Design and Product Development of a Residential Energy Storage System

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Abstract

This document is the extended abstract of a Master Thesis Dissertation carried out through a thesis-related internship in Azolis, a small enterprise in Morocco. The document focuses on the project management of the design and development of an energy storage solution for residential application. The work conducted is the practice of initiating the process of the expansion of a business into a new field, analysing the market, its trends and competitors, carrying out the product development of a RESS with innovative technology and overall high performance that adds value to the customer, and designing a business strategy showing some promising financial results to implement it into the market. All the thinking process, idea generation, decision making and strategy definition is meticulously developed and argued for a better understanding of the lector.

Keywords: energy storage, residential application, project management, product development, innovation, business.

I. Introduction

During the last decades, climate change concern has been increasingly inculcated in society until it has become a reality. The planet is now entering in a point of no return caused (or highly accelerated) by human activity. Part of the population believes the duty is on politicians and the regulation they establish, that this is outside their control. Even still some small lost part of society denies its evidence. The reality is that climate change is on every one of us and it is happening.

Technology advancement in renewable energy is driving down the cost of clean energy, making it affordable to a big percent of the population and reaching grid parity in some cases. Electricity prices are increasing yearly, and more people is now willing to install PV panels in their rooftop. However, the PV production and household consumption profiles only match in a 35% ratio on average, and feed-in-tariff prices went down to ridiculous levels. Therefore, it is time now for energy storage. By storing the energy from the PV panels, the user can harness all the "free" and clean energy coming from its rooftop installation, matching their consumption on rates up to 85%.

The main barrier for dynamiting the growth of the sector is that currently no RESS leads to a profitable investment with a return on it. Nonetheless, many people are already prioritizing the value of using green energy and become independent from the mix of energy from the grid, composed by many GHG ways of production. The market is increasing almost exponentially, and the race for companies to create the first RESS that provides a payback time to the customer is a fierce competition.

The core of the document is a business case suggested by the company Azolis and carried out by the author of the dissertation. The main activity of the company is the distribution and installation of solar PV panels and HSW systems around Africa and Middle East Asia, mainly for industrial applications. The CEO of the enterprise wanted to analyse the feasibility of expanding the market to the energy storage sector, focusing in residential applications as first approach.

In this context, it has been carried out the study on the business expansion, fully developing a RESS (Residential Energy Storage Solution) starting from zero, analysing the market and revising all the items and possibilities that can be improved, and studying where to implement economic efforts in order to achieve these results. As a result, an outstanding product in terms of performance using innovative technology in battery operation has been designed, with its corresponding business model and strategy developed, with promising financial results.

II. State of the Art of RESS

In this section, the key components and possible configurations of a RESS are presented.

In the residential energy storage sector batteries are combined mainly with PV panels, so households can store their solar energy and increase their rates of self-consumption, maximizing the ROI of their installation and becoming almost grid independent.

The main components that conform these systems are the battery module(s), the BMS (Battery Management System), the inverter(s) and the EMS (Energy Management System). The batteries store the energy, the BMS balances the SOC of the cells and ensures that batteries operate safely, the inverter(s) transfer and convert the energy within the different elements of the installation, and the EMS monitors and control the fluxes of energy. Nonetheless, the possibilities on how to combine the different technologies used are uncountable, and there is not yet a configuration that leads to a profitable investment for the customer.

The main technology of battery used is lithium-ion, because its high specific energy, long cycle lifespan, and free maintenance due to low deterioration. The most spread typologies of lithium-ion for this kind of application are NMC (Nickel, Manganese and Cobalt in the cathode) and LFP (Lithium Iron Phosphate in the cathode). As shown in Figure 1, NMC doubles LFP in terms of specific energy, so same capacity can be delivered in a more compact design, but LFP offers more lifespan and safety. Depending on the selection of battery chemistry, the battery will provide different performance.

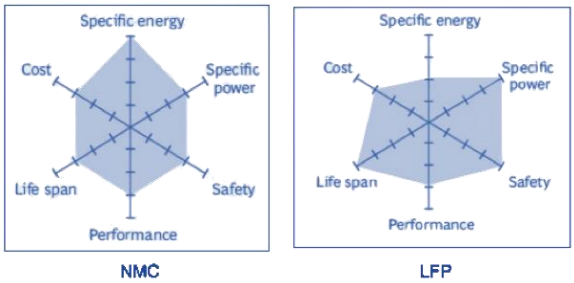


Figure 1. Snapshot of the main used chemistries of li-ion [1].

Depending on the typology of inverter selected, the system will be coupled in different ways, offering different features in performance. The three possible configurations of the installation depending on the inverter chosen are DC coupled, AC coupled or all-in-one hybrid system.

DC systems couple the batteries in the DC site of the system but requires an additional element to finish the installation and properly transfer energy to the house. AC systems couple the batteries in the AC site of the installation, but require of an external solar inverter to convert the DC energy coming from the panels into AC. On the other hand, all-in-one systems concentrate all energy conversions in one hybrid inverter, making the functions of solar and battery inverter in one device, and offering to the customer all the components needed to perform the system.

