Capital Markets Day

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Introduction

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Introduction

Welcome, it is our pleasure to welcome so many of you here with us today in Seoul. Also welcome to those who are joining us via Webcast. My name is Evelien Goovaerts, I'm in charge of Investor Relations. And before handing over to the management for the presentations I would like to go through a few practical things as well as walk you through the agenda of today.

As always, a cautionary statement. I am not going to read it to you, it is also on our website if you would like to consult it.

Agenda

Let us now move to the agenda. Powering ahead, you will have noted the theme already and that is exactly what we want to showcase today. Umicore is powering ahead and it is leading the way in clean mobility. Our CEO, Marc Grynberg will kick off today's presentations. He will start with a strategic update on Horizon 2020, he will reflect on the achievements made so far and he will also highlight the key major trends that are strengthening and that are driving our key businesses, in particular the accelerating move to clean mobility.

We then move further to Pascal Raymondet, Executive Vice President Catalysis. He will talk about the unprecedented growth opportunities in automotive catalysis, strengthening emission norms for both passenger cars and heavy-duty diesel, or driving growth in the market. And he will demonstrate that Umicore is set to outgrow the market.

After a break, we continue with Kurt Vandeputte, the Senior Vice President in charge of our battery materials. He will explain that Umicore is widening the gap in battery materials for XCV applications and he will explain that this is driving significant growth for Umicore in the years to come.

After a longer break for lunch, and also a cultural activity, we will continue with Denis Goffaux, our CTO and Executive Vice President Energy and Surface Technologies. He will walk you through the innovation road map in clean mobility materials and highlight the unique position of Umicore on every step along that innovation pipeline.

We will then go back to Marc, who will wrap up today's presentations with some key messages. That is also when we will stop the live webcast.

Those of you who are with us today will then be invited for dinner and will also have the opportunity to attend the keynote of Chancellor Professor of Material Science and Engineering, Gerbrand Ceder, who will talk about the future of energy storage and electrified vehicles.

Housekeeping

We have a very, very busy agenda, so a busy schedule. We are very anxious to get thing started, but just a few practical things before we can start it. We have foreseen official Q&A

sessions. In order to give everyone the possibility to raise their questions, may we ask you to limit your questions to one question per person? All the presentations that we will be showing today will be posted, as well, on our corporate website every time at the end of each session. Please note that today's event is being recorded and that the replay will remain available for five years on Umicore's website.

And then, last but not least, may we ask you to switch off your mobile phones. If you decide to tweet about the event, do not hesitate to mention our hashtag, #umicorecmd. And with this, I would like to ask Marc to come on stage. I wish you a very, very enjoyable day. Thank you.

Powering Ahead

Marc Grynberg

CEO, Umicore

Introduction

Thank you, Evelien, for this very thorough introduction. Good morning, everyone and welcome to Umicore's Capital Markets Day in Korea. If you attended our Capital Markets Day three years ago in London, welcome back and if you attended our Capital Markets Day six years ago, I am glad we gave you a good reason to come back to Korea.

And, of course, I would like also to welcome our web audience today.

We have prepared a very full programme for you for today and for tomorrow. A programme that is articulated around the theme of clean mobility materials and one of the key things that we want to bring across as part of the programme is we want to highlight how technology and environmental regulations are driving the growth in our business.

What we would also like to highlight during the programme is what has changed compared to the Capital Markets Day of three years ago, when we launched our strategic plan Horizon 2020.

Our Strategic Journey

History

Before doing so and before highlighting those changes, I would like to go a little bit back in history. Actually, I would like to bring you some 15 years back in history and that in order to put the strategic journey of Umicore in somewhat of a good context and perspective.

15 years ago – M&A

So 15 years ago we started to drastically transform the portfolio of Umicore and that was done through intensive M&A activities. 15 years ago we acquired the catalyst activities that are one of our flagship activities and one of our largest activities today. And we also started the divestment process of the historical activities of Umicore in smelting and refining.

At the same time, we were rolling out the recycling business model and we were also starting to plant the seeds for some organic developments. So a very intensive phase of transformation for the group and, as I mentioned, driven, or executed to a very large extent through M&A activities.

2010 – 2015 Organic growth potential

After that, we decided to put much more focus on the organic growth potential of the company and, as I mentioned, we had planted some seeds for organic growth and during the 2010 – 2015 time frame we started to make choices. We actually started to make selections and invest in those activities, those seeds that had developed the best and were showing the best promise.

At the same time, we also decided to put some more investment on the ground in those activities and prepare for the next phase.

So M&A transformation in the first decade of this century, followed by a more significant focus on organic growth.

2015 – 2020 Horizon 2020

And then, when we met three years ago and we launched the Horizon 2020 strategic plan, I told you that we would seek a somewhat more balanced approach. Of course the focus would still be on organic growth, but I told you that we would want to compliment the organic growth with some selected M&A activities.

Horizon 2020

Having now passed the halfway mark of Horizon 2020, I can actually comment a bit more as to how things have developed in reality.

Configuration of Umicore

Over the past three years we have really spent significant efforts to change the configuration of Umicore and to simplify the configuration of Umicore. First of all, we have streamlined all portfolio of activities. You will recall that, early 2015, we announced that we wanted to streamline the portfolio of activities in order to increase the focus on clean mobility materials and on recycling. That is by and large done by now.

In 2016 we divested Horizon Chemicals activities. In 2017 we divested building products and the large area coating activities of Thin Film Products. And earlier this year we sold the European operations of technical materials.

So, all in all, over the past few years we reduced the number of business units from 15 to nine and we reduced the number of production sites from 64 to 51, so quite a significant simplification.

Acquisitions

During the same period of time we've completed some selected acquisitions in energy and surface technologies and in catalysis. These acquisitions were meant to strengthen our positions or market positions or strengthen our technology offering.

Catalysis

In catalysis, we acquired the remaining shares in our Korean joint venture that is producing automotive catalysts, ORDEG. We also acquired the HDD and the stationery emission control activities of Haldor Topsoe and we acquired the metathesis catalyst activities of Materium.

Energy and surface technologies

In energy and surface technologies, we acquired a very critical IP portfolio a few years ago and we also acquired French company, Eurotungsten.

At the same time, during the past three years, we stepped up and accelerated our investments in rechargeable battery materials in quite a considerable manner and we will have a chance to come back to that and elaborate on these investments and how we stepped them up.

As a result of that phase of the past three years, we have now a new Umicore, if I may put it this way, with a very clear and much sharper focus on clean mobility materials and on recycling. We have also used this period of time to build very strong foundations, which we can use to accelerate the growth of our business going forward.

And that is what we will see next; so more organic growth actually as a result of the previous phase of preparation and a very, very significant acceleration of that growth.

Foundations

Talking about foundations, there is one thing that has not changed at Umicore and these are our foundations. Our foundations are exactly the same as three years ago when we talked about them. They are the same as six or ten years ago. This is the common denominator across our businesses and it is also the basis on which we make key strategic decisions.

Business model

Our business model consists of transforming metals into functional materials and we do that using a blend of competencies in chemistry, in material science and in metallurgy. And actually, we are strongest in those areas where a combination or all three types of competencies are required simultaneously.

We differentiate ourselves through a very deep application now and we differentiate ourselves by closing the materials loop.

Sustainability

Also a very significant part of our foundations is our approach to sustainability. We are and we act as a leader in sustainability. And, at Umicore, I would like to emphasise that this means more than trying to minimise the potential negative impact that industrial operations could have. At Umicore, as part of our sustainability leadership, we are striving to have a positive impact around us by using our technologies, using our competencies to address a certain number of societal challenges. And this is reflected in the way we select our businesses. The businesses that we want to pursue and in which we invest. It is also invested in our mission statement of making materials for a better life.

Megatrends

I would like now to elaborate on the megatrends that are actually the underlying factor behind our strategy and show you why the megatrends that were selected a number of years ago to support the strategy are still very relevant and even have strengthened over the years.

Resource scarcity

Let me start with what I believe is the most obvious case, resource scarcity. Why obvious? Well because mineral resources are available on the earth in finite quantities. So as we dig them from the ground, by definition, their scarcity can only increase and so, in a way, will the need for recycling.

What we observed though is that over time the perception of what is scarce may change and may move from one element to the other. I recall that, when we spoke about that some six years ago during our Capital Markets Day here in Korea, what was hot on the agenda was the availability of Rare Earth and that was following the introduction of export quotas by China.

Three years ago, the question mark was about the availability of lithium as we saw the first sign of emerging demand for battery materials for electrified vehicles. And now the spotlight has clearly moved to cobalt. So the scarcity increases, the need for recycling follows and the elements, which are perceived, or which are actually scarce can change over time in function of market regulatory or technology developments.

Clean air

There is another megatrend that has also strengthened in recent years and that's the need for cleaner air. And one of the catalyst factors in the recent past that has changed the perception about the need and the urgency to make the air cleaner is no doubt the diesel scandal.

Diesel scandal

And as a matter of coincidence, you may recall or you may have noticed that the diesel scandal broke out in September 2015, just a matter of days after our Capital Markets Day back in London. And the diesel scandal has done a few things. It has changed the perception in the public opinion and it has also reduced quite dramatically the tolerance for pollution, not only in public opinion, but also in the regulator's eyes. And as a result of that, you have seen an accelerated introduction of tighter emission norms and, for the first time, some of these norms will be applicable in real driving conditions, which Pascal will explain later, which will boost actually the value of the catalysts that are required for vehicles.

Diesel fuel costs

The other thing that has changed following the diesel scandal is that the regulators have decided to raise taxes on diesel fuel. And if you take the combined effect of tighter emission norms and more catalyst, or more sophisticated catalysts being required for cars because of that, and the increase of the fuel cost because of higher taxes, and I am talking about Europe, the effect is that diesel engines have become less competitive and less affordable in particular for compact cars.

I have already mentioned what is on the slide now, the fact that for the first time the new emission norms will be applicable in real driving conditions and that will have an effect on the catalyst value.

Ban on diesel in cities

Another thing that has changed, and that's a recent trend or recent strengthening of the trend for cleaner air, is that you have seen a certain number of municipalities considering or

announcing bans on diesel. So a certain number of municipalities do no longer want to have diesel cars in city traffic conditions.

And if you consider that diesel will become more expensive, diesel configurations will become more expensive in Europe and that there is an uncertainty now as to whether you will have the authorisation to drive your diesel car in city centres, you can infer from that that these factors are keeping quite a number of consumers away from diesel today and that explains the declining sales of diesel cars in Europe.

Vehicle manufacturers and diesel

As a result of that, we have recently seen a series of announcements from leading global car OEMs such as Nissan, Toyota and Volvo that they would stop developing diesel platforms and that they would seek to accelerate their exit from diesel sales.

If you take another leading car manufacturer, Volkswagen, whilst they decided not to abandon diesel, at the same time they clearly decided to step up and accelerate significantly their electrification strategy.

China 6 emission standards

The other key development that actually took place shortly after our Capital Markets Day of three years ago was China's decision to introduce China 6 emission standards, much tighter emission standards, both for passenger cars and for heavy-duty diesel applications and that implementation will start in 2020.

Later today we will show you how this is going to impact the value of catalysts per car and how this is going to boost the value of the catalyst market. It is also worth noting that the emission norms that China is going to introduce shortly are going to be tighter than those that we know in Europe. And China has been a follower in terms of emission norms for quite a number of years and have decided to now leapfrog what others are doing and to lead with the tightest emission norms.

We can also say that this is normal because the air quality problem is much more acute in China than in any other region.

Also worth noting is that India decided to follow suit and, while the Indian market is somewhat smaller than China, this is also a significant development.

If you consider that China and India together account for some 35% of global car production and about half of the heavy-duty engine production, you can imagine what effect this will have on the global markets.

So, all in all, this is leading us to believe that the growth in the catalyst market is going to be much more pronounced than what we thought three years ago when we started, when we launched the Horizon 2020 strategy.

Market acceleration

Catalyst growth

Historically, we have told you that the catalyst market was growing at about 1.5 times the rate of car production growth and it was not a linear growth, of course, because it was

depending on a few steps achieved at the time of the introduction of new norms, but that's been the historical average.

With what is happening in Europe, what is happening in China and in India on the passenger car side and for heavy duty, you will see now a much more pronounced growth going forward and actually in the not so distant future.

Electrification

At the same time, we also see a very significant acceleration of the electrification of car production. So this is actually not so new compared to what we discussed three years ago at the time of the Capital Markets Day in London, because actually the main regulations that are driving the introduction of electrified vehicles, that is the CO_2 regulation in Europe and the CO_2 regulations in China, those regulations were in place in 2014 already. So before we launched Horizon 2020.

However, what has happened in the recent couple of years is that there has been an acceleration of the electrification and a step up of the electrification efforts of the car OEMs. In China, which is the leading market in terms of electrification, and which probably accounts for more than 40% of global EV demand going forward, in China the acceleration is pushed by the government that has recently introduced EV or new energy vehicle production quotas over and above the subsidy mechanism that was encouraging already the adoption of electrified vehicles. You have now a much stronger regulatory push and a much stronger government mandate to introduce electrified vehicles in the marketplace.

In Europe, the push is coming from the fall out of the diesel decline, which will make it even more challenging for car makers to achieve the 2021 CO_2 regulations and new limits in Europe and will force them to increase the proportion of electrified vehicles in their model line up.

Now when we met six years ago for the Capital Markets Day in Korea clearly there were more sceptics at the time than believers in electrification and the question at the time really was, will electrification ever happen?

The question was sometimes expressed in another manner. The question was sometimes expressed, by the sceptics mostly, in the following way: where does the oil price need to go in order for electrification to make sense? And some people, some observers were saying, below $200 per barrel, electrification will not make sense and therefore will not happen. That was six years ago, and if you were an early adopter, it is also true to say that you had a limited choice of EV models on offer at that time, which was not really creating the best conditions for EV models to penetrate the market and to convince the sceptics.

When we met three years ago in London and when we were launching the Horizon 2020 strategy, the question no longer was, will electrification ever happen? The question at the time was, how fast will it go? Because regulations have been adopted and so there was a clear indication, or more than indication, there was a confirmation that electrified models would be required in a certain proportion in order for car owners to be able to meet the new and more stringent CO_2 limits.

At the time, some models were developed to try and simulate what was the required reduction in battery cost to make battery electric vehicles, or plug-in hybrid vehicles

competitive with combustion engines. And I think that has occupied many of you for quite a while.

And at the same time, I have to say that, and you will see that also from the images, that we are projecting now, the number of models on offer had been multiplied quite substantially and still for the early adopters, clearly, you had back then, three years ago, quite a number of models to choose from if you wanted to make the effort, the financial effort, to acquire an electrified vehicle.

Today I would say that the question no longer is how fast will electrification happen? The question really has become how much faster can it go? You see a proliferation of models that are being offered; and, actually, this will even be more visible next year in Europe. Why next year? Because next year the credits that the European Union is giving to car producers for electrified vehicles are starting to accrue, while the potential penalties if you don't meet CO_2 regulations will only start to kick in in 2021.

So that's one factor and the other thing is that clearly the perception of the urgency of improving air quality has really changed in recent times. So the question today as I mentioned is: how much faster can it go?

Horizon 2020 objectives

Having explained why the megatrends that are supporting our growth and supporting our strategy of Horizon 2020 are still relevant and have even strengthened, let me now go back to the objectives that we had set ourselves as part of Horizon 2020.

Financial objectives

And let me start with the financial part of these objectives, you will recall that three years ago we told you that as a result of the growth and the organic growth that we had in mind that we would double the recurring EBIT by 2020, starting from the 2014 base, excluding discontinued operations. So at the time the REBIT in 2014, excluding discontinued, was slightly over €240 million, which meant that we were expecting to reach €0.5 billion in recurring EBIT by 2020.

I'm pretty sure that you will recall what we communicated in February at the time of the full year earnings release and at the time we launched our capital increase. And you will also recall the guidance that was provided at the end of April, which basically means that we now expect to reach the Horizon 2020 target or even to exceed it as early as this year, so two years ahead of schedule.

And the faster growth that we see in energy and surface technologies, and the fact that we've been able to accommodate the faster growth of demand and to accelerate our investment now means that we see a potential to exceed the original Horizon 2020 target by some 35 to 45%.

I also told you three years ago that, as a result of the faster growth in energy and surface technologies compared to the catalysis and recycling segments, by 2020 we would have rebalanced the contribution to earnings from the three segments. As a matter of fact, this rebalancing was achieved in 2017 already as a result again of the faster than anticipated growth in battery materials. And with the investment programme that is in place and where

we see now demand heading, it is fair to expect that by 2020 the energy and surface technologies segment will have become the largest contributor to earnings.

Sustainability objectives

Let me now address our sustainability objectives as we set them out back in 2015. And there, again, I have to say that we have achieved very, very significant progress. In terms of eco efficiency in the first instance, and despite the significant growth in production and in our business configuration, we have achieved significant improvements.

For instance, we have reduced our energy consumption by 20%, more than 20%, compared to the baseline of 2015. We have also reduced our metal emissions to air and water by respectively 41% and 69%. This is the result of significant investments that were made in our largest facilities and significant projects that were successfully achieved in order to make our facilities way more eco efficient than was the case.

And again, still with the idea in the back of our minds that we want our operations to be benchmark, the benchmark in the industry.

Ethical and sustainable sourcing

Another area where Umicore is creating distinction, competitive distinction is in the area of ethical and sustainable sourcing. Actually some more than 10 years ago, back in 2005, we decided to introduce an ethical and sustainable sourcing charter and to impose it to all of our raw materials suppliers.

I have to admit that we have hardly been rewarded for that so far, but things are changing. Things are changing because there is an increased level of scrutiny by the public opinion, by the NGOs and by leading customers in the automotive and the electronics segments about the origin of the raw materials going into their products. And this is a trend that we're building on to play out our competitive advantage and our early positioning in that respect.

Early positioning – for instance, I have to say that Umicore was the first company last year to obtain third-party certification that our cobalt supplies are 100% of ethical and clean origin, which in today's environment and high scrutiny environment clearly positions Umicore quite apart from the rest of the industry.

Recycling

Next to that, of course, we have our closed loop, our recycling capabilities, which offer our customers full traceability. So this is one of the key distinctive factors in our business model. And when we talk about making, or turning our leadership in sustainability into a greater competitive advantage this is I think one of the best ways to illustrate what we mean with that.

Now let me briefly show a few examples, selected examples, of how we are establishing or strengthening our leadership in clean mobility materials and recycling. Short examples and selected examples because actually this will be developed in way more detail and depth by my colleagues during the rest of the programme today.

Let me start with recycling; and I actually have to clarify in the first instance that you will not have, and you may have noticed that from the agenda that Evelien presented, you will not have a fully-fledged presentation on recycling today. It doesn't mean that we have a lesser

interest in recycling from a strategic point of view, it is just that we wanted to focus today and tomorrow on what has changed the most since we spoke last in September 2015, and that is in the area of clean mobility materials in catalysis and in battery materials.

The interest and the willingness to develop our activities in recycling are totally unchanged compared to three years ago.

Our leadership in recycling hinges, I would say, in the short to medium term mostly on the capacity expansion of our flagship operation in Hoboken. The ramp up of the new capacity is proceeding well and, as I mentioned to you on a few occasions in recent communications, the results of this ramp up should become more visible starting this year; more visible in terms of financial impact.

While we will not focus on recycling today and while the growth profile may not be as sharp as it is in catalysis or in battery materials, I would like to repeat and I would like you to continue to bear in mind that our recycling activities generate outstanding returns and has an extremely attractive cash flow profile.

So nothing to be read between the lines. We will not talk a lot about recycling today. It doesn't mean that we have less interest from a strategic point of view and, of course, I will be happy to take your questions on recycling during one of the Q&A sessions.

I've talked about the leadership in recycling in the short to medium term, in the longer term what we see as the next big thing is, of course, the recycling of spent lithium-ion batteries. It will take a bit of time to materialise as a new business. I still expect that this business will take off in the mid-2020s and that it will have a growth curve that is likely to mimic the growth curve in battery demand that we see today, with a time lag of about 10–12 years. Which means, or implies, that we are likely to make investment decisions to scale up our recycling capacities and capabilities sometime in the first part of the next decade and the first part of the 2020s.

Acquisitions

In catalysis, we are also strengthening our leadership position and Pascal will elaborate on that. I would just like to highlight a few things and I have selected as a picture, as an image, the tech centre of Ordeg, the research and tech centre that you will visit tomorrow as part of the visit programme. That's an acquisition that was completed in the first part of last year. We had a 50% stake in that catalysis joint venture and we moved to 100% and with the full integration being done in the meantime.

We also acquired the HDD and the stationery business of Haldor Topsoe in the course of last year. This will strengthen our technology offering in HDD and in particular in China, which is set to become the largest HDD market in the world. And it's also given us an entry into a new segment for us, that's the DeNox segment for some stationery applications such as forestations.

Pascal will also show you later today how we are strengthening our market position in the passenger car segment with very significant technology leadership in gasoline applications.

Battery materials

And I will say even less about the battery materials, because this will be highlighted today during the presentation and tomorrow during the visit in Cheonan. And what I told you three years ago when we presented Horizon 2020 is that we would make use of the time window of Horizon 2020 to increase the gap in battery materials. And today, what I can say with a lot of confidence and what I think you will see today and tomorrow is that we have done so. That is really what is happening, these days we are increasing the gap and we continue to qualify for large platforms in the automotive segment and we continue to add capacity much faster than anyone else in the industry. As I would like to remind you, with some of the press releases that were issued recently and that outlined the pace at which we are adding capacity and which imply that we are actually out-pacing the market growth in battery materials.

And clearly, with the visit tomorrow in Cheonan, you will get a visual impression of what we mean when we talk about building scale in this battery materials activity for electrified vehicles.

As I get near to the end of my introduction, I would like to re-use a slide that I showed you three years ago at the Capital Markets Day in London. Why do I want to re-use it? Because it is still very much relevant, and what I told you three years ago is that Umicore was uniquely positioned to serve the move to cleaner mobility in the automotive industry. And today this is as true as it was three years ago. It is even more visible I believe that Umicore is in that unique position.

