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Análisis de viabilidad del sector de baterías de Ion de Litio para vehículos eléctricos y su perspectiva de futuro.

Feasibility analysis of the lithium ion battery manufacturing sector and its future prospects.

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Table of contents

Resumen

La concienciación sobre el medioambiente en los últimos años y el mayor control sobre las emisiones de gases de efecto invernadero pueden hacer del vehículo eléctrico, el vehículo del futuro. Esto, añadido a la aparición de Tesla en la industria automotriz, ha hecho que muchos fabricantes tradicionales, siguiendo sus pasos, hayan comenzado a desarrollar sus propios vehículos eléctricos. Pero esta nueva generación de vehículos es altamente dependiente de las baterías de Ion de litio que alimentan con electricidad a los motores eléctricos que los propulsan.

Las baterías de Ion de litio de estos automóviles son una pieza clave y fundamental para la industria de la automoción eléctrica y la evolución de las innovaciones determinará la capacidad de competir en el futuro con los vehículos de gasolina y diésel. Por esta razón, he considerado oportuno realizar un estudio sobre la situación económica y financiera de la industria fabricante de baterías de Ion de litio que nutre al sector automotriz con una de las partes fundamentales de estos vehículos. Para ello, he identificado a los mayores fabricantes de baterías de Ion de litio a nivel mundial (las localizaciones geográficas donde esta industria está creciendo de mayor manera) y he realizado un análisis económico financiero de su información contable. Además de la clasificación por su tamaño, he realizado el seguimiento continuo y exhaustivo de la evolución de las ventas de vehículos eléctricos a nivel mundial durante los últimos años.

El cálculo de ratios basados en la información financiera publicada en las cuentas anuales de las compañías identificadas como líderes sectoriales ha permitido obtener una imagen fiel a la realidad de la situación económica de dichas corporaciones, y han arrojado unos resultados positivos que auguran un buen futuro para estas empresas y para esta industria.

Abstract

Environmental concerns during the last few years and stricter policies related to greenhouse gas emissions could make the electric vehicle, the vehicle of the future. This, and the emergence of Tesla in the automotive industry, has led many traditional automakers to follow its steps and begin developing their own electric vehicles. But this new generation of vehicles is highly dependent on the Lithium Ion batteries that supply electricity to the electric motors that power the drivetrain.

The Lithium-ion batteries used in these vehicles are a key and fundamental part for the electric automotive industry and the evolution of innovations will determine the ability to compete in the future with gasoline and diesel vehicles. For this reason, I have considered it appropriate to conduct a study about the economic and financial situation of the industry that manufactures lithium-ion batteries and that supplies the automotive industry with a key component. In order to do this, I have identified the main manufacturers of Lithium-ion batteries in the world (the geographic locations in which this industry is growing the most) and I have carried out an economic and financial analysis of their accounting information. In addition to classifying them by size, I have continuously followed the evolution of electric vehicle sales worldwide during the last few years.

The calculation of ratios based financial information published in the annual reports of the companies identified as leading manufacturers has allowed obtaining a truthful image of the economic situation of said corporations, and the results obtained ensure a good future to these companies and this industry.

1. Introduction

During the last decade, concerns about global warming have grown to become part of our daily life and greenhouse gasses have been targeted as the main cause of climate change. Recent studies have shown that carbon dioxide accounted for 65%[1] of all greenhouse gas emissions in 2010. If these emissions are broken down by economic sectors, transportation represents 14% of the total emissions.

The transport sector main energy sources, which represent 95% of the energy used in the sector, are petroleum-based fuels such as gasoline and diesel. Based on this data, it is reasonable to assume, that a decrease in the amount of vehicles depending on petroleum-based fuels and an increase in electric and hybrid vehicles including Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs) and Hybrid Electric Vehicles (HEV) would result in a significant reduction of greenhouse gas emissions. Introducing Electric Vehicles (EV) would be a very effective measure against pollution and pollution related illnesses in countries like China, a country which has a vast population, densely populated areas and where road transport has been growing exponentially.

Thus, the electric vehicle industry has been growing at a staggering rate during the last five years, and it will continue growing, particularly in China. At the beginning of 2011 there were less than 50.000 electric passenger cars worldwide and by the end of 2014 the number of electric passenger cars has reached 740.000[2].

Although the EV industry has a very promising future, it also has to face a series of challenges in order to be able to compete with vehicles running on conventional fuels. Competition within the sector and the demand of fuel efficient vehicles that pollute less, have pushed automotive multinationals to take questionable paths like the one taken by Volkswagen, that led to Volkswagen´s emissions scandal, which resulted in after tax earnings attributable to Volkswagen AG of €-1.582 million[3] for fiscal year 2015. The challenges that the EV industry has to face are mainly due to the limitations presented by the batteries used in EVs.

Currently, pure electric vehicles cannot match the rage of vehicles running on petroleum-based fuels. In addition to this, the charging time required by batteries is considerably higher than the refuelling time needed to fill a tank with gasoline or diesel. Although steps have been taken towards developing efficient charged batteries replacement strategies and infrastructures, which allow for battery replacements of approximately 5 minutes, the existing battery replacement stations are far from reaching the optimum number. Lastly, nowadays, while normal vehicles can be refuelled as many times as needed, batteries have a finite life span and can only be recharged a finite number of times.

Electric car batteries are one of the most expensive parts in EVs and require a great amount of research and development in order to be able to compete with conventional cars in range and refuelling time. A higher demand of electric vehicles, and consequently,

[1] www3.epa.gov/climatechange/ghgemissions/global.html
[2] www.ibtimes.com/global-electric-car-market-about-43-all-electric-passenger-cars-were-bought-2014-say-1857670
[3] Volkswagen 2015 Annual Report

a higher demand of batteries would reduce the cost of batteries due to the economies of scale which would allow for more competitively priced vehicles.

Tesla Motors, one of most important EV manufacturers in the world, has been able to identify the importance of electric batteries in the electric car manufacturing sector. Electric batteries and electric battery packs are of such importance for this sector that Tesla Motors and Panasonic have joined forces in order to build a “Gigafactory” worth $5 billion that will be capable of producing more lithium-ion batteries annually than were produced in 2013 worldwide.

The challenges that the EV industry has to face, the limitations presented by electric batteries, the R&D involved in this field and the dependency of EVs on batteries present a very interesting field of investigation.

This paper aims to identify if the manufacturing of electric batteries for electric vehicles is a profitable activity through an analysis of the electric car battery industry and a comparison of the leading companies in the sector from an economic and financial point of view. We will do it using the financial information provided in annual reports and other financial disclosures. This analysis will ultimately lead to concluding if electric vehicles are the vehicles of the future.

2. Objectives

First of all, this paper aims to identify whether or not the lithium-ion battery industry that supplies the electric vehicle industry with one of the most important components of this type of vehicles is economically viable. This will be done through a financial and economic analysis of the main manufacturing companies in this industry.

Secondly, the intention behind this investigation is to analyse in which geographic locations the lithium-ion battery industry is growing the most. This can be done by identifying the countries in which batteries are being manufactured and locating the battery production facilities that exist.

Lastly, by analysing the evolution of the EV industry worldwide, identifying the volume in which electric vehicles and hybrid vehicles are being sold and comparing past and present data related to demand and growth, it will be possible to obtain a fairly precise prediction of the evolution of the lithium-ion battery industry.

3. Car battery definition

Before describing the electric car battery manufacturing sector two important questions arise. First of all, what is a car battery? And second of all, what kind of car batteries exist in the market?

Answering these questions briefly will allow for a deeper understanding of the matter and for a well-focused analysis that will favour reaching clearer conclusions about the economic viability of manufacturing electric car batteries.

Car batteries are electrochemical storage devices that can release energy when needed and are a key component of conventional, hybrid and electric vehicles. Conventional batteries used in vehicles can be split up in three groups:

1. Lead-Acid
2. Nickel-Metal-Hydride
3. Lithium-ion

Lead-Acid batteries are the ones used in conventionally fuelled vehicles and hybrids in order to start the engine and power a wide range of electrical devices, in other words, Lead-Acid batteries fulfil SLI functions (Starting, Lighting and Ignition). These batteries offer low specific energy[4] and high specific power[5].

Nickel-Metal-Hydride (Ni-MH) batteries are used in small electrically powered items such as electric razors, cameras or toothbrushes as well as in hybrid vehicles. They offer a higher specific energy than Lead-Acid but a lower specific power in terms of volume. This type of battery tends to discharge if left unused for long periods of time and it´s life cycle is reduced when rapid discharges and loads take place repeatedly.

Lithium-ion (Li-ion) are the batteries of choice for laptop computers and cell phones and have also become the batteries of choice for PHEVs and BEVs. Their specific energy and power is several times higher than that of Lead-Acid and Ni-MH batteries and have higher charge/discharge efficiency, but their temperature must be well controlled which sometimes leads to expensive cooling systems. There are several variants within the Li-ion battery group that are commonly used in the electric and hybrid automotive industry.

The five most common variants manufactured and used in the automotive industry are the lithium-nickel-cobalt aluminium (NCA), the lithium-nickel-manganese-cobalt (NMC), the lithium-manganese spinel (LMO), the lithium titanate (LTO) and the lithium-iron phosphate (LFP). These battery types and chemical combinations have different advantages and disadvantages in relation to cost, performance, safety, specific energy and power, life span, etc.

Lithium-cobalt oxide (LCO) batteries are also part of the Lithium-ion family. LCO´s are the most common in consumer applications but this battery type is not considered suitable for electric vehicles because of its safety risks.

Figure 1 shows the specific energy and power of rechargeable batteries, characteristics which ultimately define the purpose of each battery type.

[4] Measure of the amount of energy a battery can hold.
[5] Measure of the amount of energy a battery can deliver at a given time.

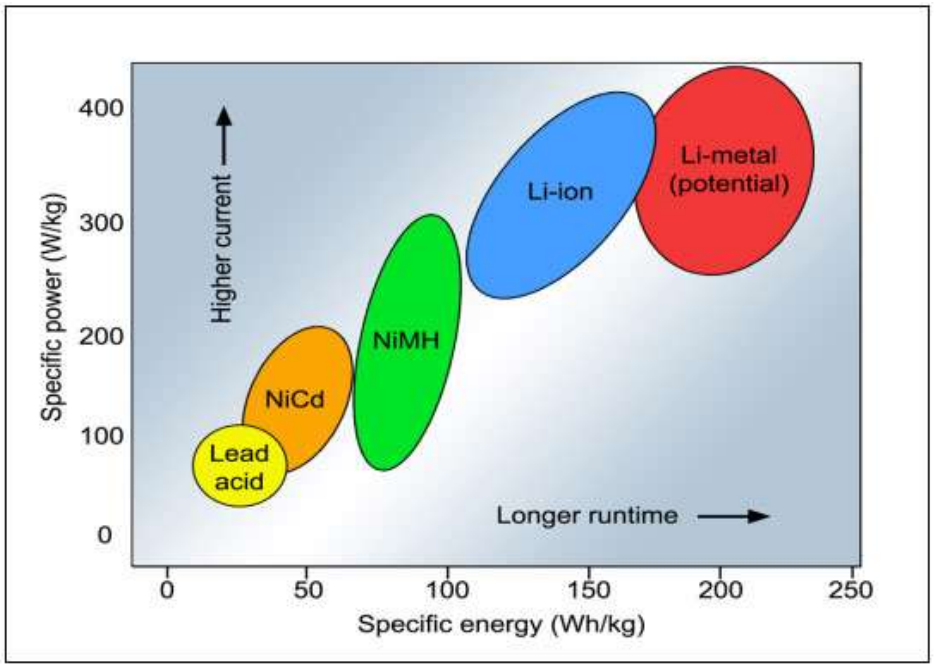

Figure 1 Specific energy and power of rechargeable batteries

Source: http://batteryuniversity.com/learn/article/global_battery_markets

Depending on the use given to the battery, some batteries meet the requirements and fulfil the needs better than others. In some cases, even the combination of two battery types is recommended. A combination of batteries is commonly used in hybrid vehicles since Lead-Acid batteries are adequate for SLI functions, while Ni-MH or Li-Ion are better suited to power the electric motor.

Although Lead-Acid batteries are used in conventional and hybrid vehicles, their main purpose is to provide enough current to electric components. Since lead-acid batteries are not used to power the electric drivetrain in hybrid vehicles, this battery type will not be part of the study. This study will focus on Lithium-Ion batteries since these are the batteries of choice for manufacturers of hybrid and electric vehicles except for Toyota which continues using Ni-MH.