Regarding the BMS, the difference in the performance of the system will rely on the balancing cells method chosen. There are two main typologies of balancing with different subtypologies on every of them: passive and active. Passive balancing acts by removing the surplus of energy of the most charged cells through a resistor, until the lowest charged cells match them, levering the state of charge of all the cells. Active balancing acts by transferring energy from the most charged cells to the less charged ones, ensuring a more continuous and optimized level of balance in between the charge/discharge of the cells, but more sophisticated and thus, expensive.

Finally, the EMS will vary the performance of the system depending on its sophistication. Its premium features can optimize the overall efficiency of the system by weather forecasts, studies on the consumption profiles of the household and home automation, offering remote control and monitoring to the customer through an app. A basic EMS, on the contrary, will just control the fluxes of energy between the main components, but at a lower price.

III. Analysis of the Market

In this section, the market of Residential Energy Storage Systems (RESS) will be analysed, identifying which are the pain of the customers that makes this sector so demanding nowadays, the expected trends for the following years in terms of market volume, and which countries are leading the growth of the market. Afterwards, an analysis of the main competitors that offer residential battery systems will be performed, deeply studying weaknesses and possible improvements in what do they offer, to better understand how a RESS is performing.

Figure 2 shows the evolution of electricity prices, LCOE of PV technology and feed-in-tariff prices from 2000 to 2017, in Germany. The increasingly gross domestic electricity price, PV technology reaching grid parity and the steep decrease of feed-in-tariff subsidies, makes energy storage systems financially more appealing for households. Moreover, this trend is expected to be grow stronger over the time, increasing the pain of the customer.

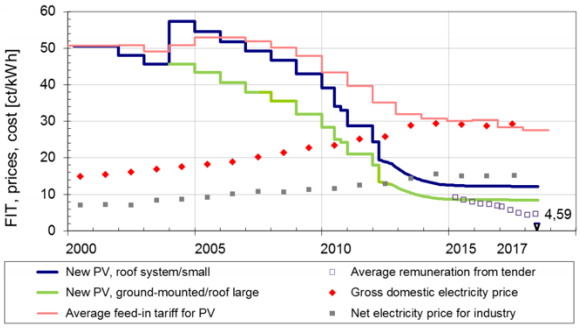


Figure 2. Electricity prices, FIT, and PV LCOE evolution [2]

As stated before, currently no RESS leads to profitable investment for the customer yet. The turning point will happen when the increase in self-consumption overcomes the price of a battery storage system. Figure 3 shows when the investment could make sense for households regarding the difference in revenues and generation cost (LCOE) of a residential PV system, in €/kWh. The upper blue arrow represents the net present value of revenues during the lifetime of a PV system with storage backup up to 70% of self-consumption in France. The lower blue curve represents the declining PV LCOE. Furthermore, recent announcements in the battery business expect that this window of opportunity might appear earlier, due to an increase in self-consumption rates because of technology advancements.

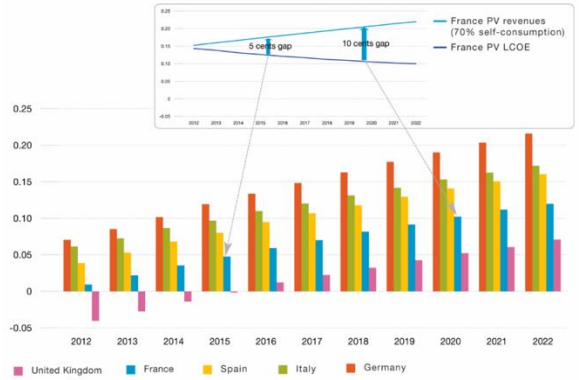


Figure 3. Window of opportunity to use storage for households. [3]

Nonetheless, households are prioritizing the fact of using clean energy and become more independent, since the market is exponentially growing. Figures 4 provides the market trend in the last years for Australia, USA, Europe and Germany, the country leaders of the sector.

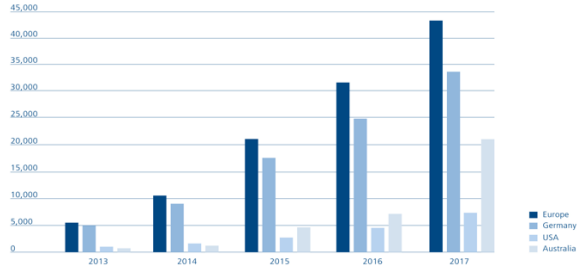


Figure 4. New RESS installed per year. [4]

Focusing on Europe, it can be observed that Germany accounts for almost 75% of the market, both in million € (Figure 5 left) and in MWh (Figure 5 right). The expected trend in capacity installed will continue growing during the next years, meanwhile the market volume in € will maintain stable, as prices of RESS and going down.