We are the only company that is actually offering the entire spectrum of materials technologies to support the cleaner mobility transition. A bit through catalysts for conversion engines, with gasoline particulate filters for instance now becoming necessary in certain engine configurations. A bit through our materials for plug in hybrids or battery/electric vehicles. Through the catalysts for fuel cells applications and, please bear in mind that we are also the only company that is closing the materials loop and offers the customers in the automotive segment that want to have a true clean solution the ability to recycle these materials that are used in drive chains when they reach end of life.

Engine mix changes

The other reason that I wanted to show you again this image is to outline, once again, that at Umicore this is not an aspiration. This is who we are today. So we are indeed already offering the full spectrum and, given the changes that we constantly see in engine mix, in drive train mix, for a number of reasons I am convinced more than ever that our versatility and our ability to cover the entire spectrum is going to play out in our favour.

How is it playing out? Well, as I mentioned, there are a lot of changes in the engine mix and if you remember the discussions that we had three years ago at the Capital Markets Day or even a longer time ago, quite a number of assumptions in terms of engine mix trends have had to be revisited since then.

The first change that we've seen, and that's a recent change, is that there is a reduction in the engine mix and that's a trend, a clear trend. There is a reduction in the proportion of diesel sales in the engine mix.

A second change compared to the assumptions that were made three years ago is that there is more electric, more electrified drive trains in the engine mix now and the trend is going to be even more pronounced going forward.

Another change in terms of assumptions is that a number of car OEMs have started to narrow down the number of development avenues. While, until recently, they were keeping all options open, all kinds of combustion engines, fuel cells, electrified drive trains and you name it, today they are starting to narrow down their options to a more limited number of choices for cost and efficiency reasons, but also because the urgency to meet the new CO_2 regulations is actually pushing them in that direction.

As a result, we see car OEMs streamlining their development programmes and coming up with a reduced number of platforms that are open for bidding, but these platforms are each much larger and covering a larger number of models and a larger number of cars. So every time we bid for a platform there is a lot at stake in terms of business development. The good news about that as well is that this is giving us quite a lot of visibility in the medium to long term, so that we can easily adjust our capacity planning.

And the last change, I would say in the engine mix is that fuel cells are clearly part of the mix. The timing is still quite a bit uncertain as to when this will reach mass production, but what is getting increasingly certain is that fuel cell vehicles will be on the road at a certain point in time.

So the mix is changing, it continues to change; you have different forces, regulatory forces, consumer choices, etc. that have an influence on the mix. We don't have a crystal ball, so we don't know exactly which drive train is going to come in which proportion at every point in time but there is one certainty that we have, is that there will be a diversity of drive trains on the road. We don't see today and we don't see in the foreseeable future any single drive train technology taking a dominant position and winning the entire or close to the entire market potential.

This will not happen because, first of all, there isn't a single technology that covers the entire spectrum of application requirements. They can be very different in terms of the consumer choices and the functional requirements of each mobility solution. And also because most technologies, when you talk about drive trains, most technologies for clean mobility require raw materials that may have some scarcity attached to them and so they may hit, some of these technologies may hit supply chain bottlenecks at a certain point in time. So we are absolutely convinced that there will be a co-existence of drive train technologies in the foreseeable future. And, again, this is why I believe that our versatile position is unique and is going to continue to play out in our favour.

And with that, I would like now to hand over to Pascal, who will elaborate on the developments in catalysis.

Growth in Automotive Catalysts

Pascal Reymondel

EVP Catalysis, Umicore

Introduction

Catalysts 30-year growth

Morning, can you hear me? The switch is on, good. Thank you, Marc, for the introduction. After this presentation, actually, I have a question: is automotive catalysts a business still worth investing in? And I get that question once in a while from friends and from other people. And if you look back, I've been in the business for about 30 years and in the last 30 years that question could have seemed a bit awkward, because automotive catalysts has been growing steadily for the last 30 years. But with electrification coming in, and Marc has explained it is happening and it is good for society. It is very good for Umicore. With electrification coming in the question of whether automotive catalysts is a business worth investing in is a valid question, a legitimate question. And my goal today is to show you that automotive catalysts still has growth potential and we even call it unprecedented growth potential.

The agenda will present the profile of the automotive catalyst business and then go through the different markets so we can show you how much growth potential there is in these different markets.

Business model

Our business model of automotive catalysts: we develop catalysts for customers, we help our customers to meet emission legislation at the lowest total cost of ownership. For those of you who were here with us in London three years ago, you will notice that that slide hasn't changed. Our business model is still the same. It's good. It means that it is efficient, it is successful. We have not changed our business model.

The business is still technology- and innovation-driven and will be in the foreseeable future. Why? Because emission legislation is getting more stringent. Emission legislation getting more stringent is supporting and actually requiring that we develop ever better catalysts, so our business for the foreseeable future will be technology- and innovation-driven.

For that purpose we develop catalysts with our customers, in co-operation with our suppliers; we have very strong relationships with universities to develop basic science, to come up with the best catalyst technologies. We are also technology-driven and customer-focused. It is not sufficient to develop a catalyst technology in the lab, you have to adjust that technology to the customer requirements. We do that in our technical centres. You will visit our newest technical centre tomorrow, so you will get a sense of what we mean by technical centre.

And then, we strongly work on operational excellence, because we have to make science affordable for our customers. So the technology-driven business model has not changed and will not change for the foreseeable future.

Marketplace

So let us go through the different markets.

Light duty vehicles

Light duty vehicles, passenger cars; we have been in that business for more than 30 years. We have a very strong track record, we work with all OEMs worldwide. When we started, more than 30 years ago, we only had one plant in Rheinfelden, in Germany and over the years we have developed a footprint worldwide, with manufacturing plants covering all the regions for all customers worldwide.

Interesting is what happened since we last met in London in 2015. When we met in London, we had just opened up our plant in Poland. Now we have ramped up this plant, so we were hardly in Europe, basically two plants in Germany and one plant in Sweden. In '15 we opened up our plant in Poland. By the end of next year we will have closed our historical plant in Rheinfelden, so at the end of this process instead of two plants in Germany we will have one plant in Germany. And we will have increased the capacity of our plant in Poland, resulting after this restructuring process into more capacity in Europe than we had before these restructuring plans. That's the first major step we took in Europe; more capacity with expansion in Poland.

What happened, as well, in Suzhou in our plant in China is, I know we are not supposed to give capacity, so I will only say that we very much increased capacity strongly increased capacity in China to support our market share gains and to support the growth in China.

What has also happened is we have opened a plant in Thailand that was necessary to support our Japanese OEMs and our plant in Pune in 2015 in India had just been opened and in the meantime is ramping up, it is going very well and we have approved an expansion of this plant in India.

So manufacturing footprint covering all the customers worldwide; restructuring in Europe resulting in more capacity and strong expansion in Asia. In America, the market is not growing as fast as in other regions, so you do not see much happening, but in these plants we are also very strongly working on operational excellence to make capacity available for future growth.

Heavy Duty

Contrary to light duty vehicles, we are more of a newcomer in this business. Umicore decided in 2006 to enter this market, 2006, only 12 years ago. In London in 2015, at that time we had just opened up our plant in Florange. We were ramping it up and we had just opened up our plant in Suzhou. That was the picture. Today, our plant in Florange is running full. Our plant in China, I said, the light duty vehicle plant capacity had been strongly expanded. The heavy duty plant in China over the next three years will be very, very much expanded and we expect a very strong capacity expansion in China.

What happens as well is we will open up a heavy duty line in Pune, it should be scheduled for next year. We have a plant in Korea to service our customers in Korea, it is not mentioned, we've added three plants in heavy duty through the acquisition of the heavy duty business of Haloe Topsoe. We added a plant in Denmark for Europe, a plant in China and a plant in Brazil.

We were a newcomer – ten years ago we decided to enter this market, five years ago we were a newcomer and now we have development programmes with most OEMs, which will lead to major growth and I will discuss that a bit later.

North America, we do not show any manufacturing plants there. It is no secret that our market share in heavy duty diesel in North America is small and we service that, actually, from our plant in Burlington because, when quantities are too high, we can make heavy duty parts on our passenger car production lines. Whenever we have a commercial success in North America we will expand in North America.

Technical centres

I said our business is technically driven so a short update on our technical centres. We have technical centres across the globe to adapt our technologies to the customer needs across the globe. So what has happened in technical centres? Quite a bit has happened actually. In Auburn Hills since London last year, in Auburn Hills we have revamped our chassis dyno. In Korea we have built a new tech centre in Songdo. You will see that tomorrow. And in China we have expanded our test centre capacity.

So, again, we have not only spent money on production plant, we spent quite a bit of money on tech centres because it is the success factor of our business.

Marc mentioned that we also went through a few acquisitions. We bought the 50% remaining share of Ordeg in Korea. Why did we do that? When we built the joint venture in 1985, at that time Ordeg was supplying, and is still, the purpose was to supply the Korean customers. And in these days, I am talking back more than 35 years ago, the Korean customers were mostly making cars in Korea, so Ordeg was supplying Korean customers in Korea.

In the meantime, Korean customers produce more cars outside Korea than in Korea and these cars produced by Korean customers outside of Korea are supplied by Umicore plants, to allow a better co-ordination between the supply in Korea by Ordeg and the supply by Umicore outside of Korea, we decided to buy the rest of the acquisition to allow a better service for our customers.

And Marc mentioned we also bought the heavy duty catalysts activity of Haldor Topsoe, with a plant in Brazil, Denmark, China and a fixed centre in Denmark that gives us an expanded product portfolio and a much stronger access to a few key customers.

So that is where we are. Now the automotive catalysts needs two things to be successful. It needs combustion engines, because without combustion engines I have a problem. And it needs emission legislation. And Marc mentioned that the public awareness towards emission legislation, towards emissions has been increasing dramatically over the last three years, for good reasons, for bad reasons, the fact is awareness is much higher.

The result of that is our customers, when they make an award decision for catalysts, they now go for the best technology. You can always make an engine work with good technology, but now our customers who have to pick between the good technology and the better technology go for the better technology. That is what has happened in, you know, Marc called it the diesel scandal. That is one of the impact of the diesel scandal, customers now go for the best technology.

Legislation

So I said we need combustion engines, but we also need legislation. That picture is very busy, but you should only focus on the visual, what is that picture saying? Each line represents a country or a region and on each line, every time there is a change of colour, it means that emission legislation is changed.

You see all these colours? It means all the different countries have different legislations and if you look horizontally, colours keep changing, meaning legislations keep changing. Legislation changes, we have to develop a new catalysts for our customers. That is the driver and the reason why we believe that innovation and technology is the success factor of this business.

The other thing you see on this picture is that, for 2025, discussions have started now to establish a new emission legislation. Today in Europe, I take Europe as an example, you know, emission legislations are governed by Euro 6. Discussions are ongoing now to define Euro 7. Euro 7 will be more stringent. How? We do not know yet, but we do know it will be more stringent. It will be applicable 2025 and we have to work now in R&D to be prepared for Euro 7. Again, another reason for still developing and still investing in R&D in automotive catalysts.

One example, if you look at USA, as I said, whenever colours change it means a step in technology. If you look at this picture, first line, USA apparently nothing is happening. Actually things are happening because within Tier 3, within Tier 3 there is a regular upgrade of emissions. Emissions are continuously going down.

So now I will not go through all these lines. We will focus on the three regions where most is happening in terms of legislation. And that is Europe, China and India. Let us go through China first.

China

Marc mentioned that before China will become the pace setter, or has become the pace setter in terms of emission legislation. And if you allow me, I will go into a bit more detail on this slide so that you understand what it means for the business. The first line you see emission standards is going from China 4, China 5, China 6A, China 6B; these different steps mean reduction of emission.

Going from China 5 to China 6A, basically carbon monoxide emission limit is reduced and particular number are being reduced. Going from China 6A to China 6B, it is reduced again. Actually reduced by half. On the China 6B, the emission limits in China are half the emission limits in Europe… half.

Changes in testing

The next line is about this cycle, because it is not only about emissions, it is about how you measure emission. Until China 5, which is still today, emissions are measured with a test cycle, which is called NEDC and we will move to the WLTC, which is the world harmonised test cycle and this test cycle is a lot more severe, a lot more dynamic and requires a much better catalyst to meet the legislation. So limits are going down, the test cycle is getting more aggressive.

Real driving, with all that there will be what we call real driving. So emissions will have to be met not only in the lab but they will have to be met on the street under real driving conditions. That is another criteria to be met by customers. Durability is increasing and the last line, fuel efficiency; and this fuel efficiency increase, or fuel consumption reduction will drive a faster introduction of GDI, gasoline direct injection. And gasoline direct injection also has an impact on the catalysts architecture.

So legislation is actually interesting bedtime reading. It is complex, it is the basis for business, drives our growth. So now that you have seen what is happening, let us see what it means in terms of catalyst value.

That is the market in China for passenger cars in 2025, 34 million cars. These are not our numbers, these are the numbers from IHS. We pay a lot of money for these numbers, we decided to believe these numbers. 34 million cars in China in 2025, about 6 million fully electric, so it leaves still 29 million cars with combustion engines. So what is happening with this combustion engine?

China 5 current legislations; basically all cars out there, they have either one TWC, three way catalyst. The TWC is what converts carbon monoxide, unburned hydrocarbons and NOx, basically reducing the pollutants. So cars within China under China 5 basically have one fuel catalyst or two fuel catalysts.

China 6A is coming; China 6A reduces the emission limits for carbon monoxide, introduces particulate number. Some customers will use what we call GPF, gasoline particulate filter, that green part on top of the three-way catalyst. Some will not use it as of 2020. Catalysts will get bigger because emissions limits go down and the result of all that, that is the beauty of an Excel sheet, is we see an increase of value per car of 70%. In 2020, which is two years from now, the value of catalysts per car in China will be 70% higher than today.

In 2023, that is when the legislation cuts emissions even more, at that time emissions are 50% the level of Europe, that is when China introduce real drive emission with a confirmative factor of 2.1 and at that time all gasoline engines will be equipped with a catalysed gasoline particulate filter, that green part on this picture. Sorry, that picture represents an exhaust line, okay? So the green part is the filter. All cars will have one. Three way cats will get bigger again, resulting in the value of catalysts per car being 2.4 higher than today. That is the result. Legislations gives work to our R&D people and gives food for the innovation, that's the result on business.

In 2023, five years from now, the value per car will be 2.4 times what it is today.

I said we will go through three markets. I will go a bit faster now, because you went through the logic.

Europe

Europe, similar things are happening. The CO_2 target is getting tighter, that has implications on introduction of gasoline direct injection engines. Emissions, Euro 6B saw the introduction of particulate numbers. Euro 5 had less of that. You will see a change of cycle, same as in China, Euro 6B today is being tested on the NEDC, will move to the WLTC. Real drive emissions will be implemented, actually similar trends, so let us not go through these details again, similar to what is happening in China. A bit different but similar things. The

importance is what is the impact of these legislations on the catalyst value per car? Again 20 million passenger cars in 2025, I am talking Western Europe here, including electrical cars.

Today what you see in Europe is exhaust lines with fewer catalysts basically. Starting September 2018, which is three months from now, most cars will be equipped with a filter, some with a pure filter, some with a catalysed filter. Catalysts will get bigger. At the end of the day, the value per car will be 80% higher. The value that we sell to the customers will be 1.8 what it is today.

2021, that is when Europe introduces real drive emission; at that time, all gasoline cars will be equipped – or GDI cars or most 80% of the GDI cars, the gasoline cars will be equipped with a particulate filter. Three way cats will have got to be bigger again, meaning in 2021, which is three years from now only, the value per car will be 2.2 what it is today. A factor of two in three years. The same number of cars, just the value is twice as high for us as it is today.

Diesel vehicles

The same thing is happening in diesel, 20 million again is total car population in Europe, gasoline, diesel, electrical, the whole thing. The same thing is happening in diesel. I will go a bit faster here. Euro 6B, the two different types of systems, you know, different types of catalysts, you know diesel oxidation catalysts, filters, NOx reduction catalyst. Important here is, as of September 2019, all vehicles will be equipped with different systems and the value per car will be 30% higher than it is today.

I have to say, here, the same thing applies to gasoline. The dates I am giving you here is the dates when all vehicles are equipped with these new systems. In Europe, new type approval gets equipped a year earlier. '19 is when all diesel vehicles will be equipped with these systems. What I said for gasoline it was '18 and '21, that's the dates when all vehicles are equipped. New types are equipped before.

And in 2021, that's when the real drive emission comes in. All diesel cars in Europe will be equipped with an even bigger system, resulting in catalyst value per car being 50% higher than today.

India

I will go faster over the upcoming Indian legislation because it is comparable to the other regions: emissions getting tougher, test cycling getting tougher. At the end of the day the Indian market will be 8 million cars in 2025. Bharat 4 is the current legislation; catalysts are small. Under Bharat 6 catalysts will be bigger, 50% more value, that's in 2020, that's in two years. And Bharat 6, 2023 still to be defined in terms of real drive emission, introduction of catalyst filter at that time, the catalyst value what we sell to the customer is three times higher than today.

Same thing for diesel, Bharat 4, the system simpler. Bharat 6, a much more extensive system, resulting in the catalyst sold to the customer valued three times higher.

Concluding remarks

So, thank you for your patience. I think it was worth spending the time so you understand where all these legislations are coming from, what is happening, why it is happening and the impact on what we do and what we sell.

So what we saw is the impact of legislations on the gasoline catalysts market will result in what we sell being between 70% to three times higher, at constant engine quantities. You see the same factor for diesel, and I am only using these three regions there, which basically allows us to say because in some markets, in America a bit less is happening. But basically the conclusion is, I am not going through all the countries, I went through the GDI impact in China, Europe and India, you saw where it is coming from, but the conclusion is that the gasoline catalyst market value will at least double between now and 2025, driven by these legislations.

I am not talking car quantities increase, I am talking the value we sell per car that will double. In diesel, the value of what we sell to the industry, the value will increase by 50%.

Plug in hybrid

And what comes on top of it is the impact of plug-in hybrid, plug-in hybrid is driven by, is supported by electrification. But plug-in hybrid, you know that, but I have to repeat it once in a while, a plug-in hybrid has a combustion engine, so a plug-in hybrid is a customer for me and the plug-in hybrid today requires 20% more catalyst volume than a non-plug-in hybrid. So plug-in hybrid will increase the catalyst consumption.

Catalyst Market

So when you put all that together in an Excel sheet, that's what comes out. The market, the catalyst market for passenger car will double until 2025 and that number in 2025 is around about 9 billion and China is the biggest share of that growth. Doubling, China the biggest growth. Assumptions behind that, we have taken some assumptions in terms of internal combustion engine growth but less than 1%.

So to tell me, 'I don't believe that the combustion engine will grow by 1% per year,' that is fine. The doubling of the market value comes mostly from the legislation value uplift, not because of engine growth.

In these assumptions we have assumed that diesel share in Europe will be 30%. If it is only 10% that number out there reduces by 5%. So basically, in any type of conditions you can think of, lower engine growth, lower diesel, bear one number in your mind, the catalyst market for passenger car application will double until 2025.

The future for Umicore

So that is good for the market. Now what is on for us, Umicore? Today Umicore, at Umicore we are increasing our market share in the gasoline segment. Specifically in China, and this market share increase will become even more visible in 2020. And we increase our market share in gasoline, this increase is supported by our very strong technology for GDI application, GDI, gasoline direct injection, is the gasoline engine of the future and for this specific engine Umicore has a very strong technology and is supporting our growth in market

share. It is happening today and will become even more visible in 2020 and in the years thereafter.

In diesel we are smaller, but, in the few applications where we are supplying, we have a strong technology; otherwise we would not be smaller, but we would be nowhere, because again, customers only go for the best. So wherever we have business, we have a very good technology, but we are smaller.

But if you look at our relative market share in gasoline and in diesel, if diesel decreases faster, because we are so much stronger in gasoline, the impact on Umicore automotive catalysts is not there. We can compensate, whatever we lose in diesel we can compensate with our gasoline business.

Heavy duty

Now let us go into heavy duty. Heavy duty, same thing, same picture. Let us not go through the details, every region has the legislation, change of colour means different legislations, means growth potential for our business.

I will focus on the two regions where things happen the most and where legislation is changing the fastest, is in India and China. China, there is a norm for on-road application and off-road application. The total engine market in China in 2025 is predicted by another marketing company, KGP, to be 3.6 million engines. These engines are going partially for on-road application, partially for off-road application.

I will look at the impact of legislations on the on-road applications. Okay, so China, the 3.6 million engines in 2025, 40% off-road, 60% on-road. Now I will focus on the on-road applications. We are currently on the China 5. China 5 on-road basically engines are equipped with an ACR, which is a NOx reduction catalyst. China 6 will come in 2021 nationwide. China 6 will start a bit sooner in some cities, some regions, but to make it simple, every time I present these figures, whether it is for passenger car or for heavy duty, I take the date when the whole region and all vehicles are affected by the new legislations.

So in 2021 all China 6 engines, heavy-duty engines will be equipped with a much more sophisticated exhaust system, with a DOC filter and ACR, resulting in the value per truck almost tripling, 2.8.

If you look at India, similar things happening. In 2025 we see 1.1 million engines, about, we see, KGP sees and we believe that, 1.1 million. At that time, this is about 60% off-road, 40% on-road and again I will only focus on the on-road legislation. Today these on-road engines are governed by Bharat 4 with a NOx limit of 3,500 mg per kilowatt/hour. Meaning the exhaust system either has a small DOC or a small ACR. DOC, diesel oxidation catalyst, ACR, NOx reduction.

With Bharat 6, coming in in 2020, legislation is similar to what we have in Europe and customers will move from this simple system, either DOC or ACR to much more complex systems and value per truck will increase by four, times four.

So when we say heavy duty, when we've seen heavy duty, we've seen that legislation is getting tighter in China and India for on-road application resulting in value increase for catalysts per engine and what we also see in heavy duty, contrary to passenger car, is an increase of engine volumes between now and 2025 by 60%. I am not talking about a 60%

increase of engine production, I am talking about almost 50% increase of engines being regulated. The off-road engines today are not regulated.

