WORLD TELEVISION

Johnson Matthey

Analyst and Investor Day - 4th February 2016

Johnson Matthey

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John Walker, Executive Director, Emission Control Technologies

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Martin Green, Director, Battery Technologies

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QUESTIONS FROM

Evgenia Molotova, Berenberg

Andrew Benson, Citigroup

Peter Cartwright, Fiske

Martin Dunwoodie, Deutsche Bank

Adam Collins, Liberum

Mathew Waugh, Credit Suisse

Alex Stewart, Barclays

Simon Fickling, Exane BNP Paribas

Martin Evans, JP Morgan

Introduction

Sally Jones, Director, Investor Relations and Corporate Communications
Good afternoon ladies and gentlemen - thank you very much to you all for coming to Johnson Matthey's Investor Event today. Just before we start, a quick health and safety notice, if there is a fire alarm if you could just make your way out via the fire exits, which are signposted in green. And also the event is being webcast live, so if I could ask you to please turn off mobile phones and devices. Thank you. With that I'll hand over to Robert.

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Introduction and Strategy Update

Robert MacLeod, Chief Executive
Thank you Sally and good afternoon everybody and a very warm welcome to all of you to Johnson Matthey's Investor Day 2016, in which we're going to outline the growth opportunities from the evolving powertrain for Johnson Matthey.

So we've got a full schedule for you this afternoon with presentations from me and a number of the JM team. There should, I hope, be plenty of opportunities for you to ask questions, both in the session here in this room, but also out during the coffee breaks, please take every opportunity that you can to grab a JM person and get them to answer any questions that you might have. This is, after all, a session for you and we hope that you get the benefit out of it that you are looking for.

And we aim to finish today around about 5.45 or something like that and then I know and I look forward to seeing many of you who are going to come for dinner and carry on the discussion there.

So as I said our topic today is Johnson Matthey and our involvement in the evolution of the powertrain. But I'll start by giving you an update on the good progress we're making on delivering our strategy. And then we'll explain why and how the automotive powertrain developments are good for Johnson Matthey, how they're diversifying and as a result creating new market opportunities for us.

These require high technology solutions in both emission control and battery technologies. And in the presentations this afternoon we'll show you how Johnson Matthey is well placed to create value for our shareholders and at the same time make a major contribution to improving air quality around the world.

Today is all about the long term and as a high tech company, with R&D and the timescales we work with in R&D we have to be long term, however, I'll start with a short term overview on current trading.

So yesterday we did our Q3 statement and sales for our continuing businesses were up 3% on last year. Underlying operating profit was however lower because it was adversely impacted by the challenging macroeconomic climate which continued to weigh on Process Technologies and Precious Metal Products divisions.

Our actions to reduce costs by about £30m are well underway and as I said in November we expect about £5m of those savings to come through in the final quarter of this year and the rest into next year.

ECT continues to perform well and had a strong third quarter. Fine Chemicals and New Business also made good progress too, so I'm pleased about that. And overall the outlook for the full year is in line with market expectations.

But the external macroeconomic factors mean that trading conditions for us in some of our markets is very challenging right now. The oil price, about 40% lower than this time last year, has and will continue to limit opportunities in the chemical industry and how the investment plans are working there and hence demand for new licences and plant catalysts first fills for Process Technologies.

China has slowed down; they have sufficient chemical capacity right now for the technologies we licence, so the outlook for new plant builds is subdued. In addition their review of their coal strategy also points to a reduced market for the coal to SNG technologies we've talked to you about in the past.

And finally PGM prices, with platinum and palladium down 30% and 35% respectively on this time last year the volumes and profitability in our PGM refining business are adversely impacted.

So against this backdrop it won't surprise you to hear that we expect these internal factors to limit the Group's growth opportunities in the short run. But the long term still looks very positive with the structural growth drivers being strong and consequently we continue to invest in the business in line with our strategy for growth.

And here is our strategy which we took you through last year. We would like to provide you with a bit of an update on progress to date.

Investment, as I said, Johnson Matthey is a long term growth business and we're continuing to invest for future growth. That includes investment in R&D, which of course remains vitally important to the Group and at the core of JM's competitive advantage.

So this has been a touch higher than 5% of sales in the last couple of years, I would expect it to come back closer to that 5% level for the years ahead. And on capex given the current business climate this will be at around 1.5 times depreciation for next year, so at the lower end of the range that we gave you last year, but still investing for growth and ahead of maintenance capex levels.

So taken together we're still investing for the future, but we are mindful of the current constraints on the business and have adjusted these investment levels accordingly.

We've continued to build on our core strengths. In the last 12 months we've disposed of gold and silver refining, and research chemicals, both of which were non-core. But there remain plenty of organic growth opportunities across the Group, and we will continue to invest in these going forward.

We're also making very good progress in growing our New Businesses division too. Over the last year we've established ourselves in battery technologies and in atmosphere control technologies, where we made a small acquisition back in May to help us on our way.

So overall I'm very pleased with the progress that we are making in the New Businesses division.

Turning next to operational excellence and sustainability, we've made lots of progress here as well, especially on improving the efficiency in our manufacturing plants. But the two points I'd pull out are firstly to reiterate the increased focus we have across the whole company on health and safety.

And secondly, an update on the investment in upgrading our business systems which we told you about a year ago. This programme, which as you know is to install SAP across the Group, is, I'm pleased to say, on track. We're rolling out on a site by site basis to mitigate the risk and our first site is scheduled to come online in the summer this year.

We continue to expect our overall investment to be around £100m over five years, with the cost largely being frontend loaded. But I believe the annual cash savings are at least £20m per year can be facilitated by these business systems. But of course these will be backend loaded as greater savings will come as more and more sites come online.

On customer focus, it's true what they say; next year's profits are in our customers' pockets. And with customer focus it's all about leveraging more value from the breadth of products and technology that we can supply to our customers. And it's about using the strength and reputation of JM's name to facilitate our entry into new markets. And the automotive powertrain market is a great example of that and hopefully you'll hear more about that today.

As you know JM has a great reputation with OEMs for its emission control products and now we're using this as we expand on our position in battery technologies.

And last but not least create value, JM has and will continue to create value for you our shareholders. The special dividend of 150 pence per share was paid to you on Tuesday and this return on capital from the proceeds of the two disposals recently made ensures we retain an efficient balance sheet, whilst maintaining capacity to invest to grow in the future.

But capital efficiency is absolutely embedded in what we do, our long term target of 20% return on capital remains in place, but that will be quite challenging to achieve in the current environment in the next couple of years. However, I want to assure all of you that we remain focused upon delivering earnings growth at the same time as enhancing capital efficiency and that our target of 20% return on capital for investments that we make is firmly in place.

And we remain well placed to create value from a range of opportunities where JM can supply high tech products that have a positive benefit on the world around us. And

those global sustainability drivers that we talked about last year continue to provide opportunities for superior growth.

So looking at these drivers, at the top, population growth, urbanisation and increasing wealth is driving demand for our products and is particularly relevant to the evolving powertrain as you'll hear about. It also links to growth in emerging markets and there JM is very well positioned across all of our divisions, especially in China today and longer term potentially South America and other emerging markets.

Moving on to natural resource constraints, energy security remains a key concern for a number of countries, particularly China and the US, and in turn a major driver for PT's technologies. And despite recent price weakness recycling of PGMs remains a strategic service, both for our customers and for JM. As you know PGMs are a key raw material for our emission control business and having that security of supply is strategically important for the Group.

Longer term technologies to enable renewable and alternative energy sources provides opportunities for Process Technologies and Alan Nelson, our new CTO will talk a little bit more about that later today.

Environmental factors, climate change, and regulation are a major driver for JM's business and as I said before legislation is our friend. Without a doubt focus on air quality, emissions and electrification has intensified over the past 12 months and JM is very much, we believe, part of the solution and you'll hear about that.

Finally the fourth driver - health and nutrition, the ongoing pressure on healthcare costs continues to tighten. For JM our biggest customers in the healthcare market are the generic pharmaceutical industry and the pressure on overall healthcare costs will continue to drive complex chemistry solutions for our fine chem business.

So as you can see the drivers fundamentally haven't changed and I'm confident that they will continue to provide opportunities for JM through the use of technology.

And now to the topic of the day powertrain technology, all four drivers that I've talked about drive the need for evolving technology for the powertrain. The increased demand for mobility through population growth, urbanisation and increasing wealth, will, without intervention, contribute to increased pollution.

Linked to this are constraints on fuel availability and type, this is driving the need for improved fuel efficiency, alternative fuels, and ultimately more sustainable energy production. But of course environmental factors and regulation to combat increased pollution are all driving ever tighter emission standards, not only for regulated pollutants, but also for CO_2 and zero emission vehicles. As a result today's technology will need to evolve and therein lies the opportunity for JM.

Now as we'll show you today there is an imperative for improved air quality and this is driving diversification in the powertrain technology. Hybridisation is set to increase and these vehicles need both emission control systems and battery technologies. We hope

to show you today that this is not a risk for JM, rather it provides an increased opportunity for us.

It's important not to forget that hybrids still have an internal combustion engine and this is expected to remain the main powertrain technology over at least the next decade. We expect that in ten years time around 97% of vehicles will still have an internal combustion engine and hence require emission control to the same or even higher standards than today.

And this is positive for ECT with increased demand for complex catalysts, through increasing numbers of vehicles, including hybrids, and tightening legislation. This gives more value for JM over the next decade. The market as a whole, which we estimate today to be about $8bn, and that's for light duty and heavy duty combined, is expected to reach more than $13bn by 2025.

We have a strong position in this market which we expect to sustain over this period and hence our medium term targets that we talked about last year remain in place.

But not only do we have a good position in emission control, the market for battery technologies is set to grow too. JM is a player in the market today and the opportunities for our existing technologies and the opportunities in the market, which as you know are based on high power dense lithium iron phosphate cathode materials are set to grow over the next decade.

Notwithstanding this we're also investing R&D and actively pursuing other ways to enhance our position in the potentially very significant high energy cathode materials market. You'll hear more about that today and why we believe that we can be successful. As a whole we estimate that the market for automotive transport materials, cathode materials that is, i.e. for cars, buses, and trucks, is around about a billion dollars today, but by 2025 will be around about $8.5bn.

From where we started just over three years ago I'm very pleased with what we have achieved and we have a clear roadmap for the future which we're on track to deliver. Our aim is to get a double digit market share of this market which is partly predicated upon the further development of our current lithium iron phosphate technology.

So why are we well placed to succeed? Success in this market starts with chemistry and its applications and as you know this is a sweet spot for JM. It's how we differentiate ourselves and it's the combination of chemistry and applications knowhow that underpin new powertrain technology solutions. In both emission control and battery technologies the chemistry requirements are complex and difficult to do. And it is this that enables JM to have high margins, high barriers to entry and gives us opportunity to bring a constant stream of new products and new technologies to the market.

But chemistry alone is not enough. It's the combination of that with applications knowledge of how to make the products actually work in real life conditions for our customers that really matters. And JM has extensive knowledge and experience of auto applications and the technology development plans of the OEMs. This will continue to

support us in our ECT business, but also as we expand our position in the battery technology space.

In addition to our chemistry and applications knowhow our operational efficiency and customer focus give us an advantage in powertrain solutions. We're experts in scaling up from the lab to full plant scale and in manufacturing our products efficiently and safely across the globe.

Please don't assume that is as straightforward as it sounds. Once a material, catalyst or product has been developed in the lab, it has to be scaled up to full production in a reliable, safe and efficient way. That can be extremely challenging and this is an absolute core competence for JM.

Once we've then taken a product to full scale production then we continue to drive operational efficiency across its lifetime and it is this that you've seen that's helped us grow our margins in ECT.

Not only that, but we're well positioned in the supply chain. In ECT we are technically a Tier 2 supplier, but we have a Tier 1 relationship with the OEMs and we believe that a similar model will evolve in the battery technology space too and Martin will talk more about that later.

But given the direct impact of the battery material on vehicle performance and the highly complex and technical nature of that battery material we envisage a similar technical relationship with the OEMs. And we can leverage the relationships and reputation that we have today to support growth in our battery technology business going forward.

So it's that combination of the chemistry and applications with the drive for operational efficiency and the strong customer focus, all stemming from a strong base in ECT, that I believe will give JM the advantage in powertrain solutions. And we're already well placed today to capture value from the evolving powertrain.

So before I hand over to Nick and John to summarise from me I would say we gave you a trading update yesterday and given the current environment I'm pleased with the Q3 results. But the challenging macro picture looks set to continue right now and I do expect that will limit the short term growth opportunities for JM. But we are a long term company, we'll be 200 years old next year, and our strategy is robust. We'll keep investing in the business to take advantage of the long term structural growth drivers that remain firmly in place and there are plenty of medium to long term opportunities for our business.

Evolution of the powertrain is one of these. And here high tech JM solutions will be needed to further improve air quality for an increasingly wealthy population. The market for powertrain technologies is set to grow substantially out to 2025, and you'll hear today that we expect JM sales from those powertrain technologies to nearly double over this ten year period, from just under $3bn today, to around $5.5bn then.

And all of this growth is predicated upon our well established Emission Control Technologies business, and our Lithium Iron Phosphate Battery Materials business. And I do believe that JM is well placed to capture value and to deliver long term sustained growth.

Now I'll hand over to Nick and John who will explain in more detail how we expect those markets to evolve.

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Capturing Value from Powertrain Evolution

Nick Garner, Division Director, New Businesses and Corporate Development
Good afternoon everybody, my name's Nick Garner and I look after New Business and Corporate Development within Johnson Matthey. And just for a brief time John and I would like to take you through how the key trends in powertrain evolution present Johnson Matthey with great opportunities. And that's as a set up to a deeper dive that Chris and Andy and Martin will take you through in particular areas later. So this is very much just a quick overview.

So in our overview the key highlights of these trends and opportunities are - well the combination of tightening legislation and fuel economy and one can interpret that as CO_2 reduction and in emissions, such as NOx and particulate, is a clear driver for the adaptation of Johnson Matthey technologies, and that's a well-established trend and one we see strongly continuing.

The internal combustion engine in itself in its various forms will continue to grow through to 2025. With improving fuel efficiency requirements actually placing evermore demand on emission abatement systems of those internal combustion engines and therefore the requirement for more advanced systems which we are well suited to deliver.

Diesel, diesel is an inherently more efficient powertrain and that advantage will continue to be used and more on that later. And with the ongoing introduction of electrification we are already delivering benefit to Johnson Matthey and Martin will explain to what extent and what our plans look like going ahead.

So how is Johnson Matthey positioned today? Well, we are very well placed in the emissions control environment; we've got a great reputation as a supplier of advanced technologies to the automotive industry. And we're also well placed in the lithium-ion sector. We already have $60m of sales in this particular sector, of battery materials, cathode materials. And that represents approximately 5% of the market share today.

I just want to make it clear that we focus on the automotive sector for our battery materials; we do not play in the wider and much larger electronic components into the energy storage for the wider electronics market. We have assessed this market, which has got far different characteristics to the automotive market and it's less well suited to our business model; the business model of chemistry and application knowledge which extracts value as Robert has explained.

We have extensive large global operations already established and we have considerable track record and experience in this sector. So today we are well set up to face the automotive sector in these two key technologies. And going ahead legislation is the key driver for increased value, but there are some others.

Here are some well-established themes that continue to drive innovation and opportunities in the auto space. And Alan will touch on a few of these as he talks about our technology portfolio later.

But there are two key drivers that we're going to focus on for the majority of this afternoon, regulation and electrification. And as new technologies are adopted into the auto sector, our customer led, solutions based approach we think enables us to develop rapidly and implement new products into this market.

Turning then to the first of those drivers - legislation - regulations of emissions continue to tighten around the world and this is further restricted by the introduction of Real World Standards. And Real World Standards means different things depending on how you drive in the real world naturally.

Tendentially in light duty vehicles the real world driving experience is more harder, motorway driving at speed, more acceleration than the standard cycle of the test. That kind of driving characteristic in the light duty sector means higher rates of NOx production out of the cylinder, more gases to treat. And solutions involve more catalyst area, better catalysts. And these are needed to convert the increasing flows coming through from the cylinder and the increasing levels of NOx.

However, in heaving duty a real world experience, as against the standard cycle is more variable, there's a lot more cold starts, there's a lot more idling, there's a lot more need at the edges of the capability to convert the gases to do that conversion effectively. And that talks to more sophisticated emissions control systems to enable that to happen. So real world driving a very, very positive move towards tightening the ability to control emissions.

But as these key named pollutants are driven down the need for fuel economy means that the internal combustion engine is used harder, it's driven harder and stressed further in order to drive out of it as much efficiency as possible. And this kind of mode of operation tendentially will produce more NOx, even more NOx. And therefore that further enhances the need for advanced emissions control systems and Chris and Andy will spend some time taking you through those later.

