R&D and capex to support growth

Legislation drives value growth with more new opportunities
Key Trends in Automotive

- Vehicle numbers increasing
- Autonomous vehicles
- Increased connectivity
- Car sharing
- Lightweighting
- Increased regulation
- Electrification

Enabler: New technology development and implementation
## Legislation Continues to Tighten

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<th>Regulated Emissions</th>
<th>CO₂ / Fuel Economy</th>
<th>ZEV Mandates</th>
<th>City LEZs</th>
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Increased requirement for advanced emission control in combination with additional solutions
Diesel – Key to Meeting CO₂ Targets

**Diesel engine inherently more fuel efficient than gasoline counterpart**
- CO₂ emissions ~15% lower* than gasoline car

**Diesel cars continue to get cleaner**
- Advanced aftertreatment technology
- Proposed London / Paris emission zones will allow current (Euro 6b) diesel cars
- RDE will have further positive impact on emissions

**Diesel’s share of Western European car production steady at ~50%**
- Continue to expect proportion to trend down in medium term

**Total cost of ownership (TCO) will continue to favour diesel for higher mileage drivers**

*Diesel expected to remain important part of the mix for next decade and beyond*

*JM estimates calculated for typical 1.6 litre hatchback diesel and gasoline cars*
More Diverse Powertrain is Positive for JM

From this... to this...

IC Gasoline

IC Diesel

MHEV
Mild Hybrid Electric Vehicle
Honda Integrated Motor Assist
Buick LaCrosse EAssist

FHEV
Full Hybrid Electric Vehicle
Toyota Prius
Ford Fusion Hybrid

PHEV / EREV
Plug-in Hybrid / Extended Range Electric Vehicle
BYD Qin / BMW i3 RE

BEV
Battery Electric Vehicle
Tesla
Nissan Leaf

FCEV
Fuel Cell Electric Vehicle
Toyota Mirai
Hyundai ix35 Fuel Cell

Hybrids require emission control catalysts and battery technologies
In 2025 ~97% of Cars Still Have ICE

Gasoline and diesel ICE remain major technologies
• Absolute number of diesel cars continues to increase

More electrification
• Increasing hybridisation in both gasoline and diesel powertrains (stop-start to full hybrids)
• FCEV remains niche until at least 2025

Pace of evolution beyond 2025 likely to depend on progression of CO₂ regulations

Chart Data Source: LMC Automotive
Similar Story in Heavy Duty Market Too

• Good growth in regulated heavy duty engines (6% CAGR)* to 2025
• Legislation continues to tighten
  • China – Euro VI from 2017, Tier 4a/b non-road from 2018, NEV targets for EV
  • Europe – Stage V non-road from 2019
  • India – Euro VI from 2020 to 2025
  • North America CARB – ultra low NOx from 2023

• Low emission zones to improve air quality in cities
  • Requirement for higher technology catalysts
  • Strong growth in BEV and PHEV buses / trucks, mainly in China
  • Outside of cities, diesel expected to remain main technology

* LMC Automotive and JM estimates

JM well placed to benefit as leading supplier to HDD sector
## Added Value from Technology

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<tr>
<th>JM technology presence</th>
<th>IC Gasoline</th>
<th>IC Diesel</th>
<th>MHEV/FHEV (Gas / diesel)</th>
<th>PHEV / EREV</th>
<th>BEV</th>
<th>FCEV</th>
<th>Truck</th>
<th>HEV / PHEV Truck / Bus</th>
<th>Battery Electric Bus</th>
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<td><strong>Potential value - emission control</strong></td>
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<td>£ 5-7x</td>
<td>£ 1-7x</td>
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<td>£ 20x</td>
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<td><strong>Potential value battery material / MEA</strong></td>
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<td>£ 1x</td>
<td>£ Up to 12x</td>
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<td>£ Up to 120x</td>
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<td>£ Up to 80x</td>
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Electrification offers added value for JM
Market to Reach Over $20bn by 2025

Expanding market for emission control catalysts and battery materials

Market Outlook for Powertrain Technologies

sales ex pms $m

- Continued good growth in light duty catalysts market ($6bn in 2015 to >$9bn by 2025)
- HDD catalysts market offers strong growth ($1.75bn in 2015 to >$4bn by 2025)
- Significant expansion in battery materials markets for both light and heavy duty applications ($1bn in 2015 to >$8bn by 2025)

Powertrain technologies market offers good growth potential

Chart Data Source: LMC Automotive and JM estimates
Capturing the Value

Invest in R&D to develop next generation technologies
Exploit expertise in chemistry and applications

Optimise efficiencies in manufacturing and across supply chain

Use JM brand and reputation to broaden JM offering

Expand JM’s position as key technology supplier for low emission / low carbon vehicles
Key Takeaways