In 2025 they will be regulated in China and in India. So they exist today and they contribute to a big portion for this, 60% volume increase. It is a volume increase for us as catalyst manufacturers. And in 2025 this 60% volume increase, because these engines become regulated, will be regulated by the China 4 top level. So the catalyst value in these off-road engines will be still small but will increase in the future and will give another step for business increase after 2025.

So what is the result of that? Strong value increase for on-road application in China and India, some value increase in Europe, little in America. Volume increase mainly because off-road engines are not regulated today but will be in India and China in 2025, the result of that is the market, the catalyst market for heavy duty application will also actually more than double between now and 2025.

In China it is, you know, by far becoming the biggest market because on-road trucks will be regulated just as strictly, or stricter than in Europe and because off-road trucks or tractors, you know, earth-moving equipment, which today are not regulated, will become regulated in 2025. Not at China 6 level, but at China 4 level, but still will require a catalyst and in 2030 these off-road engines will become regulated at a stricter level and will provide the next growth opportunity.

Conclusion

So again, good for the market, this doubling of catalysts for heavy-duty application, but what is in it for us? We started this business a bit later than our competitors, but today we have a very competitive technology portfolio. Our plants are running at a very high utilisation rate and we have co-operation now, technical co-operation with most of the heavy-duty customers, which gives us a high level of confidence that we will benefit from this doubling of the market.

If you put everything together, that's the addition of the catalyst market for passenger cars and for heavy duty, they are both doubling, and so the sum of it is also doubling. That is the message of today: the automotive catalyst market for emission control for cars and trucks will double between now and 2025. It is a technology play, an innovation play, because this doubling is not engine-production driven, and it is not car-production driven. It is solely driven through legislations and through innovations, through the better catalysts that we supply to our customers.

I started this presentation with one question: is automotive catalysts still a business worth investing in? I hope I have convinced you that the growth potential is there, it is even unprecedented, it is driven by tighter legislation, and the market will double by 2025. China is becoming a pace-setter and we are convinced that through our very strong technology in gasoline direct injection and through our competitive technology in heavy-duty diesel, in our cooperation with our heavy-duty diesel customers, we are very well positioned to take an over-proportioned piece of that market and of the doubling of that market.

Thank you very much. Now we will open the floor for questions.

Q&A

Evelien Goovaerts: Thank you, Pascal. Mark, you are invited back on stage for the Q&A. If you have a question, could you raise your hand and we will bring the microphone to you? Could we also ask you to stand up while you ask the question and please state your name and company before asking your question? We have half an hour, so we should have sufficient time, but could I remind you to kindly limit your questions to one question per person, so we can give the chance to everyone to raise their questions. Who is first?

Sebastian Bray (Berenberg): Good morning and thank you for taking my question. Could I start, please, with one on the capital intensity or capital demands of potentially outgrowing the business in market growth in auto catalysts until 2025? How much growth capex are you going to have to allocate to this business and what is the rough maintenance figure that you would give?

Sorry, I know you asked for just one question, so this is just a point of clarification. When you mentioned that the market for light-duty auto catalysts, I think, will be worth 9 billion, is that dollars or euros? Thank you.

Pascal Reymondet: On your question on capex, I cannot give you numbers, but the key element of our business model is operational excellence. By operational excellence, we mean doing more with the same. The biggest portion of the capacity required for this doubling of the market will be provided through operational excellence: doing more with the same. There will be capex and I will leave it to Mark to give numbers, but the business will remain very strong in terms of cash flow generation.

Marc Grynberg: Before I take over, Pascal, can you clarify if the 9 billion is in euros or dollars?

Pascal Reymondet: Euros. Current euro, in 2025. I do not know what the euro will be in 2025.

Marc Grynberg: Let me add a little bit of colour on the capex and remind you that we have invested a lot to modernise the catalyst production and research-investing configuration over the past several years, which means that today we enter this new growth phase with very modern facilities – state-of-the-art facilities, with state-of-the-art capabilities – and state-of-the-art research and testing facilities as well. There will be continued investments and not more than what we invest today, which means that the cash-flow generation in this very fast growth phase is going to increase, in a way, because capex is not going to follow the pace of the revenue growth. Capex is going to stay more or less in the same region as it is today with significant revenue and profit growth, which means that the cash-flow profile of this growth business will stay quite unique.

Mutlu Gundogan (ABN AMRO): I have a question on your margins. If I look at your R&D spend in a very long time period, it has actually gone up as a percentage of sales, with the increase in the value of the markets and the potential increase in the scale of your business. Do you expect it to come down before your margin will go up?

Pascal Reymondet: Yes. R&D will increase, because all this legislations cannot be met without work, and as we have shown, they are creating value, but R&D will increase at a

much slower rate than the revenue. The R&D quarter will be much slower in 2025 than it is today.

Adam Collins (Liberum): I had a question on the commercial development on the HTD side. Your regulatory roadmap shows that in the US, we only have GHG emissions through 2025. I wondered whether that would be sufficient window, in terms of regulatory change, to enable you to enter the market in a bigger way.

On a related note, you talked about Haldor Topsoe. It might be helpful just to have a better understanding of the profile of that business. How much of that business is off-road versus on-road and what kind of scale-up in revenues for the HDD business did that provide? What is the size of that business relative to the existing base?

Pascal Reymondet: On North America, the future legislation is a bit uncertain. There was a greenhouse gas stage two. Whether that will come or not is not 100% clear. You are right that the timing of the legislation is not giving us an easy open door to this market. That is true. Customers have a system that works but we are in cooperation in development programmes with some big US customers. There is willingness in the market to see Umicore supply the American market.

Marc Grynberg: Whether that results in business remains to be seen, so today, and we have mentioned that a few times, as a late entrant in the segment, we were too late an entrant in the North American market because the main decisions had been made by the 2007-2010 timeframe, which meant that we were too late for that market and this explains our very limited position today, and indeed, we are not trying to penetrate a given market at any price. That is obvious, because we are not driven by market shares, we are driven by profitability, so we need a window of opportunity to open up for us.

There may be one and we will see how that plays out, but that remains way more uncertain compared to the developments that Pascal has highlighted for the other regions when it comes to HDD.

Pascal Reymondet: What is important is that we are truly recognised now by the American OEMs. We have technical programmes with these customers, but I do not expect sizeable business before 2023 or 2025.

Marc Grynberg: Could you also elaborate on what the Topsoe acquisition brings?

Pascal Reymondet: Yes. With Haldor Topsoe, we bought two businesses. We bought catalysts for heavy-duty applications and catalysts for stationary applications. The heavy-duty part of the business is 90% for on-road application and increases our market share by about 30%.

Chetan Udeshi (JP Morgan): You presented a very bullish case on growth in this market. EV is happening as well. How are your auto OEMs reacting to this? It seems like they have to spend on EVs, they have to spend on this side of the business as well, so clearly the spending for them is going up significantly. Are they putting some of the pressure on suppliers like yourself?

Pascal Reymondet: You see customers reorganising. Marc mentioned that the platforms are getting bigger. In diesel, there is less development happening. There used to be many, many different diesel platforms. Now, customers are basically focusing on one platform, for

the purpose of exactly that: saving resources. Diesel development departments in our customers are getting smaller. You can see some of them even merging with gasoline, and all that for the purpose of allocating more resources for electrification. On margin, because of this drive for new technology and this more stringent legislation, our expectation is that the margin will stay constant over the foreseeable future.

Marc Grynberg: There is pressure, of course. In every segment, there is pressure: there is customer pressure, there is competitive pressure, but that is not really changing compared to what we have been used to for so many years, operating in these industries. What really is changing is the fact that there are customers who, in order to save development costs – because, as you rightly point out, these are huge – are streamlining significantly their development efforts, and that is why I mentioned earlier the few examples of those customers that have done that in a drastic manner by abandoning a certain number of development avenues, like abandoning diesel altogether so that they can indeed focus more development and engineering resources to electrify drive trains and gasoline.

The most significant way for the industry to address the move to clean mobility from a development customer point of view is by reducing the number of options nowadays, while until three or four years ago, all options were kept open.

Celine Tan (GIC): Pascal, thank you very much for outlining that, for example, the addressable value for Umicore in a plug-in hybrid is 1.5 times the value in an ICE. I think that those are very interesting stats. This is perhaps a request that may be addressed later on in the day. Could you address the addressable value for the entire of Umicore for the different types of potential vehicles in the future, e.g. battery EVs and fuel cells? Other than automotive catalysts, what is the addressable value for the entire Umicore? I think that would be very interesting.

Marc Grynberg: Celine, I will ask you to bear with us, because I want first to go through the other presentations regarding what we do in respect to electrified drive trains, and then we can talk about that. This being said, I will not mention any figures about the addressable market in electrified drive trains, because there are too many estimates and projections circulating today. There is still a pretty wild range of projections and I think I prefer to look at it the other way round, by looking at how Umicore is outpacing the market growth in that segment, while it is indeed still difficult to make out today how big exactly that segment will be. Now, many factors drive the value of that segment and these factors will be outlined later today, so please bear with us.

Charles Bentley (Bernstein): You talk about the importance of China. Looking at your customer mix, one thing that you noted at full-year was challenges with Korean manufacturers in China. I was wondering if you could explain a bit more about your positioning with both local and foreign customers there.

Pascal Reymondet: Thank you for the question. There are also some major changes since 2015. It is true that in 2015, we were highly dependent on our current customers in China and we have strongly rebalanced this situation, which allows me today to say that we are growing market share in China, because we have rebalanced. We have a much bigger share of European customers in China. We have a much bigger share of American customers in

China. We are also growing with local Chinese customers. I feel much more comfortable now with Umicore's customer portfolio in China than with what we had three years ago.

Marc Grynberg: What we have also seen developing in China is that until a few years ago, or until now, many domestic Chinese car producers were actually using domestic catalyst producers, and with the move to China V, and to a much larger extent with the move to China VI, these Chinese catalyst suppliers are being phased out because they do not have the technological capabilities to provide the systems that meet these very stringent regulations.

Please bear in mind that the China VI regulations are going to be tighter than Euro VI regulations, so there is a shift away, for domestic car makers, from Chinese suppliers to the global catalyst players, and given our very strong position in gasoline technologies, and in particular in GDI-related technologies, which are starting to dominate the Chinese passenger car market we are indeed benefiting vastly from this development. We are starting to have a very well-balanced portfolio between the global brands and the local brands in that respect.

Pascal Reymondet: I did not mention this, but we are also growing with the Japanese OEMs.

Wim Hoste (KBC Securities): I have a question on hybrid vehicles, which I think in terms of temperature management are quite a challenge for catalysts. Given the growth expected in the EV markets, can you maybe explain how your technology is specifically for hybrid vehicles and what kind of market share or prospects you see in that part of the market? Thank you.

Pascal Reymondet: I cannot give you any specific market share on plug-in hybrid. What you say is correct. Thermal management is a lot more complex, with the cold start adding stress on the catalyst system, and the message I want to leave here, which I presented earlier today, is that a plug-in hybrid vehicle will require about 25% more catalyst than the equivalent non-plug-in hybrid, and we will very soon have the technology to address these cold-start type of running conditions.

Marc Grynberg: If I may add one point to that – and please correct me if I am misrepresenting technological developments – in the first instance, when car-makers thought to introduce plug-in hybrid vehicles to the market a couple of years ago, they realised, of course, this issue around the cold start and repeating cold starts with plug-in hybrids, and they addressed that typically by overloading the catalysts with PGMs, which by definition, from a cost point of view, cannot be a good solution. So the technologies that we have developed are meant to actually reduce substantially this PGM loading and address the cold starts through sophisticated methods, not just by pouring more PGMs into the catalyst.

Charlie Webb (Morgan Stanley): Marc, I have a quick question for you, going back to your initial presentation around battery recycling. What type of scale of investment do you think is required there for that big growth opportunity, first off, and also, how competitive do you think that market is? Clearly a large part of the supply chain is worried about cobalt as a scarce material, so do you see that market as being very competitive, or do you think that you have technical expertise that will differentiate you there?

Marc Grynberg: We are talking about large investments, so triple-digit million investments required to build recycling facilities, and to build industrial-scale, or larger industrial-scale,

recycling facilities for lithium ion batteries. It is going to be a very, very large market opportunity revenue-wise, and we believe indeed that we have technology that can allow us to be competitive and profitable and justify large investments going forward. Our process is different from what we see from the competitive landscape today. We are one of the few players, or probably the only player, to use high-temperature processes for recycling, which drives the recovery yields, so we are very efficient in terms of recoveries, not only in terms of yields, but also in terms of the scope of metals that we can recover from the recycling process. Therefore our investments are possibly going to be larger than those of competing technologies, but they are going to be far more efficient in terms of recoveries and in terms of profitability.

One of the other advantages that we have is that a growing number of customers are looking to have closed-loop solutions, and we mentioned already a number of years back that this was going to be probably the ultimate model, and now we see that shaping up in a more pronounced manner. Because of the growing scarcity of certain materials (such as cobalt, as you point out) and because of the need for more traceability, closed-loop is one of the favourite avenues for a number of leading OEMs, and so the fact that we are present upstream of their requirements with the battery materials and downstream at the end-of-life with the recycling solution, will be or should be a competitive advantage in the long run.

Dominik Frauendienst (Ayora Capital Management): Marc, I had a question with regard to your 2020 guidance in light of the comments that have been made so far. You talked about an increasing contribution from the recycling capacity expansion, you talked about outpacing the EV market through your battery materials business, and now what Pascal has walked us through, more than doubling of the market value for catalysts and you taking disproportionate shares, so outgrowing that market as well. If we take what we know today, the guidance for this year, which suggests about 30% EBIT growth, and then walk out to 2020, it would suggest that that EBIT growth goes down to about 15% for each of the next two years.

In light of those comments, however, I was wondering why we should see such a deceleration in EBIT growth. Now, it is still very good EBIT growth and I think a lot of companies in this sector would be very happy to have that EBIT growth, but in light of the comments, I'd like to understand why we should see an almost 50% drop in growth. Thank you.

Marc Grynberg: First of all, thank you for pointing out that many companies would be happy with that and I share your view indeed that this is a pretty enviable position to be in. First of all, let me clarify that what has not changed is our view about the contribution of recycling to the growth. This is fully in line with the assumptions that we made three years ago when we set out the target for 2020. So the comments that I made today about how the ramp-up is proceeding etc., does not imply that we see things differently from a contribution point of view comes 2020.

The main change compared to the 2015 assumptions for 2020 is definitely coming from battery materials and the vast acceleration in demand and/or ability actually to step up and accelerate our investment plans, compared to the assumptions that were made three years ago. That is immediate contribution indeed, and that is explaining the most significant increases this year and for the next couple of years. What Pascal explained about catalysis is going to have some contribution to the revised expectation for 2020, and this being said,

please bear in mind that the doubling is horizon 2025, so if you remember the graphs that were presented, most of the value increase is beyond 2020. There is already some value increase by 2020 but most of it is coming after 2020, between 2020 and 2025.

My last comment is about the non-linearity and that is a theme that I have probably highlighted many, many times in the past. Growth in revenues and growth in profits is not linear and this time is no exception. It is not going to be linear, especially as we are putting a lot of investments in the ground, which means that every time we start a green field, we have a front-loading of capex and a front-loading of fixed costs as well, which explains why the growth in earnings is not following a linear pace relative to the growth in revenues. But still, it is pretty enviable growth in total, I bet.

Geoffrey Haire (UBS): Good morning. I just wanted to ask, given the changes you are seeing in the automotive catalyst market moving away from volume growth to more value content in the car, are you seeing changes in the competitive landscape in terms of what BASF and Johnson Matthey are doing in this market? Are you seeing much more competition and more aggression in terms of what your competitors are doing?

Pascal Reymondet: Again, the success factor in this business remains technology. We are very much focused on developing the right technology, and if you have the right technology, yes, there is competition, but at the end of the day, if you have the right technology you can prevail, and margins, as I said, are expected to stay the same.

Marc Grynberg: Maybe I can add a little bit of colour to that. Overall, we are not seeing massive changes in market shares. They have been relatively stable over time and continue to be relatively stable. However, the mix is changing, so within the distribution of market shares among the global players, we see significant shifts, with one player gaining significant share in light-duty diesel applications and Umicore becoming a smaller player, and next to that Umicore gaining significant ground in gasoline applications for passenger cars. The mix change is more evident than a change in market shares globally, and I think that this is one of the points that we wanted to highlight today, because if you look at that next to the evolution of engine mix, this has an implication on the overall positioning of Umicore relative to our competitors.

There is one thing that I would like to add to make sure that there is no misunderstanding about how we see volume versus value. The point that we wanted to make today is that we do not want to really debate about volume assumptions, because volumes are going to be what they will be, in a way, and you will use your own assumptions and your own data providers in order to model these. The point that we wanted to make is that if we are off by 5% or 10% on the volume assumptions, this is going to be marginal compared to the uplift in value terms per vehicle, per engine. This is really the key underlying message.

Jean-Baptiste Rolland (Bank of America Merrill Lynch): Marc, you have just highlighted that it is quite important in that business to have a distinctive technology and the mix, as you said, is changing in light-duty vehicles. I am just wondering how you see the market share change evolving throughout the years in heavy-duty diesel catalysts. I understand that you have mentioned that you have a distinctive technology. I am still not quite clear what this distinctive technology is. I understand that the US market has, for historical reasons, maybe

not always been easy. There are regulations which have not yet opened a window of opportunity.

Yet the perception is still that heavy-duty diesel is, let us say, a less strong area for Umicore. Would you say that that is a misconception or could you perhaps highlight where you have a distinctive technology that is going to help you gain market share in this business?

Pascal Reymondet: In heavy-duty, the market growth potential is mainly happening in China and there is so much work for OEMs to develop these catalyst technologies that having a competitive technology, I would say, was sufficient to participate to this growth. That is what we have. I am not going to say that we have a better technology in heavy-duty diesel. I am not going to say that. I said that for gasoline direct injection. I will not say it for heavy-duty diesel, but this competitive technology in this fast-growing market in China, where customers need all the help they need, is sufficient to build market share in China. In America, it will take more time.

As Marc has mentioned, we need an opportunity. Opportunity can come with unique technologies, which we do not necessarily have today, besides maybe what we bought with Haldor Topsoe, and opportunity can come with a customer wanting to make a change. Opportunities will come, so with our current competitive technology, we have what we need today in the current business environment to participate in growth.

Marc Grynberg: If I may add, I just wanted to say that I am glad to see that Pascal was so keen to take your question on HDD, because I initiated the business in 2006 and it is good to see that Pascal has now adopted my baby. This being said, I would also like to make sure that there is no misinterpretation of what we say about the progress that we make in heavy-duty. We will remain a smaller player than the leader in this market, even by 2025, and even if we seize very, very successfully the opportunities that Pascal has mentioned. As a late entrant, again, we are driven by winning profitable business and not by winning market share at any cost.

Max (Occipital Capital): I have a question. You mentioned that you are gaining market share from the Chinese domestic gasoline catalyst producers, because obviously their technology is not as good as yours and you are way ahead of them. But when I look at what China is doing in terms of how they are driving leaders in EVs and in batteries and in NMC producers, who are the Chinese leaders in gasoline catalysts and what kind of market share do you have today and what do you expect in 2025 in China?

Marc Grynberg: The catalyst leaders in China are very clear: that is, Umicore, BASF and Johnson Matthey. There is no way around that and the Chinese domestic catalysts suppliers are marginal suppliers in the overall landscape. I do not want to pre-empt too much the discussion of later today regarding the battery materials, but clearly the leading Chinese supplier of catalyst materials is Umicore. China is technology-driven, like other markets. It is not nationality-driven, in terms of market shares and government attitudes.

We are not disclosing market shares and actually, again, the reason we are not commenting on market shares is twofold. First of all, there are too many definitions and conventions about defining market shares, depending on whether you look at it from a volume point of view, from a revenue point of view, or from a profit pool point of view, and typically that ends

up in the sum of market share claims exceeding 100%, so I think it is not always a very meaningful metric.

Secondly, and more importantly, we are not driven by market shares. Scale is important, clearly, but I do not want us to set market share objectives because again, profitability is more important than market shares.

Speaker: I have a question on the technical leadership in particulate filters that you have touched on here, and also Marc has talked about being a driver to market share gains on recent calls. I just wondered whether you might be able, in simplistic terms, to explain the technology advantage that you have that is driving this. I know it is a complicated subject, but just to get a sense of where the competitive edge is.

Pascal Reymondet: I suppose the first thing is the customer feedback we get. Customers are highly positive about the products we supply. Our gasoline particulate filter (GPF) offers different functions and this multi-functioned aspect means – and I do not want to get too much into the details – that there are different parameters you have to deal with, with the filter. You have to deal with filtration, you have to deal with back pressure, you have to deal with activity, and you have to deal with other parameters, and the combination of all these parameters means that our products, if I look at the feedback from the market, are very competitive at addressing all these different parameters of the customers at the same time.

Marc Grynberg: If I recall the early days of developing these GPF technologies, I remember that there was a discussion a while ago about whether the focus would be on particulate number or particulate mass, and unlike a number of other players, we have declared from the outset that we did not know whether the focus would be on particulate mass or particulate number, and because we did not know, we chose to develop in all directions and make sure that we would cover both the mass and the number, and that is why our filters today have a better, I would say, overall performance, because they cover indeed not only the chemical activity, but also they cover the filtration efficiency in a broader manner and a better manner than competing technologies.

Sebastian Bray (Berenberg): Could I please ask one follow-up question on margin development? Pascal, I think you mentioned earlier that if diesel market share were to, say, drop to 10% in Europe by 2025, you would lose about 25% of the growth. Please correct me if I am wrong. However, if the electrification trend takes off to a greater than expected extent or diesel falls faster than expected, to what extent is your operating leverage in this business and how do you think you will be able to protect your EBIT margins? Thank you.

Pascal Reymondet: I want to correct one thing. Our prediction was not a prediction. The marketing study consensus today is about 30% market share diesel in Europe. I just said that if it happened to be 10%, it will not change the message that our business would basically double. That was the message. Is it going to be 10%? Is it going to be 30%? Nobody knows. But whether it is 30% or 10%, the business will double. That was the message.