Beyond squeezing the internal combustion engine still harder there are other options to hit these fuel economy measures or CO_2 reduction. And those are really about hybridisation, introducing some sort of electrical powertrain. And this is further enforced by full electrification which of course is necessary for zero emission vehicles for which the mandates are established in the States and in China.

Low emission zones themselves tendentially in large urban areas also play into this virtuous combination of regulations between fuel economy and Real World Emission Standards, which require more emissions abatement and electrification.

So I teed it up here, fuel economy then is an essential plank, central to the regulations that are driving the evolution of the powertrain. And so a couple of minutes on diesel, we can't avoid it, sorry. Diesel engines as I said earlier are inherently more efficient than gasoline engines. A number of factors contribute to this, but principally the higher compression expansion ratio just extracts more energy from the burnt gases into motive force and less into wasted heat out of the exhaust pipe. Broadly a number of calculations will give you an average of about 15% advantage of diesel over a gasoline equivalent. So they are inherently more efficient, good for CO_2.

Further, diesel engines fitted with a modern emission control system are clean. A dirty diesel, fitted with a particulate filter and an advanced selective catalytic reduction systems, such as in Euro 6b meets the stringent standards of London and Paris ultra low emission zones by 2020.

Real world driving further drives the cleanliness and the abatement systems from diesels, making them clean and efficient solutions. Fine, so far so good.

The other factor I'd just like to note that is people tend to keep buying them. In Europe the monthly stats reveal that still approximately 50% of people are buying diesels in Europe, although we would agree with market analysts which would see this number reducing towards the low 40s towards 2025.

But with all of this good news and wonderful stories of diesel why on earth aren't they a universal panacea, why aren't they everywhere? Well there are disadvantages clearly to diesel. Efficient and clean though they can be, the very fact that those high compression ratios drives a heavier and more robust engine block, that's a more expensive block, heavier to carry around. The emissionisation - the emission control of a diesel engine requires a more sophisticated system because of the types of gases coming out and the way the combustion happens and so there's cost. So within that there's a payoff, fuel economy against capital cost. A total cost of ownership calculation.

And so for a person that wanted to drive a car regularly over long distances on motorways that choice would probably drive them towards buying a diesel vehicle, that would be the most logical choice for them. And indeed if you look at long distance haulage trucks that do make that sort of calculation they are universally diesel driven. However, someone that does short distances, maybe in a city environment, lots of start and stop, very little mileage, a small gasoline engine would suit them.

Now we all know that car purchasing decisions are not made by detailed total cost of ownership calculations or extremely rarely. That's a much more complicated area. However, we still see there are clear advantages to the diesel engine and therefore we see them maintaining a role in the future.

Moving into the future then and the second of those key drivers, which is really about electrification. So what we have is a well-established historic trend of gasoline and diesel internal combustion engines and an increasing need to emissionise and drive emission control systems in that area. And there's a lot further to go from those technologies because there is a lot of further efficiency that can be dragged out of them.

However, the need for still further fuel efficiency and the ultra-low emissions regulations that are coming drive a much more diverse range of solutions, which all OEMs are adopting.

From the mild hybrid which has some electrical assist, which catches a bit of energy and then delivers that to help with our a bit of motive source, gives you some fuel economy savings, through to a full hybrid which will have the ability to drive you around a car park, a couple of hundred metres of autonomous electric drive, of slightly more, let's say, economy saving into the internal combustion engine. Up to the proper electric vehicles, as I like to think of them, the plug ins and the batteries which have full electric drive chains, full capability to drive considerable distances, in the case of a plug in let's say 50km, considerable autonomy there. But the plug in I have to note, as well as the range extended still has an internal combustion engine on it, it still has that safety net. So it is the hybrid solution. And that's a predominant trend over the next ten years or so.

The pure electric vehicles themselves, i.e. zero emissions are batteries and the fuel cell vehicle. John will pick up on the implications of these various ranges and the opportunities for Johnson Matthey later. But I just want to pick out therefore that five out of those seven solutions have an internal combustion engine which will need a full emission system to go with it. And another five out of those seven have a battery, ranging from very small batteries to really big batteries. But they have batteries and we play into all of those battery areas and Martin will take you through those opportunities.

So that's setting up the key trends and some of the terminology of what we're looking at in terms of hybridisation. I would now like to hand over to John who will dig into some numbers and give you some ideas of scale around these opportunities for Johnson Matthey. Thank you.

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John Walker, Executive Director, Emission Control Technologies
Thank you Nick. So I'm John Walker, Division Director for the Emission Control Technologies division and I'm going to continue this powertrain evolution story. So I'm going to talk about the markets and how technology adds value into these powertrains and then put that together into a combined market outlook for powertrain technologies and finally highlight what this means for Johnson Matthey.

So when I show this market data I'll just quickly point out that our source of external data, of our market data is LMC.

So now let's take a look at the light duty market and put things in perspective over the next ten years. So as you can see from this data in 2025 about 97% of cars still have an internal combustion engine, and this includes hybrids in that statement. So over the next ten years both the internal combustion gasoline engine and diesel engines both continue to grow in absolute terms.

Diesels are still helpful in meeting tough CO_2 standards and that 3% sliver that you see at the top, the little green bit there, those do not have an internal combustion engine

and those are the battery electric vehicles and the fuel cell vehicles. So it's pretty clear from this chart that gasoline and diesel internal combustion engines remain major technologies in this timeframe.

So now I'm going to show you the market data for electrified powertrains in a little bit more detail. The first point to make is that hybridisation of gasoline and diesel powertrains is increasing. Over 87% of these electrified powertrains still have either a gasoline or a diesel internal combustion engine. We expect to see around a 3:1 ratio of gasoline to diesel hybrids by 2025. So you know hybrids are not a bad thing for Johnson Matthey they're actually a good thing for Johnson Matthey. As Nick said, you know these systems now have both an aftermarket treatment and battery technologies in them.

So the second point to make about this chart is again - as I said this is LMC data, so they've recently changed the way they treat the mild hybrid sector there and they've added in the 48 volt mild hybrids to this category. So 48 volt stop/start and coasting battery regeneration can give up to a 10 to 15% fuel economy benefit, so it's very helpful with tougher regulations and lithium iron phosphate is well suited to these applications.

So the 48 volt mild hybrid technology will be used on many hybrid vehicles, but just to be clear from a battery materials value standpoint the larger battery in plug in hybrids results in significantly more battery materials than mild hybrids and likewise when we move to full battery electric vehicles that has even more battery materials again because of the larger battery size.

In this timeframe fuel cells and extended range electric vehicles remain niche, there is actually a line on there for both of them but you can't really see it on that graph.

And then beyond 2025 I think the powertrain evolution is very dependent on the progression of CO_2 regulations, very low CO_2 regulations could drive more full battery electric vehicles and also fuel cell cars. But for the next ten years the internal combustion engines remain key.

So now if we look at heavy duty we see a similar story here, the regulated heavy duty diesel engine market shows good growth. So we have a compound annual growth rate from 2015 to 2025 of 6% on these regulated engines and legislation continues to tighten, driving more complex, high value add emissions solutions.

So what's different from the past to the future is where the growth is coming from. So legislation is driving strong growth in Asia and South America, where we see a compound annual growth rate of 8% in regulated engines. By far the biggest impact is China, Euro VI equivalent. But legislation is also driving first catalyst fitment on non-road vehicles in China.

We also see growth in India, when they follow suit on the Indian equivalent of Euro VI, but the timing of this is less certain.

The catalyst market value will grow significantly more than the regulated engine growth rate. So in Europe we expect to see more filters being fitted to non-road vehicles when Stage 5 is implemented, so that sees a catalyst value benefit from post 2019 when that legislation kicks in. And we also see the second generation of Euro VI heavy duty catalyst systems, which are new systems optimised for fuel economy benefits. So again this is the second generation of technology for the same legislation, beginning to penetrate the market starting in 2017 and this will help to maintain our European heavy duty margins.

So in Europe this results in a compound annual growth rate of regulated engines of 6% and we see the catalyst market value will grow at similar rates in Europe.

So there's a lack of any significant new legislation in North America until later in the plan, which results in a compound annual growth rate of regulated engines there of 3%. And here we see catalyst values growing at a slightly lower rate than the regulated engine compound annual growth rate.

So switching gears from the traditional ECT part to electrification, low emission zones as Nick said in cities are going to drive more electrification of transport vehicles and more electrified buses, manufactured in China for mostly domestic China, but also some export markets. Safety is critical for electric buses, where you have very large batteries and lots of passengers, and so high quality LFP is again the preferred material of choice for those applications.

But outside of cities diesel powertrains are expected to remain the main technology for quite some time. We see global regulated engine compound annual growth rate of 6%, so that's the global regulated engine rate and we see a catalyst market value growth rate of 10%. So still lots of opportunity for the traditional ECT heavy duty business, but also new opportunities with electrified transport vehicles and electric buses for Johnson Matthey's battery technologies group.

So this is a kind of follow on from Nick's intro, so now we're going to take a look at where Johnson Matthey earns value from these powertrains. We've tried to do it on this slide to show where - to try to highlight where Johnson Matthey already has a technology presence. So a big tick means we have a strong presence and a small tick means that we have less of a presence.

We then split out the potential value of the emission control part and the battery materials or the MEA value separately, so you can see where the value is going to be captured in Johnson Matthey.

So we've already reviewed these first two, in great detail in some of our previous meetings. And it's clear that this value is captured in ECT, the baseline for all this, just to remind everybody is a gasoline three way catalyst emission control system. So for those gasoline systems, they have a future potential value doubling when Euro 6c comes into play and we start adding filters to gasoline vehicles. And likewise on the diesel versions we see a potential value for diesel from five to up to seven times compared to this base gasoline system.

Five times the baseline gasoline system comes when we add the filter to the diesel system, another 20% when we do the NOx control, and that's for kind of the Euro 6b type applications and then real world driving and advanced SCR is going to bring that up to seven times. And that's when we get to Euro 6d, Andy and Chris will go through that.

So next if we layer in the other light duty powertrain variants including hybrids, battery electric vehicles and fuel cell vehicles, so the gasoline and diesel hybrids the two on the left there. We see that Johnson Matthey has a strong technology presence, we have the same potential value in the emission control part, because hybrids have an internal combustion engine and these smaller engines are basically using common after treatment systems to the base gasoline and diesel internal combustion engines. So even though the engines are generally smaller they're working harder to the catalyst value for us is pretty much the same.

So the hybrids also have a battery. So in addition to the ECT part we have the potential of adding another one time value in the mild and full gasoline and diesel hybrids if we supply the battery materials. And up to 12 times more value for the plug in and the extended range hybrids that have bigger batteries.

So looking at the next two the battery electric vehicles and fuel cell vehicles we see that Johnson Matthey has less of a technology presence here today. So we're present in the battery electric vehicle market, but we need to expand our technology offerings in the future. In the fuel cell area we make MEAs, membrane electrode assemblies, but we have a bigger position in stationary than we do in automotive today. So the potential value in battery electric vehicles is actually similar to a heavy duty truck. And the potential value in fuel cells is very large, but as I already mentioned the market is not developed yet, and it does not look like it will do so in the 2025 timeframe.

So then finally when we add in the trucks here you see that Johnson Matthey has a very strong technology presence in all the categories, heavy duty trucks, hybrids and battery electric buses. With all of these variants offering very high value to either ECT, battery technologies or both. So it's very clear from this chart that hybridisation and electrification offers added value for Johnson Matthey on top of our very strong position in ECT.

So now earlier we talked about the regulated engine market volumes and how legislation drives added value with a variety of different powertrain options. So what we've attempted to do here is create a combined market outlook for powertrain technologies looking at both emission control catalyst and battery materials.

So starting at the bottom green bit there, the light duty market, the light duty market continues to offer good growth opportunities. We expect market shares in the light duty sector to remain stable. And just to remind you Johnson Matthey is in the kind of 30% range of that, and the market as a whole to grow from $6bn in 2015 to more than $9bn by 2025. So that's a compound annual growth rate, as you see there on the right of over 5% in this period.

So in heavy duty, which is the next purple bit there, we see strong growth in the heavy duty sector. This is heavily weighted to China, but we also see market growth in South

America and India. I've already given you a little bit of a health warning on India, we're taking a rather conservative approach, just because the legislation is not really nailed down on when it's going to be introduced. So maybe we're a little bit conservative in where we've done that, I think we're kind of assuming 2022 now, but we've kind of given a range of 2020 to 2025, so kind of a broad range there. So you can take that comment with whatever you want.

So we see our heavy duty market share moving from 60% or so today to around 50% by 2025. I've said that before. And the heavy duty market as a whole growing from about $1.75bn in 2015 to greater than $4bn by 2025.

So now looking at the new part on this chart is we've added the light duty and the heavy duty battery materials. So we see significant expansion from a low base in the battery materials market for both light duty and heavy duty applications. The market will see a compound annual growth rate, as you'll see there over 20% for the next ten years. The whole battery materials market is around $1bn today, growing to more than $8bn by 2025.

So where does Johnson Matthey fit into this market? So if we look at our existing business in battery materials, which is predominately LFP as Nick was talking earlier. Today the LFP market is around $300m and we see that growing to about $1.5bn by 2025. And our market share of the LFP market is stable at around 20% through this period.

So all three of these sectors offer good growth, good opportunities for JM with our current battery materials portfolio and as you'll hear later we have a strategy to expand our position in batteries beyond lithium iron phosphate. So there is some potential to go beyond where our current position is.

So what's our strategy to capture this value? In the ECT business we have market growth and legislation driving the need to develop the next generation technologies, so we continue to invest in R&D and use our strengths in chemistry and applications to win in this area. Chris Morgan and Andy Walker will go through that in more detail later. We're still investing in ECT, we have capital projects for both light duty and heavy duty in Europe; the light duty investment being for real world driving and the heavy duty investment being on the second generation of heavy duty catalyst as I mentioned earlier.

We also have some continued investments in Asia, primarily in China, and as far as manufacturing excellence goes we have a very strong culture of continuous improvement and we continue to improve our equipment effectiveness and we're continuing to leverage those activities.

In the electrified powertrains we'll use Johnson Matthey's brand and reputation to broaden our technology offering and customer base. We continue to invest in R&D, and we'll expand our technology offering into other materials.

We see £50m to £100m of capex in the next five years for the battery materials business, backend loaded, with some bolt-on acquisitions of less than £50m. And Martin will get into this in more detail in his talk.

So expanding our position as a key technology supplier for low emission, low carbon vehicles will also lead to us to new customers and suppliers who are not in our existing portfolio.

So key takeaways - as powertrains evolve there's increased opportunities for Johnson Matthey technologies as the trends in the automotive market play out. The internal combustion engine is alive and well through the next decade and beyond and ECT still has lots of growth opportunities in both the light duty and heavy duty markets.

So to sum this all up, I'll try and do this similar to how I did this in the previous Investor Day sessions and I'll start with the ECT market. So on light duty vehicles, if you go back to the charts on the previous slides the catalyst market grows by over $3bn in the next ten year period in light duty, from about $6bn today to over $9bn by 2025. As I said, Johnson Matthey's share is around 30% of that. So that light duty market will deliver at least $1bn of additional growth for Johnson Matthey.

In the heavy duty vehicles we see this sector for catalysts growing at about $2.7bn in this period, as I said our share today is around 60%, moving to 50% by 2025. So in heavy duty you know we also will deliver at least another $1bn of additional value over this period, you can do that math, we're kind of rounding down, but you have calculators as well.

If we then sum up ECT we see the total market, light and heavy duty growing from around $8bn today to around $14bn by 2025 and Johnson Matthey would expect to win over $2bn of value from the traditional ECT markets.

The battery materials market is still at an early stage of development, but is projected to grow strongly over the next ten years, a successful expansion of our battery materials portfolio and other legislation pull forward will be upside for Johnson Matthey. We get good value from our current position in LFP and we expect our share of this sector to remain stable over the next decade, with the market projected to grow from $300m to $1.5bn in 2025. There's an opportunity for Johnson Matthey to capture an additional quarter of a billion dollars value for Johnson Matthey.

So if we sum this all up the total market for ECT and the current Battery Materials portfolio grows from about $8bn today to over $15bn in 2025. Johnson Matthey's combined sales for ECT and Battery Materials are a little over $2.8bn today and we expect this to almost double by 2025, so that would give us a compound annual growth rate of around 7% over this period.

So you can see that Johnson Matthey is well placed to capture value from the evolving powertrains, where our advanced technologies will make a continued contribution to improving air quality around the world.