4. The car battery industry

Lithium-Ion batteries are commonly used in consumer electronics as well as in the automotive EV industry and accounted for 37% of the total battery industry sales which reached a global revenue of $47.5 billion[6] in 2009. This industry is expected to grow a 7.7% annually in order to reach $120 Billion by 2019 mainly thanks to secondary batteries. The battery industry can be divided into two categories, primary batteries and secondary batteries which can then be divided into smaller groups by chemistries. All non-rechargeable batteries are part of the primary category, while rechargeable batteries fall in the secondary category. Although mass producing non-rechargeable batteries might seem needless, this battery type fulfils the needs for which it was designed, since accessing the battery is not always an option and therefore the use of rechargeable batteries would not add any value or additional properties to the good itself. Figure 2 illustrates the revenue contribution to the whole battery industry by category in 2009.

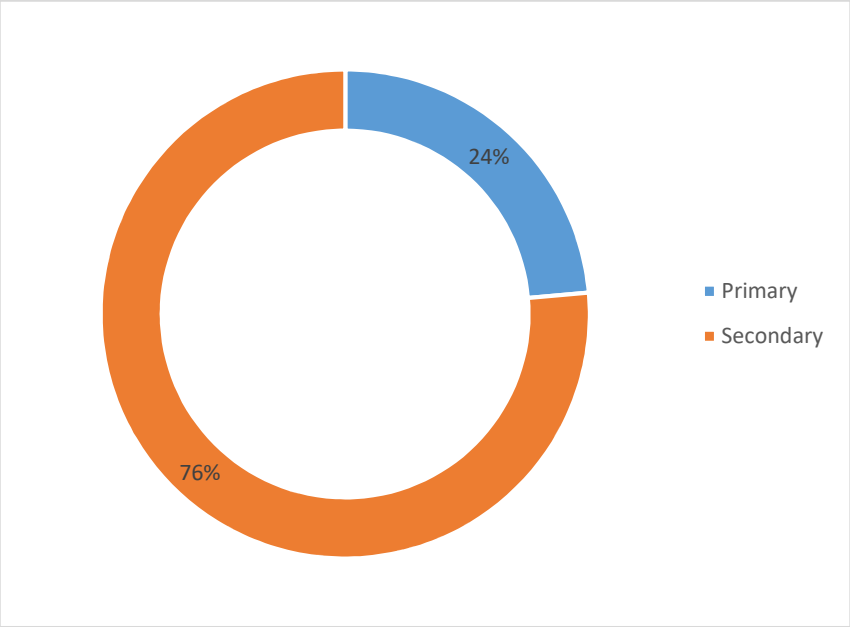

Figure 2 Revenue contribution to the whole battery industry by category in 2009

Source: http://batteryuniversity.com/learn/article/global_battery_markets

As mentioned before, battery types can also be divided by chemistries. Figure 2 illustrates the revenue contribution by chemistries in 2009.

[6] Frost & Sullivan (2009)

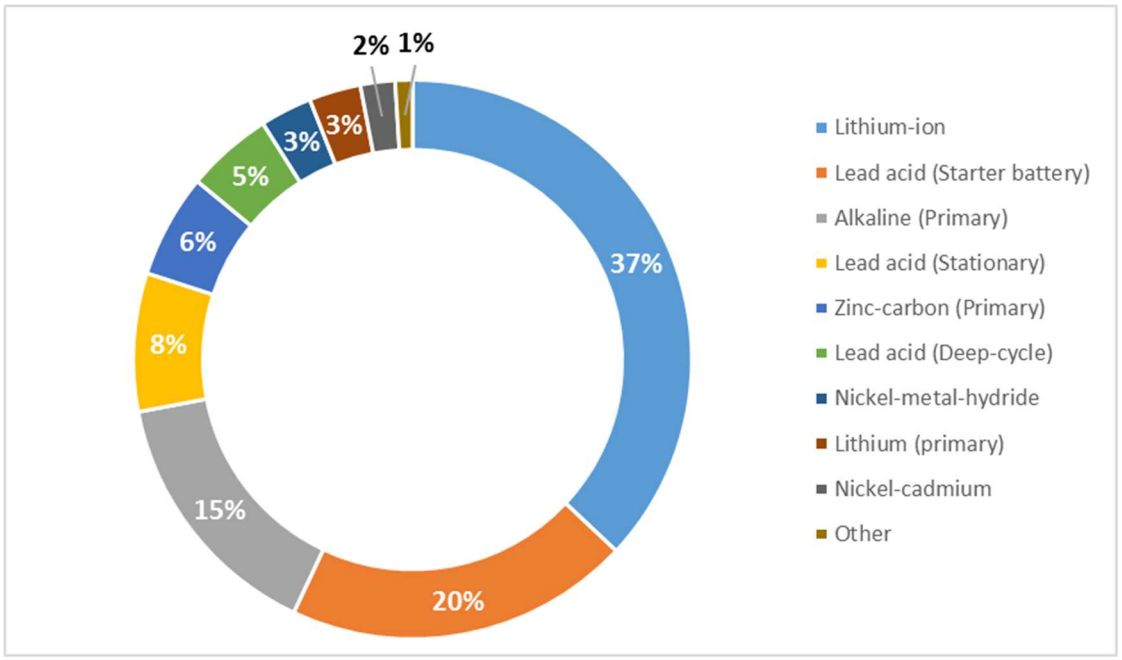

Figure 3 Revenue contribution by chemistries in 2009.

Source: http://batteryuniversity.com/learn/article/global_battery_markets

The above graphs can be used to show the size and volume in economic terms of the battery market in which batteries for the automotive industry are included and accounted for. The important information for this paper lies within the secondary category, and more precisely within the lithium-ion group. When dividing the revenue contribution by chemistries, lithium-ion batteries represent the largest portion of the market but it includes Li-Ion batteries used in all sectors and for all purposes (EV´s, laptops, tablets, phones, etc.). In order to identify the magnitude of Li-Ion batteries for EV´s additional data is required.

Rechargeable lithium-ion batteries are a significant part of the battery market with over 100 companies developing and manufacturing Li-ion cells worldwide, but most of these companies produce cells for consumer electronics. Meanwhile, the electric car Li-Ion battery manufacturing industry is reasonably recent and has just begun to develop. The number of companies in the battery sector that focus in batteries for electric vehicles is quite small, but these corporations are lager financially stable companies or subsidiaries of large multinationals.

There are six companies actively and significantly contributing to this sector, these six companies manufactured in 2013 the totality of the Li-ion batteries for EV industry, 94.13% of the total in 2014 and 89.54% in 2015. The companies leading this industry are Panasonic, AESC, LG Chem, Lithium Energy Japan, BYD and Samsung SDI. Table 1 and Figure 4 show the location of the headquarters of each company, the local currency, the ranking by sales in 2015 and the EV battery manufacturing by company during the period 2013 – 2015 in Mwh.

Corporation	Headquarters	Currency	Ranking by sales in 2015
Panasonic	Kadoma, Osaka, Japan	Yen	1st
BYD	Shenzhen, P.R. China	Yuan	4th
LG Chem	Seoul, South Korea	Won	3rd
Samsung SDI	Yongin, South Korea	Won	2nd
AESC	Zama, Kanagawa, Japan	Yen	-
Lithium Energy Japan	Rito, Shiga, Japan	Yen	-

Table 1 Companies headquarters, local currency and ranking by sales in 2015

Source: Own elaboration

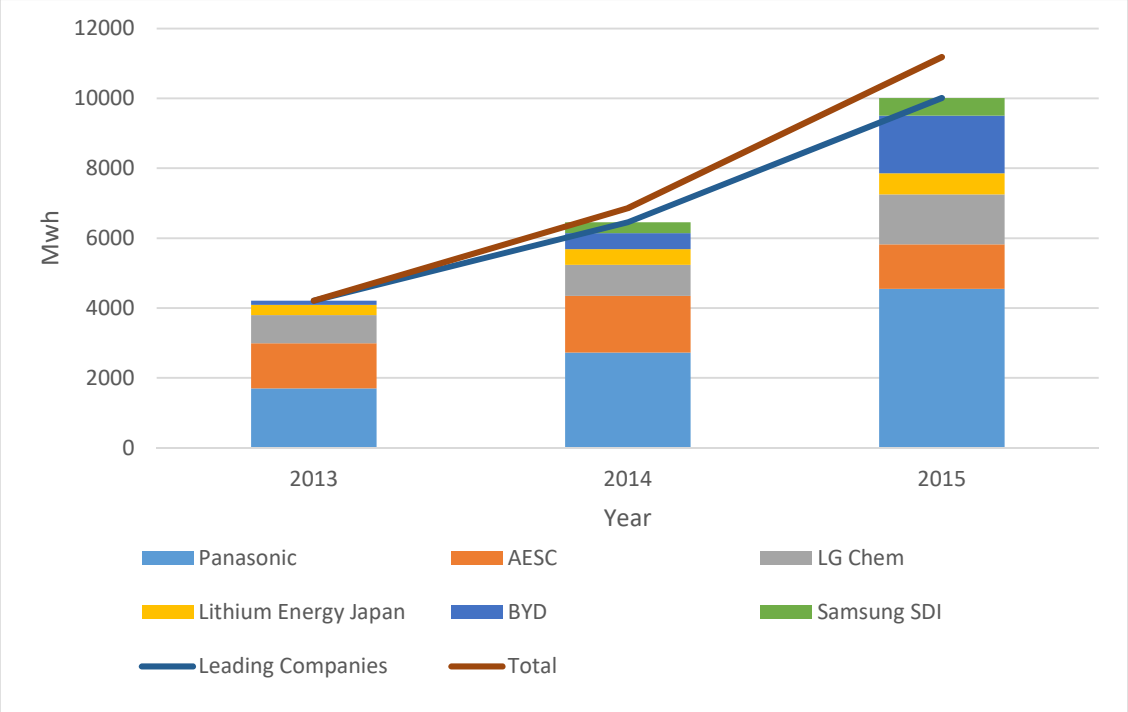

Figure 4 EV battery manufacturing by company 2013-2015 in Mwh.

Source: https://cleantechnica.com/2016/03/26/top-ev-battery-producers-2015-vs-2014-top-10-list/

The Li-ion battery manufacturing sector for EV´s is considerably "young". But it has been growing at a very high rate with just a handful of companies manufacturing most of the batteries that supply the electric vehicle automotive industry worldwide. Battery production grew a 62.93% from 2013 to 2014 and 62.96% from 2014 to 2015. Additionally, Tesla´s Gigafactory, currently being built in cooperation with Panasonic and planned to start production in 2017 and reach maximum capacity by 2020, will manufacture more batteries by itself in terms of energy (MWh/GWh) than the total number of batteries manufactured in 2013. This plant is being built in order for Tesla to be able to supply enough batteries to its car manufacturing plants, thus meeting the projected car sales for 2020 which has been estimated to reach 500,000 cars per year.

In 2015 the manufacturer´s ranking in Mwh is as follows:

1st) **Panasonic** is the leading company in this industry with a 40.71% market share in 2015 having produced batteries amounting to 4,552 MWh (4.552GWh). Panasonic is a Japanese multinational electronics corporation headquartered in Osaka that offers a wide range of products and services which go from cameras and optical devices to refrigerators and air conditioning systems. It supplies batteries to Tesla Motors, Volkswagen and Ford for vehicles such as the Tesla Model S, the Volkswagen GTE and the C-Max.

2nd) **BYD** ranked fifth in 2013, fourth in 2014 and now ranks second with a 14.78% market share after producing batteries that reached 1,652 MWh (1.652 GWh) in 2015. BYD is a Chinese automobiles and batteries manufacturer headquartered in Shenzhen. BYD has several subsidiaries such as BYD Auto, BYD Electronic, etc. and supplies battery cells and packs to itself which are then used by vehicles produced by BYD Auto such as the Qin and the Tang. BYD also manufactures electric buses and batteries for theses buses which are not included in the study.

3rd) **LG Chem** ranks third with a 12.81% market share and it is expected to keep growing and could even surpass Panasonic if Tesla´s predicted demand of the Model 3 is not reached. LG Chem is the largest chemical company in South Korea and it is part of the LG Corporation. This company, unlike the rest of the companies in this sector, is a materials and chemical supplier, not an electronics company, which allows it to manufacture cells for different applications with low failure rates, making it very popular with car makers. LG Chem has contracts with several car companies such as General Motors, Renault, Volvo, Daimler and Volkswagen.