Marc Grynberg: Because actually, if it is not 30% and if it is 10%, the impact on the market value – and we are not talking about the Umicore position – is 5%, so that is why it does not change the overall message of doubling. This being said, I would like to add two elements of response. One is that our market share position in light-duty gasoline, and in direct injection

engines and gasoline particulate filters in particular, is so much stronger than in diesel that actually we would not see an impact of a faster decline in diesel sales on the automotive catalyst business.

Now, if we look at Umicore globally – and I mentioned this on previous occasions – the faster the diesel decline, the better off we are, because first of all we compensate significantly through better sales of gasoline particulate filters or gasoline configurations with the filter, and secondly we benefit disproportionately from the higher number of electrified vehicles that would have to be brought to the market to make up for a lower diesel market share, because you know that diesel has a CO_2 advantage compared to gasoline, so if car OEMs sell less diesel cars in the mix, they will have to compensate for that through more electrified vehicles.

I think you should basically ignore how it would impact the automotive catalyst activity on a standalone basis and keep in mind that the broad picture that Umicore benefits directly and significantly from a faster decline in diesel. That is why we did not want to have a discussion today – and we are not really in a position to have a discussion today – about whether it is going to be 30% or 25% or 35% or 10%. We do not know and we are using market projects. We do not know because at the end of the day, the consumers will choose and we will see how that plays out. I am just happy that our position from a technology and market point of view, as I highlighted earlier, is such that we would benefit from a faster move to cleaner mobility.

Pascal Reymondet: If I may make one more comment, I get that question from my employees – the employees working for Umicore in the automotive catalyst business. We tell them that the business will double between now and 2025. You say, 'Pascal, it sounds good, but I am 40. In 2025, I will be 47. What is happening then?' And now I will take an even more long-term perspective. I say that we need combustion engines. Combustion engine today, production worldwide, passenger car, is about 90 million. It is expected to grow to maybe 100 million in 2025. This is small growth again – 90 to 100 – still doubling the business. And then long-term perspectives see combustion engines maybe going back down to 90 million in 2050.

But in 2050, almost all passenger cars will be completely plug-in hybrid, this would be 90 million, and on top of the 90 million you have full electrical cars and you have fuel cell. I will give you the answer I give the employees working for me, which is that combustion engines will still be there in 2050, so if you are 40, you are okay.

Marc Grynberg: I would say that even if you are 25, you are okay, because Umicore is so well-positioned that in a way, we are not concerned about where the engine mix is going as long as it is going in the direction of cleaner mobility, because that is what we are betting on.

Moderator: Thank you for your questions. You will have plenty of opportunities to interact with management later today and tomorrow as well. We have a break now and we will come back in half an hour, when Kurt will kick off his presentation. Thank you.

[BREAK]

Evelien Goovaerts: Welcome back. We're ready to continue the presentations. Maybe one practical thing, because I got some questions – all presentations will be uploaded or are being uploaded already on the corporate website. So there is no need to take pictures. You will have access to all the material.

So I will now hand over to Kurt Vandeputte, who will talk about the widening gap in rechargeable battery materials.

Rechargeable Battery Materials

Kurt Vandeputte

SVP, Umicore

Increasing the gap in Rechargeable Battery Materials

Thank you, Evelien. Can everybody hear me at the back, as well? I see. Good morning everybody here in Seoul. Good evening, the people in the US following through webcast. I almost don't dare to say welcome to the European listeners, because it's probably a terrible hour over there. Nevertheless, if there are brave people in Europe, welcome. My name is Kurt Vandeputte. I'm Senior Vice President for Umicore's Rechargeable Battery Materials and, in the next hour or so, I would like to help you understand how we are going to increase the gap.

When you say increase the gap, you can think of a lot of things. We think of increasing the gap with our products, our technology, our enthusiastic people. But I would like you to think about increasing the gap – by the way, who is driving in the audience an EV or a pHEV today? I didn't expect anything less than that, so that's more than the penetration worldwide. So that's good.

When I talk about increasing the gap, ladies and gentlemen, think about leaving at the traffic light and letting – sorry, Pascal – an ICE-based Porsche behind. That's increasing the gap. That's how electrification feels. And once you've gone electric, I see barely no people go back to standard transportation modes.

Closing or increasing the gaps – sorry. You warned me, Evelien. Nevertheless, my presentation is basically structured the same as Pascal's. I will start by setting the scene, explaining about the business profile of the day, what is our daily environment that Umicore's battery materials team is working in. Later on, I will explain where that acceleration is suddenly coming from. We all expected the market to increase but, nevertheless, hundreds of smart people misjudged it for years and we were all taken by surprise by the speed.

Thirdly, I want to focus on why is Umicore's RBMs, why is Umicore's battery materials business so successful? I'm 20 years in this business, so I think I have a fair credibility to look back and to explain or try to explain, at least, how I feel we made it to the position of today and how I hope that with the talents, with the motivation that we have, the technology that we master, how we are going to further increase the gap. And last but not least, of course, the key takeaways to conclude.

I have been 21 years with the company. Since day one, I was either directly or indirectly involved with Umicore's battery materials project. This means in reality that I've seen a

project team with one young PhD material scientist and two researchers grow into a business unit of more than 1,000 people. That's the reality. That's the journey we've gone to. That's where we are. And believe me, this has not been through a very aggressive pricing model. This has been through the use of brains of people. This has been through technology. Technology and innovation is driving our current and future market presence.

20+ years of innovation in li-ion battery materials

This is a timeline of the last 20-25 years and without going into all the details, I mean the presentation is going to be available. I invite you to go and explore that later on. But I will highlight a number of dates, the ones in red.

1995, a team within Umicore starts to look into an application that we are serving with cobalt chemicals. We are serving the Japanese market with cobalt oxide, in the past a chemical used for the pigment industry or the catalyst industry. Suddenly there is a use in Japan and Asia for electronics sector. It seems to be – it is a cathode material for lithium ion, a very, very promising market at that moment in time for portable electronics.

And soon, we realised the value was not in the chemical. The value is in the active electrochemical component. And that's how we started and that's how we tumbled into this industry.

1998, I remember, vividly, one of the very first product meetings that I attended was a product review where we were evaluating different chemistries. What is the potential of different chemistries as a cathode material? What products did we evaluate in that meeting? Lithium cobalt oxide, NCA, NMC and LMO.

In early 2000s – so I want to correct maybe a wrong perception living now in the market, that high nickel products are the products of today and the products of tomorrow because there is more energy inside. No, ladies and gentlemen, no. NCA was actually the very first mixed transition metal component layered oxide that has been studied. The oldest patents have expired. That's the reality. Why did such a promising material never make it to the market? Very simple. Because the product doesn't or was very difficult to be applied in a battery, in the form factor that the battery makers were using or that you and I were using in our first mobile phone.

The product was not matching the application. And if that's not happening, if the product doesn't match the application, there is no application. If there is no application, there is definitely no customer. So this is really what you have to remember. It's all about having a product that, of course, works, but that is fit for the application. And I will come and elaborate. I will really discuss more about that in the next couple of minutes.

We can go a little bit faster now over history. In 2003, we produced the first NMC materials that are today the key products in our portfolio. In 2003, we made the first 5, 10 and 50g of these materials. 10 to 15 years later, these products go mainstream. I invite you to analyse the battery industry. Many, many technical-reference people will always say it takes 10 years to get a product from lab bench into mass-scale production. This is the right example. This is also saying the same thing. It's not because it's NMC. It's not because it's LCO. You see exactly the same happening with other chemicals.

2007, I was enormously excited when we were or when the first track – left this Korean plant that you will see tomorrow – left for our customer overseas to produce the first EV batteries. That was a prototype series for one of the big OEMs still around and Umicore material was inside. That was the start of NMC in automotive.

2011, I highlight this year because in 2011, based on years of technical research, we decided to buy an IP portfolio from the company, FMC, which was a former competitor of ours. They left the business but they had to our understanding, a critical piece of IP. In this industry, IP has become key. I will come to that later on. That was the start. That is basically the foundation for our high-energy LCO products that we have developed and that we are currently still selling to the portables.

2012 – please rewind mentally 10 years, let's say seven years back. At that moment in time, the industry had absolutely not decided which technology they would use as a cathode material. Automotive industry had not decided what kind of battery technologies they would use for which different sub-segment in their portfolio. That's why we started our work on lithium ion phosphate. Lithium ion phosphate has some really specific product performances that are very interesting for certain applications. The product, the components are cheap, iron, phosphate. They are abundantly available, so everybody has access to it. There could be a huge potential for that.

Now next bullet, 2015, I'll immediately focus to the bottom one. We decided to focus on LCO and NMC. Also, this is innovation. Innovation is daring to focus, is daring to explore things but at a certain moment in time you also have to close those. You have to say 'no'. And there is always a customer trying to convince you that you should continue. There is always one who wants to seize the opportunities, but in the end you have to make your own opinion based on data, based on experience.

And then the last one, 2017, I want to conclude here the innovation, history lesson, 2017 was for us also a very important and critical year because we complemented, we expanded our IP portfolio for NMC. You all know, we had first the license on the 3M IP. We finally acquired that IP and then, in 2017, we complemented that with ANL IP and less-known but, nevertheless, quite important for us, we bought also an IP portfolio from a company, CSEM. This is a Japanese joint-venture that stopped operations, but that had both for NMC precursors as well as for NMC materials quite critical IP.

So what I want you to remember: it takes time to build your technology position in this field. It takes time. You have to be quite perseverant or you have to show perseverance to get where we are.

Business model

Just like Pascal, I can show slides that I've shown three years ago in London, as well and actually it's not because I wanted to save time to prepare it. It's because it works and I'm proud to work under such a business model. Our business model fits perfectly in the business model that Marc has presented for the group. We work with metals. We work close with the customer to develop active materials that provide a functionality and we bring this to market in the fastest possible way. I hope you agree with me that, at this moment in time, speed in the battery materials world is of strategic advantage.

Last but not least, we have an integrated process flow. Integrated process flow means that we basically – and I come to that in more detail, but I want already, somehow, to define the criticality of that. When you make cathode materials, take NMC as an example, you are combining four critical metals: of course, lithium and then nickel, cobalt, manganese. All of that has to come nicely together at the right moment in time with the right quantities, at the right price. And it's not because pure cobalt metal today is the most competitive form of cobalt you can buy, but it will not necessarily be the case tomorrow. Things change over time. It's function of supply and demand, depending on how that evolves in the supply chain. And it's because of that integrated supply, together with the recycling, that we have such a solid and intensified supply chain.

In the end, supply chain for such cost-competitive, critical components in these applications, full-supply chains are going to compete. And we are part of the cost competitiveness of our customers.

Battery market projections

We have an exciting market in front of us. We are basically defining three sub-segments. First of all, the lithium-ion battery market is serving the energy storage systems. Energy storage systems go from a kilowatt or a couple of kilowatts hour, all the way to megawatt hour systems that are connected to the grid or that are used as a back-up, out in remote areas.

This market is going to grow. I think industry observers are at least agreeing that this market segment is, at this moment in time, the most difficult to predict. You see quite a bit of variability in size. In our predictions, we see this going to 40-50-55 gigawatt hours in 2025.

The second market segment is portables. So let's say the oldest, the historical segment, where we are present with our high energy lithium cobalt oxide. This market continues to grow. We, as individual customers, we all like to buy more gadgets. We like to buy phones with bigger batteries inside. We like to talk more. We like to stream more, which translates to a continuously increasing battery capacity for portables.

Three years ago, I presented at that moment in time, younger and proudly and enthusiastically, a market potential for transportation. And I kind of left a bit of flexibility and I presented two cases. I presented a base case and I presented a high case. And today, I'm actually here to confirm that even that high case was by far not high enough. So Pascal is saying some markets are growing strong or even stronger. Well, I don't know what else I can use, but I think this is even stronger than strong, Pascal, sorry.

This is, let's say, transportation for passenger cars. But on top of that, you have, still, the heavy-duty segment. So buses, trucks, garbage collection and so on. Heavy duty is the smallest segment, nevertheless important.

I told you, at a certain moment in time, you have to focus. Well, from now on, I'm going to focus my talk on the green part of the graph. So from now on we talk about transportation, I will focus there. And in our case, transportation means NMC-type cathode materials.

Accelerated growth in Electrification

Where is that growth acceleration coming from actually? What has changed compared to three years? How have we maybe been misled or what kind of ideas did we have in the past that were completely wrong?

Well, honestly speaking, not that much, but the regulator has further pushed the button. And I'm going to give a bit more details on two important regions. Pascal has three important regions, I focus on only two. The two regions are actually the same. I will focus on China and then, Europe.

So what has changed compared to three years ago when we met in London? That is amplifying, that is accelerating, actually, electrification. Let's have a look in China.

Intensified regulatory push in China

The Chinese government is rolling out a two-track promotion subsidy incentive system for electrification, two tracks. The first track is impacting or is influencing the car makers. And that's through a new credit system that they launched in April this year. This credit system is promoting actually higher technology, higher driving range, higher performance vehicles.

The target of the government is, partially through this credit system, to increase the number of NEVs, so new electric vehicles, to increase that number to approximately 5 million by 2020. With this number, China is going to be 40% or more of total xEV market. So this slide alone shows the critical importance of China as a target market.

The second element of the policy is the subsidy system. The subsidy system basically helps the consumer. And for the NEV cars, it's basically similar in a sense to the credit system, similar in a sense that they promote higher performance, better batteries, higher energy density. That's the target. And we've seen the similar system for e-buses. Higher range, higher subsidy, better batteries, better energy density, more subsidy. So it's all about improving the technology.

What is the consequence of that? Four years ago, the Chinese government basically promoted LFP cathode systems for electrification. Now they switched 180 degrees. With the new policy systems, basically, they promote NMC because of higher energy density. And that is an enormous driving force for our market.

Intensified regulatory push in Europe

Let's go to Europe. We all know CO_2 emission regulation goes in one direction, less. We have to produce less CO_2 per driven kilometre. The target is 95 g/km in 2021. The numbers published by the European Environment Agency for 2017 show an average emission of 118 g/km. This is higher than 2016. Everybody is expecting now that, even for this year, the numbers are going to further increase, not decrease as the target is, increase, because amongst others, the impact of fewer diesel cars being sold.

The regulator in Europe has also established what we call a super credit system. As of next year, car OEMs will get for electrified cars, so really low CO_2 emission emitting cars, they will get double credit. They have four years to build up credits that they can use later on in the 20s to compensate and to include that in the calculation of their average CO_2 emission number. So, this is critical for them. It's not a coincidence that as of next year, you will see a lot more low CO_2-emitting cars coming on the road. This is the background.

With all the measures, we expect the European region market to account for about 30% of total electrified cars in the future. So China about 40%. Europe about 30%. Total, we talk about 70% of market potential. So if we look at what happens in these markets, we really have a good view on where this is going. And this is partially the background of the acceleration.

Legislation triggered electrification

It's not only legislation. It's also perception of society and, very important, it's the change of strategy of the car OEMs. Until a couple of years ago, it was – I almost dare to say – denial, compliance, but now you clearly see that the strategy is changing with the car OEMs. They embrace electrification. They make it a part of their strategy for whatever reason, because they have always followed a performance strategy, because they have to make up for things that went wrong the last couple of years. But nevertheless, I bring here a couple of quotes.

Your representatives for, let's say, global car market, you see the brands from all over the world and they basically all say the same. 'We go for more electrification in whatever degree that might be.' It's not only more electrification. It's not only more cars. It's a very complex situation to be a CEO of a car company today. What do you have to prepare for?

With all the customer questionnaires they have, all the marketing teams they have, honestly speaking, none of these smart people know today what we, as a society, are going to buy in the next seven, eight, ten years for electrification. So what can you then do? Open the options. Keep your options open and be prepared for either long-range EV and, let's say, a lower-cost, more compliant-type car with a 48-volt complementary system on your ICE engine that reduces CO_2 emission by 50%.

So all degrees of electrification are open and let the customer decide in the end. This is what we currently see.

Success Factors

Coming back to success factors. What do we typically do? How do we try to bring value for the customers? What did we maybe do different than others in the last 10 years that gave us the position of today? And what are we going to focus on in the next 5 to 10 years to further increase the gap?

It takes a lot to play in the automotive league

The title says it all. It takes a lot to play in the automotive league. I compare that with soccer. Do you think that the teams playing in the European Champions League, all the teams qualifying for the European Champions League, do you think that there are low quality teams in there? No way. To get there, you have to be the best of your country, otherwise you don't get there.

Take motor sports. If you are a team of Formula One and even if you are doing sixth in the championship, do you have bad engineers? No way, you don't. But somebody was maybe a little bit smarter than you were.

The same is true in this industry. Supplying for automotive today, there is no low segment. If you supply to automotive today, whatever kilogram you sell there for cathode material, this is high quality and this is a high segment product.

What do they actually want? What do we have to supply? First of all, high quality. What is that? It has to be custom-made for different types of xEVs. I hope I already could convince you that there is not just one type of product or one type of cell that fits all. That means you have to customise your material. We have to provide that in massive volumes. We have to do that fast and flexible because you can make 10 plans for the next five years. You can be damn sure that it's going to be the 11th scenario that will happen a reality and you will have to reshuffle and you are going to ask as a car OEM, as a battery maker, you're going to ask flexibility from your material supplier.

We have to do that at a competitive price. This is the key component of a future car. It's the biggest cost component of future cars. There is no relaxation on price or on the cost price. There will be always pressure.

And last but not least, the materials that are being used serve a sustainable application. Amongst others, people are buying electric cars out of a certain conviction. If you do that, would you be happy if you hear that, in the supply chain, corners have been cut somewhere? No, you wouldn't. You would probably drop that brand the next time. So we have to bring materials with a very clear and clean ethical sourced, raw material.

What is Umicore setting against these requirements? I hope I can – together with you, we can go over all these numbers. I can tick the box. We supply. We sell. We develop different products, quality requirements. I have recently not seen any specification document being signed with our customers with less than 20 items. That's the situation today. It's different than portable electronics. The technical – the quality requirements go up by the platform just like the emission control limits get harsher, also for us, the quality requirements get more stringent.

We provide a wide family of products. I am happily inviting you tomorrow to show and to let you feel that we have very strong industrial capabilities that we know how to scale up. And then last but not least, scale is definitely bringing us – scale and technology are bringing us cost-efficient processes. And Marc, earlier on, explained that we are a front-leader in sourcing in a sustainable way our key materials.

Product, process and supply

Summarising on that part, what are the three key elements that I want to offer to our customers? It's product technology. It's process technology, because for long-lasting platforms this is going to determine the cost competitiveness and my cost competitiveness, and it's supply.

We talk about huge volumes, a car OEM cannot accept that you're going to do all this investment, that you're going to roll out electrification strategy if, after three years, they realise one of the key partners in the supply chain is just not able to deliver. This cannot happen.

I tried to visualise this a little bit more – talking about, let's say, an overall development cycle of a product. We start by synthesising different compositions, different products, couple of grams scale, really, in the lab. This is the starting point. Product technology, you introduce from the first 10 grams you make and it's not only cathode material. Cathode material is produced out of an intermediate. I can show you plenty of graphs where I make a correlation between some product parameters of the intermediate and you will see a perfect correlation

with the performance of the cathode material, after this product has been heat-treated to a certain level that you don't want to bear. And you will see tomorrow what that means, a heat treatment.

These products have a memory. Sometimes I get a bit nuts, right. But these products have a memory. They know what happened in their life before, even before they have seen 1,000 degrees. So you don't have to master only the cathode-making step. You have to master everything. You have to master precursor production. And a precursor is produced out of metal. I need pure metal. So all that comes together for me in product technology. I will do that for different grades.

Once you have an idea on 'I will make product X' and you see some interesting performances, you will bring this to scale. I've already mentioned right now in the development of electrification lithium ion electrification, speed is of strategic importance. A car maker is typically testing its cars over at least two seasons, meaning they do winter tests up north, in Europe, for instance, they do summer tests where it's very hot.

If something – or if you miss one deadline, the 12-month test cycle of a prototype is screwed up and it becomes at least 18. If there is something that today, me, as responsible of this business, do not want to go and explain to a car OEM development team, it's that I missed a time slot during the scale-up.

So scaling up product technologies right now is of extreme importance. And scaling up is not something you learn at university. I have done a PhD myself. I had no clue what industrialisation was. I dare to say that as a chemist. Scaling up is not something you read in published patents. Patents are about products. It's not about how you master processes. Scaling up is in the grey mass of 100 people at Umicore. That's where it's about. And I'm proud, also, to give these people recognition and somehow the floor, because in the end, it's thanks to hard work and perseverance, like I said, on the technology front that we are today where we are.

This brings us to industrial capabilities. I can waste 10 or 15 minutes here on trying to explain you what it means. That's not going to be half as efficient as seeing tomorrow what we are going to do. I'm sorry, I have now to apologise to the people following on the webcast, people here in Korea, we can at least give them the feeling, give them a flavour of what we do in reality and you will understand, in battery materials today, what scale means for Umicore. This is our definition of scale.

And, of course, our business fits perfectly in the closed loop model and also we offer more and more and we interact more and more with cell makers and car OEMs to close the loop. Closing the loop goes from taking back production scrap of the cell maker. Taking back of spec materials during packaging and pack making, it happens that things get off spec along the road. Or taking back crashed car batteries for now and finally, also, end of life batteries.

I am looking forward, as a battery materials developer, I'm really looking forward to receive more recycled batteries in our plant. For the very simple reason that it gives me peace of mind. I know where the material is coming from and I also know that whatever item I reuse is of the best and the highest quality I can ever buy. I've made it myself. I purified it myself and we do this in a way that allows me to produce high quality cathode materials.

Maybe today we talk about, I don't know, 10-15% that can be recycled, that will come back into the flow. As long as the market is growing stellar as it is today, it's impossible to feed the market or the new flow with recycled stuff. But as we go further, as we develop further, the fraction of recycled material is going to increase and is basically going also to help us in the sense to stabilise our quality and to further increase the performance of our products.

So being successful today is a combination of developing and timing product, listening to what your customer wants and then bringing that to scale in the fastest possible time.