Question and Answers

Robert MacLeod, Chief Executive
Thank you John, now we've got about 15 minutes or so before we break for coffee, so we're very happy, the three of us to take any questions if anybody has any now or we can do it over the coffee break.

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Evgenia Molotova, Berenberg
Good afternoon, I just wanted to talk about diesel again, to ask about Real World Driving Standards, because as far as I understand the issue which VW had was with small sized vehicles and they were using LNT with the software, so it's nothing wrong with the catalyst. But as far as I understand it's very difficult to put SCR into small size vehicles before of the size of the SCR tank and then if you use LNT then the fuel efficiency of the diesel car falls to the level of fuel efficiency of direct injection petrol. So do you see this as a threat for small size vehicles in particular? That's the first question.

The second question is on LFP and so whether you are looking at other technologies, because obviously LFP is quite expensive for passenger vehicles and that's why it's mostly used in stationary, so are you considering acquisition to go to NMC, or you are not seeing this as a leading technology for electric vehicles going forward? Thank you.

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Robert MacLeod, Chief Executive
Thank you they are quite detailed questions I have to say and to some extent if we answer them all now we're going to get into why bother coming to the next session, because we are going to get into some of that detail, Chris will talk a little bit about the LNT versus SCR system, but you're right one of the issues is to do with size for smaller cars, but Chris can go through that, he is planning to answer that question anyway.

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Evgenia Molotova, Berenberg
Thank you so much.

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Robert MacLeod, Chief Executive
And on the LFP side again Martin is going to answer that question later too. But the long and the short of it is you're absolutely right, lean NOx traps, it's harder for a smaller car, which is why advanced SCR is going to be used for the bigger cars, and that's true, John isn't that true?

And as - who said it, we're looking at ways of how we can expand our market out of LFP into other high energy materials, which is what we said. We'll talk a little bit more about it in the next session.

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Nick Garner, Division Director, New Businesses and Corporate Development

You'll have to stick around I'm afraid.

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Andrew Benson, Citigroup
Just in terms of the risk profile of acquisitions and making acquisitions, clearly you can spend a lot of money and get dud technology, but equally you cannot spend money and then miss out on a market that grows. And I would imagine the risk of not being involved in the time when batteries become an established commercial technology is quite high. So in that sense would it make more sense to if you like up the risk curve on acquisitions somewhat to make sure you're there at the ground floor with a range of technologies rather than just one technology at this point in time?

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Robert MacLeod, Chief Executive
Nick do you want to have a go at that one?

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Nick Garner, Division Director, New Businesses and Corporate Development
I'm happy to, and I think the key is range of technologies - you're absolutely right and that remains our intention. It's about how to access them. We do look hard at M&A, and the appropriate available targets and continue to do so. Of high scale we've found precious few, and so a combination of more targeted M&A and in licensing of technology is the way we would aim to access the ground floor as you're saying of these sort of evolving battery technologies areas.

And I think the point is it is evolving, I think the bus hasn't left yet, but it is kind of leaving. And so there is some urgency to sort of evolve your platforms and be there for sort of five years time and that's the sort of timescale we're working to at the moment.

I'm not sure if that answers your question about upping the risk profile, all I can say is we look hard and we assess the long term potential in terms of the sorts of targets we're looking at, so they don't have to necessarily meet the short term criteria we'd expect, but they clearly have to deliver to a long term plan. Does that?

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Andrew Benson, Citigroup
Yeah, that's fine.

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Peter Cartwright, Fiske
On the cathode material at the moment nearly all the battery plants are in Asia, so doesn't this imply a huge shift in your manufacturing base to shift your cathode material out to Asia so that you're adjacent to where the batteries - these large flat plate batteries are made?

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Nick Garner, Division Director, New Businesses and Corporate Development
We have currently two plants, one of them is in China and the other one is Canada, for various reasons the Canadian one - most of the product from Canada goes to Asia, as you point out Peter. And the current investment plans are primarily based on further investment in Asia, so I think we're there.

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Martin Dunwoodie, Deutsche Bank
You've made the assumption of 20% market share remaining flat in the period, I was just wondering why you'd - I don't if that's just for simplicity sake, but if you can talk to that and how you see the competitive environment now and how you see that developing over time, both in LFP and whether you see - I know you've talked about expanding into other areas, but how you see those in terms of competitive environments well? And maybe where - sorry there's loads of these things, and maybe where you see your overall market share in Battery Materials 2025 across the piece? Probably an impossible one to answer but just an idea of what you're thinking of.

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Robert MacLeod, Chief Executive
Well I'll answer the last one first - our target, our aim is to get to double digit market shares when we get to 2025, which is what I said. Now some of that will be in the what we would call our established market today, which is in lithium iron phosphate, but of course if we're successful at 20% with lithium iron phosphate in 2025 that will not equate to a double digit share of the whole market, so we're going to have to, and we're going to try, and we're going to target getting into the high energy material space. And you know hopefully by the end of today you'll get an idea of why we think we can be successful at that.

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Nick Garner, Division Director, New Businesses and Corporate Development
The competitive environment I think - as I was hopefully trying to point out we're talking of the automotive batteries market itself, and I think that's at a point of inflection and evolution. What this market is historically is dominated by electronics, it's power storage into the electronics markets. And that follows a very different sort of supply chain and approach to the sort of OEM led supply chains that the automotive sector tends to have and the OEMs sort of insistence on input into technology.

Into that trend I think we're very well placed and that's what we're seeing, LFP is effectively mainly used in the automotive sector because of its power qualities, whereas high energy materials are used broadly within energy storage and in consumer electronics.

So in LFP our competitive position has been enhanced, certainly as we have taken our abilities from ECT across into the automotive sector. 20% it is a simple calculation, but there's logic behind it and it doe move over time. Big movers in LFP are things like buses and how you play into the bus market, particularly in China is important, and assumptions around that. So it's not just a flat 20% throughout, there's some granularity around it, I'm not going to go into it particularly, but there is. So we come

back to that, as well as sort of some of the milder hybrids, you know less volume there but they still add to the number as it were.

In other technologies I go back to my comments, as that market evolves we think we're well positioned because our approach to this market and the applications led development into the automotive sector to bring in evolving energy materials and to the point I think the bus hasn't left yet but it's leaving pretty soon, so we need to get those - starting to be established in that sector within the next few years.

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Robert MacLeod, Chief Executive
And I think I'd also just add finally on the LFP market, LFP is not just LFP simple as that. It's emerging, there's further technology to go and further developments to be made in that and as you're able to use your R&D and technology and enhance those products then we would hope to maintain that share. That's our goal and it's not something we just plucked out the air just because it's the same number, there's a bit more science behind how we got that.

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Martin Dunwoodie, Deutsche Bank
Great thank you.

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Adam Collins, Liberum
One thing we should be talking about in a powertrain discussion is the fuel cell business, so could we spend a few minutes just discussing where we see that going in the next ten years or so? What kind of business do you think it will look like in 2025?

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Robert MacLeod, Chief Executive
Well I think we're talking about today the automotive powertrain development. And I think as John showed you on that chart by 2025 the fuel cell vehicles will still be very, very much a niche play. So the growth prospects for the automotive component of the fuels cells is modest.

We continue to look at the stationary element of it, but that's not the topic of today, and as we said six months ago, or four months ago now when we did our results we're looking at the overall R&D spend and the requirements that we have for investment requirements for fuel cells in light of where the market is going. But we still want to be part of the fuel cell business in the future, but I think on the automotive side over the next decade it's going to be a small component.

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Mathew Waugh, Credit Suisse
I just wanted to touch on your diesel projections on the total cost of ownership, when you say for a higher mileage driver you think it will be beneficial still, does that factor in

the added cost of moving to SCR and advanced SCR and the fact that gasoline engines are improving efficiency continually as well?

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Robert MacLeod, Chief Executive
In regards to that very short question the answer is yes.

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Nick Garner, Division Director, New Businesses and Corporate Development
We can discuss it in more detail.

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Robert MacLeod, Chief Executive
We can give you much more detail. But John do you want to say anymore other than yes.

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Mathew Waugh, Credit Suisse
Maybe you could tell us where the breakeven mileage is?

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John Walker, Executive Director, Emission Control Technologies
I'm looking for a cup of coffee.

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Robert MacLeod, Chief Executive
I think the answer - we and LMC Automotive when they put these projections out aren't doing these in splendid isolation ignoring what else is going on in the powertrain evolution, not just with hybridisation but gasoline, diesel, the improvements in both, etc. And these are all factored in. And at the same time what is factored in, remember over the next decade that we are talking to the OEMs all the time, so we understand what their powertrain developments are. So we're factoring in a whole series of information points that come into us to come up with that analysis.

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Mathew Waugh, Credit Suisse
Thanks.

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Alex Stewart, Barclays
There's a lot of talk about the death of diesel, but what's your view on the death of the car. There are indications for example that younger people, millennials, are less attached to driving, carpooling, car sharing, taxi, Uber, all of these things potentially threaten the car ownership market in Western Europe. And we talk a lot about the split within that without really ever wondering whether car sales might go down in the future.

Is that something that you think about, that you take into account in your internal planning and strategic processes?

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Robert MacLeod, Chief Executive
Well the short answer to that is yes.

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Nick Garner, Division Director, New Businesses and Corporate Development
Autonomous vehicles, car ownership are interesting themes which come together and they were sort of briefly flashed up as themes there. And I think over the next ten years and this is the data - that does, you can see the vehicles numbers, and one of the factors that's moderating the inevitable growth of automobiles is car ownership, particularly in urban environments, where car sharing, or carpooling, or other transport solutions are there towards the end of the decade. And if you took that curve on at some point it starts to curve down. But who's guessing out several decades and those are factors that come to play in it and they're all enabled by these sorts of technologies that come together, because those are necessary I think to control the fleet as it were.

On the counter side to that one, if there is a shared vehicle as it were, that's being used much more often. A personally owned vehicle tends to spend most of its time sitting unused; a vehicle that is used communally will be used harder. And people want those vehicles not to be sort of tatty. And so there's also a counter argument, I haven't worked this through; I don't think anyone has yet, which increases the volume of new cars coming in and out of the fleet as it were. But a tendency to those things will certainly play into towards the end of this decade coming up, I would agree.

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Alex Stewart, Barclays
Thank you.

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Robert MacLeod, Chief Executive
Okay shall we break for coffee, it's twenty to three, the schedule has us starting at three o'clock where we'll get into much more detail on the actual sort of emission issues in light duty and heavy duty, so back at three o'clock if we could please.

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Coffee Break

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Introduction

Robert MacLeod, Chief Executive

This is from, as you can see on the slide, Dr Chris Morgan and Dr Andy Walker. Both work in John's business, in Emission Control Technologies, and they're going to go through very much from an emissions control side some of the developments over the next decade or so. So I'll hand over to Chris.

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Automotive Emission Control Regulations and Technology Trends

Dr Chris Morgan, European Technology Director ECT
Okay so this next session we're going to focus on the prospects for Emission Controls Technologies, and specifically what we'll do is outline the global growth trends in both vehicle and engine production, look at the incoming global regulatory trends, and as Nick and John have referred to that's both the tightening of criteria pollutant legislation and the increasing focus on CO2 and fuel economy, show how we maintain differentiation through our technology at Johnson Matthey, and highlight the opportunities that result as a combination of those regulatory consumer - customer market drivers, and describe how those opportunities drive future sales growth in ECT.

And the way that we'll do it, we'll split into two sections. I'll talk about the light duty market, then I'll hand over to Andy to talk about the heavy duty situation.

So to start with in light duty this is the LMC data looking at vehicle numbers. John presented this in total earlier but looking at it split out by region we see good growth around the world, so 3% global compound annual growth rate in light duty vehicles, particularly in the BRICs and the Asian markets, the rate of growth is faster there. Europe close to average and perhaps lower growth in North America.

There was a question raised just before the coffee break about shared mobility models and the impact that has and Nick gave an answer to that question, and I think our view chimes with that as well that yes there'll be a proportion of predominantly urban people who won't own a car who do today, but if they are going to use the shared mobility models they would expect those cars to be in good condition, to be modern and they will be used more heavily than the standard vehicles so there will be a higher turnover of those vehicles. So those effects in our view will only have a very small impact on the overall vehicle market and we see good growth over the next decade.

And of course that growth in vehicle production leads to a growth in demand for JM's powertrain technologies both catalyst systems and batteries.

There's also been several mentions already about legislation and how important that is for us as a business, and as is traditional on these occasions here's the roadmap of legislation tightening around the world. A very complicated chart and I'll go into the details over the next few slides, but really the key message from this first one is just as we go from left to right over the next ten years in every one of those markets there's at least one change of legislation. So around the world we're getting tighter and tighter legislation which is driving improved requirements for the catalyst technology.

And we'll start by focusing on Europe and the situation here has become much clearer over the last six months. We knew that Euro 6b would have taken full effect by last September and that's now for all new vehicles sold in Europe they have to comply with that level. And the big change for Euro 6b was the introduction of a tighter diesel NOx limit reducing from 180 to 80 milligrams per kilometre, and that has meant the widespread use of diesel NOx control systems and I'll talk more about those on a subsequent slide.

And the next round of legislation comes in September 2017, so called Euro 6c and here we get a tightening of the gasoline particle number limits, that reduces by an order of magnitude which will start to introduce gasoline particulate filters into the market.

But the real news for the last six months is the clarification around Real World Driving Emissions after years of negotiations in Brussels, and actually just yesterday a vote was held in the European parliament where that legislation was ratified and was confirmed to be going ahead.

It comes in two phases, what we used to call RDE Phase 1 now seems to be being called Euro 6d Temp which isn't very catchy but seems to be the way the industry are referring to it, and that comes into effect in 2017 for new models brought to the market and 2019 for all vehicles. And what that legislation says in simple terms is that when you do a real world drive, and a real world drive has a very careful definition which is roughly a third urban driving, a third rural driving, a third highway driving, when you do that drive you put a portable emissions measurement system in the boot of your car, you measure how much NOx is generated throughout that two hour drive and then you have to ratio that amount of NOx against the current limits that apply to the European drive cycle today. And that ratio is called the conformity factor and the agreement is that from 2017 for new vehicles you're not allowed to emit more than 2.1 times more NOx in a real world drive than you are during the standard drive cycle.

We're expecting a conformity factor to apply to particle number as well. Those negotiations are ongoing and an announcement is expected in the next few months. So that's Euro 6d Temp. And then Euro 6d Final or Phase 2 comes into effect from 2020 for new models, 2021 for all vehicles. And there we get a further tightening of conformity factors to 1.5 times for NOx, and again we expect a tighter limit for particle number once those are announced.

So those were confirmed yesterday in a vote in the European parliament. One other piece of information that came out during those discussions was the Commissioner has an ambition to reduce those conformity factors to one by 2023. And I think there's a lot of political pressure built up around the VW scandal and the realisation that vehicles do emit more under real world drive than under the emissions test, and there's no doubt that had an impact on the politicians and their braveness in setting these conformity factors. These are considerably lower than we would have expected six or nine months ago. And I think that push towards one is genuine and really is only limited by the ability of the measurement system and the ability of the emissions control systems. So there'll be pressure to improve both of those and drive the conformity factors down as quickly as we can.

The impact of all of that for Johnson Matthey is that we need to have both gasoline particulate filters and advanced diesel NOx control systems available. As I'll show you later, one of those or one set of those is already on sale, the other is very close.

North America the situation is rather more stable. California the CARB and the Environmental Protection Agency have previously announced their plans for the next ten years, and for CARB the so called LEV III legislation has a tightening over that period down to what is called the SULEV level so that's 30 milligrams per mile combined hydrocarbon and NOx and a particle mass limit of 1 milligram per mile by 2025. And the EPA has a very similar scheme for their Tier 3 legislation, basically follows CARB except for the particle mass limit which comes in a little earlier and is higher at 3 milligrams per mile.

So that means more complexity in the current catalyst systems, more vehicles are going to have to meet the very lowest emission standards so we need more robust catalyst systems and high conversion levels with those catalysts.

On top of that in North America there's an additional set of regulations around greenhouse gases and particularly methane and N2O which have very high greenhouse gas potential. And there are caps on the amounts of those gases that vehicles are allowed to emit which gives further constraints on catalyst system design.

And then in Asia again there's been a lot of change over the last year in terms of the proposals for the next five to ten years. In Japan they have proposed a new JP18 standard which is essentially the same emissions limits as today but over a more demanding drive cycle, the world harmonised light duty test cycle. In India there's a recent proposal that they will jump straight from their Bharat Stage IV, Euro 4 equivalent legislation to Euro 6 equivalent, to Bharat Stage VI skipping the stage 5 level. And the introduction of that Bharat Stage VI has been brought forward to 2020, so earlier than was otherwise expected.