4th) **Automotive Energy Supply Corporation** (AESC) was the second largest electric car battery manufacturer in the world in 2013 and 2014 but fell back to fourth in 2015. AESC was founded in April 2007 as part of a joint venture between Nissan Motor Company and NEC Corporation to develop, produce and market high performance Li-ion batteries for automotive applications. AESC manufactures batteries for the Nissan Leaf but after Nissan decided to find a new battery supplier, LG Chem, AESC´s market share has been dropping from 30.61% in 2013 to 11.38% in 2015 and this negative trend is expected to continue since Nissan will maintain its outsourcing strategy and keep demanding LG Chem batteries.

5th) **Lithium Energy Japan** was established in 2007 as a joint venture between GS Yuasa International, Mitsubishi Corporation and Mitsubishi Motors Corporation in order to develop, manufacture and sell large Li-ion batteries. Lithium Energy Japan supplies batteries to Mitsubishi which are used in the Outlander PHEV. Its market share in 2015 was 5.37%, it has decreased compared to 2013 and 2014 but battery production increased all three years. In 2013 Bosch, GS Yuasa and the Mitsubishi Corporation formed the joint venture Lithium Energy and Power in order to develop the next the generation of lithium-ion batteries which may or may not affect Lithium Energy Japan negatively.

6th) **Samsung SDI** ranked sixth in 2015 with a market share of 4.51% and a production that reached 504 MWh. Samsung SDI is a subsidiary of Samsung, a multinational conglomerate headquartered in Seoul with a large number of affiliates and subsidiaries. Samsung SDI supplies batteries to Fiat which are used in the Fiat 500e and to BMW for the i3 and the i8 models. In 2008 Samsung SDI and Bosch formed the joint venture SB LiMotive which was dissolved in 2012. Additionally, Samsung SDI and BWM agreed in

2014 to increase the supply of batteries to respond to growing demand of electronic mobility over the medium term.

The five biggest companies alone were responsible for almost 90% of the total amount of batteries manufactured worldwide for light duty electric vehicles. **Competition within this sector is quite intensive and complicated. Manufacturers and clients try to find the best partner in order to ensure continuity and growth, at the same time battery manufacturers have to keep developing their products in order to improve recharge time, range, and other factors that make batteries more attractive to car manufacturers.**

In addition to the previous point, the amount of resources required to build a plant capable of producing batteries, supplying the plant with the materials needed and actually manufacturing batteries, allows only large financially stable companies to get involved in this sector due to the large investments required. It is for these reasons that getting involved in this sector and becoming a major EV battery manufacturer turns out to be very difficult.

4.1 Battery manufacturing process

All the companies in the battery manufacturing sector for electric vehicles follow the same four step process when producing batteries as shown in figure 5.

Figure 5 Battery manufacturing process

Source: Batteries for electric cars, challenges, opportunities, and the outlook to 2020 (The Boston Consulting group)

First of all, the anode and cathode active materials, binder, electrolyte and separator are produced, this step is what typically differentiates the various Li-ion battery technologies.

The second step is to produce the cells, cells can be cylindrical, prismatic or polymer depending on the purpose of the battery.

Step three consists in producing the module by connecting cells in parallel and/or in series.

Finally, in step four, battery packs are assembled by connecting modules and installing systems to manage power, charging and temperature.

As previously mentioned in step one, component production is the step that defines the battery chemistry and therefore defines the performance of the battery. In the battery description, the most common variations of lithium ion batteries were mentioned but these were not deeply described.

A deep description of the battery chemistries will not provide any significant information that may benefit the development of this paper nor help obtain better or more precise conclusions and therefore it will not be provided. But a comparison of the performances

of the different chemistries may facilitate understand the results. Figure 6 shows a comparison of the performance of the different Li-ion battery types.

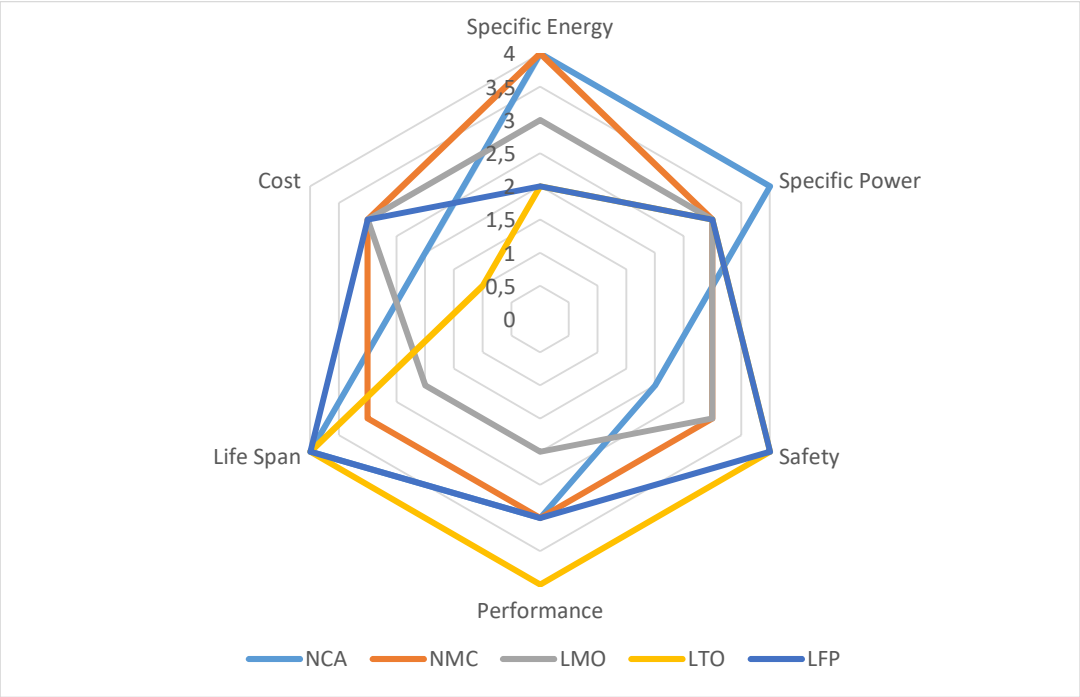

Figure 6 Comparison of the performance of the different Li-Ion batteries.

Source: Batteries for electric cars, challenges, opportunities, and the outlook to 2020 (The Boston Consulting group)

4.2 Business risks

As part of the same industry, battery manufacturers for electric vehicles have to face similar risks and challenges which may affect their performance negatively. There is a wide range of risk factors ranging from economic to political which could impact the industry severely and which should be considered and kept in mind, some of these risk factors will be described next.

Changing economic conditions

Negative economic conditions, both local and global, may affect the lithium ion battery industry for electric vehicles. Economic downturns in countries demanding batteries for their automotive industry could have a severe impact in the battery industry due to possibility of a reduction in vehicle demand by consumers. This would adversely affect the business, operating results and financial condition of the companies involved in this sector.

Currency exchange rate fluctuations

All companies involved in this sector operate internationally, this means that the companies work with different currencies which may fluctuate affecting the costs and prices of products.

Interest rate fluctuations

Companies are exposed to interest rate fluctuations which may affect their operating costs, interest expenses, interest income and the value of financial assets and liabilities.

Competition in the industry

Companies in the sector compete with each other in order to obtain higher market shares and to supply the best clients. Due to the intense competition, the allocation of resources to R&D, the financial strength, the technological capabilities and the marketing resources are key in order to favour the best possible positioning in the market. Competition within the industry can go from technological changes and pricing strategies to product format.

Shortage of supply of parts, raw materials, components, services, electricity and increase of purchase price

Manufacturing depends on obtaining parts and components, raw materials, equipment, supplies and services from suppliers at the adequate quality and quantity in a timely manner. Supplies may be interrupted due to natural disasters, accidents or even the bankruptcy of the supplier. Additionally, raw materials pricing may fluctuate due to factors such as global demand or inflow of investment funds.

The list of risk factors is quite extensive and includes many others in addition to the ones mentioned before such as legal restrictions, environmental regulation issues, information security, disasters and accidents, etc. all these factors are to be taken into consideration since every single one of them can affect and disrupt the normal manufacturing process with disastrous results for the sector.

5. Remarkable issues of the research

As in many research papers, issues may emerge along the way and complicate the investigation being carried out. These issues may be harder to overcome in certain situations and taking them into account makes it easier when trying to understand the results obtained.

5.1. Different fiscal years

Probably one of the main problems was the fact that the companies under study were not all from the same country. As shown in table 1, working with multinationals that do not have their headquarters in the same country leads to different fiscal years and different currencies.

While all the Japanese companies that have been part of this investigation ended their fiscal year on March 31st, Chinese and South Korean companies ended their fiscal year on December 31st. Additionally, the companies presented their annual reports as well as all the information contained within, in their local currency. This meant having to work with the Japanese Yen, the Chinese Yuan and the Korean Won. Balance sheets and Income statements cannot be compared if they are in different currencies which forced me to find a fourth currency, the US Dollar.

Fiscal years that end in different dates is a problem without a solution since nothing can be done about it, but it may generate significant differences depending on the evolution of the currencies exchange rates with respect to the dollar. In this case, the currencies behaved in a similar way and the effect of the exchange rates on the calculations will not have a deep effect on the results obtained.

5.2. Consolidated annual reports

The annual reports presented by the companies were all consolidated, this means that the company is presented as a whole to the public and information related to where the revenues come from or how debt and assets are allocated within the company may only be available if the information is explicitly broken down by divisions or subsidiaries.

While all the companies detailed the composition of the revenue and the net income as additional information to the income statement, the companies did not break down the balance sheet and only presented it as a consolidated balance sheet. Not having separate income statements and balance sheets for each of the divisions within a company makes it virtually impossible to calculate precise ratios that focus only, or at least with a certain degree of precision, the divisions that manufacture Li-ion batteries in order to be able to see and describe the economic and financial health and stability of said divisions.

This leads to having to analyse the entire company and comparing it to the rest of leading companies of the sector, which is only fair when the contribution to the revenues and to the net income come mainly or at least in the same proportion from the segment that manufactures the batteries and not from other sources.

5.3. Differences between groups

AESC and Lithium Energy Japan are joint ventures of Nissan Motor Company and NEC Corporation and Mitsubishi Corporation, Mitsubishi Motor Corporation and GS Yuasa International respectively. While the companies that formed the JV did present annual reports with their financial information, the JVs did not and were simply mentioned in the annual reports of the parent companies, but no additional financial information could be found.

After contacting with AESC, I was able to obtain a copy of their last balance sheet and income statement but no additional information could be obtained in order to precisely asses the evolution and financial condition.

5.4. Data precision

All these companies do present important economic indicators of their divisions which grants a large amount of relevant information to work with but depending of the structure of the company this information is more precise in some cases than in others. For example, while Panasonic had a division called Energy during the period 2010-2013 that only focused in battery manufacturing, it was then merged with the Automotive division. This means that during the period 2010-2013 the revenues from the energy division were purely related to batteries but after the merger, the division revenues inform about the performance of the entire segment.

It is true that in 2014 the Automotive & Industrial Systems division[7] mentioned how the revenues of the division were formed but that was no longer the case in 2015. Under this situation an estimation could be made about the weight that battery manufacturing had within the division but these are mere estimations based on the evolution and not exact data.

5.5. Prior information

Last but not least, Samsung SDI was previously CHEIL Industries and it is possible to obtain Samsung SDI´s annual reports from 2011 to 2015 but obtaining information prior to that hasn´t been possible. For this reason, the analysis does not include any information about Samsung SDI prior to 2011.

[7] Name given to the division after the merger of Energy and Automotive divisions.

6. Principal manufacturers financial analysis

Obtaining a general overview of the industry in economic terms rather than in kw/h is an important step before deeply analysing the financial structure of the companies leading the electric battery industry for EV´s. This broad and brief analysis allows a deeper understanding of the industry being studied and offers a significant amount of information.

Out of the six companies under study, four of them present annual reports in order to inform shareholders and other people interested, about the company´s activities and financial performance. Since AESC and Lithium Energy Japan are joint ventures, these "companies" do not have to publish annual reports and therefore accessing financial information about them becomes a challenging task.

Between 2010 and 2015, Panasonic, BYD, LG Chem and Samsung SDI had revenues from their battery divisions that amounted to $6.49 billion in 2010, $12.95 billion in 2011, $13.96 billion in 2012, $12.89 billion in 2013, $18.28 billion in 2014 and $17.57 billion in 2015 as represented on Figure 7.