- Increasing opportunities for JM technologies from automotive trends
- Emission control technologies continue to be key enabler – ICE remains major powertrain technology
- Battery technologies market set to expand – JM business on track
- JM well placed to capture value
Automotive Emission Control Regulations and Technology Trends

Dr Chris Morgan
European Technology Director, Emission Control Technologies

Dr Andy Walker
Divisional Technology Director, Emission Control Technologies
Overview

Outline
global growth trends in vehicle and engine production

Present
incoming global regulatory trends – continued tightening of criteria pollutants and increasing focus on CO₂ / fuel economy

Show
how we maintain differentiation through technology

Highlight
opportunities resulting from regulatory, customer and market drivers

Describe
how these opportunities drive future sales growth in ECT
Vehicle Numbers Continue to Increase

Light Vehicle Sales Outlook by Region
(calendar years)

- Continued steady global growth
- Good growth in BRICs
- Shared mobility models likely to increase
  - Shorter holding times and faster wear

3% Global CAGR 2015-2025

- North America
- Total Europe
- Total Asia
- Rest of World

Continued growth in vehicle production drives demand for JM’s powertrain technologies

Chart Data Source: LMC Automotive
Legislation Continues to Tighten Around the World

Light Duty Emissions Control Legislative Roadmap

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Focus on Gasoline and Diesel Emissions in Europe

Light Duty Emissions Control Legislative Roadmap

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- **Euro 6b** - In full effect from September 2015
  - Common use of diesel NOx control
- **Euro 6c** - From September 2017
  - Gasoline particle number (PN) limit to $6 \times 10^{11}$/km

Real World Driving Emissions (RDE)
- Euro 6d Temp 2017/2019
  - NOx conformity factor (CF) of 2.1x, PN CF decision expected in 2016
- Euro 6d Final 2020/2021
  - NOx CF of 1.5x, PN CF to follow

Gasoline particulate filters and advanced diesel NOx control required
## North America – California Still Leads the Way

### Light Duty Emissions Control Legislative Roadmap

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### LEV III
- Phased in tightening of NMOG+NOx and particulate mass (PM) to 30 mg/mi and 1 mg/mi in 2025
- Subject to mid term review in 2016

### Tier 3
- Finalised by EPA and closely aligned to CARB, except PM limit 3 mg/mi by 2022
- GHG
  - 30 mg/mi CH₄ and 10 mg/mi N₂O

---

More complexity in current catalyst systems
Tightening Legislation Continues at Pace in Asia

Light Duty Emissions Control Legislative Roadmap

Europe
North America EPA
North America CARB
Japan
South Korea (Gasoline)
South Korea (Diesel)
China (Beijing)
China (Nationwide)
India
Indonesia
Thailand

- **Japan JP18** – From 2018
  - WLTC excluding high speed phase, CO 1.15, HC 0.1, NOx 0.05, PM 0.005 g/km
- **Beijing BJ6** – Phase in from 2017
  - ULEV70 from Dec 2017, SULEV30 from 2020, 3 mg/mi PM, no PN regulation yet

- **China Nationwide**
  - CN5 - Euro 5 equivalent from 2017
  - CN6 - From 2021 Euro 6 equivalent, adopt WLTC, maybe PN limits
- **India**
  - No BS5, BS6 brought forward to 2020

**More advanced gasoline systems required, including particulate filters in China**
Tightening CO₂ / Fuel Economy / GHG Requirements

Additional GHG limits for the US:
- N₂O: 0.010 g/mile
- CH₄: 0.030 g/mile

[1] China’s target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.

Leads to lower catalyst temperatures and increased electrification
Euro 7?

Formal discussions on Euro 7 delayed until RDE legislation is fixed

Likely topics include:
- Fuel neutral limits (i.e. lower diesel NOx)
- Further tightening of RDE CFs
- (Urban?) NO$_2$ limits
- Addition of criteria pollutants including N$_2$O and NH$_3$

The European Commission also has an ambition to reduce CO$_2$ emissions further, e.g. to 75 g/km by 2025
- Drives further hybridisation
Other Technology Drivers

**Engine technology developments**
- More downsized, turbocharged engines
- Stop-start, more energy recuperation, mild and plug-in hybrids
- GDI increases, lean burn gasoline remains niche
- Improved injectors and cylinder design to reduce gasoline PN
- Cooled EGR to reduce diesel engine out NOx emissions
- NA fuel economy targets lead to diesel penetration into large SUV / light truck market

**Fuels**
- CNG, LPG, ethanol remain small except for certain local markets

**System costs**
- OEMs want to minimise additional costs for more complex or advanced aftertreatment systems
Johnson Matthey Clean Diesel Technologies

Solutions to control NOx emissions

**NOx Adsorber Catalysts (NAC)**
- Pgm based catalyst
- Requires fuel addition, hence penalty on fuel consumption
- Favoured on smaller vehicles