And then in China we're in the position where with current proposals Beijing by the end of the decade will have the most demanding emissions regulations anywhere in the world, so they'll leapfrog California. So the proposals there at the moment are that from December 2017 all cars must meet the ULEV70 standard, so that's 70 milligrams per mile hydrocarbon plus NOx, and from 2020 all cars must meet SULEV30. And that's a tighter legislation than California, California is a fleet average of 30 milligrams per mile. In Beijing the proposal that will be a maximum amount for all vehicles.

There'll be a limit on particle mass; there have been lots of discussion about particle number but as yet no clear proposal on particle number, perhaps that will come in the second phase of Beijing 6.

The China national standards in contrast are still based upon the European emissions standards and Euro 5 equivalent will be adopted from 2017. And from 2021, or perhaps 2020 from recent things that we've heard, there will be a Euro 6 equivalent adopted, probably using the world harmonised drive cycle as in Japan, and probably including some particle number limits as well.

So all of those mean that more advanced gasoline systems will be required, including particulate filters in China. There's still an ongoing debate between Beijing and the rest of China about whether it's the right thing to have two different emissions controls legislation and we'll watch this space over the next six months.

So that's the criteria pollutants, the hydrocarbons, CO and NOx. And then on top of that there's again as we mentioned several times there's increasing tightening on CO2 limits or improving fuel economy standards around the world. This chart is generated by an organisation called the ICCT, it's a fairly well-known chart within the industry, but it just shows how in all the major markets the CO2 performance is trending down over time. Europe at the moment is leading the way with the 95 gram per kilometre fleet average by 2020, but all markets are reducing.

And that has two implications for Johnson Matthey, firstly more fuel efficient engines means less waste heat entering the exhaust and lower operating temperatures for the catalyst system and that means we need to develop catalysts which work better at those low temperatures. And secondly one way to improve the fleet average is increase electrification of vehicles whether that's hybridisation, mild, full plug in or full battery electric vehicles. So as those trends continue downwards then that will play to Johnson Matthey's strength in both the battery materials and catalyst technology areas.

And what comes next? There have been unofficial discussions about Euro 7 for some time but nothing formal, and within the European parliament really the position is that while the complicated RDE legislation discussions have been ongoing then there have been no formal discussions on Euro 7 because there has been no desire to potentially derail RDE by bringing that into a new set of legislation.

But with RDE due to be concluded over the next year it's likely those Euro 7 discussions will start soon. And likely topics for that next round of legislation are listed there. One very probable inclusion is fuel neutral limits. The diesel NOx limits have been reduced substantially for Euro 6 but still a diesel passenger car can emit 80 milligrams per kilometre NOx compared to 60 milligrams per kilometre for a gasoline vehicle, and it's likely those two will be brought together which will mean further tightening of diesel NOx control. As I said there's an ambition to reduce those conformity factors down towards one, and if that isn't done through the standard RDE legislation then it's likely to be included as part of Euro 7.

And looking at where the major problems with air pollution are today in Europe, urban air control, urban air quality is a major issue so it's possible that NO2 limits will be introduced in the urban phase of the drive cycle, and also that other criteria pollutants will be added such as ammonia and N2O.

We showed that chart of CO2 trending down over time, but also the European Commission has stated they have an ambition to reduce those CO2 emissions even further. No firm figures but people have talked about values of 75 to 80 grams per kilometre by the middle of the 2020s. So if that is the case that's likely to drive further hybridisation, further electrification of vehicles in order to meet those targets.

So initially that's very much focused on the regulation, both criteria pollutants and CO2, but there are other technology drivers that we have to be aware of that inform our choice of catalyst targets for the future.

Engine technology has come on enormously over the last 10 to 15 years in response to many of the challenges that I've outlined on the previous slides. And today we see many more downsized turbocharged engines in the market in order to deliver better fuel economy. In Europe in particular many of those have stop-start in order to give better fuel economy over the drive cycle. And we're seeing increasing amounts of energy recuperation mild and plug in hybrids and more of those coming in future cycle plans at the OEMs.

On the gasoline side a higher proportion of engines are now direct injection. That gives benefits for both power and fuel economy. But today lean burn gasoline still remains a niche application constrained by the cost and complexity of the control system and the catalyst system compared to the fuel economy benefits that are attained.

Another issue in gasoline engines that we're seeing at the moment is a lot of effort to improve injectors and cylinder design in order to reduce the engine out particle number emissions and reduce the demand or eliminate the demand for filters. On the diesel side there's measures such as cooled EGR that help to reduce diesel engine out NOx emissions and again help to reduce the load on the catalyst system. And in North American those fuel economy targets, the CAFÉ targets are leading to increased diesel penetration in some of the larger vehicles, the large SUV and light truck markets in order to meet those tighter fuel economy regulations that are coming through.

In terms of fuels there's still some niche areas where compressed natural gas, liquid petroleum gas and ethanol are important. But generally most vehicles today use diesel or gasoline fuel with some bio fuel blended in, but the market for specific alternative fuel vehicles remains small and we expect that to remain so.

And perhaps not a technology driver but certainly a development driver is system cost. So we see catalyst systems becoming more complex and there's a desire from the vehicle manufacturers to want to minimise the additional costs that those mean for the sale of their vehicles. So if we can reduce the cost of the system while delivering improved catalytic performance then that's certainly to our advantage.

So let's talk a little bit about the technologies then. I think this is a slide that many of you will have seen before highlighting the clean diesel technologies. And today there are three families of catalysts that are being employed and as I say all three are being used to meet Euro 6b regulations.

On the left hand side we have the NOx adsorber catalysts. These are a precious metal based catalyst that stores NOx during normal operation, and then you can purge the catalyst by running the engine rich by using excess fuel. And under those conditions the NOx is desorbed and converted to nitrogen. This has the advantage of being compact, it's favoured on smaller vehicles, but it does require fuel addition in order to purge the catalyst and that penalty on fuel consumption perhaps makes it less attractive on larger vehicles, but favoured on smaller vehicles.

The central and the right hand box are the SCR based systems, selective catalytic reduction, and here the chemistry is based on a base metal zeolite catalyst, and the injection of urea which generates ammonia in the exhaust. The ammonia is stored on the zeolite and reacts with NOx during the normal operation of the engine. It's good particularly at higher speeds and higher temperatures; it gives a wide range of conversion. The disadvantage is you have the requirement to add the urea tank and the urea injection system into the vehicle. That takes some space. It also adds cost for the OEM, and back of the envelope figures we've heard are that perhaps €500, €600 additional cost to add the urea injection system compared to the NOx adsorber catalyst system, but it does allow better NOx conversion.

And on the right hand side the advanced SCR is where we're combining the SCR coating onto the particulate filter. A very demanding system technically but delivers benefits in terms of compactness and in terms of the rate at which the SCR component heats up. It's closer to the engine and gets to its operating temperature more quickly and therefore you get better NOx conversion particularly in the urban environment.

We're well positioned in all of those technologies and I guess the real question is what do we see happening with the advent of the RDE limits. And really what we expect and what we're seeing in conversations with our customers is that the NOx adsorber catalyst becomes a much smaller part of the market going forwards, and there'll be a trend towards use of the SCR and advanced SCR system, and within that a trend towards more of the advanced SCR.

To answer the question that was asked earlier about NOx adsorber catalysts and diesel vehicles, yes it certainly is true it's harder to meet the tight conformity factors for RDE with the NOx adsorber catalyst and that's one of the reasons why I expect more SCR. And I think it's also true to say that that does have an impact on the share of diesel in smaller vehicles, and we are aware of a number of programmes that have been cancelled or much reduced in size for small diesel engines. And some of that reduction in diesel share that Nick and John referred to earlier from 50% down to the low to mid 40s is due to the reduction in sales of small diesel engines in favour of the high technology gasoline engines that are much more suited to those small city cars.

So we see more focus on the SCR and advanced SCR systems going forward. John talked earlier about the value to Johnson Matthey of five to seven times for these types of clean diesel systems. And I think this trend is good for Johnson Matthey in two ways. Firstly we have very strong technologies in the SCR area, we were very successful with today's customers and we expect that to continue. So that move to SCR is a good thing for Johnson Matthey. And also within that value range the SCR and advanced SCR system are at the higher end of that range, so also delivers increased value to Johnson Matthey.

The other trend that we expect for clean diesel, even with the advanced SCR system there's a period early on in the drive cycle when the SCR catalyst is still cold and we need to deal with NOx that's emitted from the engine. So I think a likely trend is that we will incorporate some of the chemistry currently employed in NOx adsorber catalysts into the diesel oxidation catalysts in the front of those SCR and advanced SCR systems

that will help to trap some of the NOx emitted very early on after the vehicle is switched on, and then release those and convert them over the SCR or SCRF component later on in driving. So good technologies today but more improvements to be made as well.

And this is an interesting slide that was released by an organisation called Emissions Analytics back in November, and they're an organisation that have been taking a wide range of vehicles commercially available today and doing real world driving. And if we start with the blue line which is the Euro 5 limit, 180 milligrams per kilometre NOx, and the blue dots are where the vehicles were during real world testing. Now I must emphasise all of those vehicles met the Euro 5 limit over the drive cycle. What we're seeing here is the difference between a vehicle driving over the European drive cycle and a vehicle driving in real world conditions. And many of those vehicles are emitting three, four, five times as much as they do over the drive cycle and in the worst case nearly ten times as much. So clearly that's the problem that real world driving had to address, how do we get systems that give good NOx conversion in the real world, not just in the laboratory.

But for me the really encouraging thing about this slide is the purple dots. So the purple line at the bottom is the Euro 6 NOx limit and the dashed pink and green lines are the Phase 2 and Phase 1 conformity factors for RDE. And what we see with the purple lines, even before OEMs have to meet the RDE limits is a significant reduction in real world NOx. So those new advanced diesel systems are delivering much better NOx emissions in the real world. Some of those systems are already meeting the Euro 6 limit, the conformity factor of one in the real world, and a third of the vehicles that were tested are meeting the Euro 6d Temp, the Phase 1 RDE conformity factors. So this is manufacturers voluntarily fitting systems that are better than required in order to meet the conformity factors, and I think it emphasises the fact that it's technologically possible and we can meet these in the future.

Another interesting aspect to this is that from this year when an OEM launches a new vehicle they all have to publish the conformity factors; even though there is no limit they have to meet until 2017 they'll be required to publish those figures. And our expectation, and we've again seen this reflected in conversations with a number of OEMs, is that that will start to make emissions control competitive. We already see this for CO2 emissions today, there's an advantage in having a car that delivers lower CO2 emissions or better fuel economy than your competitor, and we expect a similar thing to start to imply for NOx emissions. Nobody will want to be the worst for NOx emissions in the real world, and some OEMs will see an advantage in being able to be the best and sell vehicles as clean diesel and promote their environmental image.

So I think this means that it's something very strong. It's going to mean a drive for better and better emissions control systems, and again we can take advantage of that going into the future.

And then on the gasoline side, I've mentioned gasoline particulate filters a number of times and we are now in a position where we're going to launch two types of systems in this calendar year. One on the left hand side is the traditional three way catalyst with a coated gasoline filter downstream. That filter's primary role is to remove the particles from the exhaust system. But it will also have a three way catalyst type coating on it

that will deliver some additional conversion activity for any NOx and hydrocarbons that slip through the three way catalyst.

And then the second more demanding system has what we're calling a three way filter at the front of the system close to the engine, and this is required to filter out the particulates and have all the activity of the traditional three way catalyst. That means a higher loading of catalyst which adds some challenges in terms of the back pressure of that system. But that has some advantages particularly on smaller vehicles; it's a more compact system and enables those vehicles to meet the future limits.

So we're launching those systems this year. We're continuing development partnerships with a number of OEMs. We are aware that some applications will be able to meet that initial Euro 6c limit either through improved engine technology alone, that improvement in injected design and cylinder design I mentioned earlier, or some are using an uncoated GPF. But our expectation is that with the advent of particle number RDE limits that will drive increased uptake of this coated gasoline filter technology. And as John I think mentioned earlier that additional technology increases the value of the gasoline after treatment system as well.

So that's the technologies. We're well positioned today, those are either on sale or about to be launched. But we can't rest on our laurels, we need to keep investing in R&D and improve our offering. When I was preparing these slides I found it interesting that there's very similar themes in both gasoline and diesel catalyst development for the next few years. Temperature is a critical one, I've talked about the lower catalyst temperatures we see with more fuel efficient engines. So in both areas we need catalysts that light off, become active at lower temperatures, and give you good conversion efficiency in those cooler conditions you see in urban driving. Particularly relevant for RDE.

Almost paradoxically we have low temperature but also a requirement for increased thermal durability. Gasoline peak ageing temperatures are increasing. That's partly engine design and the way that the injection strategy is used. It's also partly the removal of fuel enrichment to control peak temperatures. So generally we're seeing higher peak ageing temperatures. And on diesel systems the requirement to regenerate components in the system to remove soot and sulphur also leads to higher temperatures. So we need to find catalyst systems that work well at low temperature but also materials that give better thermal durability and survive longer under those conditions.

The increased number of downsized turbo charged engines means there's also a drive to reduce system back pressure. Those engines have to work hard, and if there's too much back pressure in the exhaust then that minimises - or that affects the power delivery from the engine. So if we can make the systems smaller and lower back pressure that's an advantage. And to control cost, whatever we can do to remove precious metal content from the system is also beneficial for the OEMs. So these themes are all critical for us to keep offering competitive products to our customers and protect our market position going forward.

So John mentioned the headline figure earlier on in terms of the light duty sales, the catalyst market. We see that growing from $6bn today to over $9bn by 2025. If you break that down into different components you can see European diesel, that dark green bar near the bottom, remains a very important sector and those clean diesel technologies are critical to that. And the RDE legislation and the introduction of GPFs provide further growth opportunities in Europe.

And then another significant area of growth is in Asia and that's partly through increasing car sales and also tighter legislation, not just the Chinese regulations I mentioned earlier but also on the diesel side, the introduction of filters in some markets such as Thailand. So generally we're seeing the light duty market continues to grow faster than global vehicle sales, and we would expect our market share to remain at about 30% throughout this period.

So to summarise the light duty section, emissions legislation is continuing to tighten around the world and perhaps at a faster rate than we've seen over the last few years. And there's clearly increased pressure both political and public for clean vehicles. That has led to an increased uptake of the latest catalyst technologies and Johnson Matthey are very well placed. We have a strong range of technologies in the clean diesel, advanced diesel systems and we're about to launch gasoline particulate filters as well. But we have to keep investing in R&D to further develop the catalysts and make sure we remain competitive over the next decade to maintain that market share. And hopefully you've seen from these slides that in combination there's good opportunity for growth into the next decade for light duty catalysts, supported by that increase in vehicle production, the tighter legislation and the improved technologies.

So thank you for your attention. I'll wait for questions till after Andy has spoken.

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Regulatory and Technology Trends in the Global HDD Market

Dr Andy Walker, Divisional Technology Director ECT
Thanks very much Chris. So I am Andy walker, I am the Divisional Technology Director for our ECT catalyst business, and what I am going to do over the next 15 or 20 minutes is really draw some parallels between what Chris has talked about in the passenger car side with where we see the heavy duty diesel market going over the course of the next ten years and a little bit beyond.

So what we can see, we break this down, we look again at what's going to happen to the number of regulated engines because that's obviously one of the key drivers for us in this business. The other key driver is the legislation, so then we'll take a look at the legislation around the world. And then we'll look at what that means in terms of JM value going forward, and then the value of the total market of HDD, building up to the kind of headline figure that John gave in his earlier presentation.

So what you can see here is heavy duty regulated engines. We're continuing to see an increase in those numbers globally over the next ten years. We see the more significant increases are in Asia and these are dominated really by India and China as you would

expect. We'll talk about the legislative picture in a moment as I said, but there's also a bit of growth in North America, a bit of growth in Europe. So you can see numbers of engines, 2.5 million going up to around about 4.5 million, something like that. So we've got a CAGR of round about 8%, something like that over the next ten years.

If we look at legislation, again as Chris said these are fairly complicated slides. There will be a quiz just before dinner this evening for any of you there so please pay close attention here.

Laughter

The key thing here is that as the colours change as we move across the chart we're seeing tighter legislation, and of course tighter legislation offers new opportunities for the Johnson Matthey organisation. And what I'll do as Chris did is I'll take a look at some of these areas specifically but I think two of them to draw out immediately, what we can see as Chris and John both said is one of the most dramatic changes recently has been in India where we expected Euro V to come in around about 2025 or so, that's been brought forward, it looks like that could be as early as 2020. We're taking a relatively conservative view as John said with our numbers which does mean there is some potential for upside in these numbers, because perhaps a middle of the road would say round about 2022 will be when the Indian heavy duty diesel market moves to Euro VI which obviously adds significant value for JMM.