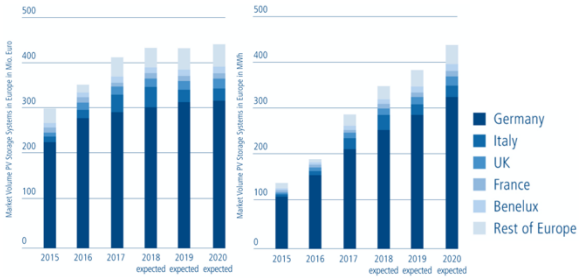


Figure 5. RESS market volume in Europe in M€ and in MWh. [4]

Analysing the data, the most appealing market to launch the product is the German one, as it will be discussed in the Business Strategy section. Therefore, the competitors' analysis will be focused in this country. Figure 6 shows the share of the market in the residential storage sector.

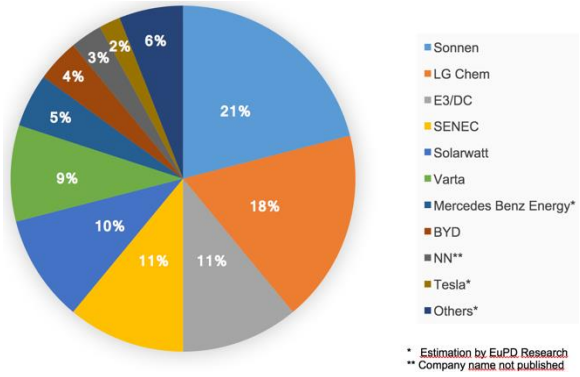
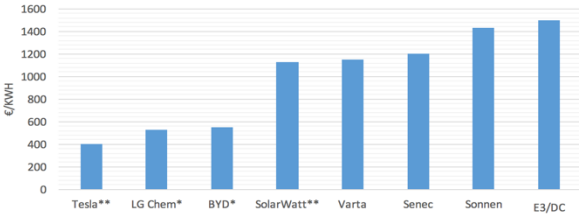


Figure 6. Market share in the residential storage sector. [5]

Each of them offer different configurations, features, performance and values to the customer at different prices. A summary can be found in Figures 7 and 8.

	Chemistry	Modularity	All in one	Performance	Warranty conditions	Compact design
Sonnen	LFP	★★★★½	Yes	★★★★☆	★★★★½	★★☆☆☆
LG Chem	NMC	★★☆☆☆	No	★★★☆☆	★★☆☆☆	★★★☆☆
E3/DC	NMC	★★★☆☆	Yes	★★★★★	★★★★★	★★★★★
Senec	NMC	★★★★½	Yes	★★★½☆	★★★☆☆	★★★½☆
SolarWatt	NMC	★★★★★	No	★★★☆☆	★★★★☆	★★★★★
Varta	NMC	★★★★½	Yes	★★★☆☆	★★★★☆	★★★☆☆
Tesla	NMC	★☆☆☆☆	No	★★★★☆	★★★★☆	★★★★★
BYD	LFP	★★★★½	No	★★★½☆	★★★★☆	★★☆☆☆



Figures 7 & 8. Competitors' performance and price comparison. [6]

IV. Product Development and Design

Design Thinking and Strategy Definition

To better understand the features listed in Figure 7 and the possibilities to overcome competitors in the design of the product, each of the features listed are explained down below.

Having a modular battery, in which different modules can be connected to offer different energy capacities, the system can adapt better to the customer needs, depending on their consumption and PV array size, optimizing the system.

By offering all-in-one solutions, the customer does not need to search for external products to complete the installation and the components are supposed to perform better, since they are designed to work together at an optimal point.

A very important aspect that the customer prioritizes over others is the warranty conditions. The more kWh warranted, the more appealing will be the system for the customer. Companies offer different warranty conditions within the market, which gives an idea on the lifespan of the product. Usually, they offer two conditions with energy capacity constraints: either X cycles or 10 years under usually 60% of the original capacity of the system. The condition that usually happens before is 10 years under a capacity constraint of about 60% of original capacity, because companies assure a big amount of cycles that will not happen when cycling the battery once a day. Enterprises do that because of marketing reasons. The best warranty in the market offers 10 years without any capacity constrains for the whole system, batteries and inverter, by E3/DC.

Performance takes into account many factors such as power delivery, PV input power, emergency power supply in case of grid outage, etc., plus all the parameters already listed above.

Last, the majority of the batteries are designed to be installed indoors. Some of them occupy a very big space in the home when a high number of modularities is applied, being an uncomfortable factor for the customer. NMC batteries are supposed to store same capacity values in almost half of the space of a LFP battery.