**Selective Catalytic Reduction (SCR)**
- Metal-zeolite based catalyst
- Requires urea injection system, with tank, doser and injection systems
- Favoured on larger vehicles
- More reliable at higher speeds

**Advanced SCR**
- Allows improved thermal management of catalyst on vehicle
- Technically very demanding system
- May require additional SCR / ammonia slip catalyst (ASC) to maximise NOx conversion
- Higher technology product adds value

- Johnson Matthey well positioned in all technologies
- All three approaches being used to meet Euro 6b regulations
Johnson Matthey Clean Diesel Technologies

Solutions to control NOx emissions

**Selective Catalytic Reduction (SCR)**
- Metal-zeolite based catalyst
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**Advanced SCR**
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- May require additional SCR/ammonia slip catalyst (ASC) to maximise NOx conversion
- Higher technology product adds value

**Expect shift towards SCR and Advanced SCR for RDE compliance**
- Plus some NOx adsorber capability to be incorporated into the DOC for urban NOx control
Euro 6 Technology Already Improving Real World NOx

A third of Euro 6b diesel (and all Euro 6 gasoline) cars tested met 2.1x NOx CF

Real World NOx (g/km)

Source: www.emissionsanalytics.com
Johnson Matthey Gasoline Filter Technologies

**Solutions to control gasoline PN emissions**

JM to launch two types of coated Gasoline Particulate Filter systems in 2016:

- Three Way Catalyst (TWC) plus coated Gasoline Particulate Filter (cGPF)
- Three Way Filter (TWFTM) plus downstream TWC

- Development partnerships continue with OEMs
- Some applications to meet Euro 6c PN limit through improved engine technology or use of an uncoated GPF
- Expect TWFTM / cGPF uptake to increase with RDE PN limits

**Additional technology increases the value of gasoline aftertreatment systems**
JM Catalyst Development Focus

Similar themes for both diesel and gasoline catalyst development:

**Temperature**
- Lower catalyst light-off temperatures and improved cool efficiency
- Improved fuel efficiency reduces catalyst operating temperatures
- Increased focus on urban driving

**Increased thermal durability**
- Gasoline peak ageing temperatures increasing with latest engines
- Effect of soot and sulfur regeneration strategies in diesel systems

**Reduced system backpressure**
- To maximise power delivery from engine

**Reduced precious metal content**
- Cost control for multi-catalyst systems

Enables JM to offer competitive products to OEMs, protecting our market position
Good Sales Growth Continues in Light Duty

- Market size $6bn in 2015 growing to over $9bn by 2025
- European diesel remains a very important sector
- RDE legislation and GPFs provide opportunities in Europe
- Increasing Asian car sales and tighter legislation adds further growth

Light duty market continues to grow ahead of global vehicle sales

Chart Data Source: LMC Automotive and JM estimates
Summary

Emissions legislation continues to tighten around the world
Political and public pressure for clean vehicles

Further catalyst development required

Increased uptake of latest catalyst technologies

Opportunity for growth into next decade, supported by vehicle production, legislation and improved technologies
Regulatory and Technology Trends in the Global HDD Market

Dr Andy Walker
Divisional Technology Director, Emission Control Technologies
Heavy Duty Vehicle Regulated Engines To Increase

Heavy Duty Regulated Engines Outlook by Region
(california years)
thousands

Continued growth to 2025

- Rapid growth in Asia, led by China and India
- Good growth in Europe

6% Global CAGR 2015-2025

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Chart Data Source: LMC Automotive and JM estimates for proportion regulated
Further Tightening of Heavy Duty Regulation

Heavy Duty Diesel Emission Control Legislative Roadmap

**On Road**
- **Europe**
- **North America**
- **North America (CARB)**
- **Japan**
- **South Korea**
- **Brazil**
- **Russia**
- **India (Main Cities)**
- **India (Nationwide)**
- **China (Beijing)**
- **China (Nationwide)**

**Non-road**
- **Europe**
- **North America**
- **Japan**
- **South Korea**
- **Brazil**
- **China (Beijing)**
- **China (Nationwide)**


- **EU VI**
- **EU VII?**
- **GHG Phase 1**
- **GHG Phase 2**
- **GHG Phase 2 and CARB Ultra Low NOx**
- **JP09**
- **JP16**
- **EU V**
- **EU V?**
- **EU VI**
- **EU IV**
- **EU V**
- **EU VI**
- **Tier 4b**
- **Stage V**
- **CARB/EPA Reduced NOx/PM?**
- **Tier 4b**
- **Tier 4a?**
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### Incoming Europe and North America Regulations

#### Heavy Duty Diesel Emission Control Legislative Roadmap

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#### Key Points:

- **EU VII**
  - Possible NO$_2$, N$_2$O and fuel economy regulation to drive new systems design opportunities

- **EPA GHG Phase 2**
  - Further increases in fuel efficiency mandated from engines,
  - Lower catalyst operating temperatures and increased catalyst system NOx conversion needs