Long wish list of users' requirements

Where do technical product requirements come from? If you look at the wish list – I made a wish list along the value chain for electrification and, then, I tried to translate that into product specifications. Sometimes I wonder myself as well, why the hell are you now asking again an additional requirement? Why do we have to measure that? To increase complexity? I hope not. To increase cost? Probably not. There must be good reasons for it. Let's go together through that.

If you look at the, let's say, the chain of customers we have below us, we have, of course directly the cell maker, then the car OEM, the regulator – somehow, it's a stakeholder. You can argue whether it's a customer, but let's call it a stakeholder. And then finally, the customers: you, me, my brother, my sister-in-law and so on.

The cell maker has certain requirements and his wish list, let's say, depends on technological choices that he has made. You have cell makers who have decided to make cylindrical cells or you have people who may decide to make pouch type cells. The type of cell they make is imposing certain requirements on the products and it can be completely different depending on what they have chosen. But the market is very diverse. People have chosen for 18615s or now 21700s like Tesla. You have people who go to 120Ah hard case prismatic. This is imposing completely different demands on our products.

Secondly, what kind of electrode technology have they chosen? How do they produce cells? You have people who wind their cells. So basically the electrode is bent slightly in a circle. You have other people who stack, so who cut the electrodes in pieces and really nicely stack the electrodes. So the electrode is never really bound together. That is asking, again, other things to me.

Can you imagine if some people are folding an electrode really 180 degrees, at the neck where the folding is taking place, your electrode, your material needs to be glued to the substrate very well and it has to show elasticity. If not, it just breaks and it peels off. Gone cycle life. So somebody who is stacking, he doesn't care because he is never bending electrodes. But he is cutting electrodes in the production process a lot. He cannot afford that; while cutting, product is kind of jumping left and right and contaminating all other stuff. So this may sound all very, I should say, trivial but industrially, if we talk about 700 GWh hour in a couple of years from now, this is not trivial. I invite you to be with the production engineers of a cell maker. They break, day and night, their brains on this kind of things. And that is imposing on how we should make and cook and design cathode materials. Commodities you think? I'm not so sure about that.

The solvent. Today the first thing that people do with our material is basically they make a slurry, which means they have a solvent, a liquid. They bring cathode material inside and

they make a kind of ink or a paint, you can compare it with a paint. The solvent today is an organic solvent. It's called NMP. Now, NMP is not one of the nicest chemicals, in Europe it's going to be put on the list of most severe chemicals and the end game is banning NMP.

This means that cell makers today are actively looking, certainly the ones who go and produce in Europe to change the use of NMP. It's hazardous. It's costly. You have to recycle, that so that makes their production quite complex. The most obvious solvent is water. It's cheap. Abundantly available. The problem with water is that nickel based products are sensitive to it or at least that the products are damaged by being in contact with water. We have developed technologies that really prevent that. We have shown – we are selling today cathode materials that are being used in water-based processes and coated industrially without any performance impact on cell.

Future technologies are even looking at eliminating solvent at all, so really printing cathode material on a dry basis on the electrode. These kinds of industrial decisions impose requirements on a cathode material producer.

And then, size. When you make, let's say, a 21700, so now the cylindrical cell, the most common cylindrical cell. The capacity is around 4Ah. So that's also why I put this one here on the slide. A shortcut in that cell is caused, typically, just by one micron size, a couple of micron sizes. One particle is killing the battery. If you produce a cell of 40Ah, so 10 times bigger than the cylindrical cell, the very same single particle is killing that cell, for short. What does that mean for me? That's the product has to be at least 10 times more pure to reach the same yield at the cell maker.

Please realise, in the future, people think about making cells of 120Ah, 150Ah. So today, commonly used already in industry is close to 100Ah. We will soon shift to 120Ah. So that means that for 120Ah cell, Umicore is making material that is 30 times purer than for, let's say standard use cylindrical cells. That's what I mean. Playing for automotive is playing, like, in the Champion's League. Tomorrow I invite you – the ones here, I invite you tomorrow, you're going to visualise that. We're going to show what that reality is. I am going to give – I am going to teach you a new expression for seeking a needle in a haystack. As of tomorrow, you will have a different nomenclature for that.

A car OEM, he has also a wish list and not just a small one: how does he approach safety, on a cell level or on a system level? That's a big difference from a material maker point of view. What kind of strategy is he deriving, compliance or embrace? Remember, stepping really massively into electrification means that he wants to offer, maybe, more performance. He wants to offer, maybe, a higher range. So, this is determining material choices. And another one that I would like to highlight is warranty. Warranty is for carmakers a big headache because there are huge liabilities involved. And it's very critical for them how they are going to approach the battery warranty. How are they going to achieve guaranteed performance after eight years?

You have people who do that by, for instance, introducing an active cooling system. Making sure that the battery runs during operation always at a very similar temperature. So by doing that, you are not stressing the chemistry inside. There are other approaches. You have people who say, okay, I will not use active cooling, but I will be on the very safe side in material decisions. I will not use a cell that is charged to 4.3 volts. I will stay at 4.2 and I

will have less capacity, but I don't add active cooling. So all these things really impact what kind of material choice you're going to have.

The regulator, I explained already what happened in China. It's very clear that the way the regulator further defines incentive schemes and so on is impacting technology choices on cathode material level, whether it – it's hard to believe but, in the end, that's a fact. The decisions taken by governments basically impact what kind of material choices we have to make.

And then, last but not least, the customer. What is important for us if we buy a car? Do we focus on TCO or maybe, for somebody else, range is of absolute importance? Most likely, if you go for a TCO offer, the car will have a different cathode material than if you would go for the absolute highest range, kilometre range. And who knows today, in five years or eight years from now, what we are all going to choose. I don't dare to place my bets on that.

Obviously, the car size: light-duty, high-duty, e-buses. The car size determines the battery size and, as I will explain you, battery size has an impact on what kind of materials you want or eventually even cannot use.

If you bring now all this together, for the different wishes from the supply chain or the value chain, you can wrap that up in a set of cell performance specifications: on safety, on capacity, warranty that they have to give, power, costs and cycleability. That's what it's all about and that's what we have to serve with cathode materials.

Cathode material specs to fulfil cell performance specs

How does that translate now? A cathode material has different specs and you basically can group them or bring them in two groups. The first group is what I call product specs. It's about how the product feel, smell, looks like. Of course, in reality, it doesn't smell and it's all black powder. You know what I mean? It's about physical things. What does it mean, physical things? Particle size. How much more than 5 micron or 10 micron or what's the largest particle that can be in a big bag of material? These kinds of things. What's the purity? What's the composition of NMC? How much nickel? This is a product specification.

The second group is about performance. As a material maker, I have to offer a product that gives a certain performance in the cell. I am not making the cell, but I have to guarantee that. What do we have to guarantee amongst others? Of course, safety performance, capacity performance, cycle life obviously. Cycle life is hugely determined by the characterisation of cathode materials. All these requirements and these requests basically ask for a tailoring of different chemistries and different products. When you read certain market reviews, market reports, technology reviews – I am kind of smiling in my seat in the airplane, that's typically where I read this kind of things – smiling when I see, when people say like there are four types of NMC. Come on, guys. There is more than NMC111 and 5362 and 811. It's just like the world is only four grades.

There is much more than that. There are infinite amount of combinations possible. I'm not advocating for this complexity, because I have our operations director in the back. That's a nightmare, of course, for the operations and that's not the way we want to go. But at least I want you to understand that within a family, a big family of NMC and even within NMC 111, you have so many sub-grades that all serve a different specific customer application.

There is no such thing as one xEV

Let me summarise a bit now, per segment of transportation and per performance specification of the cell, where I believe that different NMC grades are more or less suitable. And I have prepared this, a heat map for four segments: BEV long range, BEV mid-range, pHEV and then heavy-duty E-bus type. And the graph shows, from the left to the right, low-nickel NMC, so let's say NMC 111 – that's 30% of the transition metals or nickel – and, on the right side of the graph, high-nickel NMC. The end of my heat map or my heat part is really high-nickel. Think of 95% nickel. This is today being tested in labs. This is not being used in the industry at all, because the customers cannot handle that product, but I just want to show how things evolve over that nickel access. Because it's usually a very hot point of discussion in the industry.

Looking for long range battery EV, let me guide you through this one. If we look at safety, lower-nickel cathode materials usually offer a much better safety than higher-nickel. I think this is commonly understood and agreed upon in the industry. The more nickel you introduce intrinsically, the more difficult it gets to keep your cell and/or your system safe. Driving range: with low-nickel, it's difficult to get to the necessary driving range. Durability, the less nickel, the better the product holds upon cycling; the more nickel you introduce, the more difficult it gets. I am not saying that is impossible, I am putting it here yellow or orange, but it's getting more difficult.

On the cost side, the lower the nickel, the higher the input. We all know today that we are at high cobalt prices and this can be pretty painful. On the other hand, going to high-nickel gives you also a cost disadvantage. Increasing power via a larger sized battery is not really a constraint. This is for long-range BEV. If we go now to the mid-range, it's a similar pattern. However, you do have less constraints on the range, for instance here, with low NMC – low-nickel NMC.

An interesting one is pHEV. For pHEV, you basically load the battery very heavily. You cycle a lot. It's a sizeable battery, which means that the use of high-nickel gets pretty complex in terms of cost and durability. Getting a pHEV to cycle 5,000-6,000 times over its lifetime and still having a performance with high-nickel products, that's, at this moment in time, a real challenge.

And then, last but not least, bigger systems. For bigger systems using high-nickel, you are limited with the safety. Having a 350 KWh high-nickel battery on top or below a bus chassis, I don't see that happening very soon in terms of safety. And, of course these kinds of systems are less volume-sensitive, but they are very price-sensitive, so you get into trouble here as well.

If we combine all that for transportation, how are different NMCs being used? Basically, you see, depending on the sub-segment and the nickel composition that specifically at the extremities you have some difficult usage. In the middle, that is where the compromises in the industry are being sought at this moment in time.

Process technology as enabler for fast growth and cost efficiency

Of course process technology is another important element that is supporting our growth and our cost efficiency. Fast growth from lab to industrial scale and guaranteeing high product quality at industrial, large-scale volumes is really, at this moment in time, pretty key.

How can you be cost efficient? Obviously, control your capital intensity. I think, at this moment in time, thanks to our process technology and equipment being used, we control this very well. We have introduced a couple of years ago really high-throughput production processes that differentiate us from others and maximising first pass yield. I think first pass yield is critical on the cost side in our industry.

That brings us really to the total package, so we bring industrial capabilities for excellent products and we do that in a cost-efficient way.

Recent expansions deploying Umicore's innovative proprietary process technology

Where are we with our expansions? We are expanding right now in Korea, getting close to the expansion in China; we are in the midst of it. We are on track. We have communicated earlier this year that we project 100,000 tonnes of sales in 2019. With the current expansion plan that we have communicated, we should reach at least 175,000 tonnes cathode material production in 2021.

As I mentioned, currently Korea is most advanced – China following suit – and in Europe we have decided to increase our efforts on the process side, so we are going to increase the efforts on the process competence in Belgium. Furthermore, as we communicated last week, we have selected a site in Poland; it is the city of Nysa in the south of Poland, where we are going to be operational towards the end of 2020 to serve the European market.

Access to raw materials

Our position in the market I would say is unique in the sense that we combine scale, geographical presence and recycling capabilities. So we cover and we span the supply chain; from raw materials coming out of the mine, we source pure metals where needed and where we can and then we transform that into an active cathode material. That helps us to be extremely agile in this industry.

Marc has mentioned the recycling; already one of the questions went in that direction. Where do we want to go? I think that has been addressed. Today we have an industrial demonstration unit, and in let's say five years from now we definitely see there the potential to further industrialise that and to combine it with the production of our cathode materials.

Increasing the gap

I hope I could help you to understand where we are and that we have definite plans to continue increasing the gap. It is based on technology and market leadership in that area.

You are not going to be a leader in this industry if you do not master your costs well, and that aspect is very critical to be successful in the future. Then of course, last but not least, this industry will need strong ties, almost let's say from mine to consumer.

Key takeaways

I am coming to the end of my talk. What do I want you to remember tonight at the dinner table when I ask you the question? There is a huge market. There is a huge and massive market demand. I think – at least, I hope – I have explained the background on where the technology requirements come from. There is a trend to product customisation, not commoditisation. Last but not least, I hope I could also convince you that Umicore is, today and in the future, uniquely positioned to grab a big share of this massive market demand.

With that, I would like to conclude, and I think I have to invite Marc to the stage for a Q&A session.

Q&A

Marc Grynberg: So, actually we are going to have probably the Q&A session in two sections. We are going to start now with 15 minutes so that we stay on schedule with the day's agenda. We will then have another section of Q&A for Kurt later in the day, before we close the session. And as you understood from Kurt's closing remarks, we will also quiz you tonight during dinner – a reverse Q&A.

Thomas Wrigglesworth (Citigroup): To keep my question high-level, can you see any technologies that are in development today that will solve or address a large number of the challenges you face in process and manufacturing? I guess I start that question with solid-state batteries in mind, given you were talking about the heat management, the safety, the processing, etc. It will not be a single-shot solution, but can you see a step change coming already? Thank you.

Marc Grynberg: The answer is no, there is not going to be a single technology that will solve, or that will address, all the challenges. For more details I would ask you to bear with us because Denis Goffaux, our CTO, is going to explain that this afternoon and is going to outline the innovation roadmap, including elements such as solid state and why solid state could make sense.

Jean-Baptiste Rolland (Bank of America Merrill Lynch): Very recently, a company which you expect to become a more significant competitor within the next 10–15 years claimed that ultra-high energy density grades would basically account for about 50% of the overall cathode market. Looking at the heat map that you presented, I am just wondering whether you would expect this sort of average industry consensus between low and high nickel content to actually be shifting to the right within the foreseeable future? Thank you.

Kurt Vandeputte: Maybe the first element of my answer is that it is not because you go to a high nickel that would translate in the high end of the market. For me the automotive market is basically –

Marc Grynberg: High-end.

Kurt Vandeputte: – all high-end. Nature is nature; every percentage of nickel gives a certain capacity. Whether you are company A, B or C, we are not going to transform nature, so the capacity is linked to the amount of nickel being used. I do not see there any specific change, or any step change being able to be made by person one or person two.

Marc Grynberg: It is not going to be a binary market from a product technology point of view at all, far from that. It is going to be a market which will be characterised by a wide spectrum of product technologies meeting a wide spectrum of requirements from the customers at large.

If you bear in mind what Kurt presented about the requirements from each participant in the value chain – the cell-makers, the car OEMs, the customers, etc. – these are plentiful. Actually, the way you have to look at it is the number of permutations, considering all the

possibilities that these permutations mean. It is therefore going to be a technology play requiring a vast portfolio of technologies and nothing that looks like a binary market.

Mark Newman (Sanford C. Bernstein): I appreciate there are lots of different types of chemistries that are always going to continue for the long term. However, I would appreciate if you can give a little bit more information on Umicore's blend today, in its chemistry, within NMC. How might that change going forwards? I think one of the two big trends we are seeing at the moment is cobalt price has gone up a lot. I think cobalt is about ten times more expensive than nickel so that motivation to go to high nickel content is getting higher and higher. Plus, of course, a lot of the new EVs that are coming out in the next few years are with longer range. The motivation, again, towards high nickel content is therefore getting higher and higher. So, I think it would be very helpful to talk about what Umicore's blend is today: for example, 'NMC 111 is X%,' or any kind of comment. If you can talk about that and where you are in the move to high nickel content going forwards.

Kurt Vandeputte: In terms of our blend, I explained that we offer a wide set of compositions and that we really fine-tune these compositions depending on the requirements. Our blend is a natural historical blend. The technologies evolve over time and our business and our activity is purely reflecting that.

Marc Grynberg: I would put it somewhat differently to add to that response: the blend is what the customers want, to put it very simply. We have the entire spectrum of technologies and chemistries available. We produce what the customers require in function of the application requirements, as was demonstrated by Kurt. There is not a Umicore blend, or there is not a Umicore product. There is a vast portfolio of products and chemistries that we produce.

This afternoon, during the technology presentation of Denis, Denis will also explain and demystify some conceptions or misconceptions about high nickel. You pointed out things that nickel brings, like for instance higher range and a cost differential compared to cobalt. Denis will also bring you a more balanced picture by also explaining what you give up in terms of characteristics and performance when you use more nickel relative to cobalt.

I think it is important to understand the trade-offs that the customers have to make when selecting chemistries. It is not only just a matter of higher nickels being a holy grail that brings everything lower cost and higher driving ranges. It is a matter of trade-offs and this will be outlined in more detail this afternoon. We will also help you understand the complexity around the questions that you have raised and the reason why having a vast portfolio of technologies makes a lot of sense to play in this market.

Wim Hoste (KBC Securities): I have a question on raw materials sourcing. With the accelerated scenario you now provide, are you confident there will be enough cobalt and other metals out there to accommodate for that? How do you see the metal pricing risk to your accelerated growth scenario?

Marc Grynberg: That is indeed quite a big concern, the raw materials availability in absolute terms and also in terms of timing. In certain cases, you can think of new sources that could come on-stream in the future; the question is how fast that will happen. When I raised the question earlier in my presentation about how much faster electrification can go, clearly one

of the limiting factors today is the time it takes for the supply chain upstream to develop, to grow and to adjust to the kind of growth rates that we see today on the demand side.

I would answer to your question also by saying that without recycling in the long run, the bottlenecks to electrification will be significant. Recycling will be a major contributor to the electrification by easing the scarcity of certain raw materials, like cobalt, or certain others clearly. Without recycling, there will be a limit to how far we can go with electricity.

The other aspect is – again, I repeat myself – I do not see one technology or one family of chemistries taking the entire market for two reasons. One, because there is not one solution that addresses all the requirements that have just been presented. Secondly, because in many cases the technologies to cleaner mobility are hitting raw materials constraints, whether it is an absolute value or in terms of timing.

I think electrification can get where society wants it to go using a combination of technologies, provided recycling kicks in, in a significant manner, in due course.

Chetan Udeshi (JP Morgan): You mentioned a trend towards more customisation of different grades. Is that coming from auto OEMs or battery OEMs? Is there a risk that with more customisation some of the IP is then owned by either the battery OEMs or the car OEMs and you just become a blender, as such, in the long run?

Kurt Vandeputte: Thank you for the question, actually a very relevant one. I think the request comes from a combination of the two: it is either linked with the performance of the cell or sometimes linked with how cells are being produced. In terms of IP, that is more or less the final product level. I would say we see there even quite a bit of opportunity. I would like to refer, for instance, to the example I gave to make products for water-based systems or even for dry-coating. There are quite a few requirements asked from us as a cathode material maker, so I really see that as an opportunity for us to differentiate and to excel, actually.

Marc Grynberg: Actually, there is an analogy with the catalyst industry. The automotive industry relies on the leading catalyst makers to come up with new and innovative formulations to meet ever more stringent regulations. The catalyst makers have not developed into toll producers that are actually just producing the recipes that are owned by the car makers. We see the same model developing in the electrified drivetrain's technologies.

Question: I wanted to go back to the high-nickel discussion just a minute ago. I am just curious; I guess the reason there is so much interest about that is we are trying to understand what the economic impact of this transition will be. I appreciate that there will not be one solution and I think that is really helpful to note. However, we all need to make our assumptions as to where we evolve to and if there are different solutions for different parts of the market. At the same time, as far as Umicore is concerned, can you just help us get our heads around whether high nickel is good for you, or bad for you, or you do not care and you can evolve to basically experience the same type of economic benefit you do with low-nickel type of strategies? I think that is the one question that you could really help us get comfortable with, and I would appreciate that.

Kurt Vandeputte: It is very hard to predict where the market will go. That is basically also what I tried to give as a key message. In the end, you and me, society and the regulator, will decide what the technologies of choice will be. In the end, for us, as I have shown in the beginning, all these materials are layered oxides. As soon as the customer is asking for either a low-nickel component or a high-nickel component, we have the capabilities to develop and to produce that.

Marc Grynberg: Adding to that, I want to address in possibly a more specific manner your question about the margin impact or the economic benefit impact: we do not mind. For us it is about the same, because we have the technologies, we have the products and we have the industrial capabilities. I would like to reuse a sentence that I have used earlier in another context. It is not an aspiration in our case. It is equipment that is on the ground that is producing. We have versatile process technologies, so the product can be made, is being made at the request of the customers. From a margin point of view, we do not mind. The mix is going to be what the consumers decide depending on their requirements and depending on what they buy.

For instance, I drive a pHEV with Umicore materials, of course; that is key selection criteria. I need a robust battery because I am going to be in the configuration that Kurt alluded to earlier, with thousands of charging/discharging cycles; not hundreds, thousands. That is because I am charging during the day when the car is in the underground parking in the office and I am charging at home overnight. Over the warranty life of the battery – which is eight years – I am going to have thousands of cycles, so high-nickel is not relevant for me for that model of car that I have chosen so far. Robustness of the battery is more important, is more relevant.

Again, we do not know where the mix is going. We have prepared ourselves actually to be able to deal with any mix depending on where the consumers decide to go.

Ranulf Orr (Redburn Partners): Hi, a quick question on the guidance to your output capacity of 175,000 tonnes. As I understand it the higher-grade nickels have a much slower production throughput, due to the multiple sinterings, for instance. What is the mix assumption in your tonnage? How do you derive that? Thank you.

Kurt Vandeputte: We have made a rather conservative assumption in defining that number. I think depending on which direction it goes, I do not see us getting, in the end, below 175,000.

Marc Grynberg: That is conservative, because in a way we are talking about 2021. Things are unknown, pretty much, for that period of time between now and 2021. There is a significant proportion of higher and high-nickel products in the assumptions. It is probably overstated considering what we see as the market take-up rate and how we see the market take-up rate progressing nowadays. That is why we mentioned at least 175,000 tonnes, because your observation is absolutely right: the throughput is not the same.

I am sorry that we have to break this Q&A session for now. However, again, there will be more occasions to come back to that subject later in the day, so I would like us to stay on schedule because we have a pretty full programme for now.

Innovation Roadmap in Clean Mobility Materials

Denis Goffaux

Executive Vice President, Energy & Surface Technologies, Umicore

Opening Remarks

Good afternoon everyone; I am glad to be here. Kurt talked a little bit about the last 20 years, what has made us what we are in rechargeable battery materials. I will try to draw a picture of what we are going to do in the next 20 years. It is about our innovation roadmap in clean mobility materials. I will try to picture a little bit the why and the how we are working on these products.