But if we start at the top of the picture with Europe. We've got Euro VI in place today; Euro VI systems comprise an oxidation catalyst, a filter, an SCR system which includes both an SCR component and an ammonia slip catalyst component. So four different catalyst components in these systems. And what we can see going forward in Europe is the drive towards further improvements in fuel economy. As John mentioned this is already leading to some new systems being developed so we're not actually relying on the next stage of legislation to drive a change in the systems that are being used, because the drive for improved fuel efficiency and also the drive for lower cost systems which we can obtain by taking out precious metal is what's driving these midterm changes between the emission regulation changes.

And what we can do is we can leverage our information and our knowledge from what we've seen happen in Europe where we're moving towards a relatively mature situation now in technology with these stage two systems that John mentioned, and look at what that's going to mean for what we're going to see in India and China going forward, where again the focus there is going to be on meeting the emissions legislation but doing it at the lowest possible cost. And we've already started on that journey in Europe.

So what we can see in Europe is we've got the potential to move from a Euro VI to a Euro VII, probably part way through the next decade, and this again as Chris mentioned is likely going to mean some different pollutants are going to be the focus, NO2 particularly in urban areas has been a focus in London and in other major cities, particularly across Europe, for several years now. And N2O is something that's already regulated in North America in both heavy duty and light duty. The main focus for N2O is the greenhouse gas potential. So N2O is about 300 times worse than CO2 on a molecular basis for global warming which means that there's a strong focus on making

sure that any catalyst systems that are applied to vehicles absolutely minimise the increase in N2O that comes from treating the NOx emissions.

If we look into - and the other thing that we will see with Euro VII again is this ongoing drive towards improved fuel efficiency but we expect to see that being more formally regulated going forward in the European market on that timescale.

In North America the EPA has already moved into the greenhouse gas Phase 1 regulations, and what we've seen here is former regulations based around CO2 and fuel economy as well as N2O and methane. So very consistent with the picture that Chris painted in his earlier presentation. What's going to happen in 2021 is they're going to move to the second phase of this legislation which is going to tighten things further. So we'll have further tightening in fuel efficiency, engine efficiency is going to have to improve by at least 4% on that sort of timeframe, and we'll also see - on the back of that we will see a reduction in typical temperatures that the catalyst sees, so that requires a new generation of catalysts with more capability to work effectively at lower temperatures. And it will also mean that the engine out NOx emissions in general will tend to increase further because if you increase the fuel efficiency you often get an increase in the NOx emissions coming out of the engine. So the catalyst system has got to do more. So again good opportunities for further technical development and further value addition for the JM organisation.

So what we'll see as we move into EPA greenhouse gas Phase 2 as well is further tightening on N2O, and as I mentioned there again there's some good opportunities there for new generations of catalysts to come through. So there's a lot of good technology still to come in the more developed markets.

I'll skip California for the moment because I'll come back to them towards the end because California really is moving very dramatically forward when it comes to driving down NOx emissions, but I'll come to that in a second.

Let's look at Asia. We saw that the number of regulated engines in the Asian market is really what's the key underlying, the main driver, behind the CAGRs that we just talked about in terms of regulated engine numbers globally. And what we can see here is that both in India and China we're going to have this movement from Euro IV and Euro V systems, which in heavy duty is normally an SCR system, to a much higher value typically for the JM group round about a threefold increase in value as we move towards these SCRT systems that we use in Europe today, so the oxidation catalyst, the filter and then the SCR system.

So both in China and in India we're going to see this happen. In China in Beijing this legislation is going to come in over the course of the next year or so, so we'll have the initial numbers of these systems going into the Beijing market. We expect Shanghai and other major cities in China to follow on shortly beyond that as we move through 2018. And then somewhere on the 2020, 2021 timeframe the formal Euro VI legislation will be enacted nationwide across China. So with the huge number of diesel engines that we have there in the heavy duty side and the additional value creation for JM you'll see what this does to the market as we move through the presentation.

India as I mentioned looks like they're actually going to skip Euro V and go straight from Euro IV to Euro VI as they are doing in the passenger car market that Chris referred to earlier. And so again we expect a similar increase in value, perhaps significantly earlier than we thought because it is looking as if that could be as early as 2020, although as I say we're taking a slightly more conservative view than that.

John mentioned in his presentation looking at the non-road market in Europe. What we've seen in the non-road heavy duty diesel market is we've seen complete alignment really in the regulations between Europe, North America and Japan, so the more advanced regulated markets. What Europe has decided to do though is become the first place in the world to introduce a particle number regulation for the non-road market. What particle number regulation means is that filters will be required. So while the current regulations globally in the non-road area can be met for example just with an SCR system, as soon as you introduce particle number you can't do that anymore.

So the particle number regulation forces, mandates, the fitment of filter technology on there, so again what we can see here is the kind of systems that we've seen in Europe now in on the on road side and in the developed markets for several years, as well as in the non-road market we're going to see some of these advanced SCR, so where we've got some of the SCR on the filter. This is being done for two reasons. First of all as Chris mentioned you put the SCR component closer to the engine, it gets hotter earlier after the vehicle starts working so you get better NOx conversion over the cycle and over a typical working duty cycle, so it's good for the environment from that perspective.

The other thing is with a lot of non-road vehicles you've got a tremendous constraint on the amount of space that you have available for catalyst treatment systems. So by compressing the system down towards this SCRF type component we see additional value creation there. And again in moving from Tier 4b to stage 5, from SCR to SCRT this sort of threefold increase in value for the JM organisation is a good rule of thumb to use.

What we're going to see as well in China, China at the moment in the non-road space there's no need for any after treatment, and as we go through the next five years or so what we'll see first of all in Beijing where obviously there's a lot of construction ongoing in Beijing and then some of the other major cities in China, we'll see some non-road regulations being introduced there which again will force the fitment of catalyst technology. And then that will gradually tighten as we go through the next ten years towards the kind of levels that we've got in Europe and North America and Japan today. So again some significant additional value creation for JM in the non-road market within the emerging markets.

California. So California has some unique challenges associated with ozone and one of the key things that leads to ozone generation is having significant levels of NOx in the environment. So what California is looking at doing as we move through the next decade, so round about 2023 or so is probably the best estimate at the moment, is to look at taking what is currently already the most stringent NOx emission legislation in the world which is the US regulations that we introduced in 2010, and reducing them by up to 90% in order to give them the power to really bring down the NOx emissions which will really help them with the ozone problems that they have across California.

We would also expect that legislation to permeate certainly into the north eastern states of North America which usually follow California legislation, and certainly the California Air Resources Board and the EPA are in conversations already about whether this at some point would become a nationwide standard.

So this will require significantly more complex and more capable emission control systems that we have in place at the moment. And to give you an example of where we are, so this is a chart which just shows NOx emissions on the bottom, particulate emissions. And this is the NOx emission today of EPA 10. It's the lowest NOx emission anywhere in the world in terms of regulation for heavy duty, and that's what California is planning to do with it. Now what this will do essentially is mean that a heavy duty diesel vehicle driving on the highways of California will be as clean in terms of NOx on a per mile basis as the most sophisticated gasoline systems on the market today. So a tremendous improvement in the NOx emissions from heavy duty diesel vehicles will be mandated by this.

And if we look at where the engine out NOx is going to be, so how much NOx do we have to convert here, the engine out NOx is pretty much where Chris is sitting over there okay. So what we're looking at is requiring something north of 99% NOx conversion from these systems.

And what this will mean is that as well as having systems that can convert NOx at high efficiency when the vehicle is moving and everything is warmed up and things like that, the assumption at the moment is we're going to be hitting somewhere between 99.8% and 100% NOx conversion under those conditions. So once your vehicle is cruising along the highway it's done, there's nothing coming out of the tailpipe at all in terms of NOx.

But because of the way the cycles are constructed and because a lot of these vehicles there is some stop-start, there are cold starts, the main focus of the technology now moves towards the low temperature operation and particularly the cold start. And the challenge here is that SCR systems, because you need to inject urea to get the catalysis to go, they can't really operate effectively at temperatures below about 170 degrees. So you're starting off at room temperature, and before you get the system warm what are you going to do with the NOx that comes out? Because the way these regulations are constructed you've got to convert somewhere round about 98.5% of that NOx that comes out in the cold start before your SCR catalyst is hot enough to deal with it.

So the approach that we're taking here with some very exciting technical developments, and obviously these are things that we've got patents on and things like that, what we're looking at here is what we call the cold start concept. And this stores the NOx when the system is too cold to deal with it and then releases it once the downstream SCRF and SCR system are warm enough to deal with it. And we believe that by using this combination of technologies, so the NOx storage catalyst, the cold start concept here, with the advanced SCR so the SCRF system, again as close to the engine as we can get it so it's getting hot as possible as quickly as possible, will be the way to drive towards meeting this next stage of emission legislation. And again we do expect this to lead to a

significant improvement, significant increase in the value of the systems realised by Johnson Matthey as we look at these California regulations.

So similar to the picture that Chris presented us, we look at what we need to focus on going forward. You know still the need for ongoing R&D spend; you would expect me to say that in front of the CEO right. What we can see is the systems where enhanced NOx reduction are clearly required, so this is better fuel efficiency, lower CO2, generally leading to lower temperatures which leads to requirement for enhanced technology. The lower temperatures mean that we do need to do a significantly better job in low temperature NOx conversion as I just discussed.

We mentioned N2O, significant challenge when it comes to global warming, greenhouse gases so continuing developments to pull down the N2O emissions from these systems. Making the systems as small as possible, as light as possible and doing what we can to minimise the cost. And a lot of that focus is around minimising the precious metal content that we have in these systems. And then also as Chris said we need to generate a lot of power from these engines, so making sure that we minimise the system back pressure by looking at the way that we add the wash coats to the catalysts and develop the formulations in that way.

So we've seen the increase in the number of regulated engines and we've also seen the impact of regulations on technology trends going forward. What's that likely to mean in terms of the value of the market? So this is the total value of the market, this is sales ex PGM the way that we normally present it. And as John mentioned round about $1.75bn today increasing to somewhere north of $4bn over the next ten years. And you can see here a lot of that is driven by the pink profile here which is the big increase as we move into the Euro VI equivalent regulations in the Chinese heavy duty diesel market.

Europe remains a strong contributor to this as well, and we do see as I mentioned both India and also South America we're looking at the Brazilian market again as we move into the next decade tightening their emission control requirements and increasing the value opportunity for JM. And non-road as I say continues to add value, that will step up again as we see the Chinese introduction of the technology. And as well as John mentioned, as John highlighted, the stage 5 in Europe which drives filters on non-road equipment.

So to summarise the overall picture for ECT, so this is the light and the heavy duty side, what we can see is that regulations which are clearly good for our business, they are going to continue to tighten over the course of the next yen years. And these are going to be on the pollutants that we're used to and the ones that there's going to be an increased focus on going forwards such as NO2, N2O and particularly fuel economy and other greenhouse gases. The regulations obviously drive the need for technical improvements so there's a lot of value to be generated and obtained through that.

Within JM we've talked a lot about we don't just offer the catalyst, we really look to offer the solution. So we combine our catalyst knowledge with our applications knowledge, with our knowledge of the way that the customers are going to be using these catalysts, working very, very closely with the customers to make sure that our next generation

development is very much aligned with what the customers are going to need and what the regulations are going to require going forward because there's a common theme there. And so I hope what we've done is shown that ECT is very well placed to continue to deliver significant value from the opportunities in the emission control area from the automotive sector.

So with that we'll close this section and we'll be happy to take any questions from the audience.

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Questions and Answers

Robert MacLeod, Chief Executive
I'll join the guys up here. Happy to take any questions that any of you have. And just beware we'll be asking you, as Andy said, questions later on three letter acronyms.

Laughter

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Simon Fickling, Exane BNP Paribas
Can I kick off on margins? So talked a lot about market size, sorry to see you rolling your eyes, someone had to ask.

Laughter

How should we think about margins? I mean I think the first half was sort of close to peak margins in ECT. I think the OEMs are feeling a bit of the pressure. How should we think about margin progression as all these new technologies are brought in about investments ahead of these new technology introductions and things like that?

And the second question was specifically on India, there's been a bit of focus on India. Should we think of India in the same way as China I think where you've indicated it does take a bit of time for the legislation to roll out sort of three, four, five years, so it's something we shouldn't think of stepping up in the same way as Europe does?

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Robert MacLeod, Chief Executive
Okay well I'll do the margin question and then I'll hand over to Andy to do the India question. So look I think when we did our results in November we said that we did have pretty good margins in the first half. We were helped by a little bit of a one off gain, I can't remember exactly how much that was but we were high 13% type margin is where we were. And I think throughout the decade, through 2025, we would expect our margins to be in the 13s ish range. Some years we might be in the low end of that 13s, some we might be in the higher end of that 13s but it's in that sort of range. I don't think we're going to get far north of that and at the same time I don't think, you know in the world as we see it today, obviously with operational deleverage if there was a crash to happen then it might go below, but we're in that sort of 13s type range.

Dr Andy Walker, Divisional Technology Director ECT
And I think on the India question, you know your point is very well made in the sense that the Chinese legislation does tend to take a while to get full traction and be fully introduced. In India historically it's been sharper than that. It's not the same as doing it in Europe where you do have a defined date and then everything is beyond that, but I think our assumptions would normally be that with India certainly over a one to two year period we'd see that phasing into the full Euro VI compliance.

Adam Collins, Liberum
It's a question for Chris, couple of questions on so called Euro 6d Temp and otherwise. So first one is I think we know what the test cycle is now and you discussed the conformity factors. Do we know what the testing regime will be? Will it be 100% portable measuring devices or will there still be a lab content? That's the first question.

Dr Chris Morgan, European Technology Director ECT
I think that's still to be fully defined but portable measurement system is the primary route. We have one of those systems, we're using it today. It's viable technology for NOx. That is one of the reasons why the particle number conformity factor is delayed because there's still some question about how accurate that portable measurement is.

Adam Collins, Liberum
Okay. And the second question then is if it's mainly going to be portable measurement devices and those monitors today indicate that real driving emissions can sometimes be as much as six to ten times higher than existing limits, even with a conformity factor of two times initially we're talking about levels which are three to five times the new conformity factors. So the question is how confident are you that advanced SCR can meet that challenge, if indeed that is the case? And why does that drive only a 20% increase in value add on diesel and ten on gasoline? Seems like it's a bigger challenge than you're suggesting.

Dr Chris Morgan, European Technology Director ECT
So the first part of that I mean when you look at the vehicles that are equipped with those advanced SCR and SCR systems those are much lower in terms of the ratio. So those are the ones that are typically down at one and a half to two rather than in the very high numbers. The ones that were in the top left of that chart at six to ten times are pre Euro 6 systems with no NOx control. So I think our experience, and borne out by that data, is that when you put a diesel NOx control system onto a vehicle and when you employ it properly using the right amount of urea then you can certainly get down to the conformity factors quite readily.

Adam Collins, Liberum
So I guess the question is if I could just ask one final one, what would be the average Euro 6 real driving emission today in milligrams per kilometre? Is it 300?

Dr Chris Morgan, European Technology Director ECT
Today looking at those numbers for the purple dots, the Euro 6 cars, then it's probably around two to three times the limit. But as I say those vehicles have those advanced diesel systems in order to meet the 80 milligrams per kilometre limit over the standard drive cycle, they're not necessarily designed and calibrated to work over the wider range of driving conditions that you experience in a real world drive. But that's possible, it's just a question of designing how much urea you inject and when, making sure that catalyst temperatures are in the right conditions. So I think at the moment systems are optimised around this part of the envelope that is for the Euro 6, the standard European drive cycle test, and to be RDE compliant they need to calibrate over a wider range and that is happening.

Robert MacLeod, Chief Executive
And just to try and answer your question on value, remember the vast majority of value accretion when you go for the big step up that we had before, and Andy referred to the three times more value when you go to the SCRT system, is because you're putting another brick. And standard SCR to an advanced SCR there's not another brick there, it's a more complex brick while you get some added value but you don't get that big step up that you get when you put another component on. So it's higher value as we've already said and said for some time, but it's just not quite that big a step because of that.

–Peter Cartwright, Fiske
Yes it was on the real world testing again. If it's on vehicle how do you reconcile winter to summer and sort of Italy to Scotland? I mean surely it has to go to a lab system, a calibrated lab system in the end?