---

**Optimised systems with improved NOx conversion and low temperature performance**
# China / India EUVI Adds Filters

## Heavy Duty Diesel Emission Control Legislative Roadmap

### On Road

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### Key Points

- **India EUVI**: Filters and SCR on all HDD vehicles
- **China EUVI**: Filters and SCR on all HDD vehicles

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Transition from SCR to SCRT systems increases JM value
EU Non-road Stage V Mandates Filter Fitment

Heavy Duty Diesel Emission Control Legislative Roadmap

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- Europe
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- Russia
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- India (Nationwide)
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- China (Nationwide)

**Non-road**
- Europe
- North America
- Japan
- South Korea
- Brazil
- China (Beijing)
- China (Nationwide)

**EU Stage V**: Filters and SCR on all HDD Non Road Mobile Machinery

Transition to SCRT and SCRF systems increases JM value
China Non-road Regulations Require Emission Control

Heavy Duty Diesel Emission Control Legislative Roadmap

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- **China Tier 4a/b**: Filters and/or SCR on all HDD non-road mobile machinery

Introduction of emission control technology brings value to JM
CARB Ultra Low NOx Regulation Proposals

Heavy Duty Diesel Emission Control Legislative Roadmap

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- **CARB Ultra Low NOx**: Reduces current NOx level by up to 90%

Complex emission control systems required, likely involving advanced cold start NOx control and SCRF® technology
Regulations in the Global On Road HDD market

Focus from NOx control at speed to NOx control at cold start — requires new family of technologies

-90%
Potential Future Systems Design

Next generation of catalyst technologies

JM’s diesel Cold Start Concept (dCSC™) stores NOx at very low temperature, before the downstream SCRF®/SCR system is hot enough to convert NOx.

This low temperature NOx storage enables outstanding NOx conversion from cold start, when using the dCSC™ in combination with SCRF® and SCR technology.

Potential regulation from 2023 – Increased JM value from more advanced systems.
Ongoing Catalyst System Development Opportunities

**Systems for enhanced NOx reduction**
- Better fuel efficiency / lower CO₂ typically leads to increased engine-out NOx emissions

**Lower temperatures**
- The drive for improved fuel efficiency / reduced CO₂ leads to lower catalyst operating temperatures

**Lower N₂O (potent GHG)**
- Catalyst systems which generate lower N₂O levels

**Smaller, lighter systems at lower cost**
- Cost reductions, through e.g. size reduction and pgm reduction

**Reduced system backpressure**
- To maximise power delivery from engine and minimise fuel consumption
A $1.75bn Market in 2015, Growing to Over $4bn by 2025

- Significant growth in China driven by EU VI equivalent implementation
- Europe remains strong contributor
- Regulatory tightening in India and South America adds further growth
- Non-road sector continues to add value

Significant further growth in HDD market driven by tightening legislation and increased production of regulated engines

Chart Data Source: LMC Automotive and JM estimates
Summary

Regulations continue to tighten in the light and heavy duty areas
Criteria pollutants plus fuel economy / CO₂

Regulations drive technology opportunities
R&D and applications expertise leveraged to maintain strong position

Strong customer relationships and regulatory knowledge aligns development to future needs

ECT well placed to drive future growth and capture value
Creating Value from Market Opportunities in Battery Technologies

Martin Green
Director, Battery Technologies
Overview

Update
on JM’s Battery Technologies business and its position as a credible supplier to the auto industry

Explain
the market opportunities for high performance battery technologies in the transportation sector

Detail
the complexity of the battery materials landscape, current limitations and opportunities to develop next generation products

Highlight
How JM is well placed to capture value as a battery technologies supplier over the next decade
Battery Technologies

Business vision

Vision to be a leading supplier of battery technologies to the LiB sector
- Functional materials
- Automotive focus

Start with M&A to build initial position as a credible supplier
- Internal R&D and further technology acquisitions to build the business

October 2012
- Axeon (£41m)
  - Applications

October 2014
- A123 Assets (£16m)
  - Manufacturing
  - China
  - Exclusive supply

February 2015
- Clariant Battery Materials (£49m)
  - IP
  - Prod development
  - Manufacturing
  - Established customer base
JM Battery Technologies

Current status

Global business established
- Customer relationships and sales
- Installed materials capacity ~5,000 tonnes p.a.