Therefore, the objectives to achieve on the product development is to strategically establish the appropriated partnerships to define a RESS with modular adaptability, all-in-one hybrid solution, overall high performance, long lifespan that allows the company to provide warranty conditions above average, and a compact design, offering a competitive price. In order to achieve outstanding performance results, more economic efforts will be deployed in the management of the system, to optimize its lifespan and performance. The range of price that the company wants to target regarding the market is located between Senec and Sonnen in Figure 8, so to offer outstanding performance at a lower price than Sonnen or E3/DC. For that purpose, the assembly will be conducted in Morocco and minor technical designs will be simplified to lower the cost.

Battery Development and Design

The development of the battery will follow the next stages: preliminary design of the parameters, defining the chemistry used in the cells and the desired operation ranges, to later go to the market and evaluate the different options that manufacturers provide, to finally choose the more suitable option regarding the requirements established and prices.

Briefly explained, the chemistry chosen to implement in the batteries is **NMC**. The huge difference in high capacity that this technology offers in front of LFP, it is considered to weight more than the difference in lifespan between both chemistries. But the real reason who pushed for the choice relies on the trend in prices of NMC. It is a relatively new chemistry that started to be commercially available few years ago, doubling the price of LFP. Nowadays, thanks to the impressive advances in the automotive sector, that pushes towards this chemistry, the prices of both typologies are even. Figure 9 shows the price projection for this chemistry.

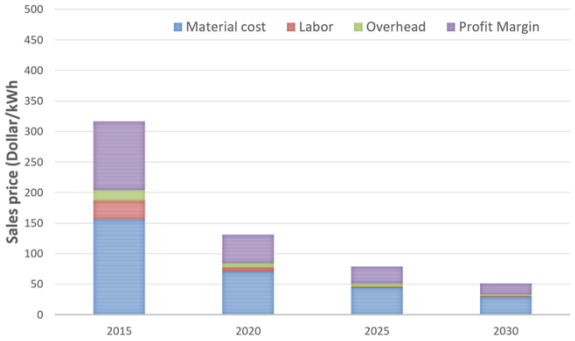


Figure 8. Sales price prediction for NMC technology. [7]

Another factor that must be set in the design of the system is the voltage of the batteries. Typical ones are low-voltage of 48V, and lately high-voltage systems of 400V are emerging in the market. Low voltage batteries offer better battery price; meanwhile high voltage batteries offer slightly higher efficiencies due to the use of lower currents. However, and again, the influence of automotive sector is key to determine the system configuration. The sector that drives down costs of NMC batteries leads to the use of cells

of low voltage and high capacity. Therefore, and also because of its lower price, **low-voltage system**s have been preferred.

The last point, but not least, it is to define a range on **energy capacity and number of modularities** that can satisfy the main volume of the market. Taking into account different average PV array sizes, PV capacity factors and self-consumption rates in countries of the EU [8], the energy capacity range of the battery has been defined from 50Ah to 70Ah, offering energies from 2.5kWh to 3.5kWh. The range of modularities for reaching a maximum energy between 10kWh and 12kWh has been set from 3 to 5.

With these parameters set, the contacting work to dozens of manufacturers started. Since the project is developed from a start-up, it was very difficult to get positive feedback from many big manufacturers. Some of them did not reply, some others answered that to start a partnership the company needs to have a market volume of MWh. At the end, in between four manufacturers that share their entire portfolio of NMC cells, the most promising partnership was offered by **Company 1**, with the final parameters of the battery shown as follows:

Chemistry	NMC			
Cell capacity	17.5 Ah|			
Cell combination	3P14S			
Nominal voltage	51.1 V			
Nominal capacity	52.5 Ah			
Nominal energy capacity	2.7 kWh	5.4 kWh	8.1 kWh	10.7 kWh
DOD	90%			
Impedance	≤150 mΩ			
Certifications	CE, UN 38.3			
IP Protection class	IP21			
Operating temperature	-20 to 55 ºC (-20 to 0 ºC only discharge)			
Dimensions	400x220x100 mm			
Weight	14.5 kg			

Figure 9. Main parameters of the battery.

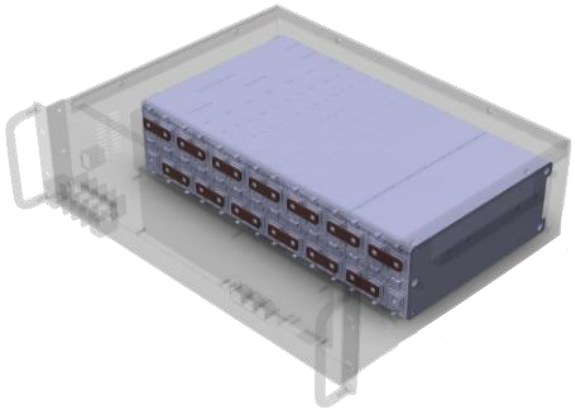


Figure 10. 3D model of the battery pack.

BMS Development and Warranty Conditions

The BMS is the key component of the RESS developed, the element that is going to differentiate the product above the average and is going to add value to the customer.