Dr Chris Morgan, European Technology Director ECT
There's a defined window of temperature, speed, altitude that you're allowed to use and yes the cynical view might be that you would choose to test your car in Spain in nice conditions rather than in Finland in nasty conditions. There's another phase being discussed, so the RDE comes in four packages and I can't remember if it's three or four, which way round it is, but there is still a discussion to have about in field compliance and how that is going to be monitored. So as well as certification by the supplier when they launch the vehicle there'll be an expectation for member states to do in field compliance

testing and make sure vehicles are meeting the limits. And you would expect those to be done under a wider range of conditions rather than perhaps the most favourable conditions.

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–Peter Cartwright, Fiske
So are you ruling out a laboratory test?

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Dr Chris Morgan, European Technology Director ECT
The requirements for real world driving are very clearly to put it on the road and measure it in that way. I think for development purposes what we expect to do is to define a number of real world compliance cycles and bring that back into the laboratory for development purposes because otherwise, and we know from experience to date, we've defined two or three compliance cycles around Royston that we're running tests on, and you send the same car out on successive days and you get a different answer because if you're stuck behind a tractor at a certain point on the road you get a different answer.

So for development purposes to know if system A is better or worse than system B you need to have the same drive and we're taking, we're logging real world drives and then replaying them in the laboratory. And I suspect that is the way that many vehicle manufacturers will move in terms of designing their systems but the acid test will be a real world drive.

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Robert MacLeod, Chief Executive
I mean therein lies one of the challenges about the whole setting of the real world driving emissions standards because as you said it's Finland or Spain and what temperature and conditions and altitude.

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–Peter Cartwright, Fiske
Or not just one but an average of a thousand.

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Dr Chris Morgan, European Technology Director ECT
But I think with the fact that numbers will be published and I've had conversations with engineers at many OEMs, that emissions analytic data they know anyone could take a car and drive it anywhere, and if that's a proper real world drive cycle and your emissions are suddenly turned to be much higher then that's going to be put your organisation into a discreditable position. So I think there is an acceptance within the industry that they can't just take the softest case, they have to be robust in their engineering.

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John Walker, Executive Director, ECT
I think the other point you may want to mention Chris is just how new this portable - equipment is.

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Dr Chris Morgan, European Technology Director ECT
Yeah that's true. I mean I think we took delivery of our system last summer and there have been previous generations but that was really the first time we could have had an up to date system. I don't know of anyone who's got more than about 18 months experience of testing on the road, so the people are learning fast as well.

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–Evgenia Molotova, Berenberg
I have three. One is on the size of the vehicle and the size of the engine. So this chart on page 44 which showed discrepancies between real world driving and controlled environment driving, so does the size of the engine play a role meaning that the small size engines tend to be less compliant?

The second question is about pricing strategies because if small cars are being switched from diesel to direct injection petrol obviously I remember you have this chart which looked like teeth, when you introduce the product the price is high and then you need to improve efficiencies to keep the margins because the price is falling, and three way catalyst is an old technology which exists for quite a while, and the competitive edge probably is smaller than for advanced SCR where you can justify premium pricing. So if we go to more direct injection petrol, more three way catalysts what will it do to your profitability?

And the last question is on India and China. Being from emerging market myself it's kind of very difficult to enforce any regulation even if the intentions are very good at the beginning. So do you adjust your timelines for this or how do you see enforcement of new regulations in China going forward and in India? Thank you.

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Robert MacLeod, Chief Executive
You're welcome. Well since you gave us three questions we'll go for them - each one of us will get the chance to answer a question.

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Dr Chris Morgan, European Technology Director ECT
I thought I was going to get two.

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Robert MacLeod, Chief Executive
Why don't you go with the chart question?

Dr Chris Morgan, European Technology Director ECT
I think there is some correlation between engine size, vehicle size and the difference between on cycle and real world emissions. It's not a one to one correlation but it's certainly true to say that if you have a very downsized engine in a larger vehicle which some OEMs have used as an approach to improve fuel economy, then under those conditions when the engine is working hard you can generate more NOx when you go to those harder driving points off cycle.

So yes there is some correlation there. Equally some larger vehicles with large engines, they don't work very hard over the range of speeds you have to do in real world driving and perhaps the NOx is a little lower. So I think there is some correlation. I don't think you could say all of the points at the top are small engines. But there is a tension there within the market that the direction the OEMs have been moving in to maximise the CO2 improvements isn't necessarily the direction you go in to maximise RDE performance.

Robert MacLeod, Chief Executive
Andy do you want to talk about India and China?

Dr Andy Walker, Divisional Technology Director ECT
Sure. Yeah it is, it's a valid point. I mean one of the things that we've seen historically for example in China in the gasoline industry is the fact that the Chinese government did start to take a hard line on compliance. And you know some of that comes from naming and shaming and some of it just comes from saying you know these are the regulations and this is what you need to do to meet them.

We expect to see that also going forward to Euro VI in heavy duty, and actually when you look at the Beijing and the Euro VI regulations it looks like the onboard diagnostics regulation is going to be tougher than it is anywhere else in the world at the moment because it's going to involve essentially a connectivity, an increased connectivity angle which means that the regulatory authorities will be able to have instruments by roadsides which would be able to interrogate the vehicles as they pass in terms of what their emissions profile looks like. Not just in terms of, you know, focusing on the tailpipe, but also focusing on the onboard diagnostics system on the vehicle which is what tells you whether the catalyst system is working properly or not.

So we are seeing a very strong focus and a very strong position being taken by the governments in China. And you know in India because India will follow on behind. But China has more of a history but we are seeing that and we do see that as a very promising step forward for enforcement here.

Robert MacLeod, Chief Executive

And then your last question about three way catalysts I think I'd draw your attention to Chris' slide 44 where we actually talked about gasoline filters and the filter technology and the fact that you've got three way filters and stuff like that. So different technologies coming through, three way catalysts aren't commodity products yet, and with the advent of Euro 6c and the requirement for filters to be fitted on gasoline for the particular control then I think that technological can still be there and we can still hold prices at a reasonable level.

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Dr Chris Morgan, European Technology Director ECT
And even with three way catalysts precious metal is still an important component of that cost and if we can improve our wash coats, make them more thermally durable, give better lower temperature performance without having to increase precious metal that's another way we can deliver value.

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–Evgenia Molotova, Berenberg
Direct injection is much more complex than - as a woman who doesn't have any idea about how to drive?

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Dr Chris Morgan, European Technology Director ECT
In terms of the impact on the catalyst system, yeah the composition of the gas and the temperature of the gas is broadly similar, whether it's direct injection or port fuel injection so it doesn't have a huge effect on the design of the three way catalyst.

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Evgenia Molotova, Berenberg
Thank you.

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Robert MacLeod, Chief Executive
Now look I can see a couple of hands up but I'm going to have to call time I'm afraid otherwise we'll get behind. We've got another quick break so ask your questions if you can during the break. We're a little bit behind schedule but if we can come together again at say 25 past then we're pretty much on time. Thank you.

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Coffee Break

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Introduction

Robert MacLeod, Chief Executive

So if we could get started, so we're on the home stretch now, so we've got two more presentations, firstly from Martin Green who is going to talk about battery technologies. And then from Alan Nelson, who as I said already is our new CTO, started in the summer last year. So I'll hand over to Martin, and again at the end of this we'll have some opportunity for questions as well.

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Creating Value from Market Opportunities in Battery Technologies

Martin Green, Director, Battery Technologies
Thank you Robert and good afternoon. As you've heard I'm going to talk about Battery Technologies and our Battery Technologies businesses. And I'm going to go through where we are today, our view of the market, Johnson Matthey's position in it today, and our prospects as we see it for the next few years. I'll share with you our perspective of the technology landscape and I'll explain why we're confident that JM will succeed in this area.

But to start with a reminder of our overall strategy, so our aim is to create a substantial new division for Johnson Matthey, supplying advanced materials into the Lithium-ion battery industry, with a focus, a clear focus on the automotive sector.

Our strategy to achieve this has been to build knowledge and market presence in the sector through some initial M&A and then to grow that, to build on that through developing a broad technology portfolio.

We're well down the line in executing that strategy. The initial build phase is essentially complete.

In terms of M&A what we did was initially acquire a systems integration business, the Axeon business there on the left, that gave us a really good understanding of the overall sector and it bought deep applications knowledge on battery system design. And then we followed that with two other acquisitions, now in the material sector, and altogether that was an investment of £100m.

So that's the strategy and a bit of history, where are we today? We've been integrating those businesses into a global operation and today we've got around 800 people, including 50 in R&D, working at five major sites worldwide as you can see. So we have the UK and Poland for our systems business, and Canada, Germany and China which is where our materials businesses operate. And I'll just pause here for a few minutes whilst we show a short video featuring our Canadian facility.

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Video played

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Martin Green, Director, Battery Technologies

So hopefully that gave you a bit of a flavour for the business, for those of you who've ever been around any other Johnson Matthey facility it should be quite familiar, lots of pipes, lots of pots, lots of powder. And actually the serious point on that is that this is a very familiar kind of processing technology for JM.

And those operations have an excellent supply history, they've got strong customer relationships and already we have substantial volumes. And that volume is mainly into our large - into our target automotive sector. As Robert has already mentioned, we're suppliers on 15 automotive platforms.

Overall then I think we've achieved our initial goal of establishing JM as a credible supplier into the lithium-ion battery industry. But as I say it's an initial goal. What you see is a snapshot of where we are today. And in line with our strategy, as I've said, we'll continue to invest, we'll invest in R&D on new product development, and here in this sector we're spending rather more than the Group average of 5% of sales. We'll also invest in capacity expansion. As our product mix and our volumes expand we plan to invest between £50m and £100m, backend loaded, over the next five years.

And also we're busy evaluating options to accelerate our growth through further bolt-on technology acquisitions and licensing. So in Battery Technologies we're on track to achieve £150m of sales this year, that includes £40m, $60m of automotive battery materials. And despite our increased R&D investment we'll breakeven overall this current year.

So our strategy talks a lot about automotive as a key focus area for us and that's for a couple of reasons. One of them I want to explain here because I think we're very well placed to serve that industry. Our existing supply chain which we're showing on the chart on the right hand side there, gives us strong relationships across that sector. Somewhat unusually in this industry were present at two distinct points in the supply chain. And this means we've got direct links both with cell developers but also with OEMs and Tier 1s.

So through the companies we've bought we're already a proven and long term supplier into the lithium-ion battery sector in automotive. And that history of course builds on JM's reputation as a supplier of advanced technologies to the automotive industry.

Our pedigree in automotive also means we understand how that industry works, how OEMs manage their supply chains to drive innovation. And we see parallels here between the developing battery sector and our experience in emission control, where of course we've been operating for many years in automotive. There's a very clear vertical structure in both of these cases, but OEMs are closely involved right the way down the supply chain, and that's particularly the case during the development process, so it's not just linear, it's also multi-level.

And we see the same sort of approach developing in lithium-ion and I think this is going to give some really profound changes to way that innovation is managed within the lithium-ion battery sector over the next two or three years as the sector re-orientates itself into an automotive supply chain and away from just being an electronics supplier. And we see that happening quite soon.

So now just focusing on battery materials, this is how we see the total battery material market developing over the next ten years. So cathode materials, I'm showing this in megawatt hours, it also of course relates to other battery materials. So looking at cathode materials now, the largest market for lithium-ion batteries today is you see the 2015 numbers here, is the electronics market - the largest single market.

It's clearly a very well established segment for lithium-ion batteries and it's a highly demanding area for innovation in some segments. However, much of it is commoditised and certainly overall as you can see over the next ten years the market is flat in terms of growth.

Conversely in the EV, automotive and heavy duty markets shown here in blue, those two blue bars, sales are already substantial and they're growing very strongly. Together these sectors already account for more than a billion dollars a year in terms of cathode materials and we predict that sales will rise to $8bn by 2025. So over the ten years that's a compound rate of more than 20% a year.

So from the market dynamics it's also a very good reason why we're focusing on automotive, rather than the more mature, more commoditised electronics market.

Within cathode materials there are several key chemistry platforms and you weren't going to get away without some more three letter acronyms, so here we go. The largest volume today in cathode materials is lithium cobalt oxide, or LCO the one on the left, but this is all in electronics. We think around 70% of the total electronics demand for lithium-ion is LCO based. But the automotive segment is very different; LCO is not used at all in automotive because of safety and cost considerations.

Instead for automotive the market splits into four main chemistry platforms that we're showing here. Firstly lithium manganese oxide, or LMO, still used in volume but it's being replaced progressively now with higher performance materials. Then the two chemistry platforms which are all about maximising energy, energy density; firstly the NMC family these are complex oxides of nickel, manganese and cobalt and also NCA, lithium cobalt aluminium oxide. And it's a variant of this NCA which is used in the Tesla.

And finally on the right lithium iron phosphate LFP, which as you see is used for high power and for safety critical applications. And this is where - LFP is where JM is operating today as we've said.

It's important to stress that these chemistry platforms are not single materials, these are broad compositions and that's why we're calling them chemistry platforms. Within each one there's a range of different compositions, each with a different performance, and often with a different cost profile too. And actually it's more complicated than that even, making a practical material that works in a real application means making a whole series of improvements, both chemical modifications, such as adding dopants or compositional gradients across the particles and physical state changes too.

These sorts of material modifications are really very familiar to JM, after all designing and manufacturing high performance structured materials is what we do.

Before we even start talking about those enhancements, those changes, there are some fundamental strengths and weaknesses of the different platform chemistries at the core compositional level. No single material meets the needs of every application. There is no silver bullet, compromises have to be made, trading off performance in one area to maximise performance in some other areas that are even more important for that specific application; whether that's range, or power, or cycle life, and cycle life is just how long the battery pack will last, or inherent safety.

So here is - and I'm going to plot some different materials that we showed on the previous chart against some of those key performance parameters. Firstly LMO, lithium manganese oxide, limited range, as you can see - limited power handling, but good lifetime, good safety performance and good on cost. And on cost here what I'm plotting is the intrinsic cost of the material, where higher means that the cost is closer to meeting the OEM targets as we understand them. So LMO is good on cost.

Now two different examples of the NMC chemistry platform, two different materials, firstly in the darker colour NMC 1,1,1 that's the more commoditised end of NMC. And the 1,1,1 just means that there are equal amounts of nickel, manganese and cobalt in this material. As you can see NMC 1,1,1 is an improvement on LMO in terms of power and range, but it comes at a higher cost, a lower cycle life and it needs careful management to ensure system safety.

The lighter line is NMC 8,1,1, so more nickel - so it's from the same family, it's an NMC, but it's a different composition from 1,1,1 and you can see has very different properties. It's currently the state of the art in NMC, everything here has been optimised for energy density and as you can see it does very well for range and energy density. But lifetime cost and intrinsic safety are again compromised.

And it's a similar story for NCA, similar overall to that NMC 8,1,1 material, good for energy dense applications, but again with issues on cost and on stability.

Finally this one is LFP, limited range capability, but excellent on power, the safest of all the chemistries and very durable too. So the message here is that no single material works well for every application, choices have got to be made based on the demands of the specific applications that you're building for. And that's what we seeing in the marketplace.

This is our view as to how those different chemistry platforms align with the different applications in the automotive sector. Moving across from small battery applications to large batteries on the right hand side, it's showing the main trends between these two. So for starters and hybrids, micro hybrids where it's important that they can handle periodic bursts of energy, for example during braking, LFP cells are the prevalent technology.

NCA and NMC are popular where electric only range is the dominant requirement. And that's often the case for PHEV, so plug in hybrids and battery electric vehicles, BEVs. When you get into the large systems, the really large systems in heavy duty safety

rather than range becomes the critical characteristic. So range is important, but safety is even more important and here - that's why LFP is dominant again.

And LMO as I've said is still used in volume for automotive application.

And a couple of other points to make before I leave this, the first one is that these broad spreads horizontally are typically not the same material. So for example the NMC on the left hand said for hybrids is typically more like that NMC 1,1,1 and not the higher nickel versions 5,3,2; 8,1,1 which are the ones which are used in pure battery electric vehicles.

And finally real life cathode compositions are not just enhanced in the way I put on the previous slides, but increasingly they're blended. So it's a mixture of more than one material in the same cell. And for example we're seeing increasing examples where LFP is blended with an NMC formulation to give a combination of good range, but with enhanced safety. And we're seeing that as a trend which is of much more interest in the industry.

So now I'm just going to move on and say a bit more about a couple of these application areas which are particularly relevant for JM today as an LFP focus.

Firstly at the small battery end of things, start stop and micro hybrids, so this is all about capturing fuel economy or CO_2 benefits on what are essentially conventional powertrains. As time goes on different configurations of these micro hybrids are being developed and you saw how LMC has recently changed the way that they're categorising it as well.