Solid automotive position
- Materials supplier to 15 automotive platforms

Continue to invest in the business
- Increased R&D materials product development
- Capacity expansion to meet growing demand
- Technology acquisition / licensing

Battery Technologies 2015/16:
On track for £150m sales (incl. £40m sales of auto battery materials)
JM Position in Automotive Value Chain

Linking chemistry and applications

Strong relationships across the value chain
- OEMs
- Cell developers

Proven, long term supplier to the sector
- 8 years in series supply for battery materials
- JM reputation in automotive sector

Deep understanding of automotive supply chain dynamics
Automotive Battery Materials Sector Growing Strongly

Largest materials market today is still the electronics sector
• Mature
xEV sales now substantial and growing strongly
• Automotive
• Bus / truck

Cathode Materials
Market size (MWh)

Source: B3, JM estimates

JM positioned towards high growth sectors
Automotive | Powertool and ebike
# Materials Landscape Highly Complex

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<th>LCO</th>
<th>LMO</th>
<th>NMC</th>
<th>NCA</th>
<th>LFP</th>
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<td>NMC 1,1,1</td>
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<td>Structure</td>
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<td>Nanostructure, particle size, channel structure, porosity</td>
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**JM expertise fits with know how required**

Images copyright of relevant manufacturer
No Single Material Meets All Requirements

- Different applications demand different properties
- Match material type to performance requirements application
- Optimise material for specific application
- JM current supply position based on LFP

JM estimates. Base bulk material properties, no dopants or optimised metal coatings
## Current Material Landscape

<table>
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<tr>
<th>12v Starter</th>
<th>Micro HEV</th>
<th>HEV</th>
<th>PHEV</th>
<th>BEV medium</th>
<th>BEV long</th>
<th>Delivery van</th>
<th>E-bus</th>
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**Legend:**
- **Major**
- **Minor**
Micro / Mild Hybrids

Moving to the mainstream

- Multiple options for a conventional powertrain
- Driven by CO₂ / mpg regulations
- Cost effective
- Rapid growth expected in EU and US
- LFP well suited to these applications

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<th>CO₂ / mpg benefit</th>
<th>Stop-Start at 0mph speed</th>
<th>Stop-Start until 12mph speed</th>
<th>Stop-Start until 60mph speed</th>
<th>Stop-Start Change of Mind and coasting</th>
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<td>4%-6%</td>
<td>6%-8%</td>
<td>10%-15%</td>
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JM Strategy
Opportunity for JM at both material and systems level | Incremental market £100m p.a. by 2025
EV Bus / Truck

Meeting the challenge of clean cities

- Substantial and growing market
- Most activity in China
  - Domestic and export market
- Safety is critical
  - High quality LFP is required
- JM well placed today with major bus producers

**JM Strategy**

Build on existing relationships and supply position  |  Optimised materials for enhanced performance  
Incremental market £1bn p.a. by 2025

Source: B3
BEV/PHEV

Rapid growth will continue

• Wide range of materials used currently
  • LMO, NMC, NCA, LFP
• Substantial gap between performance and OEM requirements
• JM participates in China (LFP)
• Major growth opportunity, building on existing relationships

Global Automotive BEV/PHEV
Market size (MWh)

JM Strategy
Advanced discussions in progress to secure IP and commercial position
Maintain and grow existing position in LFP-based BEV/PHEV

Source: B3
Adding Value Through Technology

Meeting market needs

- Performance improvements from
  - Materials
  - Cell design
  - System engineering
- Collaboration across the value chain required to deliver these improvements
- JM’s relationships with cell companies and OEMs is already building this collaboration
- JM’s applications knowledge provides insight into delivering improvements at systems and material level

An OEM Perspective
Specific power @ systems level / Wkg⁻¹

Specific energy @ systems level / Whkg⁻¹

Chart source: Andre et al., J. Mater. Chem A, 2015, 3, 6709
Battery Technologies – Key Takeaways

- **Credible Player**
  - £150m sales 2015/16
  - 15 automotive platforms

- **Strong Market Focus**
  - Automotive and other high performance sectors

- **Positive Contribution**
  - Profitable today, increased R&D

- **Good Foundation for Growth**
  - Technology, applications, OEM relationships

- **Broadening Technology Base**
  - Advanced discussions underway

- **Excellent Prospects**
  - On track to deliver long term sales targets
Science and Technology
Delivering Sustainable Solutions to Customers

Alan E Nelson, Ph.D., P.Eng.
Chief Technology Officer
Innovation Ecosystem
Innovation translating to revenue
Science and Technology Integration

Technical capabilities and applications expertise

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<thead>
<tr>
<th>Emission Control Technologies</th>
<th>Process Technologies</th>
<th>Precious Metal Products</th>
<th>Fine Chemicals</th>
<th>New Businesses</th>
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<tr>
<td>Automotive</td>
<td>Chemicals Oil and Gas</td>
<td>Chemicals Automotive Life Sciences</td>
<td>Life Sciences Chemicals</td>
<td>Automotive Life Sciences Chemicals</td>
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- Chemistry and Catalysis
- Functional Materials
- Formulation Sciences
- Pgm and Base Metals
- Advanced Characterisation

Innovation Portfolio Management
R&D Innovation Portfolio Management

Sustained value capture and growth

- **NPV portfolio valuation** to quantify return on R&D investment
- **Innovation margin** to ensure new products capture value and growth
- **Patent advantaged sales** to ensure patents protect competitive advantage