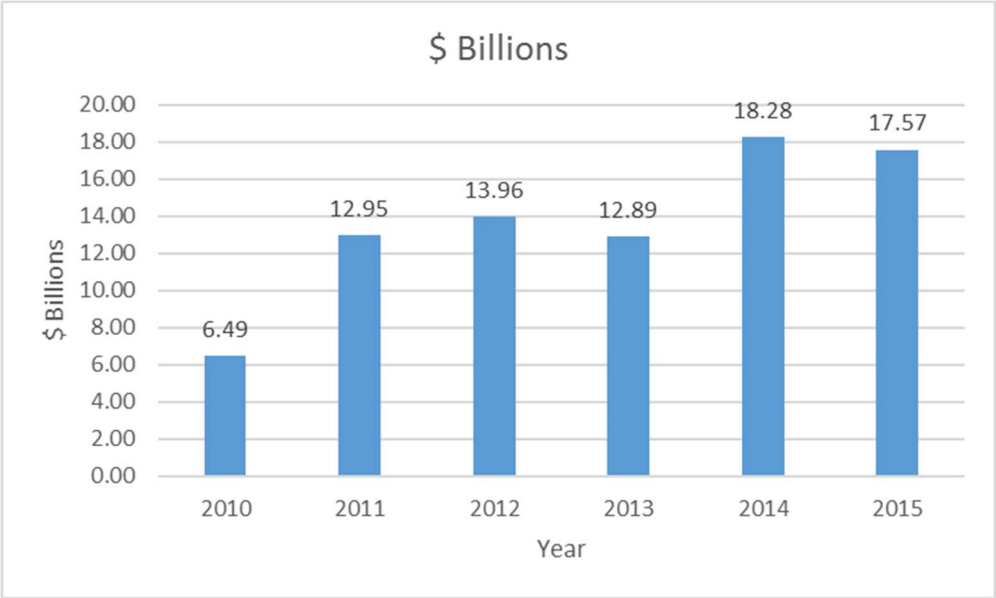

Figure 7 Principal manufacturers revenues 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

The above graph shows a positive and promising trend in the revenue growth of the companies mentioned in the above paragraph.

These figures will now be separated by company, analysed and explained individually.

6.1 Panasonic

Panasonic is one of the most important companies involved in this sector, between 2010 and 2013 Li-Ion batteries were manufactured by its Energy division but since 2014 and after a division merger, they are now produced by the Automotive & Industrial Systems division (AIS).

Although this division merger may seem as if it has no effect on the company´s results, it does have a distorting effect on the sales by divisions since there is no possible way to determine which portion of the division sales come from battery manufacturing unless sales are broken down by divisions and "sub-divisions" in the annual report.

With the above point in mind, the company has been able to achieve continuous growth in the battery sector through solid sales which can be appreciated in Figure 8. Annual reports are published on a yearly basis using the local currency which leads to the problem of not being able to compare the results unless all currencies are the same. Due to this, I have been forced to use the US dollar as a benchmark, which has brought another problem, exchange rates. Rate fluctuations can distort the results more and continuous growth in YEN may result in ups and downs when turned into US dollars.

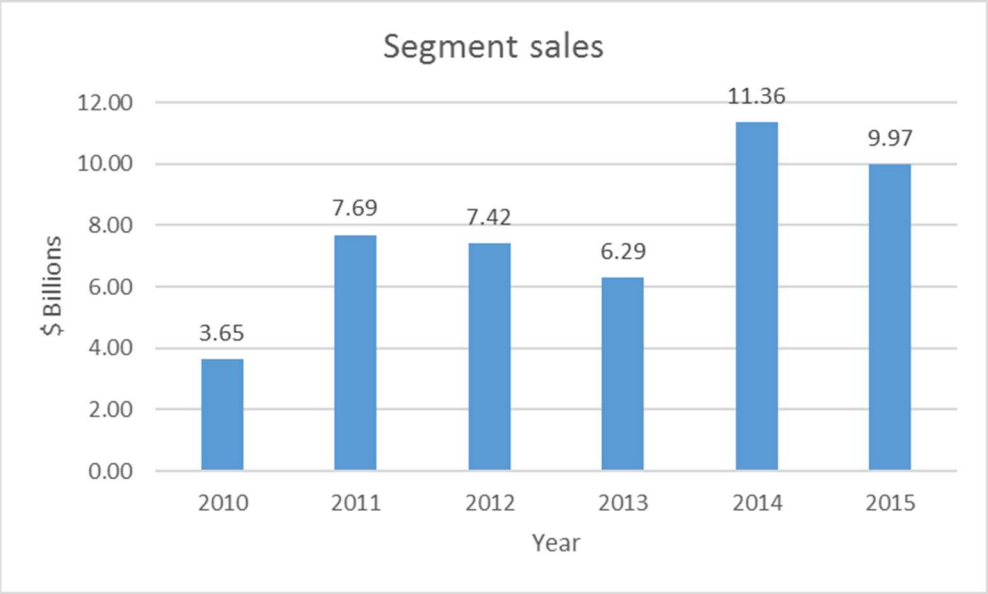

Figure 8 Panasonic Energy and AIS sales in $ Billion

Source: Own elaboration based on the annual reports of Panasonic 2010-2015

While sales could be considered inconsistent due to the ups and downs, net profit for the Energy (2010-2013) and AIS (2014-2015) divisions has experienced a substantial growth after suffering losses in 2011 and 2012. Figure 9 shows the evolution of the operating profit for these segments.

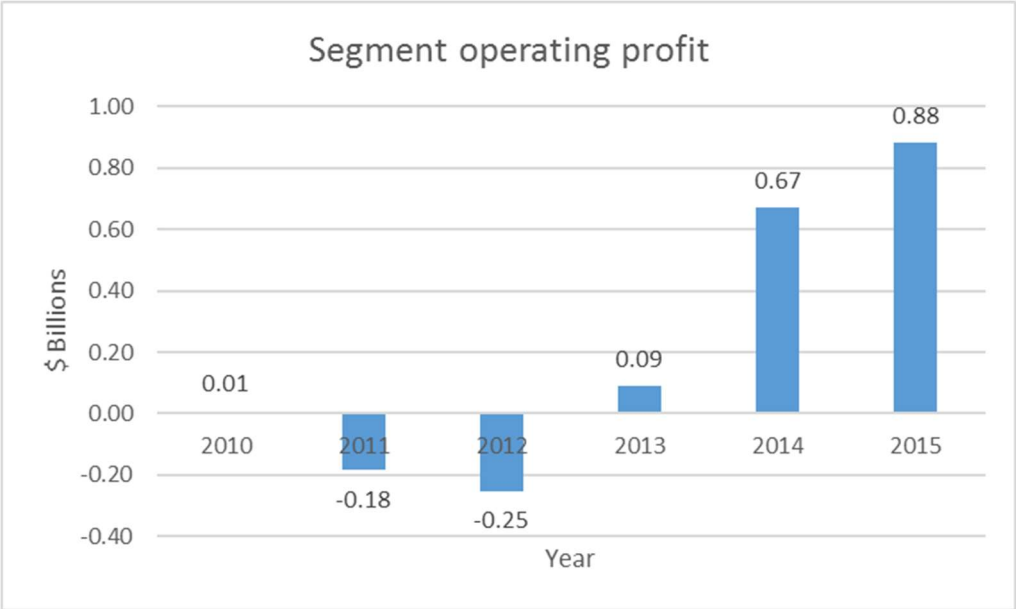

Figure 9 Panasonic Energy and AIS Operating Profit in $ Billion

Source: Own elaboration based on the annual reports of Panasonic 2010-2015

6.2 BYD

BYD is another important battery manufacturer, not only for external customers, but also for its automotive division which has launched several electric vehicles in the Chinese market. Revenues from its battery segment have been very positive since continuous and relatively constant growth has been achieved. This can be clearly seen in figure 9.

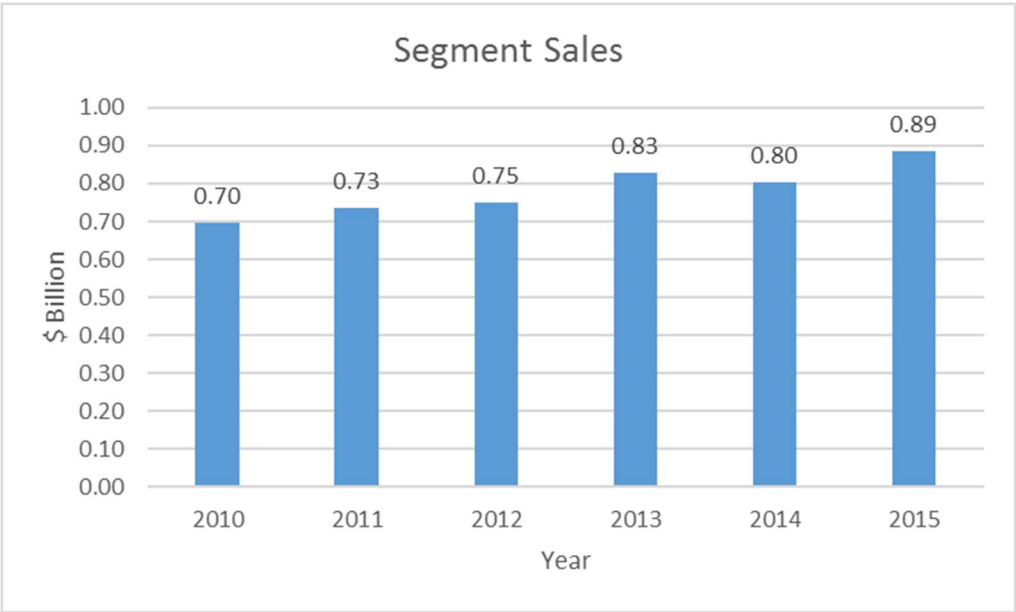

Figure 10 BYD Battery segment sales

Source: Own elaboration based on the annual reports of BYD 2010-2015

Although the sales are quite promising, the battery segment operating profit has been weak during the last five years except for fiscal year 2015. Between 2014 and 2015 the operating profit for this segment of BYD went from $ 17.05 million to $ 152 million.

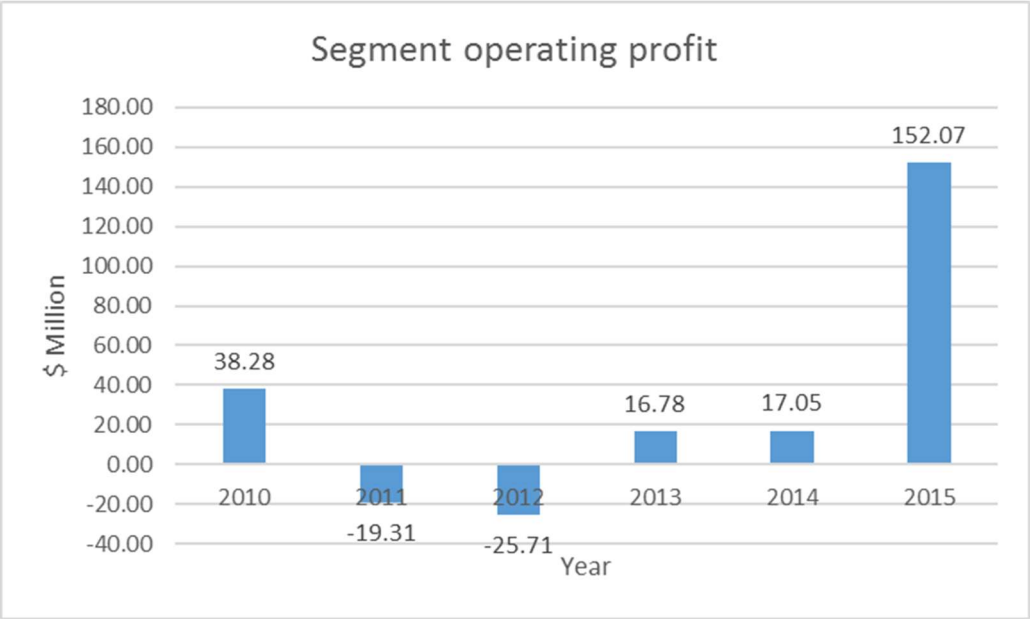

Figure 11 BYD Segment operating profit

Source: Own elaboration based on the annual reports of BYD 2010-2015

6.3 LG Chem

The performance of LG Chem´s battery division is also good based on the sales. In 2010 the battery segment was part of another division and no publications specified the weight of battery manufacturing within said division, due to this, no data is included for year 2010. Nevertheless, sales have gone up from under $ 2 billion in 2011 to $ 2.67 billion in 2015.

While sales increased year over year, the segment operating profit did not behave accordingly and obtained its worst result in fiscal year 2015 after continuous ups and downs with a negative trend as shown on figures 11 and 12.