And this is the reason why, so there are lots of different variants being developed, moving from simple start stop on the left, all the way through to a complete mild hybrid on the right, increasing the effectiveness, increasing complexity, increasing benefit and increasing cost. LFP is the material of choice for most of these configurations. And that's because it has unrivalled power handling capability.

So we see demand for LFP based hybrids helping to drive our sales growth across both systems and materials over the next five years. For materials we see an incremental market potential for £100m a year in sales by 2025.

The second sector I'm going to highlight is that of heavy duty EVs, on the right hand side of that other chart. This is perhaps less visible to us in Europe because most of the market is China.

On the chart the blue band is China bus and the pink band is China truck. The little black bars are the rest of the world everything. So it's really a China play. As you saw earlier in the total market chart for materials, the bus and truck market is already nearly half the size of the automotive one and we see that staying the case out to 2025.

In bus and truck strong sales growth of EV buses and trucks, 30% a year over the next five years this chart shows, perhaps moderating somewhat after that is going to generate a market, we estimate to be worth more than a billion pounds a year by 2025.

And this is all LFP, driven by technical performance, but also by safety concerns as I've said.

And as has already been mentioned China has just last week removed its approval for NMC based cells to be used in buses, meaning that the bus market is going to stay LFP based in China for the foreseeable future. And that was due to safety concerns for NMC containing cells.

So JM is really well placed to grow further here and we're building on our existing supplier relationships with some major China bus producers.

The final area I wanted to touch on today is automotive plug in vehicles, so full battery electric or plug in hybrids. This is going to be the largest single segment for lithium-ion batteries in automotive. In 2025 a modest plug in vehicle penetration, just 3% as we've seen, generates a cathode material demand worth £4bn. That's up tenfold on today's market.

Looking at today's vehicles and from what we can see of future model plans, it's also the sector where we see most variety in terms of sale choice. Variants of LMO, NMC, NCA and LFP are all used in volume in the sector. And that's because these vehicles demand the biggest compromises currently on performance, because there's the biggest gap between what OEMs are asking for on the one hand and what the best materials can currently provide, and that's range, safety, acceptable cost.

As Johnson Matthey we have substantial sales in this sector today from LFP, in fact we reckon we've got a share of the total automotive cathode materials market of around 5%, all of that from LFP. We've got around 20%, as we've already said, of the automotive LFP market.

But building on that and in line with our strategy we intend to expand our portfolio, from LFP into other platform chemistries over the next few months. I can't say too much about that at this stage, but we're in advanced discussions with some third parties with a view to achieving that, initially through in licensing.

As a result of this expansion in the medium term we'll have cathode materials that will cover the full automotive spectrum.

We also see opportunities across the whole sector through harnessing JM's expertise in materials design to deliver improved performance. As I've said already the current state of the art materials fall far short of automotive targets in many areas. The chart here shows BMWs view on battery performance currently and where it needs to go for a BEV. So the line marked 2014 is their view on where the technology was at that time, relative to what's required for a fully competitive BEV and that's the extreme of the shaded areas.

The lines at 2020 and 2025 show the improvement that's required relative to 2014 in order to meet BMWs targets for vehicles that they want to launch in those dates. So these are big improvements across the board. And delivering those improvements will require advances, both at the materials, the cell design and at the system design level.

And delivering them is going to require strong collaboration right the way across the supply chain.

JM is actively working with OEMs as you might expect, and cell companies to build this collaboration and we're using our materials expertise and systems insight to inform and guide these joint programmes.

So in summary then, we believe that JM is a credible player in the sector. In fact we're more than that, we're more than just a credible player, with a 20% share of the automotive LFP market we're firmly established in the key automotive cathode material platform that currently represents around 25% of the total automotive cathode material market.

We're not exposed to commoditised markets, but we have a strong and clear focus and the majority of sales into this sector. And we think we're well placed to build on this position into the future, both technically and in terms of our customer relationships. We continue to develop our strong position in LFP and we're also broadening our material portfolio.

And we believe we've got excellent prospects, today although we have £150m in sales as I've said, both our systems and our materials businesses are new. They're new businesses and they're busy investing in the future. As a result we're breaking even today for Battery Technologies, but I expect us to be firmly profitable within two to three years.

In materials we expect to grow our LFP sales this year £40m by an average of 20% a year between now and 2020. After that we forecast annual growth from LFP perhaps moderating more towards the mid teens level, out towards 2025.

Over that period we expect that to mean that we maintain our existing 20% share of the automotive LFP sector, and of course post 2020, we'd also expect to see strong new sales coming through as vehicles incorporating our high energy material platform start to come to the market.

So building our operational leverage in this way from 2020 we'd expect our materials business to be generating operating margins of the same order that we have within ECT.

Our battery systems activity, strongly synergistic with materials development will also grow over that period. But because of the nature of that business we expect margins here to be a bit lower.

Overall then we remain confident of achieving our long term aim, which is building a substantial and value accretive division for Johnson Matthey in Battery Technologies. So thank you, we'll take questions after Alan has spoken. But I'll hand over to Alan who is going to talk about the broader innovation portfolio within Johnson Matthey. Thank you.

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Delivering Sustainable Solutions to Customers

Alan Nelson, Chief Technology Officer
Good afternoon, thanks Martin. My name is Alan Nelson and I'm the Chief Technology Officer for Johnson Matthey. As Robert has mentioned I joined Johnson Matthey last summer from the Dow Chemical Company, where I led research and development for a number of market facing businesses, ventures in business development, as well as corporate research.

I'm delighted to join Johnson Matthey and bring my background in research and development to a technology centric company with a long and robust history in innovation.

Throughout the afternoon today we've discussed several areas of innovation and growth for Johnson Matthey. And of course these have been around emissions control systems, as well as lithium-ion batteries. I'd like to conclude our powertrain technology presentations this afternoon by discussing our innovation portfolio in depth to highlight how we invest for future growth.

Firstly I'll begin by discussing innovation that is how we see it, how we manage it, and most importantly how we capture value from it. Secondly I'll discuss several examples of innovation, firstly around the automotive powertrain system itself and then several examples that begin to extend beyond the powertrain system.

We innovate to effectively capture value and enable long term growth and innovation is more than coming up with a great idea, it's translating that great idea into a commercial success. That is innovation is invention, plus commercialisation to create value capture from R&D investment. And for Johnson Matthey we view that system as an ecosystem, or as a cycle if you will that encompasses product design and formulation, application development and most importantly partnering with our customers to deliver them solutions. And to be successful you need sustained investment in innovation. And of course we have a long history in innovation investment for growth.

But the competitive landscape is changing and today you need to do more than just this, you also need to leverage external partnerships, access open innovations, understand economic viability, support strategic marketing and at Johnson Matthey we combine all of these elements into our broad innovation strategy.

At the centre of this ecosystem is understanding our customers' needs and delivering them not just materials and products, but the solutions that they need. And we work very closely with our customers to answer these three questions at the centre of this ecosystem to create a win-win scenario for them as well as for us.

You're all well aware of our long standing expertise in platinum group metal science and technology. We have been industry leaders in platinum group metals from our very early days almost 200 years ago. Today many of our products are not based on platinum group metals; in fact they're based on a range of what we refer to as advanced materials. And these materials take many forms, from powder to coated catalysts, coated components, all the way through to functional materials and devices.

The design of these functional materials requires two key things, as you've already heard today it requires a deep understanding of the science and technology, this is how these systems function at the smaller scale, and in depth knowledge of how they're going to be used, and this is how we differentiate ourselves from our competitors.

In addition to our expertise in platinum group metal chemistry and science we have industry leading expertise in chemistry and catalysis, functional materials, formulation science and of course advanced characterisation. It's these skills and capabilities, together with that specialised applications experience that allows us to develop new and sustainable products for our customers.

We have outstanding talent in these areas and they extend across all of the businesses and divisions in Johnson Matthey. And we leverage these technical skills and competencies broadly across all of the divisions so we can draw on world class science and expertise across all of the divisions which is a unique capability that we have and quite frankly a competitive advantage that many of our competitors do not have.

This leveraging also includes a strong relationship between R&D and new business development to drive opportunity assessment in new technologies and in new markets. We're also unique in that we have integrated portfolio management process that extends across all of the divisions to allow us to prioritise our innovation investment across the entire company.

When most companies discuss innovation portfolio management they tend to focus on R&D spending either in total, or as a percent of revenue, or as a percent of sales and the internal business allocation of that R&D funding. And while this is useful because it does provide a benchmark and indication of R&D activity within a company measuring spending alone is insufficient to ensure innovation success.

We know from experience there is a clear correlation between innovation measurement and innovation success. And when you invest a significant amount in research, as we do at Johnson Matthey you need a high level of rigor to manage and prioritise that R&D investment.

To enhance our rigor and accelerate revenue growth we recently expanded our innovation portfolio metrics to include productivity based metrics. And this is a new approach to how we're going to manage our innovation portfolio. But moving forward we'll use these metrics to drive even greater efficiency out of our R&D investment.

NPV for the innovation portfolio will allow us to understand the potential return on that innovation investment. And when we risk adjust this for the product development stage, we'll also be able to understand the timing of product commercialisation and more importantly revenue generation.

Innovation margin - that is the difference between new and established product margins will ensure we're capturing higher value from our new product innovations in the market place.

Patent advantaged sales, not just simply counting or measuring the number of patents, but rather the revenue protected by our patent portfolio will ensure we're defending our innovations from competition and commoditisation in the market place. And going forward we'll include these metrics in our innovation portfolio to improve and accelerate value capture and growth.

And while we will not be reporting these numbers to you all today, you can expect that we will provide an update on these metrics and values at the next Capital Markets Day in about 12 months time.

We have been innovation leaders in automotive powertrain technology for many years. However the changing landscape and automotive powertrains presents both new opportunities and challenges for the industry. As we look ahead we segment the opportunities in automotive powertrain broadly across four different areas.

The first is in the area of advanced materials and of course this includes our focus in advanced emissions control materials as well as systems. But the opportunity landscape for advanced materials is rapidly expanding.

One area of growth for us is in the area of light weighting materials, that is to reduce vehicle weight and thereby improve fuel efficiency and improve overall vehicle emissions. This will require innovation in both material science and advanced manufacturing and we have capabilities today in both of these areas to be innovation leaders and capture further value. I'll speak more about this in just a minute.

Energy storage devices and systems, this is principally around the area of lithium-ion batteries as well as fuel cell vehicles. And both present high growth opportunities in powertrain systems.

These systems we believe will initially see moderate market adoption as we've discussed, primarily in internal combustion hybrid based systems. But clearly long term these systems could disrupt and eventually replace the internal combustion engine. Our investments in both of these areas are positioning us to be leading solution providers. The opportunities however don't stop there.

Another opportunity is in alternative and low carbon fuels, these have the potential to diversify the industry away from the traditional fossil fuels, into bio-renewable liquid fuels. And today these bio-renewable liquid fuels are being blended into the traditional fuels, in selected markets, and they'll likely see expanded use through higher fuel blending targets. It's an area where we can leverage our strengths in both catalysis and process engineering in our Process Technologies division, to develop sustainable solutions and fuels for the industry.

Autonomous and driver assist systems will certainly provide unique opportunities and many of these are emerging in the market place today. Although it's a new area we can already see a number of opportunities on the horizon for autonomous systems. And one clear area of opportunity for Johnson Matthey is in the area of advanced fuel efficiency and emissions control systems based on predictable braking and acceleration patterns, essentially changing driving styles.

We're actively working with our strong automotive customer base today to position us on the leading edge of technology and innovation in this area. Today we're investing across all four of these areas and I'd like to discuss several examples that highlight the strength and depth of our innovation portfolio.

One example of successful technology development and innovation in partnership with our customers is certainly in the area of advanced emissions control systems. And as Andy and Chris have discussed we're a global leader in emissions control technology with extensive operations throughout the world in close proximity to our customer base. What differentiates us from others as you've heard is our ability to connect the material science with the application knowhow not just to provide products and materials but to deliver the solutions to the industry. And for over 40 years we've been successful at connecting the material properties with that applications knowhow to meet the needs and the challenges of the industry.

And over that period of time just as well as today we've maintained differentiation through investment and technology and customer service, a deep understanding of our markets and our customers, a critical understanding and translation of science into solutions and of course manufacturing excellence. Our goal is to not only develop the technical solutions that meet the increasing requirements on emissions, but also simultaneously reduce the amount of platinum group metals that go into these systems and improve the overall sustainability. And in the face of tightening legislations, increasing legislations, we've done just that, reduced the amount of PGMs in all of these systems. It's an excellent example of not only innovation but sustainability at work at Johnson Matthey.

We have been successful through focus and that focus is we innovate where material science and engineering drive success.

As you've heard industry leading capabilities and material science and application knowhow is also the essential foundation for our innovation platform and lithium-ion battery materials. Materials are a value added component because they're essential for achieving the key requirements in that end - in that final lithium-ion battery. That is the components, the cathode, the anode, the electrolyte and the separator all function together as a system to deliver the power, the energy, the safety and the lifetime in that final battery.

And the most important and highest value material in the lithium-ion battery today is the cathode material. It is essentially the material that controls those four properties to the greatest extent. And the challenge as you've heard for the industry is that there is no one cathode that can deliver the best of all four of those properties, so different materials are used for different applications. Our investment in lithium iron phosphate or LFP is a unique and differentiated material that provides class leading performance across three of those four areas, namely power, safety and lifetime. And as Martin discussed earlier this afternoon, LFP is ideally suited for mild and micro hybrid applications.

As we all know the limitation with LFP is the energy density and to this end another class of materials, nickel manganese cobalt or NMCs, are being developed as alternative high energy cathodes. The important thing to remember again about NMCs is that they're not just one material but rather a range of materials based on different compositions and different properties. And with all cathode materials NMC does not have the best performance across all four of the requirements. So again compromises are needed.

As you've heard we're looking to expand our material offerings in high energy cathode materials and we're looking at a number of market entry options to give us a compositional range that will have the highest potential for long term success. And you can expect to hear more from us about expanding our cathode material offerings in the coming months.

Harnessing the power of material science and application knowhow is also the foundation for our innovations in fuel cell systems. We are an innovation leader in fuel cell technology, and to date we have a number of notable innovations around fuel cells including cathode catalysts that have four times the activity of the traditional platinum only systems, anode catalysts that employ proprietary technology to resist poisons and loss of activity by corrosion, and membranes that have class leading performance and quality.

Together with our customers we've developed the fuel cell catalysts and the membrane electrode assemblies, MEAs, and we've developed these for both residential as well as automotive applications. The question on hydrogen fuel cells specifically for automotive applications really requires a two part answer. First answer is the fuel cell technology itself and this technology is readily available today. The second part of that answer is around hydrogen availability, what the industry generally calls the hydrogen economy and this is still developing in the marketplace.

So what we see today is that while several automotive companies are investing in fuel cell vehicles long term, there are in fact very few meaningful commercial programmes over the next few years. And this will undoubtedly limit fuel cell growth and automotive powertrains despite fuel cell technology being readily available today.

During this initial period of moderate growth we're not standing still however. We are broadening our applications space by innovating in residential fuel cells to expand our technology base beyond transportation into other markets and new applications.

An area of innovation that begins to expand beyond the typical automotive powertrain is the area of alternative fuels. Johnson Matthey is a top supplier of catalysts and process technology to industrial gas producers, refiners and chemical manufacturers. One example of this is our Catacel stackable structural reactor, or SSR, another three letter acronym for you. Catacel is an excellent example of really clever technology that we acquired about a year ago to enable the highly efficient production of hydrogen and subsequently clean fuels. This technology can significantly increase capacity at existing facilities and reduce overall operating expenses. It's key technology because the efficient production of hydrogen enables fuel hydro treating, that is the removal of sulphur and nitrogen from petroleum, and enables the production of what the industry refers to as synthetic sweet blends, essentially synthetic clean fuels.

Today this technology has fairly moderate revenues in the range of about £5m sterling per year, but as petroleum feed stocks become heavier and the regulations on fuel quality increases it has the potential to significantly expand in this market and beyond. Another example of innovation is our ultralow emissions reforming technology. This is industry leading process technology that uses less energy compared to other technologies and it significantly reduces carbon emissions and thereby the overall footprint.

This technology was recently selected by CECC and Northwest Innovation Works for a world scale methanol facility to be located in Washington State in the USA. And clean and efficient methanol can also enable the production of sustainable advanced materials including advantaged olefins and of course subsequently polymers. As this technology gains momentum in the marketplace we'll look to expand it into further applications, to sustainable petroleum refining, fuel production and even beyond. It's also an excellent example of yet another technology that was developed right here at Johnson Matthey in the UK extending beyond our geographic borders to have true global impact.