Well to Wheel Efficiency Considerations

On the road towards clean mobility

First, some background information on what we call the well to wheel efficiency. Well to wheel efficiency is actually a way to picture the efficiency in transforming oil, crude and fossil fuels into motive energy.

Well to wheel is made of two components: one is the well to tank, so this is the energy that you are using to extract, transport and refine the crude into a usable fuel – gasoline, diesel, whatever – and by extension we are going to use the concept of well to tank to characterise the efficiency in transforming this fossil fuel into electricity, because this is going to be useful as a comparison for electrified vehicle. Then you have the second component, which is called the tank to wheel, and this is what happens actually in the car and this is the efficiency in which you transform your chemical fuel into motive energy.

If we look at tank to wheel efficiency, which is very often the main focus of the automotive industry, nothing can actually beat the battery electric vehicle. You will see that a BEV has an efficiency of up to 90%, because an electric motor is actually a very efficient way to produce motive power starting from electrons. The electric motor also is fairly flexible in terms of torque and power; a fairly wide range of rotational speed provides very good torque and very good power. That is one part, the electrical motor.

You have also the power electronics, and the battery and power electronics also have pretty high efficiency, increasing over time with new semi-conductive being introduced, and the battery in most of the conditions is also fairly efficient to extract electrons from a battery. So, all in all, we can reach efficiencies in the range of 90%. This is a big difference from the internal combustion engine, because there we are more in the range of 25–30% average efficiency.

Why is that so? First of all, there are some thermodynamic considerations; there is something called the Carnot cycle where, depending on the temperature, you cannot go above a certain efficiency. It is actually very difficult to transform heat or thermal energy into motion. An internal combustion engine is really a marvel of technology because you basically transform the heat produced by the combustion of the fuel into motive energy. We get to this 25–30% partly because of thermodynamic constraints, partly because the internal combustion engine works in a very narrow range, and that is why we have gearboxes in normal cars and that costs some efficiencies. Fuel cell is somewhere in between: it has some

thermodynamic limitation as well, but you benefit from the efficiency of the electric motor, so all in all it is around 50%.

If you look at this you may wonder – knowing that the electric motor exists for more than 200 years, the battery has been invented more than 100 years ago – why are we still using internal combustion engines? There is a good reason for that; this is the energy content of the fuel. Here the comparison is a little bit unfair, because for the gasoline, diesel and hydrogen I am counting the energy content of 1kg of the stuff; I am not counting the tank, the pipes, the ancillary equipment. This is really the energy that you have in 1kg of gasoline, 13,000; diesel same range, hydrogen much higher. Of course, it is 1kg of hydrogen; the volume it would take at normal pressure is a bit larger.

In hydrogen actually, the tank is not negligible because you need to handle seven hundred bars, so you need thick carbon fibre. So, in terms of handicap in terms of energy density, this is more relevant than for gasoline and for diesel.

Now, if you look at a lithium ion battery, all the container is there because the chemicals, the battery itself, is actually what stores the energy. But, you see that there is a factor, not only in order of magnitude between these, and this is what has limited the penetration of electric vehicles for a long, long time. That being said, these extremely high efficiencies and the fact that you can have low CO_2 vehicles is worth the effort. You would understand easily that our main focus there is to improve the energy density of the battery.

Well to wheel sets a clear trend towards BEV

If we translate this percentage into gram CO_2 – because you can do that; when you have an efficient process, you basically burn part of your fuel and this creates CO_2 , so you can express these efficiencies in terms of gram CO_2 – you will see that the purple part is actually the tank to wheel, the green part would be the well to tank, and in many cases when we talk about gram CO_2 forecast, we look only at the tank to wheel. The well to tank is actually proportional, because there is a certain percentage of energy that you lose during the extraction transport and conversion of the crude into useable fuel. You will see that, even if we look at the 95 gram per kilometre of the target of 2021, it is going to be difficult for gasoline and even diesel to reach these targets. If you look at the right side of the graph, then you see that life is much easier for battery electric vehicles because actually you will not produce any CO_2 during conversion when you are using the car. You only have the CO_2 that has been produced during the manufacturing – if we can say the production of electricity.

Coming back to the internal combustion engine, you will see gasoline, diesel and compressed natural gas is a little bit better. You can improve the efficiency somewhat by going hybrid; you reduce the overall tank to wheel and the proportional well to tank. If you go plug-in hybrid, then you have a mix of electricity and fuel and you can get much lower in terms of gram per CO_2 . This is all calculated for a C segment car, let's say the size of a Golf or something like that.

The emissions for the electric vehicle, you see that there are two values. One is when you start from full renewable, then you have basically no CO_2 emission; the other one is based on the EU mix expected for 2030. It obviously depends on how much coal versus gas versus nuclear versus renewable you have in your mix. Europe in 2030 will be around 300g CO_2 per kilowatt hour, so this will give this picture. If you are in China, you are probably going to

be a bit higher than that. If you are in very low CO_2 countries like the Nordic countries or France, then we will be lower than that.

This draws a picture of why we go to electrification, and it is very much supported by legislation. However, this is an evolution, not a revolution, because the electrical vehicle cannot fulfil the needs of all customers, cannot fulfil all users, and so you will have a mix of these power trains, an evolution towards more electrification. So we need cleaner ICEs – cleaner in a sense of emitting less CO_2 , but also fulfilling the emission legislation – and more and more xEV, and this is something we like at Umicore.

Key Developments in xEV Battery Materials

xEV battery materials technologies roadmap

This is to paint the picture; let's look at what we do in terms of active battery material development to reach these levels. First, a graph which is expressing two values, the volumetric energy density in function of the gravimetric energy density. Energy density is a range, in watt hour or kilowatt hour; this is a unit of energy and this is the given range for a given car. You want energy density to be as high as possible but of course you have limited space and limited weight in a car, so you want it to be also dense. Volumetric energy is actually more important than gravimetric energy for automotive application, because the carmakers do not want to touch the usable space in the car; they do not want to force you or me, the consumer, not to be able to put our golf equipment in the trunk or kids in the back or whatever. Therefore, there is a limited amount of space available and basically this space gives you the autonomy. If you have 100 litres at 400-watt hour per litre, you will have that much energy and that much range. Gravimetric is a bit less critical, but it is not unimportant because at the end of the day you do not want to spend a big part of your energy just moving your battery around. Where you want to be is actually in the upper-right corner of this graph.

You will understand easily why we actually stopped doing work on LFP; we stopped LFP because it is limited. It is basically a cathode material which gives limited gravimetric and volumetric energy density. You see also that if you move towards higher nickel, you get more density. Kurt mentioned it; this is electrochemistry, this is thermodynamics, it is a fact if you move. But these moves are small steps; this is limited, every percent counts. So, there is a trend towards more nickel, but it can only bring you that far.

Umicore's innovation pipeline spans the next 20 years

What do we do at Umicore to achieve that? We develop products and we take products in a wide sense; it is cathode, but you will see there is more than cathode in the future roadmap of battery materials.

We also develop processes. These are two faces of a coin because you need a process to make a product. It is not easy. You can make a few grams of a product that is very well-performing; the challenge is very often to produce it in thousands of tons, because the application needs these thousands of tons. So, when you develop a product you need a process to make it and the process needs to be cost effective, so we spend R&D money on both.

Path towards longer driving range

What is the path towards this longer driving range? I split it into three areas.

The first one is cell design. This is mostly in the hands of the battery makers or customers, because what you can do is reduce the useless parts, reduce the thickness of the casing. Useless is not the right word, because you need a casing in a battery obviously, but if you can reuse the volume it takes and the space it takes, you basically get more energy density. They can reduce the thickness of the separator, they can reduce the additives – things that are not providing more energy but are still costing some volume and some weight. Very often they need us for that, because the materials we are delivering are enablers for that. If you want to reduce the thickness of your separator and you have a cathode supplier delivering parts which are not well-controlled, you are going to pierce the separator, create a short circuit and have a lot of problems. So, we are an enabler, but we are not really in the driving seat for the cell design.

Cathode material optimisation – one big family of products

This is very different for the cathode material, because this is really our business; this is in our hands. We make the cathodes what they are. Let us first demystify something: the products that we are all talking about – the LCO lithium cobalt; all grades of NMC, 111/532/622/811/9, whatever; NCA – they are all part of the same family of products. These are the layered lithium metal oxide compounds. They all have a similar structure; this is what you see on the slide. So, the part in blue is the metal oxide side, so you have metal surrounded by oxygen; this is an octahedron, so you have the metal and you have the oxygen around. Then you have a layer full of lithium, and it is basically this lithium that you take out during charge and back in during discharge. The metal oxide can be made of a number of transition metals, three metals that actually work well – nickel, cobalt and manganese – but each of these metals have specific qualities and drawbacks.

If we look at the first one, cobalt, this was used first because it has a lot of advantages. It is good in terms of cycle life, it is good in terms of power, it is good in terms of manufacturability because the cobalt stays where it needs to stay in the metal oxide site – it does not go in the lithium site, it is basically stable through its characteristics. This is solid chemistry; the cobalt stays where it needs to stay. The only disadvantage of cobalt is actually cost, because it is a scarce metal and in portable electronics cobalt remains used in spite of its cost because it has a lot of advantages.

Now, if you look at nickel, you have a big advantage. You gain a little bit in energy; this is due to the voltage curve and at a given voltage you gain a bit in energy. But nickel has big disadvantages in terms of safety, manufacturing and cycle life. The third one is nickel has the bad habit to move in the lithium site and then it is in the way; it actually makes it difficult for lithium to get in and out of the structure.

If we look at manganese, there we have a big cost advantage; manganese is even cheaper than nickel. Safety is also good with manganese, but the power and cycle life are problems and it is actually very difficult to keep. If you go to pure manganese, it would not stay in this stable layered state, it will move to a different shape.

You can play with these three metals; it is a balance. You get pros and cons in whatever, and Kurt mentioned that in the 1990s we were working already on higher nickel, we had an 80:20 and we even filed some patents at that point in time in the ’96, ’97, ’98 area. But the breakthrough for the non-cobalt products was actually when NMC111 was introduced,

because NMC is something that could be used. It could be used and managed, and it had cycle life, safety, power, cost and energy advantages. At Umicore we have the full spectrum; we have this 33%, 50%, 60%, 80%, 90% and more, because we can play everywhere there. Some customers ask us for a specific composition; again, our operations manager does not like that too much because it creates a lot of complexity, but you can basically play with the composition. This is relatively simple in terms of decision-taking, then you need to take the product work in a real battery.

Cathode material optimisation – opening the toolbox

We can consider that we have a toolbox at our disposal to make products with higher energy density, and composition is one of the tools. It is not the only one – I have put here four tools. We have very creative scientists, they have 20 additional tools in their hands; I am not sure I want to share all of them with you, and some of them would be a little bit less relevant than others. However, these are four main ones that are known and can be used to optimise the energy density. Let us review them.

So, we have these two, and at the end of the day it is always going to be technology differentiation, because you use these tools, you give the product to your customer and they come with more questions and remarks than solutions because they tell you, 'This, this and this needs to be improved/changed.' This is the way we develop products in interaction with our customers.

Higher nickel NMC is an obvious track

Composition, again electrochemistry: you put in more nickel, you get more energy. Each step provides a few percent more, so it is not changing the face of the world, especially if you go from let's say 50% to 60% or 60% to 80%; you see that the difference is fairly limited, but it goes in the right direction. If you can manage the disadvantages, of course you want to put more nickel in your product. At the end of the day, you always need to tune a number of other characteristics; if you put more nickel you will have the problem of safety, so you will need to do something else at the cathode material level or at the cell level to compensate. Same with cycle life, same with power, and there I believe it is fair to say that our 20 years of experience is going to be extremely helpful because this is not the first time we tune a product – it happened with lithium cobalt and all the variations we made out of lithium cobalt, it happened with 111 and all the variations we made out of 111.

So, there is more than composition in a product. If you ask us if we plan to make this, of course we are interacting with our customer and we will land somewhere with our customer. Sometimes we will propose something, and they will ask us, 'Give me something different because actually I cannot use this as it is, but this one is a much better compromise for me.'

Playing with the voltage window

If we then look at another tool that we have in our box, that will be using the voltage window. If we talk about the impact of nickel on the energy density of the battery, this is always at a constant voltage, so if you cut at 4.2V, putting more nickel will give you so much percent, but you can also decide to cut at a higher voltage. Standard batteries are normally between 3V and 4.2V; the normal cathode voltage is 4.2V. If you stop at a given voltage, you stop at a given de-lithiation, so you leave some lithium in your structure because you do not want the

structure to collapse. If you stop at a given voltage you have removed so many percent of the lithium. If you cut at a higher voltage, you remove a little bit more lithium, which gives you more energy density but has other impact. You can gain 8%, so it is mathematical: 4.2 to 4.35, you gain 8%.

You need to tune not only the cathode material, but also the electrolyte – there is a big interaction between the cathode and the electrolyte. Either you need to improve the electrolyte so that it can handle the voltage, or you can actually tune the cathode so that it does not react in the wrong way with the electrolyte. We use a lot of coatings and surface engineering to avoid this reaction between cathode and electrolyte. Actually, this approach works very well; this has been used in portable electronics for the last 20 years. Portable electronics went from cathode voltage of 4.1V at the very beginning to 4.15, 4.2, 4.25, 4.30, 4.35, 4.4. Some of you have cell phones cutting off at 4.4V. Portable electronics stayed with lithium cobalt, so they did not have the luxury to play with the composition, and one of the way to get more energy out of it was to cut off at a higher voltage.

You can basically do the same with high-nickel product, with NMC, with different grades of high nickel. One thing that is worth noting is that if you take a 60% nickel and you cut at 4.35V, you actually end up with higher energy density than 80% nickel cutting at 4.2V. Again, you have two tools in your box; use one, use the other, use both, but know that in any case you will have to deal with the drawbacks of each of the tools.

There, we have patented technologies. It is a lot about surface engineering, surface treatment; we have learnt a lot from lithium cobalt for the same reason we applied today to the nickel composition.

Increase the package density to gain an additional 10%

Let us look at our third toolbox. This one was also very much used in portable electronics; this is dealing with the packing density. Kurt mentioned that there was a memory in the product, and it is true: the shape of the precursor that you make will be kept in the cathode material, so it is very important to be able to control the full supply chain because by tuning the precursor you are going to tune the cathode material. Packing it better in the battery gives you 10% additional capacity at no disadvantage, because you will not create safety problems, you will not create power problems. You just need to manage geometrically and mechanically to put more product in a given volume.

That has to be done together with the customers, so there too we have patented technologies banking on our experience in portable electronics, but this is totally valid for electric vehicles. I believe that most of our NMCs used today in automotive platforms are using this technology already, but we can push it even further. The first tool is that sometimes you decide to go to high nickel and then you need to deal with some of the side effects. A side effect which is well-known in nickel is, because the nickel goes in the lithium side, you also create surface impurities in the process. These surface impurities generate gas when you keep the battery at high temperature. This is a standard test which is done at 90°C, so it is fairly harsh, but it is not very different from what you would get if you leave your electric car on the top floor of an airport parking in say Atlanta or Seoul during summer. You may sometimes have a charged battery being held at high temperature, and this happened a lot in the past in computers when you had the CPU eating up the computer and eating up the battery which

was plugged and charged. We all remember that sometimes we never really used the batteries of our computer, but they were gone very quick; this is why.

Enabling use of high nickel in large pouch designs

In the case of high nickel, it is bulging, and bulging means that a pouch cell would increase typically at 90°C by 100% in volume. So, the cell does not look like a pouch anymore, it looks like a packet of crisps; it is really bulged by the pressure of the gas that you put inside. This is not good for the geometrical integrity of the cell. Think about that happening in a car where you have a lot of cells piled against each other. It is also not good in terms of safety, because if you puncture then you will have gas escaping. This is clearly something that needs to be avoided and this is something that prevents the use of high nickel chemistries in most applications besides the small cylindrical cell. A cylindrical cell, because of the shape, can actually hold the pressure pretty good and so if you create a bit of gas basically the shape of the cell can hold that. If you go to pouch or to prismatic cell, this is not possible.

We have been working on that. Again, it is all about surface engineering to avoid these gas-generating substances that are on the surface of the cathode material, and we patented that. We have been able to decrease the bulging to 20%, so 20% in this specific test at 90°C means that in a real-life application this is acceptable for the customers.

So, this gives you a picture of four of the tools that we have; we have many others and you can actually use them to increase capacity and energy density in your cells.

Cathode material optimisation – is higher nickel the holy grail?

One question that I have been hearing a lot from my colleagues, from customers and from some of you already: is higher nickel the holy grail? High nickel is part of the solution; I mean, if you go to higher nickel, you get more capacity. Do you get more energy? This is what we want. But you need to consider the drawbacks.

The cycle life in some applications will be simply unacceptable. Marc mentioned about plugging, but there are other applications where cycle life matters. Automotive application, you cannot play with cycle life; the battery needs to last as long as the car. OEMs do not want to take any risk with that. The high voltage stability, if you want to use them at higher voltage, which brings a number of benefits, you have more problems with high nickel than others and I would say that in general there is limited experience of integration by the current sales maker. Back in the '96, '97, '98, '99, the product was already available; it was mostly 80:20 or NCAs, and most customers would say, 'Look, very nice, I can use it in bottom cells in my lab, it gives very high capacity, but I cannot really use it in a real application.'

On top of this, performance comes at a cost, the cost of manufacturing which we mentioned. So, at some point in time, is it worse it to spend much more capex to get a few percent more in your product? Because capex will be a cost to the customer, so the balance will need to be found on the cost equation as well. Basically, when we talk about high nickel, most of the time we go to 80, sometimes 90, but above 90 is really a territory which is not demonstrated at all. We believe that we can deal with this in the future, but it is not going to be like a miracle solution; this will be again an evolution over time. The full spectrum is and will be needed, and we have it. That is the good news.

Shift in anode materials

Let us look at the third path that we have towards a longer driving range, and this is shifting the anode material. Anode materials stayed the same for the last 25 years; it was graphite from the beginning and it is still graphite. They made progress on graphite. There is R&D done on the anode materials; the shape is different, the graphite can deal much better with high power than in the past, but basically the capacity has not changed much over the last 20/25 years.

So, the idea is to replace graphite by silicon; silicon has up to ten times more capacity per gram than graphite, so it is an obvious choice, and if you manage to use silicon – and I will tell you why it is difficult to use silicon – you can have up to 50% additional energy in your battery. This is sizeable; look at the graph. You could go from say 220Wh/kg to 330, counting 50% additional capacity. If you compare the difference between 60% and 80% nickel and you look at the difference between the anode, the anode material brings you much more bang for the buck than increasing your nickel. Is it easy? No, but the capacity increase is large enough to be very appealing to the OEMs and silicon composite is in the road map of all OEMs these days.

Swelling remains a major drawback

Why is it difficult? Silicon has a bad behaviour: when you put lithium in it, it expands by 300%. If you visualise the electrode – and we have taken a picture of it live – it behaves like a lung or a bladder, it just goes up, down, up, down. So, the electrode physically bulges. This can still be managed – if you can make the silicon fine enough, you can still manage the mechanical constraints – but also another drawback is that every time this silicon expands you create fresh surfaces, and these fresh surfaces react with the electrolyte and deteriorate your cycle life. You are actually using part of the lithium and the lithium which is not available cannot be used in the battery.

So, we have developed a unique material. We have worked on it for quite some time, but we have developed a product that can actually cope with this variation in volume and the interaction with the electrolyte. We are in product qualification, we are sampling customers; we get extremely good feedback. This will certainly go to other applications before getting into xEV, into vehicles, but we believe that this is going to be a very important building block going towards higher energy density in lithium ion systems.

Path towards longer driving range – in a liquid state Li-Ion Battery

Up to now, we have stayed in liquid state batteries. There was one question this morning on solid state, and I will come to that, but even if we stay with liquid state, starting from 33% nickel cathode material, 111, and moving to 90%, you will gain 17%. You can stop on the way; you can stop at 80 or at 60, and you will gain a bit less, but then you can use the low weight cell design, so, this is in the hands of the cell maker. Higher packing density, higher voltage, and then the potentially very high jump by the silicon anode, and you can see that your range can actually increase a lot, because you would more than double your watt hour per kilo.

So there is still a lot of life in liquid systems, and the beauty of a liquid system is that this is proven technology, the battery maker plants are designed for it, they can handle it. You can have drop-in solutions – new cathode, new anode, more packing density, higher voltage;

these are things where you can still use the manufacturing line exactly the way it is, and still gain a lot of energy. So, the 500–700km range is within reach by evolution, by continuous improvement.

Solid state batteries

We are not going to stop there. Let's look at solid state. Just to put things in perspective, let me remind you what a liquid lithium ion battery is. Most of you know, but you have the cathode material which is coated on an aluminium foil; this is the cathode, this is the positive electrode. You have either graphite or silicon composite coated on copper foil; this is the negative, the anode side. You have a separator, which is a polymer; this is polyethylene, so this is plastic, let's call it for what it is. Engineered polyethylene, definitely with micro pores in it to let the lithium through. Very thin, needs to be resistant, so there is a lot of knowledge in the separator but basically this is a piece of foil, or plastic. Then you need to transport the lithium ions from the cathode to the anode and back, from the anode to the cathode, and you put an electrolyte in it, and you fill the gaps with the liquid. You could do it with a syringe – that is what we do in the lab – or you do it in an automated plant. Basically, I wouldn't say it is easy, but it is pretty obvious that if you wet all the particles then the path for lithium is clear: the lithium gets out of the cathode, it gets into the electrolyte, it moves this way through the separator and goes to the anode, and then when you discharge, you can basically get it back to where it came from. The energy density target is 280Wh/kg, 660Wh/L – and this is advanced lithium ion, so this is already beyond what we have today.