The main reason why currently no RESS leads to profitable investment for the customer is because the performance of the battery is deteriorated through time. This happens as a consequence of disparity in individual SOC and SOH in each cell. In other words, each cell ages differently, and the weak cells stop the discharging when they get discharge, meanwhile in other healthy cells there is still energy, but it remains trapped.

A good balancing BMS system can prevent this problem and make the battery last longer and work at higher performance during its lifetime. For this reason, since the beginning, the focus was to invest in an active balancing BMS, which is more efficient than passive one. Not only that though, the idea was to look for something innovative in this area, since it tackles the main customer pain.

In this context, **Company 2**, a start-up based in Grenoble, France, appeared. With their **EVER Active Balancing System cell-to-cell**, they are aiming to preserve the factory specifications of a battery all along its useful life for the user.

Actual cell-to-cell BMS work by transferring energy from the most charged cell to the adjacent ones with lower charge, levering the SOC of all cells in a module. The device works linearly, transferring charge from one cell to its neighbour cell, until it reaches the weak one and levels the SOC. The process is moderately fast. However, weak cells are not together in a battery, and it may take time and efficiency to level all the SOC of the different cells.

The innovative added value of Company 2 is the creation of an optimized active balancing system that works cell-to-cell acting like a matrix, instead of linearly like the actual ones. In other words, it tackles all the weak cells of a battery at the same time, transferring energy from all optimum cells, no matter the position or distance at which they are collocated inside the battery. In this way, the balancing of the cells works way faster and more efficiently than any other. According to the CEO of the company, their product is unique in the world and their know-how is patented. Figure 11 shows the effect of this prominent active balancing system in a NMC battery of 200Wh.

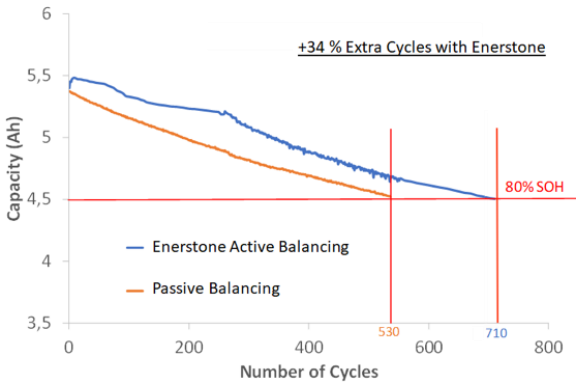


Figure 11. Ageing of two identical batteries.

From the very first cycle, it can be observed a gain in capacity, due to the fact that the active balancing compensates the inter-cells differences in capacity and resistance. Company 2 advanced that the results can be even more promising in bigger batteries where more cells and capacity are used. 30% of extra cycles in the actual project could be translated into about 4 more years of operation under the same SOH of the battery, plus performing at an optimized level since the beginning to the end. The negotiations were very pleasant since both parts are start-ups that are seeking for entering to the market as soon as possible.

After this good news, it is a must for a successful development of the project to take advantage of this BMS and offer to the customer the best warranty in the market. Company 1 engineers assured their battery can assume 3600 cycles keeping more than 60% of the original capacity with no problems under real conditions Thus, and prior to the test results, assuming a moderate gain in the lifespan of the battery of 20%, those 3600 cycles with more than 60% of the original capacity could be translated in more than 4300 cycles with still more than this 60% of capacity. Cycling the battery once per day, this is translated into **12 years**, the years that have been determined for the **warranty** in the RESS designed, overcoming any competitor in the market.

Company 2 will provide only the balancing and communication part of the BMS, meanwhile Company 1, the battery manufacturer, will provide the protection part.

Hybrid Inverter Development and Design

Following the same procedure as with the batteries, preliminary parameters and features must be set in the technical design of the hybrid inverter to afterwards look into the market for the best option. In this case, there are not many companies who manufacture hybrid inverters worldwide. Some of these companies offer hybrid inverters but with very low MPPT ranges of up to 120V, which are not suitable for this application.

MPPT ranges must go above that value and up to 600V approximately, so many PV panels can be connected in series and work at low current to minimize losses, in a more efficient way. Besides, it is very important that the inverter has integrated dual MPPT instead of one, since this allows connecting arrays with different solar azimuth, tilt angles, string lengths, non-similar modules and provide better monitoring and performance. By this, PV systems can be designed in a more flexible way, lowering labour and installation costs.

Concerning the **input power** admissible from the PV array, the higher the value, the better. Nonetheless, the higher will be translated also in the more expensive, so a value in between 5kW and 6kW could be the best in terms of quality/price.

Regarding the **charging and discharging** of the batteries, clearly it must be compatible with lithium-ion batteries of 48V, accepting the voltage range of 42V to 58.8V of the battery provider. The maximum charge/discharge current must be set at a proper value to not stress the batteries and preserve their optimum operation. For this reason, maximum values close to 1C rate of the battery, 52.5Ah, should be chosen, but also offering a good power delivery to the household.