**Distribution of Research and Development Expenditure**

- Emission Control Technologies: 20%
- Process Technologies: 17%
- Precious Metal Products: 10%
- Fine Chemicals: 6%
- New Businesses: 5%
- Central Research: 42%

£ ~5% of Sales

R&D Gross Annual Expenditure

~5% of Sales

Sustained value capture and growth
Opportunity Landscape in Automotive Powertrain

Leading solutions provider to the automotive industry

- **Advanced Materials**
  Industry leading emission control catalysts, lighter and stronger materials to reduce vehicle weight

- **Alternative and Low Carbon Fuels**
  Increased production and utilisation of low carbon and renewable fuels (incl. blends)

- **Energy Storage Devices**
  Improved performance and cost of lithium-ion batteries and hydrogen fuel cells

- **Autonomous and Driver Assist Systems**
  Improved fuel efficiency and emission control systems resulting from predictive acceleration and braking
Emissions Control Systems

Successful technology development with customers

Gasoline Pgm Demand (Europe)

- Sustained investment in emission control technology to develop customer focused solutions
- Unique combined strengths in science and application development to drive innovation
- Continued optimisation of materials and catalysts in partnership with industry – higher performance with lower pgm usage

Material science + applications know how = innovative solutions
Lithium-Ion Battery Materials

Innovating the optimum cathode material

NMC Cathode Chemistry

- Power Density
  + Energy Density
  - Safety

Li$_{x}$NiO$_2$

NMC

Li$_{x}$CoO$_2$

Li$_{x}$Mn$_2$O$_4$

- Power Density
  +/- Energy Density
  - Safety

• Energy storage applications require unique cathode materials – safety, power, energy, lifetime

• Key technology challenge to develop a cathode material with the best of all properties

• Our materials science expertise and integration in battery systems are an innovation differentiator

Material science + applications know how = innovative solutions
Fuel Cell Materials and Systems

Harnessing the power of clean energy

- Hydrogen Production
  - Hydrogen is an energy storage material
  - Must be produced from another source of energy

- Hydrogen Storage
  - Low volumetric energy density
  - Pressurisation into compressed gas or liquid

- Transmission and Distribution
  - Lack of current infrastructure
  - Point source generation and/or supply is desirable

Johnson Matthey is an innovation leader in hydrogen fuel cell science and technology

Innovation required throughout the hydrogen value chain
Alternative and Low Carbon Fuels
Innovation beyond the powertrain system

Catacel highly energy efficient catalyst solutions for clean fuel production
- Catacel’s SSR® (Stackable Structural Reactor) technology is novel catalyst technology
- Ability to increase output **10-25%** in existing hydrogen plants
- Reduction in overall OpEx due to higher operating efficiency

Ultra low emissions methanol catalyst and process technology
- Industry leading reforming technology can reduce greenhouse gas (GHG) **emissions at a methanol facility up to 75%**
- Process technology enables **2.3-3.5%** lower total gas usage in comparison to competitive schemes (US $1.8-2.8 m/year for 100mSCFD)
Advanced Materials and Lightweighting

Long term research investment for growth

Precursors for 3-D printing and additive layer manufacturing (ALM)

- Unique expertise in metals and powder metallurgy to enable the development of spherical powders
- ALM has the potential for 60-70% reduction with equal strength – key lightweighting opportunity
- Potential £100m market opportunity for ALM materials in 2025

Renewable materials for the production of engineering plastics

- Key external partnerships with Rennovia and BioAmber
- Lower energy requirement than traditional petrochemical processes – up to 50%
- GHG emissions reduction of 85% for adipic acid production (significant reduction in NO₂)
How We Deliver Innovation

Industry leadership in science and technology

**Customer focus**
Customer focused new product design and development
Strategic relationships with customers to drive long term growth

**Science and Technology**
Industry leading expertise in materials science and engineering
Innovate where material science and engineering drives success

**Portfolio Management**
Innovation metrics to drive productivity and value capture
Governance across all areas of corporate technology

**People and Culture**
200 years of innovation in material science and engineering
Outstanding scientific and technical talent close to customers
Closing Remarks

Robert MacLeod
Chief Executive
Robust Strategy and Strong Market Drivers

C³

Customer focus
Create value
Growth from new business
Collaborate to leverage our expertise
The best of big and small
Invest in people, products and technology
Build on our core strengths
Operational excellence and sustainability
The Johnson Matthey culture

Population Growth
Urbanisation
Increasing Wealth

Health & Nutrition
Ageing
Population

Natural Resource Constraints

Environmental Factors
Climate Change
Regulation

JM is high technology solutions provider into growth markets
Imperative for Improved Air Quality Supports Growth

Legislation continues to tighten at pace
• Regulated pollutants and CO₂ in focus
• ICE remains main powertrain technology for next decade; increased hybridisation
• Increased opportunity for JM from diversified powertrain

**ECT**
Increased demand for complex catalysts and hence more value over next decade
• JM a leading technology provider

Medium term targets remain

**Battery Technologies**
Growing market for battery materials expected to expand
• JM player in current market
• Investing to capture value as market evolves

JM roadmap on track
The JM Advantage in Powertrain Solutions

- Strong expertise in translating metal chemistry solutions into auto applications
- Ability to scale up
- Efficient manufacturing
- Well positioned in supply chain
- Deep relationships with OEMs
- Strong reputation
- Understand future needs

JM well placed to capture value from evolving powertrain
In Summary...