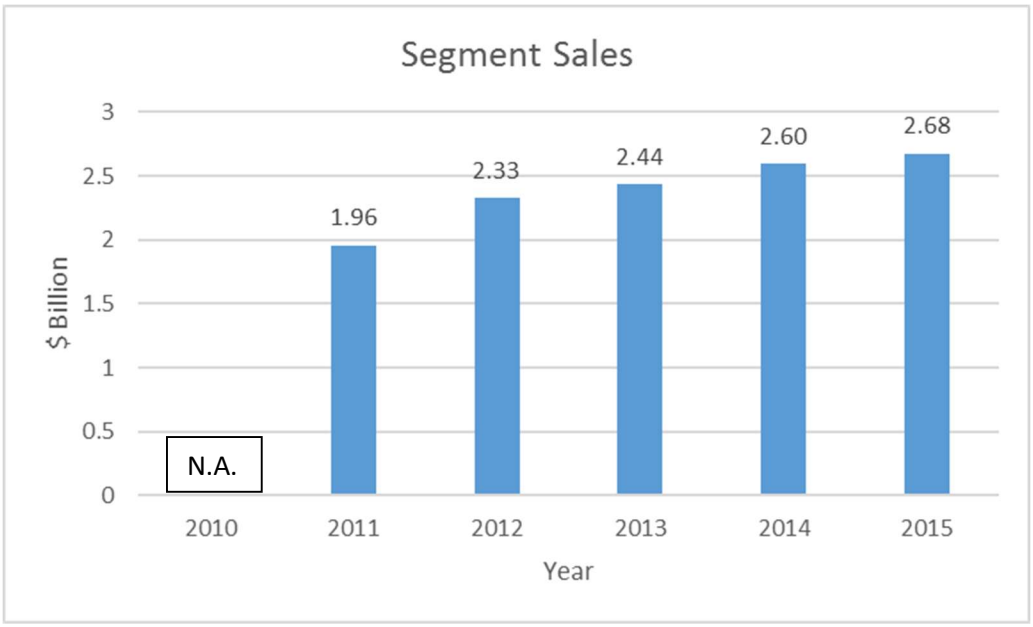

Figure 12 LG Chem segment sales

Source: Own elaboration based on the annual reports of LG Chem 2010-2015

Clearly LG Chem has been able to boost sales continuously and it seems very likely that this trend will continue.

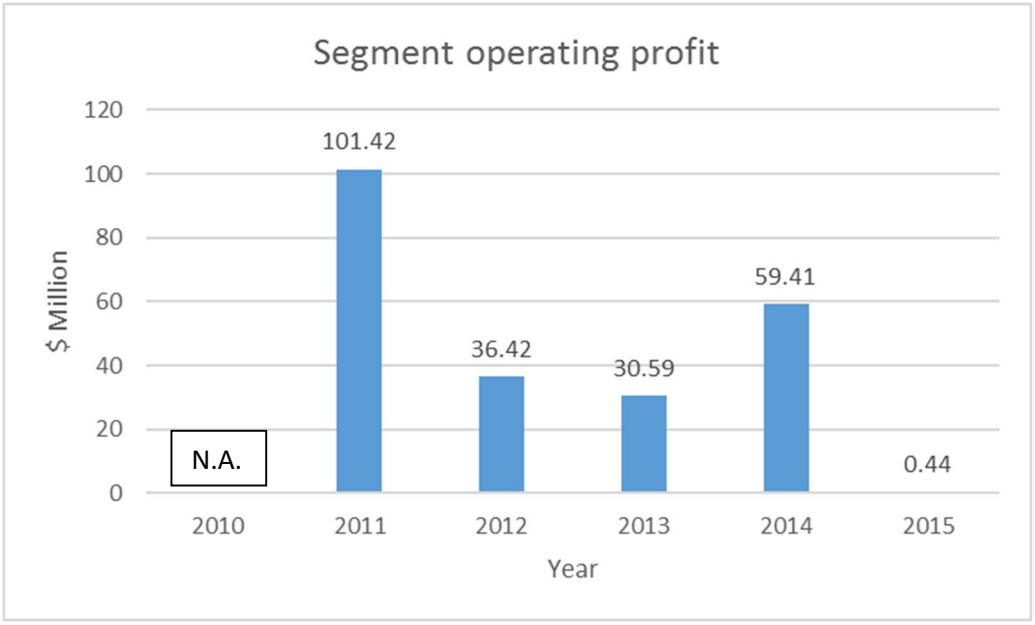

Figure 13 LG Chem segment operating profit

Source: Own elaboration based on the annual reports of LG Chem 2010-2015

In this case, the shrinkage of the operating profit for the Energy Solutions division is due to the continued loss in the automotive battery sector´s R&D costs destined to batteries for second generation electric vehicles.

6.4 Samsung SDI

Samsung SDI is partially owned by Samsung, but it publishes its own consolidated financial statements. As in the previous three companies, Samsung SDI is also divided in several segments. In this case, secondary batteries are manufactured by the Energy division.

Between fiscal years 2010 and 2012, Samsung SDI was able to increase the sales of the Energy division from $ 2.1 billion to $ 3.18 billion but since then sales have decreased slightly down to $ 2.8 billion in 2015.

Meanwhile, the Energy segment operating profit has been decreasing considerably from $ 167.64 million in 2012 to $ -421.44 million in 2015. Between 2012 and 2015 sales and operating profit were broken down by divisions but this was not the case for fiscal years 2010 and 2011. Although it could be calculated, there is no possible way to know the portion of “selling, general and administrative expenses” attributable to the Energy segment.

Figures 13 and 14 show the evolution of the Energy segment sales and operating profit for fiscal years 2010 to 2015.

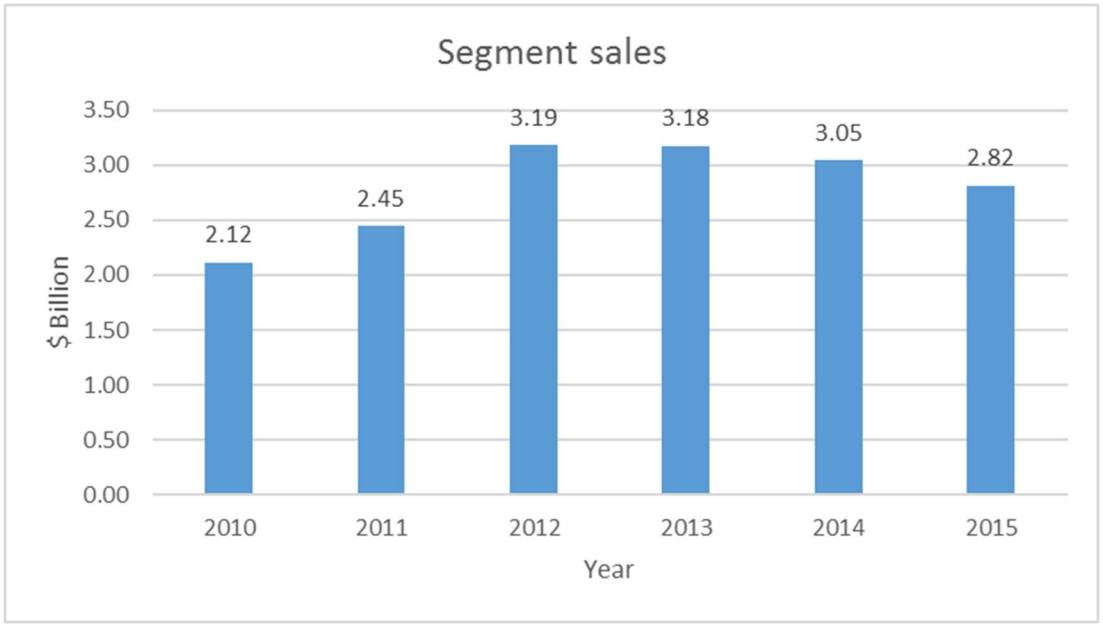

Figure 14 Samsung SDI segment sales

Source: Own elaboration based on the annual reports of Samsung SDI 2010-2015

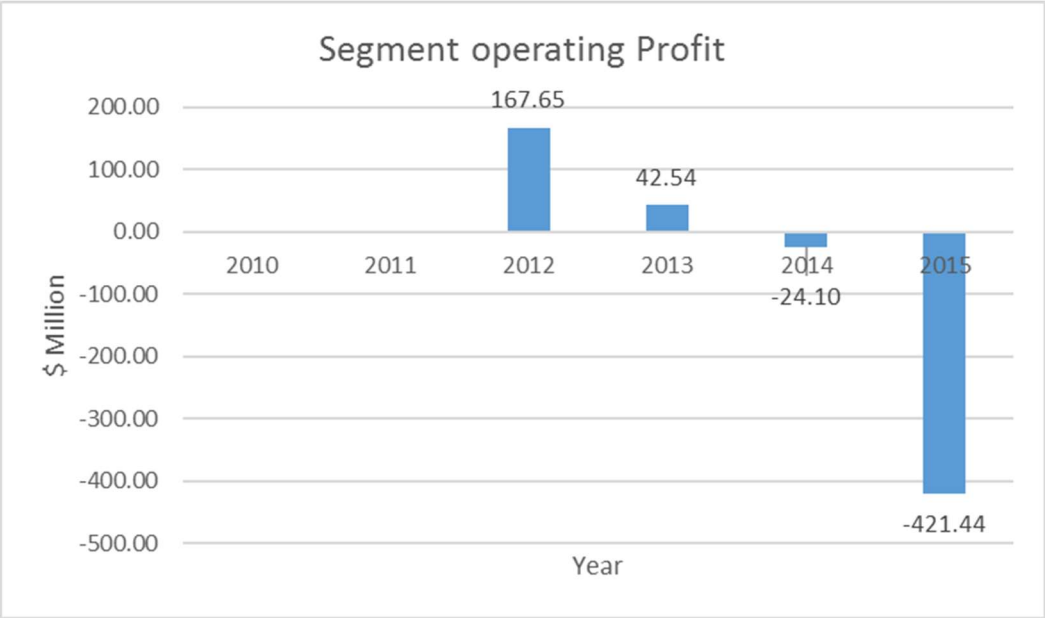

Figure 15 Samsung SDI operating profit

Source: Own elaboration based on the annual reports of Samsung SDI 2010-2015

6.5 AESC & Lithium Energy Japan

These two companies are also part of the leading group in Li-ion battery manufacturing for the automotive industry, the only difference between these and the ones mentioned above is that AESC and Lithium Energy Japan are joint ventures and therefore do not publish annual reports.

Financial information about Lithium Energy Japan is non-existing and after trying to get in contact with them I received no reply.

On the other hand, even though AESC does not publish annual reports, I did manage to get in contact with them and obtained some basic information for fiscal year 2015.

On fiscal year 2015, AESC had revenues for $ 408 million and an operating profit of $ 4.45 million. This information is helpful but it can't be compared to previous years since this is the only financial information that I could obtain. The only additional information worth mentioning about AESC is that its debt to assets ratio reaches 97.39% and that 88.75% of its liabilities are current liabilities. This tells us that the joint venture is being kept alive by the companies that form it probably because they still need AESC to manufacture batteries for their hybrid and electric vehicles.

6.6 Ratio analysis

The information related to the revenues and the operating profit of the divisions that manufacture Li-ion batteries allows us to understand in economic terms the size of the battery manufacturing industry but divisions can´t be compared unless the income statement and balance sheet of each division from each company is disclosed and presented as a separate element of the company.

As the financial data is released as a consolidated report in which all divisions are included, the only possible way to analyse the financial stability of the different companies is by calculating ratios that explain the liquidity, debt paying ability and profitability of each company. Since all the battery manufacturing divisions account for a significant portion of the revenues of each company, it is safe to assume that these divisions will not be shut down, at least in the short term, and since R&D expenditures are quite significant, a future economic return is to be expected.

In order to assess the financial stability of Panasonic, BYD, LG Chem and Samsung SDI, a series of ratios will be calculated and compared which will allow understanding the structure of the company and the continuity in future years.

6.6.1 Activity ratios, inventory and operating cash management

The companies being studied here are all manufacturing companies with physical inventories which include raw materials, work in progress and finished goods. Therefore, the revenue generated by these companies depends on the number of times that these firms can sell and replace inventory within a year.

The inventory turnover (IT) combines the costs of goods sold with the total inventory and is calculated as follows:

$$Inventory\ turnover \quad \frac{Costs\ of\ goods\ sold}{Average\ total\ inventory}$$

Therefore, the higher the IT ratio is the faster the inventories rotations are, this is, inventories are replaced in a shorter period.