What is a solid-state battery? First of all, you can replace the separator by the electrolyte, so if you look at the yellow bubbles – not the yellow strip, because this is the lithium metal side– this is so the electrolyte has a double function. It is the electrical insulator, because the role of the separator is to insulate the cathode from the anode to avoid having a short circuit. You do it with the solid electrolyte, but this is also the stuff that transports the lithium ion from the cathode to the anode and vice versa. You see that there are also some yellow dots in the cathode side, because you need to not only transport them through the separator, but you also need to take the lithium ions from each particle of cathode material and bring it to the anode, so you need what we call a catholyte and the solid electrolyte. These are both solid electrolyte but with different characteristics, because one needs to not react with the lithium side, with the anode side, whilst the other one needs to be stable against the cathode material.

What are the advantages of the solid battery? First, I will describe what it is. The solid electrolyte is a big enabler because it allows the use of lithium metal as the anode. Lithium metal can be used theoretically in liquid state batteries, but this will create a lot of safety concerns. When you plate lithium, you create dendrites; these can pass through the separator, create a short circuit and then an explosion, so this is not desired. Also, when you plate lithium you create on the surface also a safety problem. It has been tried in the past; a company went bankrupt because they could not manage it and basically people more or less decided, metal lithium in liquid electrolyte? Better to stay out of that. Now, if you replace the liquid electrolyte with the solid electrolyte then you enable the use of lithium metal, and this also participates a lot in the energy density again.

I described a little bit the way the battery functions. There, too, cathode material will be used. A solid battery uses cathode materials – NMC, NCA, LCO, you can use many different

kinds of cathode materials – but you still need something that holds the lithium and where you can take it out and take it back in. But this is not plain, normal cathode materials, because you need to engineer it so that it does not react with the solid electrolyte. The cathode material of today has been designed to interact with the liquid electrolyte. If you want them to interact with the solid electrolyte, again you need coatings, you need surface treatment so that you do not destroy the electrolyte, because a charged cathode material, so a de-lithiated cathode material, is a fairly oxidative material and then it would try to oxidise whatever it can put its hand on, and what is available is the solid electrolyte.

So, there is a lot of potential for us. We like solid electrolytes and we will be able to sell more complex cathode material in the future. We are actually doing it; we are working with a number of customers, tuning our cathode materials for them to use in solid systems. There are many advantages; I mentioned the safety, temperature stability, high energy density – partly because of the electrolyte, partly because of the lithium metal – and easier integration into a pack. You will need to change all the manufacturing systems, but there is potential gain in terms of integration. So, solid state is on all major OEMs' roadmaps for quite some time for some of them, very recently for others.

Now, the drawbacks are always there. The electrolyte conductivity is a big issue. Making the liquid electrolyte conductive has been done; it is okay, it works, even if today, as you have all experienced when you go skiing, your phone has less capacity and shuts down faster than a normal day. This is because the conductivity is also proportional to the temperature, so even in a liquid electrolyte when the temperature goes down you start to have problems of conductivity. Solid electrolyte makes it even worse, and so managing the conductivity of the electrolyte is one of the challenges for the solid-state battery. The material stability and purity is another – to avoid all these side reactions, you need very pure and very stable electrolytes – and there are the processing issues in that you will need to basically change most of the industry.

Path towards longer driving range – what could be next on the roadmap

What could be next on the roadmap? Lithium sulphur and lithium air. The optimistic people will always list the good side of life. Lithium sulphur has good gravimetric energy and potentially low cost, so it sounds good. Lithium air has a very high theoretical gravimetric and volumetric energy. Lithium air is the favourite of people doing theoretical calculations, because until you start to try to make it work, it is perfect, you reach the highest energy density. But then you need to deal with practicalities, like what do you do with the anode? Because you are using oxygen but in fact you produce lithium oxide, and where do you put it? You need a place to put it. What do you do with the CO_2 in the air? Because it is lithium air, but actually lithium oxygen, but if you have CO_2 in the air it creates some problems at the battery. How do you manage the fact that you have something which is very reactive with air, the lithium foil, and you need to separate it? The more you try to get into lithium air, the more problems you find, and we have listed here the problems.

So, back to lithium sulphur, the very low volumetric energy makes it unappealing, to say the least, for the automotive application – limited power and limited cycle life. Today the typical application for lithium sulphur will be drones and things like that, where cycle life is less important and weight is the most critical thing. For lithium air, low cycle life is also one of the problems, but the most fundamental one is that this is today still a proof of concept. So,

universities' academics are working on it, people that get funding, but we are still extremely far from a reality. So, we would define that as a technology readiness level one or two, so really ideation level, very far from practical application.

Our conclusion is that these technologies are unlikely to play a role in automotive application in the foreseeable future due to their critical limitation. We do benchmarking, we do watch these technologies, but we are not actively pursuing them because we believe that there is much more to gain by making the lithium ion better with anode and solid-state batteries than venturing into these, besides some niche applications.

Conclusions

If I want to conclude, the best way is actually to come back to my graph, which we call the Ragone plot between volumetric energy density and gravimetric energy density. You see that, though you can basically go some way with the nickel composition, the silicon-based anode would bring you much higher and you could draw dots between the 90% nickel and the silicon-based anode if you are mixing the silicon anode with graphite, because you can then have a continuous progression, putting every time more and more and more silicon. So this is still ongoing, and then if you go to full solid state you would go even higher.

You also see that the lithium sulphur has practical limitations and in terms of volumetric energy density is even worse than the current lithium ion technology, so we do not see much future there. There are practical limits for lithium ion in liquid state and practical limits in solid state. When I show this to our scientists, they hate practical limits, they want to go beyond them. Indeed, if you try to model and to get to the theoretical limit, you could even go a little bit higher for both; the lithium ion could be a little bit higher, the solid state could be a little bit higher than that. But let's keep our feet on the ground: today, it would already be so good to be at 1,000Wh/L and 500Wh/kg. It would basically nearly double or triple the range of our cars.

Key Developments in Fuel Cells

Fuel cell drivetrains are gaining traction

Changing subject completely, let's talk about fuel cells. A fuel cell is actually a system where you are using a chemical carrier, hydrogen – remember the 38,400Wh/kg that you get from hydrogen – and you use it not in an internal combustion engine, but to make electricity. If you put hydrogen and oxygen together there, nothing happens until you get a flame or a spark and then it either burns or explodes. If you want to harvest that energy in an internal combustion engine, then you will still be stuck with this efficiency problem. If you put some catalyst in it, you can generate electricity directly from this reaction between hydrogen and oxygen and use this electricity in a very efficient way in an electric model. So, that is the beauty of the fuel cell system, is that you have a very high energy carrier, the hydrogen, and a very clean use of the energy, which is electric.

The key driver there is the catalyst, and Pascal will agree with me that we tend to know a number of things about catalysts. We have been working on fuel cell catalysts for close to 30 years, because of our history in automotive catalysts. Fuel cell has seen a number of hypes and downs, but we see the technology becoming really mature today. This can be used; you have cars on the road here in Korea using fuel cell, you can buy it, you can order a fuel cell car and use it every day on your commute. We have a competitive product portfolio with a

strong R&D pipeline. We are very well-positioned; our products are on the road in cars that are sold today and are present in most of the developmental platform of the biggest OEMs.

Fuel cell drivetrains provide superior range and better refuelling time than BEV

So, what is the sweet spot for fuel cell cars? It is that it provides the best of both worlds, you have zero emissions like in a battery-operated vehicle. This is not correct; you have emission of water, which is not a big deal unless it is freezing, then you need to manage it. Water is produced during the reaction. But besides that, you have zero emissions and you have an electric car; you can be in the centre of the city, no NOx, nothing, and you can have the driving range and a refuelling time of an internal combustion engine, because basically what you do is to transfer a fuel from a tank into another tank. So, it fits very well when you need a lot of energy – long-range heavy vehicles, large vehicles, trucks come immediately to mind – but it can also be used in cars and provide that kind of range, especially when you have very large cars which are very difficult to electrify with batteries.

In terms of drawbacks, as always, cost is one. We need to reduce the platinum use, and this is something we are used to doing, reduce the platinum utilisation by catalyst engineering. We manage to disperse platinum, to put very thin surfaces of platinum where you get a lot of activity but with a very limited amount of platinum, and this is a big cost driver obviously. Then economy of scale is another, not so much for us; this is more for the automotive industry. A fuel cell car uses, besides the catalyst and the membrane, a lot of parts that are let's say known to the automotive industry – blowers, compressor, pipes, valves, the kind of things that if you produce in large amounts you can basically reduce the price quite substantially.

Maybe the biggest drawback is the need for infrastructure programmes. You need hydrogen to be available where you need to refill. This is one of the beauties of the electric car, that the electrical network exists; you are never very far away from a plug, and even if there is a need to develop more charging points, typically you need to go a few metres before you get a power line and it does not cost that much. In the case of hydrogen, you need either to transport it by pipeline, by trucks or produce it on-site. There will be a big investment needed and this is a little bit of a chicken and egg problem: until the infrastructure is there, people do not buy cars. So, this is something that can be managed; it will require a bit of government willingness to get there, but we really believe that it will serve a part of the need.

So, it is very coherent with our view that we have a number of technologies and each technology will find its sweet spot. You will have the internal combustion engine, gasoline and diesel; you will have battery vehicles and plug-in vehicles; you will have fuel cell vehicles. They will all find their way in the spectrum.

Wrap-up

Okay, I am coming to the end of my talk with a wrap-up, and basically using this picture will summarise it all. We are in internal combustion engine with a catalyst technology. We are in hybrid vehicles and plug-in hybrid vehicles with our catalyst technology and with our battery technology. We are in electric cars with our battery technology and in fuel cell with our catalyst technology, so it is all about technology.

The future of clean mobility is within reach. It is all based on materials and it is all based on technology, and this is our job: to provide the technology to our customers.

Thank you for your attention.

Q&A

Alex Stewart (Barclays): You mentioned in the presentation before lunch that in 2015 you gave some estimates for the total storage capacity for the transport markets that were out by a factor of three or four compared to your latest estimate. Could you just run through the two or three things you think you got wrong in 2015 – and indeed the rest of the world got wrong in 2015 – compared to the way that it has materialised?

Kurt Vandeputte: I think the main thing we all got wrong is the fact that there was a strategic uptake of the car OEMs to go into electrification. Most models started from the base assumption that we had to look at economic parity; there should be no financial penalty of going to electrification, and this is now clearly changing. Secondly, let's not forget that the push in China to go faster to electrification is really very significant. This is almost half of the total market.

Marc Grynberg: There is an additional factor. That is diesel again. Please bear in mind that when we spoke in 2015 diesel in Europe was accounting for 50% of new car sales, and today it is down to less than 40% and still going down, so you cannot easily achieve the same CO_2 targets with such a reduction in diesel sales in the mix. That requires then to be compensated by more electrified vehicles, so that is having a big impact on the assumptions for the European region and explains part of the acceleration that has started to take place after the 2015 presentation.

I would like to add maybe to the first point that you raised, Kurt. Clearly what you see today is that a number of car OEMs have moved from a defensive position – which is, 'Environmental regulations are a constraint, environment regulations are come at a cost and we need to push back' – a number of them have moved away from that to looking at, 'Where are the opportunities that are being supported by environmental regulations?' Those players that have moved from the defensive position to truly embrace the opportunistic view are actually accelerating the move to electrification. In a certain number of cases regardless of the cost per kilowatt hour of the batteries.

Thomas Wrigglesworth (Citigroup): This is a follow-on question again from earlier. LG Chem announced that it was going to deeper vertically integrate into cathode materials the other day. Given the complexities that you were talking about between the different levels of the chain of who wants what and the criteria, how do you think consolidation will work over the medium-term? Is there a long-term future to have separate cathode material manufacturers from battery manufacturers? Will those two have to consolidate versus to have a single face to the OEM? Thank you.

Marc Grynberg: Actually, to clarify the context, a number of battery manufacturers have produced cathode materials and certain other materials – some of them separators, anodes, etc. – for more than 20 years. That has been part of their strategy from the onset, to master the technological content and especially the materials content. We presented today why

materials were bringing so many properties and functionalities and how they were bringing these properties and functionalities to the battery. If you want as a battery cell-maker to optimise the interaction between the different components, you had better understand how these materials are being made, how they work and how you can tune them to optimise the performance and the interactions. It has therefore been their strategy. You have a number of them, like some of the Korean battery-makers and some other battery-makers, which have decided to go down that path from the outset.

However, the limiting factor in that type of strategy is that eventually what they want is the best technologies, they want the best materials. You do not see anywhere a battery cell-maker willing to go for 100% captive materials production because that means that you cut yourself as a battery-maker from third-party developments, from other technologies that may be better than your in-house developments. You therefore do not see that. Typically, they keep a balance with a minority of captive production and a majority of third-party sourcing in order to have access to the best technologies, whoever makes them. We therefore do not see this type of vertical integration going much further than that.

Ranulf Orr (Redburn Partners): Could you please elaborate on the anode technology you have in qualification? What is the timeframe for that? Is it pure silicon or is it doped graphite? Do you need new capital investment for production? How would the economics vary versus cathodes? Thank you.

Denis Goffaux: We are in the qualification stage, which means that we are already at a pilot and pre-production stage because you cannot qualify something that you are not able to produce in larger quantities. However, this is only the very beginning. We will first go to applications where the battery-maker can test the technology before going into something bigger.

In terms of adoption in electric vehicles, we are certainly talking about a 5–10 years horizon. It is not for tomorrow. It is not trivial, again, to use these technologies.

Marc Grynberg: For the intermediate use in other applications like portables, you are talking probably a timeframe of 3–5 years for market adoption. Then, only if the cell manufacturers are satisfied with the performance and the durability, will they move to the next stage, which is testing for automotive applications.

I will add, to be complete, on the capital requirements. They are not so big. They are not comparable, they are not of the same magnitude, as what we have for cathode materials. In terms of technology, what we have developed and are producing are composite materials. It is not pure silicon, it is composite materials. Pure silicon comes with too many drawbacks, as Denis indicated earlier, in terms of managing the swelling of the electrode. That is not something that could be overcome.

Adam Collins (Liberum): I had some questions on the limitations of high nickel; it is in three parts, but it relates to the same theme.

First of all, Denis, you talked about the fact that the gas creation factor is a limiting issue in terms of the packaging that can be used for high nickel. Rigid small-format is what you said was required. In the portable electronic area for high energy, LCO prevails because of the

inability of high nickel to be used in a thin polymer structure. You talked about the fact that you found a solution to the swelling issue; you could limit it to 20%. Do you envision a scenario longer-term where high nickel could displace high cobalt in portable electronics at the high-energy stage? That is the first thing.

Then, just on the large-format high nickel, I wondered if you could just talk about what the limitations are for a cobalt-free large-format battery, as you see it?

Denis Goffaux: In terms of technology, this is definitely going in the right direction if we are able to. However, we are not suppressing but we are reducing the bulging, so there is still some work to be done. Indeed, this opens a new perspective, but I will need to turn to Kurt to see what the market position is on that.

Cobalt has been entrenched in portable electronics for quite some time because of the specific requirements of portable electronics, so it is not going to be an easy path to displace. However, who knows? Maybe a few percent of some applications can be switched from cobalt and this will somewhat ease the pressure on cobalt.

Kurt Vandeputte: Again, the requirements on swelling for portable electronics are at this moment in time extremely harsh. I remember a discussion I had during a spec discussion with one of the bigger OEMs; they were debating amongst themselves about the criticality of the thickness of the paint when they put the unique identification number on the cell. That was, for them, critical. So, you can imagine that any small swelling issue in a cell is really deadly for a smartphone at this moment in time.

Denis Goffaux: I think you can visualise that in a car you can make a pack that could be a little bit against the volume. When you have a cell phone, it is really a no-go.

On the large-format question towards zero cobalt, I would need to turn to the materials scientists there. However, really making a product with zero cobalt is extremely difficult because cobalt helps to stabilise the bad behaviour of nickel. If you go to zero, then you are left with no support at all and I believe it is close to unrealistic to go to zero.

Marc Grynberg: Perhaps if I can add a small clarification: the product can be made. It is extremely difficult to be used. I do not want to give the impression that it is much more difficult to make than very high nickel. It is quasi-impossible to use for a battery-maker.

Chetan Udeshi (JP Morgan): Do you have any visibility on what your competitors are doing? You guys are talking about difficulty in reducing or getting to zero cobalt batteries in practical use cases. However, just a few days ago Panasonic was talking about reducing the use of cobalt to almost zero in the near future. Is there a risk that somebody is getting ahead of Umicore in the next generation platforms? How do you track it, if there is a way?

The second question was more on the catalyst side of things. It was mentioned in the morning presentation that the number of platforms that will be developed in the future might go down as we try to reduce cost. Would that not raise the competitive environment in the industry in general so that you guys have maybe 30% fewer platforms to win, so essentially everybody will be more aggressive in getting that limited number of platforms?

Kurt Vandeputte: I am glad to take the first one. If I would not be knowing what my competitors are doing, then my team is doing a lousy job. Of course, we have an indication. We are one of the contenders for business; we are one company in the race for product development. All I know is that what happens in the meeting room and in the lab is not always publicly shared and vice-versa. I would say the development mainstream goes for most companies in the same direction, but that does not mean that we all do exactly the same at the same speed.

Denis Goffaux: Let me just clarify a little bit my comment on the help that cobalt brings to keep nickel tamed. Definitely you can synthesise products without any trace of cobalt. It is going to be difficult, it is going to be costly, it is going to be difficult to use and at some point in time you may wonder, 'Okay, why am I going the last mile just for bragging that I have put all cobalt out of the battery?' It can be done. Does it make sense? I am not sure. However, reducing cobalt, going for higher nickel, this makes sense, definitely.

Marc Grynberg: Please bear in mind what Denis presented. This is science; it is not numbers that we have estimated, this is the laws of science. Going from 111 to 90% nickel gives you a 17% gain in energy density. The step from 80% to 90% nickel is a few percentage points in terms of energy density and a lot of drawbacks that you have to make up for, because you cannot just say, 'I will take the drawbacks.' You cannot; you have to make up for the drawbacks by adding components, adding equipment to control the performance and the reliability of the battery by doping some of the components, etc. You are therefore adding cost. At a certain point in time, as Kurt mentioned this morning with the heat map, you move completely out of the sweet spot from a cost point of view, so you defeat the purpose.

There is therefore a balance to be found between the different performance requirements that a battery has. This does not mean necessarily that you will go for the last bit of elimination of cobalt. There are many other levers that can be utilised, as was shown – on the packing density, on the anode in the future by going solid etc. – to increase the energy density much more than by removing the last percentage points of that metal.

Then there was a question about the catalyst platforms. I will take the liberty of answering that question on behalf of Pascal. I will then see from Pascal's body language whether I have done a good job.

The platforms are getting larger and fewer, indeed, which means that there is a lot of homework to be done on the technology side to win these platforms. As was indicated this morning, the platforms are not won with great technologies; they are being won with the best technology only. There is therefore a lot at stake. What you see, actually, as a result of that is not more price pressure, more competitive pressure on the pricing side; that does not help because only the best technology wins. What you see is more effort being put on the technology development side, the testing side and the joint development work with the customers to make sure you can come up with the best technologies.

Mutlu Gundogan (ABN AMRO): I have a question on your capex versus capacity ratio. I think that was broadly stable when you did the various announcements. I think you have said yourself a few times that it is a competitive advantage, where you stand versus

competition. I was just wondering how you see that developing in the next few years – where could it go theoretically? If you could spare some words on that, that would be nice.

Secondly, with these larger platforms, does it also mean that you have higher synergies between Catalysis and RBM because you might be sharing information back and forth between the various teams?

Kurt Vandeputte: In terms of capex density, of course this is for us something of prime importance, I would say. We make big steps forward. At this moment in time, like I mentioned before, speed and standardisation is of strategic importance. Currently I would prefer a stable line and maybe a slightly higher investment than continuous change because that is uncontrollable. This being said, the industry is going to grow to that magnitude, that we have to improve, and there are significant ideas in the pipeline. I therefore do see us improving over time, yes.

Denis Goffaux: It is no coincidence that we are opening a new process competence centre. One of the goals is actually to find processes that are less capex-intensive and less opex-intensive than the existing processes.

Marc Grynberg: We have a competitive advantage: we have a clear strength in process know-how for cathode materials. We want to leverage that and we want to make this strength even stronger and increase the process gap with our competitors, clearly. That will have an impact on both the capex density in the long run, as well as our operating expenses. These are the goals that we are pursuing through these process development programmes.

On the synergies between Catalysis and RBM, what you describe is the ideal state that we have in mind. It is not reality yet. I cannot tell you how many years it will take to get there, but yes, there will be more synergies, as far as the interface is concerned with the customers, between the Catalysis side and the Battery Materials side.

Geoff Haire (UBS): I just have a quick question. You said on your bridge of increasing energy density that the silicon anode gives somewhere between 10–50% uplift in energy density. Why such a wide percentage? Could you give some more detail on what drives that?

Denis Goffaux: The 50% is what is achievable with the composite that would be used as such. However, normally the customer would blend the composite with existing graphite. Therefore, depending on the blending they do, they can go anywhere from 10% increase up to the 50% increase. Maybe there is more potential for the future, but we believe that this range is manageable. However, it will take time and they will probably go to 10% first, then to 20%, 30%, 40%, before going into 50%. That is why the range is so large.

Marc Grynberg: The reason the customers are doing that is to manage the risks and so they work by smaller increments than what is theoretically possible. That is why some of these new technology introductions take ten-plus years, as was mentioned earlier in the day.

Kurt Vandeputte: The last reason is to keep it compatible with what they have as production technologies. A cell-maker does not want to change its mixers, its coating lines because they start to use a couple of percent of silicon. It is really critical.

Mark Newman (Sanford C. Bernstein): I appreciate all of the presentations here today; they are very helpful. What would be very interesting for me to learn a little bit more about is in the move to the higher nickel content you have talked quite a bit about today. I appreciate a lot of the drawbacks in high nickel content and some of the pros and cons. However, what is really the main hindrance in moving to NMC, like a high nickel content, earlier? What is the main hindrance? Can you talk about what Umicore is doing to overcome those things? Is it particle size? You talked about the packing and the particle sizes earlier; is it something around that? Is it something around dopants, is it around coatings? Is it something like that, which you have not really talked about much today?