JM has robust strategy and strong market drivers

Evolution of the powertrain requires high technology solutions

Clear technology roadmap supports strong growth for ECT over next decade

Good growth from Battery Technologies in medium term; investing for 2020 and beyond

JM remains well placed for sustained long term growth
JM Executive Board

Robert MacLeod
Chief Executive

Den Jones
Group Finance Director

Larry Pentz
Executive Director

John Walker
Executive Director
Emission Control Technologies
Presentation Team

- **Robert MacLeod**
  - Chief Executive

- **Nick Garner**
  - Division Director
  - New Businesses and Corporate Development

- **John Walker**
  - Executive Director
  - Emission Control Technologies

- **Dr Chris Morgan**
  - European Technology Director
  - Emission Control Technologies

- **Dr Andy Walker**
  - Divisional Technology Director
  - Emission Control Technologies

- **Martin Green**
  - Director
  - Battery Technologies

- **Dr Alan Nelson**
  - Chief Technology Officer
### Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>ACT</td>
<td>Atmosphere Control Technologies</td>
</tr>
<tr>
<td>ALM</td>
<td>Application lifecycle management</td>
</tr>
<tr>
<td>ASC</td>
<td>Ammonia slip catalysts</td>
</tr>
<tr>
<td>bbl</td>
<td>Oil barrel, a unit of volume</td>
</tr>
<tr>
<td>BEV</td>
<td>Battery electric vehicle</td>
</tr>
<tr>
<td>CAGR</td>
<td>Compound annual growth rate</td>
</tr>
<tr>
<td>Capex</td>
<td>Capital expenditure</td>
</tr>
<tr>
<td>CARB</td>
<td>California Air Resources Board</td>
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<tr>
<td>CF</td>
<td>Conformity factors</td>
</tr>
<tr>
<td>cGPF</td>
<td>Coated gasoline particulate filter</td>
</tr>
<tr>
<td>CH₄</td>
<td>Methane, natural gas</td>
</tr>
<tr>
<td>CNG</td>
<td>Compressed natural gas</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
</tr>
<tr>
<td>CTČ</td>
<td>Coal to chemicals</td>
</tr>
<tr>
<td>Cu</td>
<td>Copper</td>
</tr>
<tr>
<td>DOC</td>
<td>Diesel oxidation catalyst</td>
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<tr>
<td>dCSC</td>
<td>Diesel Cold Start Concept</td>
</tr>
<tr>
<td>ebike</td>
<td>Electric bike</td>
</tr>
<tr>
<td>ECT</td>
<td>Emission Control Technologies</td>
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<tr>
<td>EGR</td>
<td>Exhaust gas recirculation</td>
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<tr>
<td>EPA</td>
<td>Environmental Protection Agency (US)</td>
</tr>
<tr>
<td>EREV</td>
<td>Extended range electric vehicle</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
</tr>
<tr>
<td>EV</td>
<td>Electric vehicle</td>
</tr>
<tr>
<td>FC</td>
<td>Fine Chemicals</td>
</tr>
<tr>
<td>FCEV</td>
<td>Fuel cell electric vehicle</td>
</tr>
<tr>
<td>GDI</td>
<td>Gasoline direct injection</td>
</tr>
<tr>
<td>GHG</td>
<td>Greenhouse gas</td>
</tr>
<tr>
<td>g/km</td>
<td>Grams per kilometre</td>
</tr>
<tr>
<td>HDD</td>
<td>Heavy duty diesel</td>
</tr>
<tr>
<td>HEV</td>
<td>Hybrid electric vehicle</td>
</tr>
<tr>
<td>IC</td>
<td>Internal combustion</td>
</tr>
<tr>
<td>ICE</td>
<td>Internal combustion engine</td>
</tr>
<tr>
<td>IP</td>
<td>Intellectual property</td>
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<tr>
<td>JM</td>
<td>Johnson Matthey</td>
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<tr>
<td>JMTC</td>
<td>Johnson Matthey Technology Centre</td>
</tr>
<tr>
<td>kW</td>
<td>Kilowatt</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
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<tr>
<td>LCO</td>
<td>Lithium cobalt oxide</td>
</tr>
<tr>
<td>LDV</td>
<td>Light duty vehicle</td>
</tr>
<tr>
<td>LEV</td>
<td>Low emission vehicle</td>
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<tr>
<td>LFMnP</td>
<td>Lithium iron manganese phosphate</td>
</tr>
<tr>
<td>LFP</td>
<td>Lithium iron phosphate</td>
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<tr>
<td>Li-air</td>
<td>Lithium-air, a type of battery cell chemistry</td>
</tr>
<tr>
<td>Li-ion</td>
<td>Lithium-ion, a type of battery cell chemistry</td>
</tr>
<tr>
<td>Li-S</td>
<td>Lithium-sulfur, a type of battery cell chemistry</td>
</tr>
<tr>
<td>LiCo₂</td>
<td>Lithium cobalt oxide (chemical formula)</td>
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</table>
## Glossary