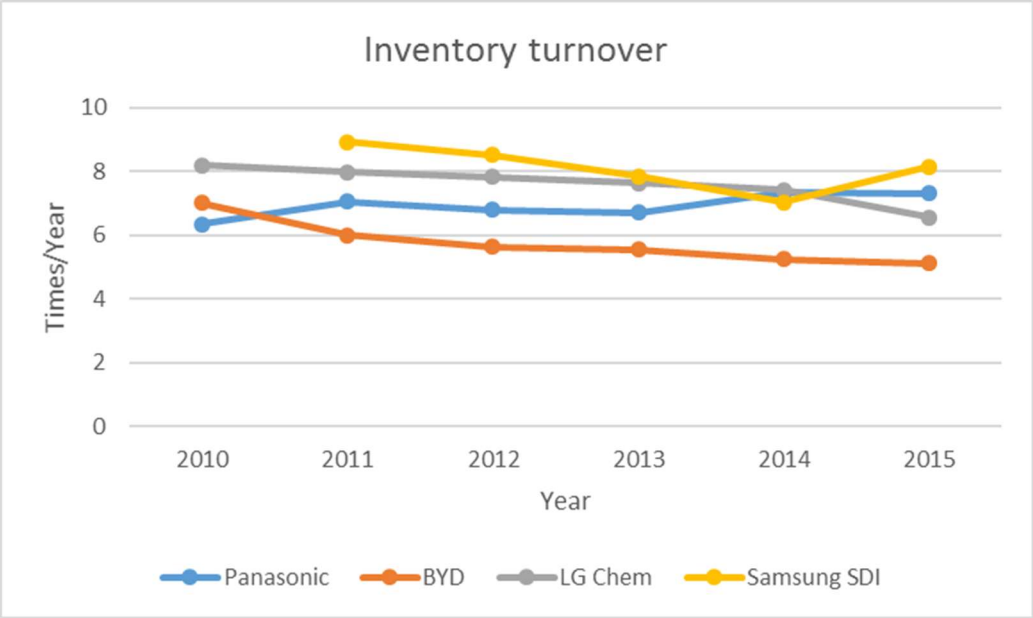

Figure 16 Inventory turnover Times/Year

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

As shown above, BYD has the lowest inventory turnover and LG Chem´s has been decreasing year after year. Meanwhile Panasonic has been able to increase the number of times that it sells and replaces the inventories despite having a minor slowdown during fiscal years 2012 and 2013.

A negative trend can be spotted for the period 2010 to 2014 that has affected all the companies with the exception of Panasonic, although it did suffer the slowdown previously mentioned. In our study, a low IT implies weak sales with long storage-periods, while a high IT means strong sales (i.e. large discounts). The best way to know if these values are high or low is by calculating the industries´ average[8] IT which was 7.06 for the 2010-2015 period. We could affirm that there has been a weakening in sales between 2010 and 2014 but Samsung SDI and Panasonic have been able to recover and overcome the average, while LG Chem and BYD are experiencing a continuous reduction of their IT. Nevertheless, while these companies are all involved in the battery industry, the rest of their divisions compete in a wide range of sectors. It may be easier for Panasonic to sell televisions than for BYD to sell a car.

Inventory turnover may also be calculated in days, this can be done dividing 365 by the inventory turnover. The number obtained is the number of days that the inventory is held in the company before selling it.

After processing raw materials into finished goods, these are then sold in order to generate a revenue, but many of these sales are credit sales[9] which have to be collected. In order to calculate the number of times in a year that a credit sale is made and collected the accounts receivable turnover (ART) ratio comes into use.

$$Accounts\ receivable\ turnover = \frac{Total\ sales}{Average\ accouts\ receivable}$$

ART values can be high or low. High values could mean that the company has an efficient accounts receivable collecting process, a considerable proportion of good customers that pay debt quickly and a conservative credit extension policy. If this ratio is too high some customers could be driven away if the credit extension policy is too strict. Low values close to one could mean a bad collecting process or bad clients (this is client´s with very soft credit conditions).

By using this formula, it is possible to calculate how many times in a year credit sales are made and collected. As on the previous ratio, when dividing 365 by the accounts receivable turnover, the number of days between sale and collection can also be calculated.

[8] An average calculated with more than four companies would offer more precise results to be set as reference.

[9] Credit sales are not always disclosed and total sales may have to be used.

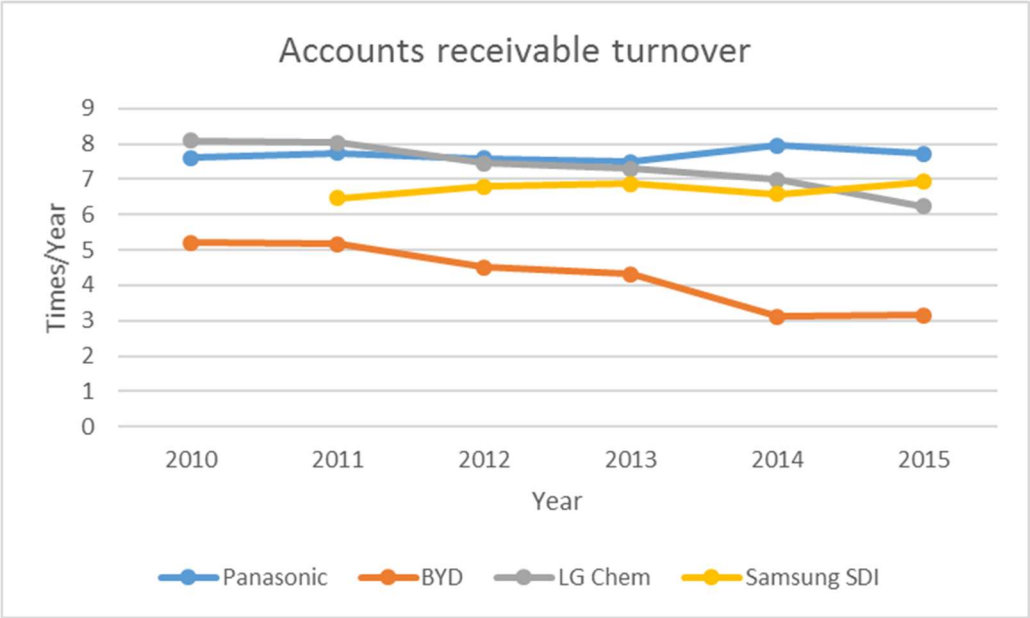

Figure 17 Accounts receivable turnover

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

A ratio of 1 is the lowest possible result and means that all credit sales made remain in receivables. As the ratio increases, it takes less time to collect receivables which increases de liquidity.

As shown on figure 16, Panasonic, LG Chem and Samsung SDI have fairly similar results that range from 6 times per year to 8 times per year and that remain reasonably constant.

LG Chem´s ART has been decreasing since 2010 but is still well above the minimum and should not be worrying unless the negative trend continues.

BYD has suffered a severe decrease of its ART during the period going from 2010 to 2014 but managed to slightly increase its result in 2015. This should not be considered a negative result but it is true that the rest of competitors are able collect receivables at least twice as many times as BYD.

The results obtained are fairly good for Panasonic and Samsung SDI since they are able to collect debt quite fast, LG Chem is struggling and its ability to collect receivables has been decreasing since 2010 but it is still above 6 and BYD is in the worst position out of the three since collecting receivables is becoming harder and harder which could be due to a bad collecting system or struggling clients that can´t pay their debt. If these values continue to drop BYD may run into serious trouble due to the fact that it won't be able to cash the sales that it makes. It's important to note that BYD manufactures cars and that is its main business.

6.6.2 Liquidity ratios

Most companies finance their operations with debt which can be both, short-term debt and long-term debt. Short-term debt is the debt incurred by a company that is due within a year and can be found under current liabilities in the balance sheet.

The continuity of any business which is financed by debt depends on the ability of that company to meet its short-term obligations. The current ratio (CR) shows if a company has adequate liquid assets to meet the obligations generated by current liabilities.

$$Current\ ratio = \frac{Current\ assets}{Current\ liabilities}$$

In normal conditions, a CR below 1 is considered low since assets are lower than liabilities and values around 2 are considered acceptable[10]. The higher this ratio the more capable the company is to meet its obligations.

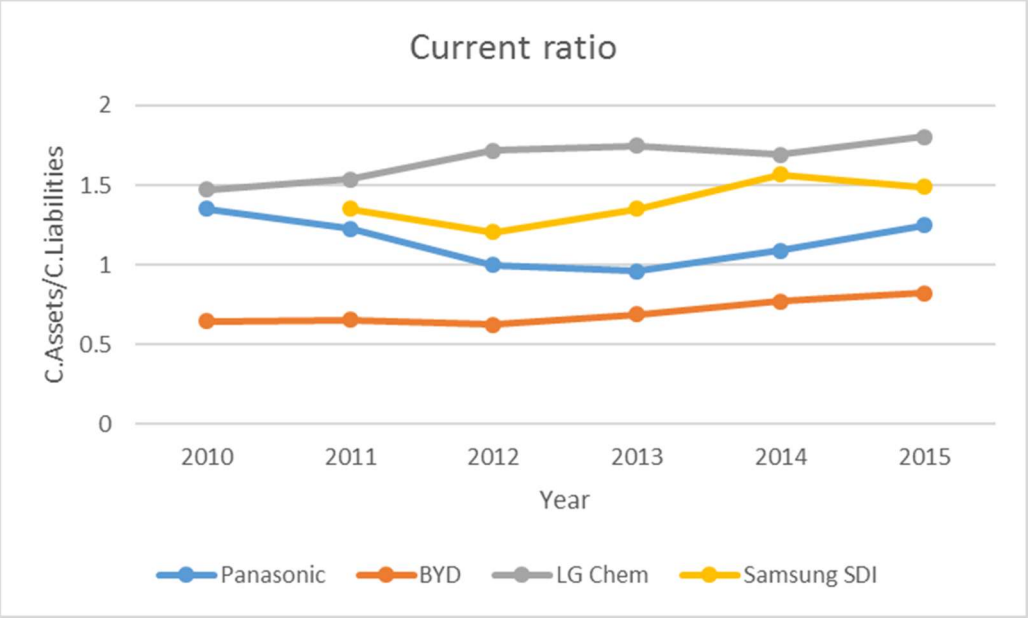

Figure 18 Current ratio 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

If current assets are less than current liabilities, the company would not have enough liquid assets to meet the obligations due in the short-term.

On the one hand, when looking at LG Chem and Samsung SDI we can see that these two companies have more current assets than liabilities and therefore have a positive working capital.

On the other hand, BYD has a negative working capital due to the fact that its current liabilities are larger than its current assets. This may be due to more intensive use of short term debt because of financing costs, a large cash disbursement or an increase in its accounts payable at some point. But this is an ongoing situation since at least 2010 and should be carefully watched because it could mean that BYD depends largely on debt or stock issuances to carry on with operations. Nevertheless, the positive trend is promising and continuing like this would lead them to at least a current ratio of 1 in the near future.

Panasonic´s current ratio did decrease from 2010 to 2013 and reached 0.959 but managed to correct it in 2014 and to continue increasing the ratio in 2015.

[10] It depends on business cycle duration: Inventory, receivables and supplying turnovers.

LG Chem has the best current ratio out of the four companies since its increasing and above 1.5, Samsung SDI and Panasonic are following its footsteps and BYD is in the worst position. This doesn't mean that BYD is going to go bankrupt but it is concerning but the positive trend towards a ratio of 1 is certainly promising.

6.6.3 Solvency ratios, debt to assets and debt to equity

As well as meeting the short-term obligations, companies have to be able to meet long-term obligations. A company has two ways of obtaining long-term financing, one option is through debt and the other is through equity.

The debt to assets ratio defines the amount of debt in relation to the assets that a company has and indicates the financial leverage of the firm.

$$Debt\ to\ assets\ ratio = \frac{Total\ liabilities}{Total\ assets}$$

This ratio indicates de degree of financial leverage of a given company. As the leverage degree increases, financial flexibility is reduced and the more leveraged a company is, the greater its financial risk. In this case a lower value for the ratio is better than a higher value because the higher the ratio the higher the liabilities with respect to the assets.

While different industries have different criterion when analysing the debt to assets ratio, a value of 0.5 of 50% is considered reasonable.

Panasonic and BYD have more liabilities in relation to the assets that they own, between 2010 and 2013 both of these companies increased their debt to assets ratio reaching 75.84% and 68.14% respectively.