We're also investing for long term growth in the area of advanced materials. For example the concept of vehicle light weighting is an important consideration when discussing fuel efficiency and overall emissions. And one promising technology is around the area of three dimensional printing or additive layer manufacturing, ALM. This process creates parts layer by layer as opposed to the traditional milling and machining processes, and thereby it allows for the creation of very highly complex and irregular geometries that would not otherwise be possible with current techniques.

The challenge for the ALM industry is to broaden the application and applicability beyond the novel parts, the plastic parts and bits that we're all familiar with, into highly complex metal parts for high performance applications. This will require the production of very fine metal powders, essentially the raw materials that go into metal ALM, and here we're utilising our experience and expertise in our Precious Metals Products division to develop these powders for the industry. It highlights the breadth and focus of Precious Metals Products well beyond our traditional areas in metals refining into new product and high growth areas. It's also an excellent example of leveraging our capabilities across the divisions, metals and powder metallurgy in Precious Metals Products to enable the production of advanced materials and structures for our customers in ECT.

Another area of longer term growth investment is in the area of renewable engineering plastics. We're collaborating with several external partners today to leverage our expertise in catalysis and process engineering to enable renewable precursors for polyurethanes and for thermoplastics. These technologies have the potential for both lower feed stock costs and higher efficiency leveraging the scale of broad chemical production. The global market for engineering plastics today is in the billions of pounds and even a moderate replacement of fossil fuel to renewable feed stocks could translate into a significant market opportunity for us.

And with these targeted investments we'll be ready for the emergence of these new materials through these early stage partnerships. And it's worth noting this investment

in renewable materials is in direct response to our automotive customer base asking us to deliver more sustainable products.

This is how we deliver innovation at Johnson Matthey. It's the combination of close customer partnerships and collaborations with a deep understanding of their end application requirements combined with excellence in science and technology and innovating where material science and engineering drive success. It's focused innovation portfolio management and productivity based metrics to make investment based decisions and drive even greater value out of R&D spending. All of this supported by the great science and technology and people that we have in Research and Development. It's been our innovation story since we began this journey many years ago and it will be our foundation well into the future.

So at this point I'd like to thank you for your attention and I think Martin and I will take some questions.

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Questions and Answers

–Evgenia Molotova, Berenberg
On LFP technology because of the lower density if you could talk a little bit about the cost because obviously it's an important parameter. And for example GM probably because they're using inferior technology were talking $145 per kilowatt hour for their vault in '16 and Tesla is at $300. So where is LFP relative to that?

And second question is on China and trucks, because Chinese trucks obviously it's a huge market which is enormous basically, but the Chinese trucks are a much cheaper selling price than the European trucks. So if LFP is a quite expensive technology how does it work with a truck which costs $25,000? Thank you.

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Robert MacLeod, Chief Executive
Well done, you managed to do it in two. Martin can you help me out here?

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Martin Green, Director, Battery Technologies
So the first question I think is about how do we rationalise the GM $145 a kilowatt hour with LFP and its properties. Perhaps I should just clarify first of all LFP is not a high cost technology. Actually one of the advantages of LFP is that it's a low cost technology, intrinsic cost. And that's simply because cobalt and nickel are more expensive than iron. So if you talk about the intrinsic cost it's a lower intrinsic cost.

But I think the other thing that's important is that these aren't commodities. So there's a commodity element to them but the $145 a kilowatt hour number is the selling price of the cells from LG once incorporated into a system. So there are a thousand things that go into that. And those cells I think for that application were NMC based cells actually from LG. So I don't think you can compare them directly. I think that the system cost is

the result of a whole series of different parameters, and the right material is the one which fits that particular application. And it's that right combination of performance and cost, and cost is one of the key angles. So I think that's the comparison.

With regard to trucks I think the comment that LFP is actually an intrinsically low cost technology also applies here. But again the reason why China has adopted and continues to adopt LFP in its vehicles is because of extreme concern in China over the safety of EVs. So if you take the most commoditised NMC 111 material today, that's cheaper on a kilowatt hour basis than LFP on a kilowatt hour basis. But China is saying [~~NMC based sales are banned~~] [Correction: it is removing subsidies for NMC based sales for e-buses]. So it's the proof that safety is actually more important in those applications than just the kilowatt hour.

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Robert MacLeod, Chief Executive
And I think just to finish off on that, on Martin's slide 72 we talked about the market opportunity for buses and trucks. And really in China the biggest opportunity for the materials side, electrification really is very much more in the bus side than the truck side. So you're right, cheap trucks are just like your trucks in America or Europe, they go long miles, they go way out into the cities and they're not going to be electrified as John said, you know the heavy duty diesel market will stay diesel for a long, long time to come. The trucks at a market there in China is kind of delivery trucks, staying inside the cities bit like buses which are staying inside the cities, much, much smaller volumes which is why I think it's a slightly different issue driven by that regulation.

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Martin Evans, JP Morgan
Just on fuel cells because you did mention that you're not standing still despite slightly more moderate growth anticipated going forward. I mean through the years as far as we're aware you've never made money in fuel cells. I think last year you lost a short 10 million it says here. I mean at what point will you possibly have a look at this business more rigorously? It's often referred to as a hedge and possibly with all the hydrogen moves going forward you still see it as important it in terms of that technology, but can you explain to us in simple terms why you are still fully committed to fuel cells? Because obviously as the losses in new businesses decline as batteries break even, as a proportion of the whole the fuel cells will stand out as haemorrhaging cash.

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Robert MacLeod, Chief Executive
I think I'll refer back to the answer I gave to Adam I think it was after the last session, wasn't it? Look as Alan said, the growth in the market for fuel cells for automotive applications looks like it's still some time away, looks like it will be still very small even in a decade's time. So we need to look at our overall investment as you said, look at our investment needs and that's what we're looking at. We're looking at it and we have done for some time and we're looking at it, like you look at everything, we're looking at that.

But having a bit - we are already a pretty good player in that market. It's a tiny market today but we want to keep that option open to us. And at the same time today look really hard at the stationary side which has more potential. So I think that's all I would say really.

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Question
Can I just ask two questions? First of all on the Battery Materials, when you look at the rest of your businesses that you've been in either currently or historically your market shares tend to be much higher and you have fewer competitors. So when you look at the Battery Materials over the next couple of years you're targeting sort of 20% market shares, what gives you confidence that A, you've got the right technology, and B, that the competition isn't going to increase much more aggressively so you're not going to quite gain the position you think you are?

And then the second question is slightly simpler, if you assume that going forward you have more batteries, is there enough lithium in the world to sustain the battery materials you need, or are we going to have to find more lithium sources?

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Robert MacLeod, Chief Executive
I'll do the first one Martin and you can tell them about lithium.

So I think Martin explained quite clearly sort of the role of the - how we think the world is going to evolve in the Battery Materials space. It is still a fairly nascent market and the OEMs we believe are going to get more involved in the decision making process around the battery materials that go into their batteries themselves. And that undoubtedly and as the complexity grows, as the challenges grow which they are much like the automated catalysts are, it started off in the old relatively easy, as the complexity grows it gets harder and harder and harder and you end up with fewer and fewer players.

What we said was that our market share today in the lithium iron phosphate market is about 20%. And all we're saying is that over the next decade we think we'll hold it there or thereabouts - could we grow it? Well let's wait and see but keeping it at that level I think is okay.

On the high energy side that's the one where we don't have an application today, we don't have a product today so we know we need to, as I think Nick said about the bus, the bus is moving and we need to jump on the bus quite quickly. So we're not anywhere today so to get to somewhere I think will be quite a good achievement if we can get there in ten years time, and therefore the overall market we're targeting a 10% share which on a market of over $8bn I think will be quite a good result if we can get there.

And these are markets that need high technology, and if those are areas that we can succeed on, we have in the past, there's no reason why we can't in the future as we continue to apply our R&D and focus on making better materials.

Lithium?

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Martin Green, Director, Battery Technologies
Yeah I think the simple answer to the question is there enough lithium in the world; yes there is enough lithium in the world. There are in terms of absolute reserves plenty of reserves for lithium, there are more reserves coming on stream all the time. The question I think is more about the balance of supply and demand. So the forecasts change a bit but 20%, 30% a year increase in demand for lithium over the next five years or so. That's the demand for it.

The supply is predicted to rise in line with that so more sources coming on stream to match that increase in demand. We know because we've been operating in commodity markets in precious metals for a long time, we know that when you have an increase like that there are likely to be some short term supply imbalances. So that's how I see the market developing but there's no fundamental shortage that supply and demand will be matched in the medium term. There may be some short term spikes when the weather is bad in Chile or whatever. So that's how I would see it.

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Andrew Benson, Citigroup
You've got your position in LFP and it would appear that the Chinese are favouring that at the moment and there's a safety issue surrounding alternative technology so it's look like you're going to do quite well over the next while on that. But your objective is to develop a capability in businesses that have a poorer safety profile that are banned in China at the moment. And I just want to validate their position, what you think of it. Is this just a temporary measure because perhaps their local players haven't caught up in technology or is this a serious issue and how surmountable that is? Because obviously NMC looks good for cars because you get range, but the realities of safety over the politics of saying there's an issue in order to help Chinese. So I just want to test that issue, its validity and the potential in those areas and how relevant safety is over performance and price etc.

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Martin Green, Director, Battery Technologies
I think it's a very valid point. The reason why China has LFP is because five, ten years ago EVs in China were terribly unsafe. And the reason why they're terribly unsafe - when I was talking about safety I'm talking about inherent safety of the material. So LFP is an inherently very safe material. The Tesla is a safe car and the reason it's a safe car is because at a cell and a system level it's been engineered to be safe. So it's not saying that NMC and NCA are dangerous, it's saying that you need to engineer them correctly to be safe. So right now - so I think it is very definitely a real concern in China. It's proven to be a real concern in China because that's why they're in LFP, that's why everything was LFP was five years ago because they mandated it because of the concerns over safety. So they chose the most inherently safe technology.

So will they move? As NMC has started to come in they've started to have more safety problems because of the less mature control systems and all the engineering around it, and the quality of the materials as well. So this is a multilevel thing. So I think that's an absolutely real thing, this isn't a protectionist measure I don't think. There are real safety concerns with that material. And as the technology improves then that situation will change I think.

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–Peter Cartwright, Fiske
You've given us several teasers on your move into other cathode chemistries, can you expand on that in any shape or form, timescale, cost, process, route, who, when?

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Robert MacLeod, Chief Executive
Peter you know the answer to that question, don't you? Do I have to answer it?

Laughter

No.

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Question
Just out of interest you've said you're a material supplier to 15 automotive platforms. How many platforms would be supplied on the ECT side? And do you expect to trade off those relationships and therefore help to sustain that 20% market share that you cited for the automotive LFP operations?

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Robert MacLeod, Chief Executive
I'm not sure if any of us know how many automotive platforms we're on. Hundreds - loads. I mean if you turn round and say how many automotive platforms are there and we're a third, roughly 30% of the world market we're going to be on roughly 30% if not more of the platforms. So it's a lot, a lot of platforms.

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Martin Green, Director, Battery Technologies
Well I think the synergy at the commercial level between ECT and Battery Technologies is very real and it's very strong, but it's more at the car company level. So it's not the number of platforms that's ECT does, it's the fact that ECT basically supplies everybody, all of the OEMs across the world, and therefore the Johnson Matthey name is known that they have a direct tangible relationship with Johnson Matthey as a developer and supplier of advanced technology. So that's a great in to go in when we're looking to introduce ourselves as a developer and supplier of advanced technology. So I would say it's at an OEM level and it's a very relevant strength.

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Alan Nelson, Chief Technology Officer
And today we do have some common shared customers, and in the future we expect more.

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Robert MacLeod, Chief Executive
Absolutely, yeah.

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–Peter Cartwright, Fiske
A quick one having failed on the last one. You're keen to hold onto the technical knowhow for example on the compositions but equally I get the view that people like LG are saying we'd like to have the technology for blending the powders and we just want to buy the base powders. So how is that going to split?

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Martin Green, Director, Battery Technologies
I think that's a facet of what I was trying to explain on this way that the industry is changing. So I think as an electronics supply chain then it's a more linear relationship. So a cell company develops a product, it then goes and says look I've got a product, and the electronics companies will take that. They may hear about it a year or two years in advance when it's just still being developed, and they'll launch a product because they can base the design on it.

In automotive it's different. We know in automotive the timescales are longer and this is a regulated market. So the automotive companies can't choose what the requirement is, they have to come up with competitive vehicles and they have to come up with them with a certain range or whatever. So they are much more involved throughout the supply chain.

So I think the comment is right for the lithium-ion industry as it currently supplies the electronics industry, and I think that model is changing. We're certainly seeing that changing, we're involved, we've invited in to go and talk to OEMs all the time. We're working closely and we're being directed to work closely with cell companies by OEMs in order to get that collaboration going.

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Closing Remarks

Robert MacLeod, Chief Executive
And I will just if I can just say a few words to sum up and finish off the day. Well done for surviving and getting through to the end. I hope you found it a useful session. So what did we talk about today? We really started the day talking about our strategy. We've got a robust strategy, very much focusing on the key four major growth drivers and sustainability drivers which are still strong and give us real opportunity using high

value technology to grow our business. The focus is for us as we said last year and we repeated it quite a lot today, it's about chemistry and its applications. And that link between the two is absolutely fundamental to our business. It's no good having a bunch of people in white coats coming up with some great chemistry idea if it's no use to our customer and also then when you get to the manufacturing if you can't even make it.

So lots of opportunities for the company, but what we really focused on today was the opportunity in the powertrain and hopefully you've understood a little bit more about that. And fundamentally about how that air quality issue is really what's at the heart of the evolution of the powertrain and how it supports growth for JM.

Legislation is continuing. We've said for some time we always worry, you always worry, is that the end of legislation. And I think both Andy and Chris showed you from a light duty and a heavy duty point pretty much every country or every region has more legislative changes to come in the next decade or so, and that's continuing to advance the development of the catalysts for emission control.

And the internal combustion engine is we believe, and it's not just us saying this, this is us in discussion with the OEMs, our customers, but also in discussion with external parties, the internal combustion engine at least for the next decade will still be the primary source of automotive power, or at least will be on roughly 97%. Okay we might be wrong with 97% but call it 95% plus. It's going to be a very large significant component of the overall powertrain. So it gives us great opportunity within ECT, but also as we showed today there's more and more electrification, more and more diversification of the powertrain and that's where having a Battery Technologies business and a clear roadmap is really beneficial for us into the future.

You heard a bit about the advantage of JM and the advantage that we have. The chemistry in the applications, the customer focus, that link between the OEMs as we just were talking about just a second ago, that OEM link between what we do in Emission Control and also what we can do on the battery materials side. It's hugely important.

But I just want to go back again to say the issue about the operational efficiency and operational effectiveness is not simple. And how you scale up and how you manufacture at scale is a huge issue and something that we're really good at and we've been driving hard over the last few years, not just driving efficiency on it but actually that just basic scale up capability is a huge attribute of the company.

And finally just to summarise it all we've got a robust strategy, the drivers are good and strong, the evolution of the powertrain will demand further high technology solutions. The roadmap for our emission control business is very clear and if you look at the growth over the next decade it's about $5bn worth of growth in the market. And if we're able to capture our fair share which you've heard about, and we're very, very well established in that market, that gives us good growth opportunities over the next decade in emission control.

In Battery Technologies we started only three years ago and I'm very pleased with the progress we've made. Martin and Nick and the team have done a great job in getting us at this stage very quickly, and I think the opportunities for the future are still strong and

give us lots of potential for the medium term to grow this business, predicated on the LFP position that we already have today.

I'm confident we'll succeed in these markets and therefore with the success in these markets and the rest of the potential of the Group as a whole I'm absolutely confident that we have got sustained, long term growth drivers for the Group as a whole.

That's all I wanted to say for the day. I wanted to finish it off there. But I just wanted to say a few words if I could just to thank some people. These presentations don't happen easily. There's an awful lot of work that goes into the background to get these done. Trust me; there's been a lot of work and a lot of late nights to get these done well. Hopefully it was helpful for you the shareholder, that's what we've done it for, for you. Use the opportunity to talk to people over dinner for those of you who are coming to dinner, we'll be around for a little bit longer before we go to dinner so if you've got any other questions please make the most of those.

So thank you guys for all your work and effort and what you've done. And also thank you to Sally and her team for putting it all together. It's again a lot of work so thank you very much to them. And thank you to you for sitting with us for the last four hours. We said we'd finish at about 5.45 and we're not far off it. 6.30 I think for drinks for those that are coming just down the road. I think hopefully everybody knows where they're going. But thank you very much and we'll see you in June when we do our full year results. And for those of you that are interested we'll probably do another one of these in another year's time. But thank you very much.

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