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>LiFePO₄</td>
<td>Lithium iron phosphate (chemical formula)</td>
</tr>
<tr>
<td>LiMn₂O₄</td>
<td>Lithium manganese oxide (chemical formula)</td>
</tr>
<tr>
<td>LMO</td>
<td>Lithium manganese oxide</td>
</tr>
<tr>
<td>LPG</td>
<td>Liquefied petroleum gas</td>
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<tr>
<td>LiB</td>
<td>Lithium-ion battery</td>
</tr>
<tr>
<td>MEA</td>
<td>Membrane electrode assembly</td>
</tr>
<tr>
<td>mpg</td>
<td>Miles per gallon</td>
</tr>
<tr>
<td>Mwh</td>
<td>Megawatt hour</td>
</tr>
<tr>
<td>N₂O</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>NAC</td>
<td>NOₓ adsorber catalyst</td>
</tr>
<tr>
<td>NB</td>
<td>New Businesses</td>
</tr>
<tr>
<td>NCA</td>
<td>Lithium nickel cobalt aluminium oxide</td>
</tr>
<tr>
<td>NEDC</td>
<td>New European driving cycle</td>
</tr>
<tr>
<td>NEV</td>
<td>New energy vehicles</td>
</tr>
<tr>
<td>NMC</td>
<td>Lithium nickel manganese cobalt oxide</td>
</tr>
<tr>
<td>NMOG</td>
<td>Non-methane organic gas</td>
</tr>
<tr>
<td>NPV</td>
<td>Net present value</td>
</tr>
<tr>
<td>NO₂</td>
<td>Nitrogen dioxide</td>
</tr>
<tr>
<td>NOₓ</td>
<td>Nitrogen oxides</td>
</tr>
<tr>
<td>OEM</td>
<td>Original equipment manufacturer</td>
</tr>
<tr>
<td>OpEx</td>
<td>Operating expenditure</td>
</tr>
<tr>
<td>Oz</td>
<td>Troy ounces</td>
</tr>
<tr>
<td>p.a.</td>
<td>Per annum</td>
</tr>
<tr>
<td>Pgm</td>
<td>Platinum group metal</td>
</tr>
<tr>
<td>PHEV</td>
<td>Plug in hybrid electric vehicle</td>
</tr>
<tr>
<td>PM</td>
<td>Particulate matter</td>
</tr>
<tr>
<td>PMP</td>
<td>Precious Metal Products</td>
</tr>
<tr>
<td>Pms</td>
<td>Precious metals</td>
</tr>
<tr>
<td>PN</td>
<td>Particulate number</td>
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<tr>
<td>PT</td>
<td>Process Technologies</td>
</tr>
<tr>
<td>Pd</td>
<td>Palladium</td>
</tr>
<tr>
<td>Pt</td>
<td>Platinum</td>
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<tr>
<td>R&amp;D</td>
<td>Research and development</td>
</tr>
<tr>
<td>RDE</td>
<td>Real world driving emissions standards</td>
</tr>
<tr>
<td>ROIC</td>
<td>Return on invested capital</td>
</tr>
<tr>
<td>SCR</td>
<td>Selective catalytic reduction</td>
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<tr>
<td>SNG</td>
<td>Substitute natural gas</td>
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<tr>
<td>SULEV</td>
<td>Super ultra low emission vehicle</td>
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<tr>
<td>SUV</td>
<td>Sports utility vehicle</td>
</tr>
<tr>
<td>TCO</td>
<td>Total cost of ownership</td>
</tr>
<tr>
<td>TWC</td>
<td>Three way catalyst</td>
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<tr>
<td>TWF</td>
<td>Three way filter</td>
</tr>
<tr>
<td>ULEV</td>
<td>Ultra low emission vehicle</td>
</tr>
<tr>
<td>VCM</td>
<td>Vinyl chloride monomer</td>
</tr>
<tr>
<td>xEV</td>
<td>Electric vehicles (of all types)</td>
</tr>
<tr>
<td>ZEV</td>
<td>Zero emission vehicle</td>
</tr>
</tbody>
</table>