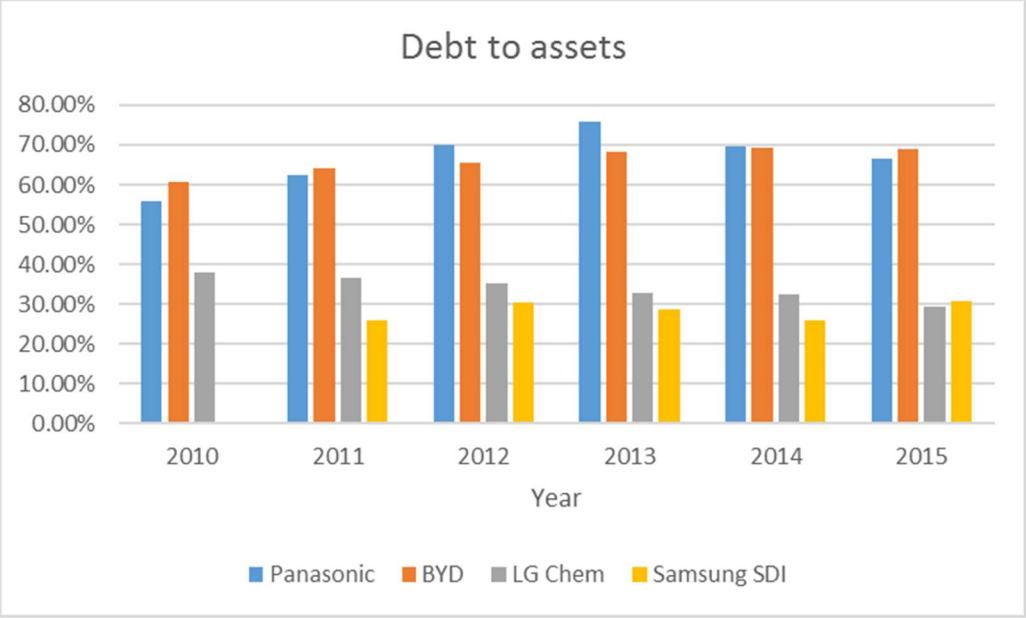

Figure 19 Debt to assets ratio 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

LG Chem and Samsung SDI managed to maintain their debt to assets ratio reasonably low, which allows for a high degree of financial flexibility when compared to the other two competitors. Figure 18 shows the evolution of debt in relation to assets.

The highest ratio possible is 100% and could only be superior if equity is negative. Panasonic and BYD have a large % of assets financed through debt but still have a sufficient margin and a reasonable degree of financial flexibility. There should be no doubts about their abilities to meet long-term debt obligations.

The long-term viability of a business can also be measured by calculating the debt to equity ratio, this ratio shows the proportion of a company´s assets that are financed by debt against equity.

$$Debt\ to\ equit \qquad \frac{Short\ term\ debt + Noncurren\ \ debt}{Total\ equity}$$

It is also another way of considering the financial leverage; this is that shareholder's profitability increases if business performance is higher than debt costs. Anyway, there is no objective benchmark in order to say if the ratio is high or low. A higher value means that the company is primarily financed with debt while a lower value means that the business is financed with equity.

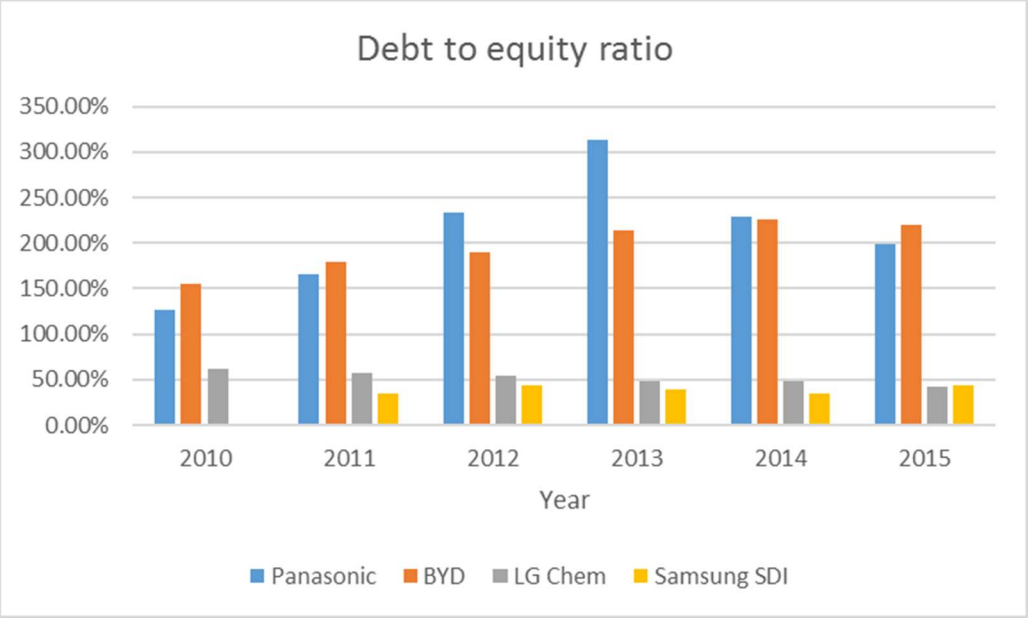

Figure 20 Debt to equity ratio 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

Panasonic has been very aggressive when financing its activities through debt, in 2010 it had a D/E ratio of 127.14% and continuously increased it during 2011, 2012 and 2013. At this point it reached 313.86% which was well above LG Chem, Samsung SDI and even BYD.

Out of the four, Panasonic and BYD have financed their business through debt rather aggressively while LG Chem and Samsung have been very conservative. A large ratio means high risk but Panasonic has been able to correct it and even lower it below that of BYD. Nevertheless, if the debt to equity ratio of Panasonic and BYD remains at around

200%, while the situation wouldn't be concerning it still would be recommended to look into it and if possible have it reduced in order to reduce the risk.

6.6.4 Profitability ratios, net profit margin, gross profit margin and ROE

Profitability is the ability of a firm to generate earnings, in order to asses a company´s profitability a variety of ratios could be studied.

Net profit margin identifies the percentage of revenues collected by a company that turns into profit. The higher this ratio is, the more efficient the company is and the better it controls its costs.

$$Net\ profit\ margi \qquad \frac{Net\ income}{Net\ sales}$$

During the period 2014 to 2015 all companies managed to increase their NPM after having it reduced for the previous four years.

LG Chem suffered an important reduction of its NPM from 11% in 2010 to 3.8% in 2014 but managed to pick it up and ended 2015 with a 5.7%. BYD behaved similarly but with a smaller NPM. Panasonic suffered the most out of the four since for fiscal years 2012 and 2013 its net profit margin was -9.8% and -10.3%, but it managed to obtain a 1.6% in 2014 and a 2.3% in 2015.

Samsung SDI followed a similar pattern to the rest of companies but had an interesting result in 2012. This fiscal year, its net profit margin reached 25.5% due to a gain on disposal of associates and joint ventures which was unrelated to the normal operating business. All this can be clearly seen in figure 20.

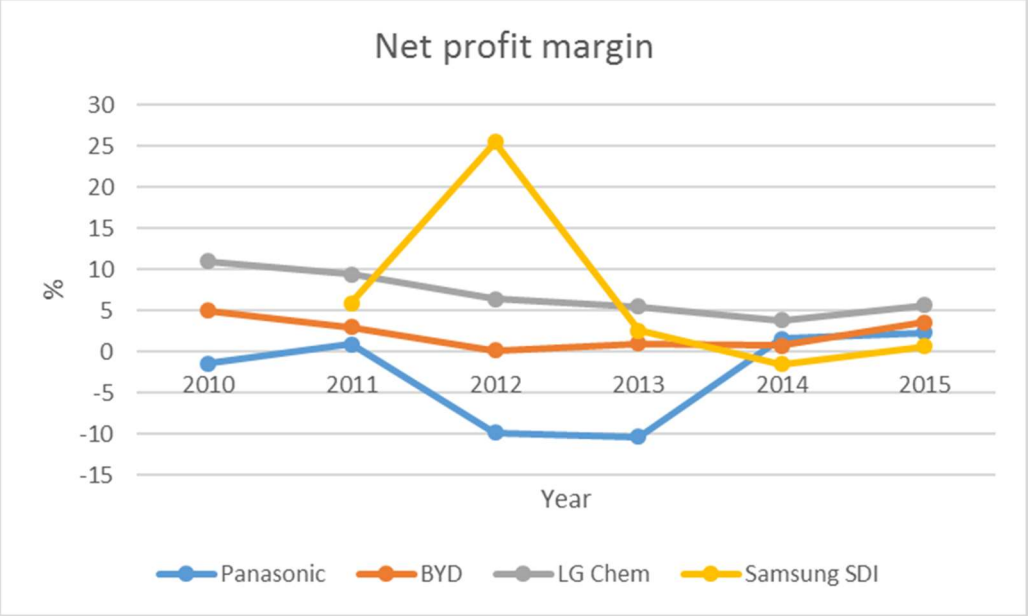

Figure 21 Net profit margin 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

In addition to the net profit margin, the gross profit margin can also be calculated. This ratio reveals the proportion of money left over from revenues after subtracting the costs of goods sold. These costs account for a very large expense and highly impacts profit.

$$Gross\ profit\ margin = \frac{Revenue - CO}{Revenue}$$

For companies within the same industry, differences in gross profit margins between them may indicate that those with higher ratio are more efficient than those with a lower ratio. This is because a more efficient company will run into less COGS which ultimately leads to higher GPM.

Having a high gross profit margin means that the companies are able to make a decent profit as long as the costs are kept under control, when the gross profit margin is low it means that the company is unable to control production costs. Therefore, higher values are preferred here.

Out of the four companies, Panasonic is the one with the highest gross profit margin but all of them suffered a decrease in their GPM´s between 2010 and 2012. Nevertheless, this situation was corrected and all of them managed to increase their ratios from 2012 onwards.

Clearly Panasonic controls its costs of goods sold fairly well and is considerably above the rest of competitors. While the rest of results are not bad, they are significantly lower than those of Panasonic which could mean high costs.

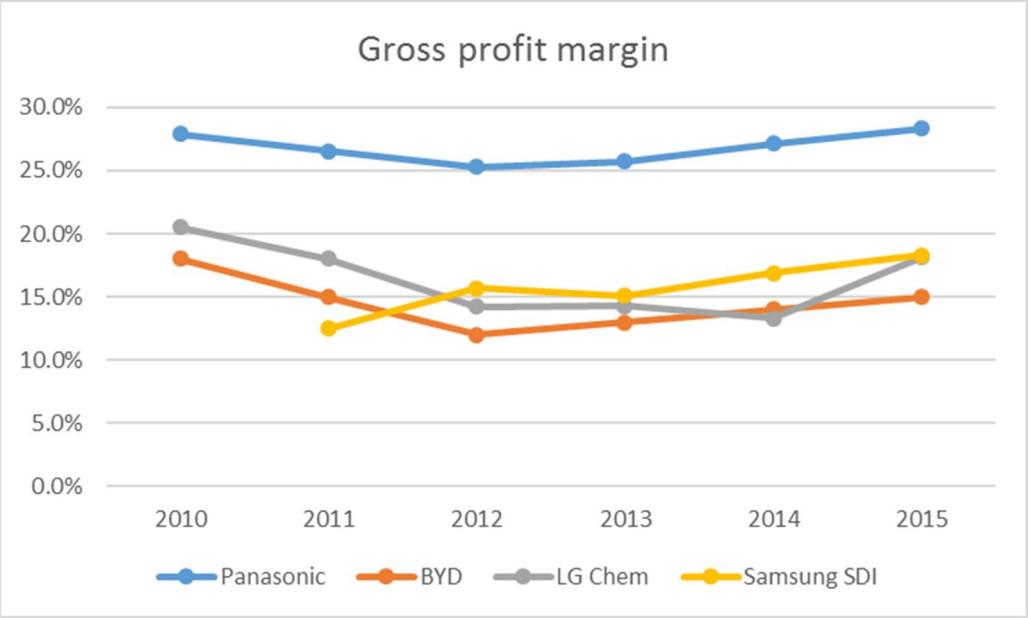

Figure 22 Gross profit margin 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

The last ratio to be considered in this section is the return on equity. This ratio measures the return generated relative to the capital provided by owners over time.

$$Return\ on\ equit \qquad \frac{Net\ income}{Shareholder´s\ equity}$$

This is a good indicator of how well a company uses its investment money to generate profits and indicates investors how well the company is reinvesting its capital. A high ROE means that the company is using investors´ funds effectively but these have to be compared against other companies from the same industry in order to obtain good conclusions.