Taking a look at the **output**, as far as the target market will be focused in Germany and Europe, it must link the grid conditions of 230V and 50Hz. The maximum output should be bigger than the power delivered by the batteries, so when big loads are connected, the household can be feed by both the PV panels and the batteries.

Another important aspect that the inverter should include are **AC entries** as input power. In the unlikely event of a PV installation bigger than the input of the inverter, a solar inverter can be connected on those panels or strings that cannot be assumed by the hybrid inverter, and reconnect them to the AC entry, so more input can arrive to the battery, even though in a less efficient process.

As recommended by Company 2, the BMS manufacturer, the better communication protocol between the inverter and the BMS is wireless communication, so the installation of the RESS is simplified. The option of adding Wi-Fi represents a very small amount of capital to the project, as it will be justified in future sections.

Going into the market, the most suitable option that better fits our requirements was **Company 3**. Not only for their performance, but mainly because of the added value they provided from a strategical point of view. Their **Business Model is ODM** (Original Design Manufacturer),

they are actually the largest ODM UPS/inverter supplier by number of units produced. They are very good at innovation, technical design and production, but they do not perform branding, neither involve marketing and sales in the global market. All the products they sold are with customers' brand name. They produce after receiving orders (Built to Order) and do not keep finished product stock. They do not apply neither marketing fee because those are branding activities performed by their customer. Therefore, they do not have so-called distributor network. In terms of **marketing strategy**, this is very advantageous, since the company can use Company 3 product under the brand Azolis, with our own boxing design. Furthermore, the model can make the system expandable, reaching capacities up to 21kWh. The parameters can be found in the link provided by [9].

EMS & Future Community idea development

The main intention with the EMS development and design is to place at the service of the customer all the technology involved in the management of the RESS. Through remote maintenance and monitoring via platform through app, computer or display in the system, the customer must be able to see and explore the different states of the system through a day, study the historical data and analyse the decision making on how to configure the installation. Through machine learning, the system must perform a state of the art of energy functions, studying the weather forecast of the corresponding location and analysing the consumption profile of the household to act in the most optimised way possible. For this purpose, **Company 4**, a Moroccan/French start-up with expertise as control software developer for solar plus storage systems, will be the partner in charge of the development of the EMS.

As stated in their webpage, Company 4 develops and markets the first artificial intelligence-based energy management software that enables industrial and commercial buildings in Morocco and Africa to produce and consume to reduce their energy bill by 20%. According to their CEO, their software can be easily adapted to residential application.

In future stages, the possibility of creating a **Cloud Community** in where customers can share their self-produced energy and become more independent will be studied. By means of blockchain process and a monthly fee, the customers will be able to share the surplus of energy to serve other members that cannot generate energy due to bad conditions. For every kWh shared, the customer will receive a financial compensation above of the feed-in-tariff level. Whenever the customer receive energy from the community, he/she will have in return electricity prices much lower than the ones of the grid providers.

Assembly, aesthetical design and coupling

The assembly of the RESS will be performed by **Company 5 Industries**, an expert in industrial electronics based in Mohammedia (Morocc), 20km away from the company's office. Company 5 specializes in all kind of electronic and mechatronic assemblies and subassemblies. Mainly oriented in exporting, the company service includes not only assembling, but also manufacturing, project management, raw materials purchasing and logistics management. All the processes and products carried out by Company 5 are certified by ISO 9001, quality management systems. With a plant of 4500m^2 and more than 200 employees, their capacity production will be able to handle the assembly industrialization of the RESS designed for a first commercial stage.

The aesthetical design of the RESS is very important from a marketing point of view, since it will be the image of the brand. As far as the system will have low IP rate protection to reduce costs, it has to be installed indoors. Taking advantage on the low dimensions of the battery packs, the intention is to make it look like a furniture, so the customer can install it everywhere. The system will have also the option of being wall-mounted. The boxing design will be performed by **Company 6**, a French company specialized in this field.

The following figure shows an idea on how the final product can look like, and how it should be coupled. The second PV array is optional, in the unlikely case that the PV installation is bigger than the input of the inverter.

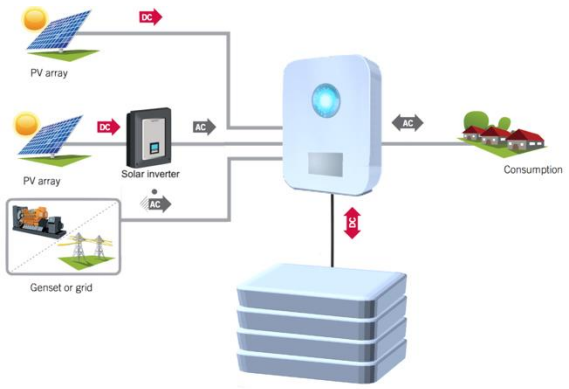


Figure 12. Aesthetical design and coupling of the RESS. Own design.