I guess the reason I am asking that is not just to get an idea about adoption; it is to try to get an idea on whether Umicore is going to maintain its lead on high-nickel content that it has today. We know that Umicore has great technology for today's NMC due to its process technology advantage. Is that going to be, in your opinion, more for the future chemistry, or less, or similar in terms of Umicore's lead?

I have a second question, if I may, a shorter one. Regarding some of the next-generation chemistries that you talked about, such as solid state and silicon anode, is Umicore going to be involved in any of those chemicals? I am not talking about fuel cells; I am talking about some of the electrolytes you mentioned. Or are you just talking about collaborating with other partners? Thanks.

Kurt Vandeputte: I will go for the first one, yes. First of all, I would like to correct a statement you made. You say a move to higher nickel. I am not talking about a move to higher nickel. We should talk about the increased use of higher-nickel cathode materials. The hindering step today is the application.

The industry does not meet all the customer requirements at battery level or at pack level with high-nickel components. This is a fact. It is not because company A or B, at a material level, is more or less advanced in making these products; it is the application. I am happy to invite you tomorrow, I will ask my collaborators, I will show you physically what it means to integrate a high-nickel component in a polymer cell. We can, together, have a look at it and then you can judge for yourself. It has nothing to do with us being more or less advanced. Honestly, as a material maker, I do not care whether people want to use NMC 111, 522, 811, 9XX; I do not care. We have the base set of capabilities to develop that, to scale it up. We have the assets and it is being made today.

I want to be very clear about that. Umicore is selling, producing a different set of NMC products today. Whether it is now 10% of that or 20% of that honestly, again, we do not really care. We are agnostic to that. The most important thing is that the customers know that whatever they need at that moment in time, they find somebody who has the capabilities to react fast, who is there with big volumes and who is reliable. That is the key element today and I think we are unique in that respect. There are very few companies in the world who can offer this.

Denis Goffaux: On the solid-state battery, this is a technology move that is upcoming. The first thing you do when we are faced with a new technology coming in is that you figure out what it really means. We start from the product we know well. The solid-state battery will require cathode materials. We are specialised in cathode materials, so let’s try to make

cathode materials that are compatible with the solid electrolyte. This is always our entry point.

When you start to understand what a solid electrolyte is, you might get ideas and say, 'Okay, maybe I should partner with that company. Maybe I have some ideas to make it better. Maybe I can contribute to that,' but this is way too early to say. At this point in time, we focus on cathode; cathode is what we make and cathode will be used in solid-state batteries – more if affinities, but today, cathode.

Marc Grynberg: This being said, the difference between solid state and liquid state is that the liquid electrolyte in the current generation of battery technologies is organic material. We do not have competencies in organic chemistry that would push us or convince us that this is an effort that Umicore should do and develop these competencies to try to compete there.

When you move to solid state, it is a new game. There may be a move away from organic to inorganic materials; then, this is our territory. I would therefore put it in a broader sense than just cathodes. With the move to solid state, the game is open again and cathodes is a known thing for us and the rest is a possibility. That is the difference between the liquid state, where clearly our focus should be on cathode and anode because the rest is organic and we are not competitive to play there. In solid state, there are more possibilities; it is a door-opener.

Scott MacLennan (Schroders): I have two questions. The first is on customer concentration for your battery materials, not in terms of the OEMs. I am assuming you have a diverse range of OEMs you are selling to, it is more the cell OEMs. Do you feel more aligned to one particular cell OEM and are you are happy with the current diversification of customers that you have at that level?

The second question is around investments and cash flow. We have spent the whole day talking about the exciting opportunities that you have. However, we have not really spent a lot of time talking about how much it is going to cost you to get there. Can you give us any numbers or any indication on the capex R&D side to help us understand the funding of this growth in each of the individual areas, if possible? Thank you.

Marc Grynberg: Let me start with the second one. Clearly, we are going to continue to invest significant amounts of money to grow this business at a very fast pace, faster than anyone else out there in the industry. We have, I would say, a strong balance sheet that allows us to do that. We also have a very strong cash flow profile from the other two segments, the Catalysis and the Recycling businesses. That allows us to sustain that investment effort and that kind of investment intensity.

More guidance on the capex in the longer run than we have given so far is not on the agenda for today because we still have some homework to do on what is beyond 2021. Earlier this year we announced the €660 million investment programme that will bring us to the capacity that we need in 2021. Clearly, all growth does not stop there, so there is homework being done in order to figure out what is coming next in order to move us then to 2023/2025 and beyond that, including then the impact on some process developments that are currently in the pipeline. It is too early to quantify that; suffice to say, at this point in time, that we will sustain the investment effort because the rewards are definitely justifying that.

The customer concentration, or lack thereof?

Kurt Vandeputte: So far, customers have been concentrated in Asia. Umicore has actually run for the last 20 years always a multi-product, a multi-application and a multi-customer strategy. In the beginning, that was rather exceptional in an Asian business where there were a lot of one-to-one business relationships. The strategy has brought us where we are today.

This being said, as heading a business you should always be happy if your team brings additional customers. Of course, these are welcome. At this moment in time we clearly see from our customer bases we have a strong shift towards Europe. It is not a coincidence that also our next investment is going to be in Europe. The geographical expansion is actually more critical for me than adding an additional customer to the list, but every customer and all the businesses, of course, are valued.

Marc Grynberg: If I may add to that, we are happy with the level of customer diversification and platform diversification we have in the portfolio, satisfied enough to give us comfort about our investment programmes. What I would not want to have to do is to decide an investment for one customer or for one platform, even if it is a very large platform. I am happy we do not have to do that.

Charlie Webb (Morgan Stanley): One point of clarification on your qualification processes: given your wide range of product offerings and the competencies you have in battery materials, are you currently going through the qualification process for high energy or high nickel-based materials with your customers? Is that on the agenda in the qualification process out to 2021? Is that happening right now?

Secondly on the IP backdrop, you have obviously bought and acquired a number of licences over the years. How do you see those licenses moving forward? I believe they start to roll after 2021 through to 2024. Are there certain materials within the NMC family that are not captured in those licences, or does that cover the whole spectrum? I am just trying to understand your protection from a licence standpoint, given you made decisions to acquire them over the last couple of years.

Kurt Vandeputte: Let me start with the first question on the qualification programmes. At this moment in time we are running qualification programmes covering all products. This may sound as a surprise, but even today we run qualification programmes for a product that everybody believes has already gone: NMC111. There are still platforms open with SOP 2021, 2022 where NMC111 is seen as a valid candidate. Two years ago, we started already qualifying platforms with really high nickel products.

The qualification programme, the evolution of chemistries is a continuum; this is not something that goes in steps. It depends on what type of platform you are qualifying for, the customer OEM strategy, and the readiness of the product for the application that drives it.

Marc Grynberg: I think, Kurt, the heat maps that you presented this morning for the four applications – BEV long range, BEV mid-range, pHEV and buses – is a good guide to what is currently in the qualification pipeline. It covers the whole range but depends on the application.

Denis Goffaux: It may also happen that customers change their mind during qualification – wanted to go for a given nickel rate and then change either down or up during the qualification phase, depending on their requirement and the platform requirement.

Kurt Vandeputte: It is actually standard practice nowadays. For the bigger platforms, there are usually two or three tracks going in parallel making to the very last stage of decisions for a technology choice of a platform.

Then the second question, on the IP, a bit similar to qualification being a continuum, you have the same on IP. At this moment in time for NMC, there are very little patents that are called base patents, and some of these we now own. Apart from that, most of the patenting activity is more improvement patents, patenting specific performances of products. NMC materials are now long enough, available, and on the market, that it is impossible to still patent compositions.

Some of the patents indeed end their lifetime in the beginning of the 2020s, but on the other hand they will be somehow replaced. All our products are covered by most of our own IP that we have been generating the last eight to ten years. I am really highly confident that the products we bring to the market are covered with Umicore IP at this moment in time, now and going forward.

Marc Grynberg: Even better covered, because I would say you can cover with IP the basic chemical composition; it is known. The kind of very specific IP protection that we have now – as Kurt described, the improvement IP – is much finer and much more complicated for anyone to reproduce. I would even call it a higher quality IP.

Question: A question about the battery management system and cooling systems. I think the rate of degradation in the Tesla batteries shows how integral those components can be in managing the battery life with their particularly unstable chemistry they use when compared to some of the batteries that you use – a higher cobalt content, such as like the Nissan Leaf for instance.

Whilst you are spending all this time and effort working on improving the stability of these high-nickel chemistries from a material perspective, a competitor of yours might team up with a battery management system provider, a cooling system provider, and realise actually the material only needs to be so good if you have the appropriate management systems wrapped round it. Is there a risk there? Would you work with these providers?

Kurt Vandeputte: Improving battery technology is nowadays always a collaborative effort. The times that one material-maker – being that cathode or anode – really can do something on their own and make a big step forward on improving the battery are over.

If we talk stability, degradation of electrolyte and leading to indeed a reduction of the performance over time, we always talk about the chemical reaction, the chemical interface between cathode and electrolyte. As Denis mentioned, you should see that as a pretty aggressive nickel atom or ion actually, that wants to eat the structure of the organics. This is a chemical process, and every chemical process can be sped up with temperature. You cannot stop that; that is also a continuum.

There is one important thing I would like to add: this is an algorithmic relationship. Increasing temperature is dramatically speeding up these chemical reactions, and they are

parasitic reactions so we really do not want them. The approach most system integrators are using now is to really keep the temperature stable. This is something we can handle. We can feed them with the base data, how materials are going to react at these temperatures given within five or ten degrees, then they can model how the systems will really survive after eight or ten years.

Like I said, it is a system effort. Are there other companies looking into collaboration with people who supply cooling systems? Maybe yes, maybe no. I have the feeling that, at this moment in time, real system integration is only handled by the car OEMs themselves.

Marc Grynberg: What we do not see is the concept that if you can make up for a certain drawback by the management system or whatever, you would settle for a lower quality product. Every time there is a quality level that is reached, that is taken for granted by the customer bases. You have to build on that. You cannot just decide to arrive at the same level of performance differently; it is not good enough.

Denis Goffaux: Do not forget that people look for more energy. If you can manage your system better by managing the temperature, you would rather use that to use a more energetic product and get less weight, less volume in your car than just settle for something of less quality.

Wim Hoste (KBC Securities): On the competitive environment, we know from the capex amount that you shared that you are outpacing the industry growth. Could you elaborate on the competition? Do you see new players emerging that are gaining credibility with the OEMs, or is it a fairly limited number of competitors you are facing?

Marc Grynberg: As I have mentioned on previous occasions, for the time being in the automotive application segment it is a game of a handful of players that are qualified and that are growing at a different pace but growing simultaneously. It is a limited number of players: Asian, Japanese, Chinese, some smaller Korean players. Please bear in mind, as I indicated earlier, that some of the battery cell-makers have captive production too, which is not directly competing because they use it for in-house purposes only, they do not put it on the market, but that also is a part of the growth. So, I would say the landscape has not fundamentally changed over the past three or four years. It is still a handful of players that are qualified today – and again, as with previous communications, I am not meaning or pretending that there will not be newcomers to the segment. The only thing that you have to bear in mind is that as the acceleration is taking place now it is getting somewhat more difficult for new entrants to step into this demanding segment.

Question: Again, I really appreciate an enlightening presentation. Just curious if we could take a sideway step and look towards 2025. We did this with Catalysis and I think it would be helpful for us if we touched on it here, just on metrics of growth and margins. The margins have grown a lot here; what kind of trajectory should we have in our minds in the medium term for that?

On the growth side, I know in one of the charts there was a huge amount of growth in gigawatt hours. What kind of growth numbers are you looking at in the medium term, if you could just help us with those? Thanks.

Marc Grynberg: It is a little bit premature, I have to say, to start talking about financial metrics beyond 2020. We have a capacity plan in place that brings us to 2021 and the homework has started to figure out what is coming next, and as usual that will be based on what we know, because we have qualified for platforms that go beyond 2021 and that will support the next phase. But it is too early to translate that into metrics. The only thing that I would like to say today is that there is no way we are going to reduce our ambitions beyond 2020 or 2021 and we will seek to grow at least as fast as the market between 2020/2021 and 2025, indeed based on technology, based on innovation and based on the competitiveness of our processes. For more meat and metrics to quantify that, you will have to bear with us.

Question: If you look across the qualification programmes that you have right now and the work you are doing with your customers, do you see any meaningful difference in the technology roadmap for the Chinese complex versus the rest of the world in terms of composition, in terms of the anode materials and some of the features that you mentioned just now?

Kurt Vandeputte: I do not really see significant differences regionally. What I do see is capability differences at cell-makers or even at car OEMs to integrate different types of cells into a workable system. Some of these companies have 20–25 years of experience in lithium ion and you can feel that. The quality of the interactions with some teams are just deeper or of a higher quality, and these teams typically better understand things beyond pure cell design or pure cell chemistry. I think this is an important measure for us to understand what kind of relationship we can develop with them. There are some nuances, yes, but dramatic differences, I would say; again, playing in automotive, you are already at a high level of quality.

Marc Grynberg: If I can add to that, the innovation roadmap that Denis has just shown with the different avenues to increase energy density – including the composition, the packing density, the anode materials, the solid state – that is a Umicore roadmap and that is very much aligned with the industry roadmaps as well. You see that across the industry and across regions. So, we are working on the same themes as our customers and the car OEMs, indeed, including up to the solid-state batteries – and there, you do not see major regional differences. This is basically the industry roadmap.

Yan Lager (Franklin Templeton Investments): I wanted to follow up on the cash flow question. There is an indication of €660 million in capex by 2021, which is relatively fixed now. The working capital part of it, I think the indication is about half of that, so let's say €1 billion in total capital. If I recall my recycling days from years back, there was a significant amount of variability of working capital depending on what is happening on the revenue side. How variable is working capital within this segment, and if it is variable, how sure are you of sustaining that 15% ROCE in this segment?

Marc Grynberg: There is a degree of variability and that is mostly related to fluctuations in metal prices. The reality is that if we have higher metal prices we have higher working capital requirements – not in the recycling business where, as you recall, we work with negative working capital, but in the energy and surface technologies segments we have a more conventional situation where, indeed, where metal prices go up, we have more working capital requirements. From a profitability point of view, we make up for that through the

recycling margins, indeed. For Umicore, it is not necessarily affecting the profitability as we measure it in ROCE terms.

Those attending the presentation physically today will have a chance to continue informal discussions and address some of your follow-on questions later today.

Closing Remarks

Marc Grynberg

Chief Executive Officer, Umicore

That was quite a bit of substance for the day, I bet, and lots of information to digest – and again, for those attending here in Seoul, there will be a chance to follow up with your additional questions informally.

Unique Position in Clean Mobility

Before we do that, though, I would like to wrap up the presentation part of the day and offer some perspective and concluding remarks. In order to do so, we will reuse a slide from the 2015 Capital Markets Day; once more we reuse a slide, but it is not out of laziness, like in the case of Kurt. It is simply because this slide is still very much relevant to visualise our unique position in clean mobility in the sense that Umicore is the only company that offers the full spectrum of materials technologies to address the technology needs of cleaner mobility. In addition, we are the only company that is offering a closed-loop model with recycling capabilities to deal with end-of-life materials coming from these more sophisticated and cleaner drivetrains.

Competitors

Automotive catalysts

It does not mean that we do not have competition. That is not what we mean by being unique or uniquely-positioned; we do have competition. In automotive catalysts, clearly we have well-established and strong competitors in this segment. We discussed about some of the competitive positions and some of the technology developments in that segment. Clearly, we have well-established competitors in that segment.

Some of them do aspire to become also competitors, to play in the EV space or in the cathode materials space. I would say that today their focus from a practical point of view is still very much on catalysts, while they are at a relatively early stage in terms of development in cathode materials or in other applications like fuel cells.

Battery materials

We also have competition in battery materials – we have just touched on that. It has not changed a lot over the past years, but we have strong and well-established competitors with longstanding experience in cathode materials, for many of them originating – like Umicore – from the portable electronics segments, and having developed over the past ten, 15 or 20 years significant product and process competencies from the electronics industry, moving then into qualification for automotive sites.

So, a well-established competitive landscape as well, with one exception: all cathode materials competitors in the battery materials space are really focused on cathode materials.

The one exception I have in mind is a well-known Japanese company that is also very active in recycling and has also, to a certain extent, very significant closed-loop capabilities for some of the battery materials.

Fuel cell catalysts

In the fuel cell space, we also have well-established competitors – less than a handful of them. Two or three good, strong competitors like in the case of Umicore, with significant development programmes to bring very good electro-catalysts to the market – one of them being a company specialising in precious metals, with no other activities than fuel cells addressing the clean mobility requirements; and another one being a company with a broader spectrum of offering.

Again, I am using this slide to show that the positioning of Umicore is pretty much the same. Our assessment of the positioning is the same as it was three years ago when we launched the Horizon 2020 strategy – a unique positioning which does not mean we do not have competitors, but unique in the sense that we are the only player that has the full spectrum of materials technology offering to support the drive to cleaner mobility in the automotive segment.

The Certainty is Diversity

Technological flexibility the only answer to mixed challenges

To have this broad offering and to cover all the technology developments, all technology avenues in terms of cleaner drivetrain matters, when we spoke three years ago I told you that there was quite a lot of uncertainty about the future engine mix. Three years ago, it was difficult to figure out or make out what the future engine mix or the drivetrain mix would be. It is still the case today.

The engine mix has changed quite a lot since 2015, but it is still difficult to make out what it is going to be in the future. We have an idea of the trend, but nobody knows today what precisely it will be and in which precise proportions. That is why it really makes a difference in being able to offer the full spectrum of technologies.

Umicore is not agnostic in terms of value and technology

I also recall a number of years ago when we started to implement that strategic concept of covering all the bases from a technology point of view, having used the adjective agnostic and having said that the strategic rationale behind this concept was to make Umicore agnostic to the consumers' choice, indeed because we did not know where the engine mix would go. That depends on consumers' choice eventually. It is still the case today; we still do not know and we still want to be sure that, whatever the consumers choose, we have the technology to support our customers.

I have to qualify that statement though in the sense that we are not agnostic in terms of value. There are certain drivetrains, certain technologies that create more value for Umicore than others. This is important for you to appreciate, so that you can also understand where our focus is in terms of investment and in terms of development.

The way I am going to explain the difference in terms of what is creating most value to Umicore is by using a combination of factors. I have tried to aggregate three factors:

1. The revenue potential per car for a materials company like Umicore;

2. Our technology leadership in a given type of technology;
3. The market share.

It is the combination of these three factors that I have used to characterise what we prefer in terms of value creation:

- Full electric long-range: Clearly what comes out first from that exercise is that full electric long-range vehicles create most value for Umicore.
- Full electric mid-range: Second in order of preference in terms of value creation is a little bit of the same – the mid-range full electric vehicle drivetrains.
- Plug-in hybrid: Following that would be the plug-in hybrid. We discussed earlier the potential of plug-in hybrid from a catalyst point of view. Combined with the battery materials, this creates a fairly compelling equation. In terms of value creation, this is second only to the full electric drivetrains.
- Fuel cells: Following that will be fuel cells. Typically, fuel cells are working in combination with a small battery, so that is helping also the value proposition for Umicore. This is one of the very compelling drivetrain developments for the company.
- Gasoline with particulate filters: Next in terms of value preference will be the gasoline configurations with gasoline particulate filters.
- Diesel: Only after that would come the cleaner diesel engines – Euro 6d for instance. Again, to make sure this does not get misinterpreted, it does not mean that the revenue per car is lower for diesel Euro 6d than for a gasoline car with a particulate filter. This presentation, this order of preference, takes into account all technologies and all market shares as well.
- Gasoline: Last in the order of preference would be the gasoline configurations without the particulate filter.

This is important and an important qualifier to the earlier statements about being agnostic to the consumers' choice. Again, it is agnostic in terms of we cover all the bases; it is not in terms of value creation. In terms of value creation potential, this is the sequence or the order of preference that clearly plays out most in our favour.

That is why it is so important for Umicore. We do not know what the precise engine mix is going to be in the future and we know there will be a co-existence of different drivetrains. This is why it is important for us to have the versatility and the breadth that I have mentioned before, and that my colleagues have presented in more detail during the day.

Catalysis or Battery Materials?

Not one or the other – BOTH

I have been asked several times over the past few years whether the catalyst business was close to the tipping point, or how close it was to the tipping point; whether it was making sense to continue to invest in Catalysis.

Clearly, I hope that we have convinced you during today's presentations that there is way more value to be captured from the catalyst business in the next ten years, that it is not a story of having to make a choice between Catalysis or Battery Materials today. We want to

continue to pursue, develop and grow both, because there is a lot of growth potential in both and not just in the electrified drive trains, not just in the Battery Materials part of the business.

Unprecedented growth driven by legislation

In both cases, there is significant growth ahead of us driven by a combination of innovative technologies and tighter environmental regulations. This is an analogy that will continue to drive the two businesses.

The other analogy is that in both cases the growth is predominantly in China and Europe – the leading forces to cleaner mobility from a geographical point of view. That is clearly translated in the market potential and value creation potential for Umicore in clean mobility materials.

Diversified technology needed

In both cases – this is another analogy – there is a lot of technology and a lot of innovation that is required. There is a diversity of technologies that are required in order to meet the variety of customer requirements and consumers' requirements in terms of performance, quality and durability.

Uniquely positioned to thrive in both areas

Last but not least, I repeat again I am really convinced and confident that Umicore is uniquely positioned to thrive in both areas simultaneously.

Those are the key messages I hope you will take away. I cannot impose on you take those away; however, if there are key messages that I would love you to take away from today, these are the ones that you see on the slide.

Closing Remarks

Talking about growth, I would like to close my presentation with one slide that shows there is one area in which the growth in our business is being matched, and that is the growth in your interest in the Company.

I will go back six years to the Capital Markets Day that we had here in Seoul, Korea in 2012. We had 20 people attending, both sell side and buy side, not including the Umicore team. Today for the Capital Markets Day and tomorrow for the site visits, we have 70 of you. Thank you very much for having joined the event today here in Seoul. It is really rewarding for the Umicore team to see that increased level of interest from your side.

[END OF TRANSCRIPT]