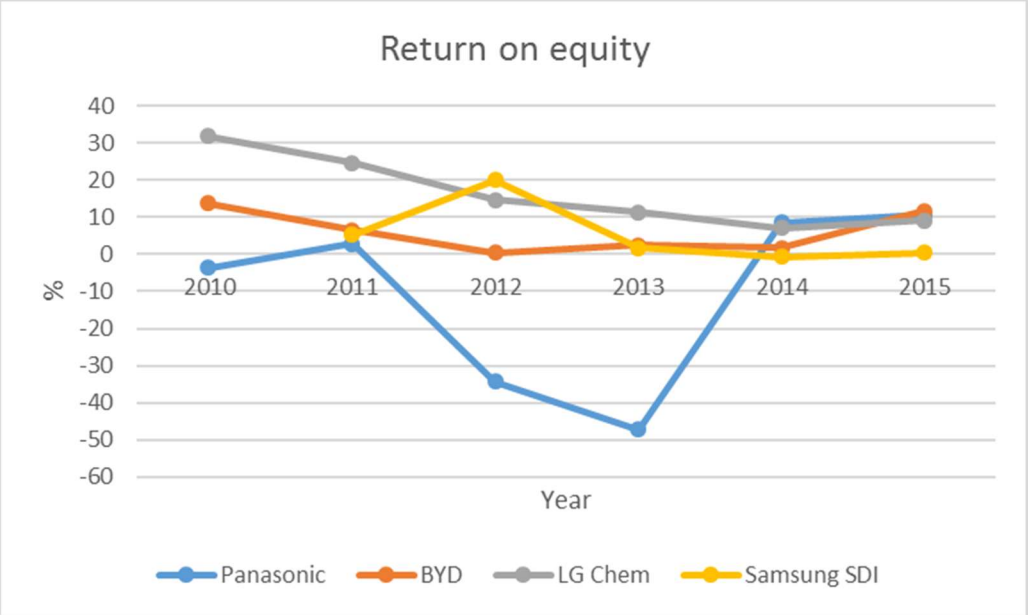

Figure 23 Return on equity 2010-2015

Source: Own elaboration based on the annual reports of Panasonic, BYD, LG Chem and Samsung SDI 2010-2015

Figure 22 shows the evolution of ROE for the period 2010 to 2015. This last figure is quite similar to the one obtained when the net profit margin was calculated. While the overall trend is negative, 2014 and 2015 show a positive turn which may continue in fiscal year 2016.

Once again, it was Panasonic the one that faced the worst results but it was able to return to positive results and match those of LG Chem and BYD. This is important because in Figure 21 it is shown that this improvement appears with debt to equity´s shortening, therefore I think that financing costs were higher than interest rates

7. The evolution of the electric automotive industry

The lithium-ion battery manufacturing sector is highly dependent on the evolution of the perspectives and evolution of the EV sales worldwide and vice versa. As of this moment it is an emerging industry, any slowdown in EV sales due to reliability, malfunctions, safety hazards or whatever other reason will have a major impact on the battery industry that supplies EV manufacturers and their expectations of the future. Therefore, an important part of this analysis is to assess the evolution of the electric vehicle industry in order to be able to foresee the future growth or shrinkage of the battery manufacturing industry.

By the end of 2012, the global EV stock had reached 180,000[11] vehicles which represented a 0.02% of total passenger cars and sales had more than doubled from 45,000 vehicles in 2011 to 113,000 in 2012.

Growth continued through 2013 and by 2014 the total number of EV´s on the road had reached 665,000[12] vehicles, this number represented 0.08% of the total passenger cars. This growth didn´t stop and by the end of 2015 the number of electric vehicles had reached 1.26[13] million.

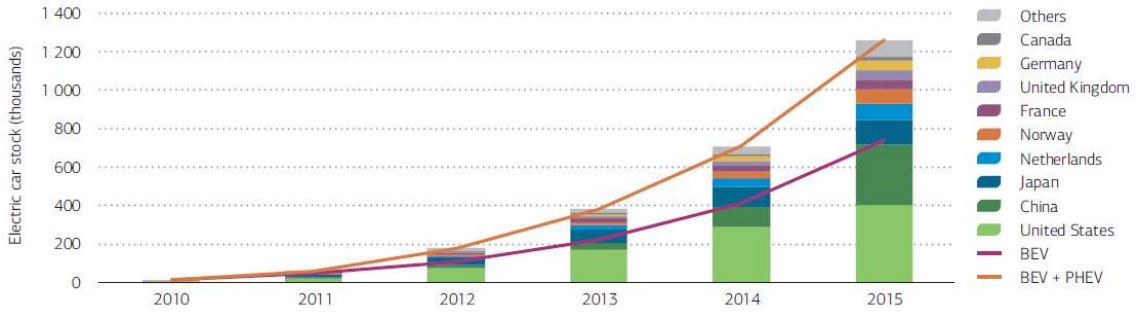

Figure 24 Evolution of the global EV stock 2010-2015

Source: Global EV Outlook 2016

While at first the United States was the mayor source of growth for the electric car industry, China has been able to catch up and during this year it will surpass the US as main EV market. China´s economic growth during the past decades and its large population have pushed pollution to the limit in urban areas and electric vehicles are an interesting form of transportation with zero emissions (BEV´s) or at least low emissions (PHEV´s).

Growth in this market will be continuous for the foreseeable future and China will certainly be the most important source of growth not only of electric passenger cars, but also of e-bikes and e-buses. The Electric Vehicle Initiative (EVI) aims to reaching a global EV stock of 20 Million by 2020 and thanks to the economies of scale and economic efforts in research and development by battery manufacturers, batteries are now much more efficient, the energy density is now considerably higher than five years ago and the price of batteries has reached a new minimum.

[11] Global EV Outlook 2013
[12] Global EV Outlook 2015
[13] Global EV Outlook 2016

8. Conclusions

We had three main research objectives: (1) identifying whether or not the lithium-ion battery industry was economically viable; (2) analysing in which geographic locations the lithium-ion battery industry was growing the most, and lastly (3) obtaining a fairly precise prediction of the evolution of the lithium-ion battery industry. The lithium-ion battery manufacturing industry for EV is mainly represented by the four companies studied here, these companies present a solid economic and financial structure and are capable of maintaining their leading positions within the industry.

From an economic and financial point of view, in general these companies are performing well and their structures are solid. We can structure sales and operative profits in two stages, until 2012 as turning point and after 2013. Probably because at that moment the sector reached the sales´ breakeven point. The activity ratios calculated show a high inventory turnover with a slow decrease between 2010 and 2014 but this was corrected in 2015. Additionally, the accounts receivable turnover follows a similar patter as the IT. The only company that is performing below the average is BYD and if the negative trend continues both in IT and ART it could lead to significant problems since it is taking BYD longer to flip inventories and to collect cash from sales.

Liquidity wise, the current ratio for these companies is not bad, Panasonic did obtain a CR below 1 in 2013 but is now at around 1.25, meanwhile LG Chem and Samsung SDI have both been able to obtain ratios above or close to 1.5. BYD is once again performing worse than the rest with a CR under 1 and this situation has been ongoing since 2010, although it has been increasing since 2012 it still hasn't reached 1. There is no doubt that BYD can still meet its obligations but it is financially weaker than the rest.

The solvency of these companies is fairly good, Panasonic and BYD owe more debt than LG Chem and Samsung SDI which lowers their financial flexibility but it isn't high enough as to be risky. However, Panasonic did not take advantage of its leverage because I think that debt costs were higher than business performance.

Profitability has increased since 2014 after decreases since 2010, there is a clear improvement probably due to measures taken in 2013 that have affected net profit margins, gross profit margins and return on equity positively.

During the five years studied, these companies have had to operate in a very competitive oligopsony market in order to supply a small number of EV manufacturers which has forced them to make strategic alliances with car manufacturers in order to maintain their leading positions in the market.

BYD should be closely followed due to its size, the amount of debt that it owes and to the decrease in their ability to collect receivables. Also, Samsung SDI shows operative loses in 2015 but it is not so in debt. Their situation is not alarming and fiscal year 2016 will certainly bring better results than previous years but an eye should be kept on their evolution in the short to medium term

The amount of resources destined to research and development by Panasonic, BYD, LG Chem and Samsung SDI have been large but are paying off. Nevertheless, these investments will have to continue in order for batteries to improve and meet the needs of EV buyers. R&D is a key aspect in this sector and resources should and will continue being directed towards it which will allow them to keep developing a rather recent product that will be the basis of worldwide transport. An interesting question is if R&D financing

efforts are based on equity or debt. Probably Panasonic´s model is different and uses more debt while LG Chem and Samsung SDI balance sheet looks more like a typical innovative firm.

Growth in the sales of electric vehicles during the last five years have been very positive and the tendency will continue during future years as more and more car manufacturers are introducing electric vehicles in the market. Tesla will be a key player in this industry and in the battery industry, its EV´s are well known and desired, and its involvement in the battery industry together with Panasonic will certainly increase the competition within an already competitive sector.

9. Future research

Although the results obtained about the financial and economic health of Panasonic, BYD, LG Chem and Samsung SDI are good and ensure a successful future for the batteries industry, and taking into account the positive evolution of the EV sales worldwide, future research in the matter could be beneficial.

First of all, battery chemistries are certainly different and so are their pros and cons, for this reason a deeper study of the battery chemistries used by the leading manufacturers could offer important information about where the industry is going and how it will affect electric vehicles.

Second of all, the raw materials used in battery manufacturing haven't been considered in this analysis, but the evolution in the price of these materials could significantly affect manufacturing and battery costs.

Lastly, while AESC and Lithium Energy Japan are part of the leading battery manufacturers, it has been impossible to obtain enough information about them in order to carry out a better analysis of the sector. It could be highly useful to monitor new manufacturers and increase the number companies analysed, which would allow for more precise results.

9. Appendix

Inventory turnover						
2010	2011	2012	2013	2014	2015	
6.34	7.06	6.79	6.70	7.33	7.30	Panasonic
7.02	6.01	5.63	5.56	5.25	5.11	BYD
8.19	7.98	7.82	7.64	7.42	6.55	LG Chem
-	8.92	8.52	7.86	7.02	8.15	Samsung SDI

Accounts receivable turnover						
2010	2011	2012	2013	2014	2015	
7.608	7.747	7.585	7.494	7.948	7.717	Panasonic
5.203	5.164	4.501	4.314	3.113	3.161	BYD
8.087	8.031	7.446	7.288	6.990	6.241	LG Chem
-	6.461	6.800	6.865	6.573	6.932	Samsung SDI

Current ratio						
2010	2011	2012	2013	2014	2015	
1.352	1.226	0.999	0.960	1.089	1.249	Panasonic
0.647	0.658	0.627	0.691	0.770	0.825	BYD
1.471	1.536	1.718	1.747	1.694	1.804	LG Chem
-	1.351	1.205	1.351	1.568	1.491	Samsung SDI

Debt to assets ratio						
2010	2011	2012	2013	2014	2015	
0.560	0.623	0.700	0.758	0.696	0.666	Panasonic
0.607	0.641	0.655	0.681	0.693	0.688	BYD
0.381	0.365	0.351	0.328	0.323	0.295	LG Chem
-	0.260	0.306	0.285	0.259	0.306	Samsung SDI

Debt to equity ratio						
2010	2011	2012	2013	2014	2015	
1.271	1.655	2.338	3.139	2.286	1.990	Panasonic
1.547	1.789	1.900	2.139	2.254	2.205	BYD
0.616	0.575	0.540	0.488	0.478	0.418	LG Chem
-	0.350	0.440	0.400	0.350	0.442	Samsung SDI

Net profit margin						
2010	2011	2012	2013	2014	2015	
-1.4	0.9	-9.8	-10.3	1.6	2.3	Panasonic
5	3	0.2	1	0.8	3.6	BYD
11	9.4	6.4	5.5	3.8	5.7	LG Chem
-	5.9	25.5	2.6	-1.5	0.7	Samsung SDI

Gross profit margin						
2010	2011	2012	2013	2014	2015	
0.279	0.265	0.253	0.257	0.271	0.283	Panasonic
0.18	0.15	0.12	0.13	0.14	0.15	BYD
0.205	0.18	0.142	0.143	0.133	0.181	LG Chem
-	0.125	0.157	0.151	0.169	0.183	Samsung SDI

ROE						
2010	2011	2012	2013	2014	2015	
-3.7	2.8	-34.4	-47.2	8.6	10.6	Panasonic
13.66	6.55	0.38	2.54	1.72	11.7	BYD
31.9	24.7	14.7	11.3	7.1	9.1	LG Chem
-	5.23	19.95	1.77	-0.723	0.488	Samsung SDI

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