V. Business Strategy & Financial results

In this section, the implementation and execution strategy of the company's plan for market penetration and expansion are discussed. The Business Strategy has been followed up by experts of the GCIP Morocco 2018 coming from Silicon Valley, USA.

Milestones prior Commercialization

As it has been illustrated in the section Analysis of the market, the residential energy sector is very demanding and promising. A rapid entry to the German market is of vital importance, since the market volume trend is very favourable and the share in between the main competitors very healthy: no company shows dominance over the others.

Nonetheless, still some milestones must be achieved prior commercialization stage. The most critical stage will be the Testing & Data Analysis, which will determine the compatibility in the integration of each of the components of the RESS, as well as the overall performance and the effect of the innovative BMS in the system. The second most critical point will be the fundraising needed to develop the first commercial stage. With the promising results of the innovative BMS working in the RESS, it should be easier to attract investors. Afterwards, the first demand of the components to the manufacturers to develop an initial commercial stage could be realised. The objective is to start marketing the product in the second half of 2019, fulfilling previous pre-orders launched by the first customers.

Market Penetration

With the available data and the number of households per region [10, 11 & 12], the Total Addressable Market has been estimated for Europe and Germany and is shown in Figure 6.

	Europe	Germany
Number of households (in millions)	221.3	40.7
Number of installations (in thousands)	160	124
TAM in potential customers (in millions)	221.1	40.5
TAM in GWh	484	85
TAM in million €	600 000	98 000

Figure 13. TAM for Europe and Germany in 2018.

Taking into account that the acceptance rate of German households to install PV panels is about 72% [8], and that 74% of residential solar power customers were considering or were interested in installing energy storage, the Serviceable Available Market targeted by the RESS designed is estimated in Figure 7.

	Germany
SAM in potential customers	21.58
SAM in GWh	45.3
SAM in million €	52 200

Figure 14. SAM for RESS in Germany in 2018.

From there, a realistic approach has been followed to determine the target market. The objective is to achieve the 0.05% of the SAM in a 4-year horizon, once commercialization is initiated, which would account for around 10800 customers, translated into a 3.6% of the forecasted share of the market. To calculate this, a linear trend of 50000 yearly new installations of RESS has been supposed until 2022, with a total number of 300,000 systems in the market. The evolution of the expected target market is shown in the following table:

	2019	2020	2021	2022
Target market (No. of customers)	35	575	2900	7300
Target market (MWh)	0.16	2.68	18.76	58.40
Target market (thousand €)	82	1405	6735	17075

Figure 15. Target market for the company.

In order to be close to this approach, marketing will be very important. To be present in the maximum possible number of solar blogs is a must, so experts can detail reviews about the system and people can get to know the brand and the product. Normally those reviews are very focused in performance, warranty conditions, and price, which are outstanding features of the RESS designed.

Financial results

For a better understanding on the financial results that are going to be shown, the breakdown cost of manufacturing the RESS is displayed down below.

Battery (with protection part of BMS)	520€/module (for orders of 25 units)
Battery Importation costs (FOB)	275€ (for orders of 25 units = 13.75€/unit)
Hybrid inverter (including importation FOB)	730€/inverter (for orders of 20 units)
Wi-Fi card for inverter communication	30€/inverter
BMS (Balancing & Communication parts)	300€/module
BMS Importation costs (FOB)	60€ (for orders of 100 units)
EMS*	750€/system
Boxing manufacture*	40€/module
Industrial assembly*	175€/system

Figure 16. Cost breakdown of the RESS.

Therefore, applying a 40% of commercial margin and a 35% on distribution costs, the basic data to implement some financial calculations can be obtained for every of the modules. The option that most probably will provide the best-selling numbers will be the one with 3 modules,

followed by the one with 2 and the full RESS with 4, regarding energy needs of the main volume of the market.

Therefore, it will be assumed that 40% of the sales correspond to the product composed by 3 modularities, 30% to the one formed by 2, 25% to the product of 4 and only 5% to 1 module option in the RESS.

	1 module	2 modules	3 modules	4 modules
Manufacturing costs (€)	2510	3360	4220	5070
In €/kWh	936	627	525	473
Commercial margin	1673	2240	2810	3380
In €/kWh	624	418	350	315
Sale price (€)	6430	8620	10810	13000
In €/kWh	2400	1610	1345	1212

Figure 17. Manufacturing costs, commercial margin and sale price.

It can be observed that the higher the modularity, the more cost-effective is the product for the customer, in terms of €/kWh. On the contrary, sales with lesser modularity, the more profitable is for the company. Following the target market estimated for a 4-year horizon, the following financial results are exposed.

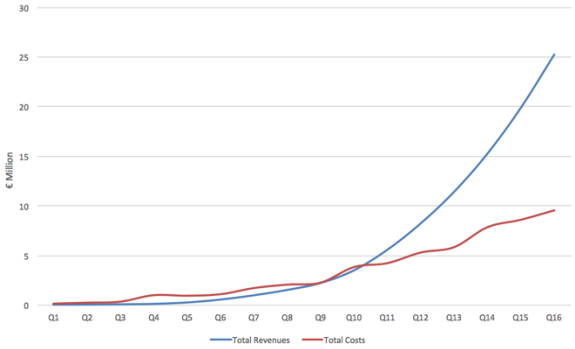


Figure 18. Total Revenues VS. Total Costs.

As it can be inferred, the costs are always higher than the revenues until the half of the 2nd year of commercialization. Not only the purchase of the components for the first commercial stage and its industrialization, but also the expansion and the establishment of the company in Germany, forces that until X quantity of sales are not achieved, the revenues do not surpass the costs of operation of the company. Furthermore, this is a Business Model in which its main revenue stream strongly depends on the sales force, so it takes time until revenues start to take-off, since the product needs time to get known in the market.

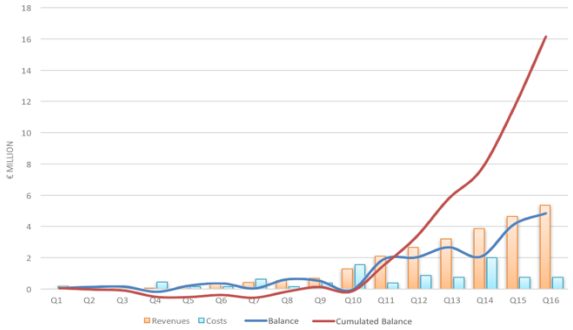


Figure 19. Balance and Cumulated Balance.

In this figure, the balance and cumulated balance are shown with the total revenues and cost from the last chart. Both balances oscillate during time, due to big amounts of components purchased of the RESS meanwhile sales are increasing. The cumulated balance stays always in negative value until the half of the 2nd year of commercialization, when revenues overcome costs for the first time. After this period of time, it is supposed that the high performance of the RESS starts causing some marketing effect and commences to gain reputation in the market, thus making sales to increase exponentially. By the end of the 4th year, the cumulated balance would reach around 16M€, with a very positive trend.

The results shown can be concluded as a realistic approach; this market is demonstrating that allows companies to expand and grow fast and rapidly. For example, Sonnen, the company with currently biggest share in the market, was founded in 2010 and after six years of operation was already registering revenues. of 42€ million, in 2016, with a total funding amount of 145.5 M€ in 2018 [13]. Similar cases happened with E3/DC or SolarWatt.

VI. Conclusions

In this document, the design and product development of a RESS have been developed, together with its business model and business strategy to penetrate the market. Overall, it can be stated that, pending tests and evaluation, the product is expected to offer higher performance and longer lifespan over the time, far above market average, at an average price. Moreover, financial results show a promising scenario in a market growing exponentially.

Taking a look to the business part, especially on the market analysis and on the results estimated in the previous section, it can be concluded that is a must to launch the product and go to the market as soon as it is possible. The exponentially favourable market trends and the healthy market share where no company is showing predominance

over others, constitute a context favourable to the entry of new companies. As shown by the financial analysis, the solution appears to be very promising and profitable, showing a payback on initial investments by the half of the 2nd year of commercialization. Revenues are expected to reach cumulative values of 25 million € within a 4-year horizon scenario, with around 16 million € in cumulative balance. This scenario can look optimistic, but as stated before, the market has shown with other companies that allows rapid growth and expansion in short periods of time. All these evidences given support the idea that now is the moment to invest in this specific market.

With regard to the technical side of the RESS, very positive conclusions can be extracted. The partnership with the BMS manufacturer has been a successful deal, since it provides the main differentiation of the product when comparing it to the market. Active balancing cell-to-cell by means of a matrix interconnection in between cells, allows the BMS to act very efficiently, very fast and in a continuous way in the balancing of the cells, levering the SOC at any moment. By this, the lifespan of the product can be extended around 20-30%, which is translated into 4-5 more years of maximum performance. Thanks to this extremely low deterioration, the RESS can offer the best warranty conditions in the market, surpassing all competitors.

Not only that, but taking a look on the rest of parameters designed and defined of the RESS, the entire product keeps an overall optimal performance. It offers very good ranges of modularities and energy capacities, capable to adapt to a wide variety of customers regarding their specific energy needs. In some cases, customers must buy external components to the RESS purchased, and not always matches at 100% in terms of performance. The company's RESS designed provides an all-in-one product in which every component has been configured to work together in the most optimal possible way. Even the RESS with one battery module can provide good power delivery, and the hybrid inverter switches rapidly to off-grid mode, assuring power back-up in case of grid outage. Last but not least, the high performance of the EMS software will optimise all flux of energy within the RESS and provide to the client a high customer experience, through consumption data processing, weather forecast and remote control and monitoring.

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