**Project Portfolio**

**CARBONE SAVOIE**

Notre-Dame de Briançon - 73260 AIGUEBLANCHE - France



**Work Stream 1 “Active materials for batteries”**

**VERSION 14/10/2019**

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1. Project Outline
   1. Company Presentation & project executive summary

Carbone Savoie, a French company established in 1897, is a 35,000 tons a year producer of synthetic graphite and carbon solutions. Carbone Savoie supplies a full range of high-quality graphite products for various applications and offers valuable services to customers all around the world. Every day Carbone Savoie delivers excellence in the world of aluminum production, specialties graphite, and graphite powders.

Carbone Savoie is located in France and employs 400 persons. The total turnover has reached 119 million Euros in 2018. Carbone Savoie is certified ISO 9001, ISO 14001, OHSAS18001 and ISO 50001.

By joining the IPCEI on Batteries initiative, Carbone Savoie intends to become one of the leading technological innovator on Secondary Synthetic Graphite (SSG) powders for the manufacturing of the anodes for lithium-ion batteries (henceforth LiB).

Carbone Savoie innovative project is directly in line with the European Commission strategic objectives:

* + *Fight against climate change and reduce CO2 emission*: Carbone Savoie innovative project will deliver high-quality graphite, using 50% less energy per ton than current mainstream technology.
  + *Contribution to growth*: Carbone Savoie innovative project is driven by improvement of the performance-cost balance. Carbone Savoie process could become a mainstream technology and provide a competitive advantage to its European customers.
  + *High value job creation*: Synthetic graphite industry is a very demanding process-driven chemical industry. This industry requires a lot of expertise. As of today, 40% of the company’s employees are white collars. Carbone Savoie project will increase the proportion of white collars and lead to more than 100 direct job creations.
  + *Circular economy*: Carbone Savoie innovative project aims at dividing by 5 waste generated by the production of synthetic graphite for Lithium ion batteries and at reincorporating waste and scrap products into its production process.

Graphite is an essential raw material for LiB. In 2018, according the Avicenne consulting firm, LiB anode production has reached 218 000 tons[[1]](#footnote-2) worldwide, 93% of it being graphite materials (202,000 tons in 2018). The consumption of graphite is then split between synthetic graphite (61% - 120,000 tons 2018) and natural graphite (39% - 82,000 tons in 2018).

Graphite demand is driven by the rapid growth for lithium-ion battery sector. According to the report from the European Commission on the *Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe*[[2]](#footnote-3), number of Electrical Vehicule with LiB on the road will grow to between 50 and 200 million by 2028 and to reach up to 900 million by 2040.

Graphite, as the unchallenged material for anode in LiB, is expected to grow globally at a CAGR of 24.4% from 2018 to 2028. Total graphite demand for EV only would reach an extraordinary 1.2 million tons by 2030, equivalent to the current worldwide market for graphite electrodes for the steel industry. By 2027, consumption of graphite in battery applications could be 10 times higher than the current level.

Historically, the development of lithium-ion batteries has been driven by consumer electronic applications (laptop, cellphone, etc…). Energy capacity and cost have always been critical for such applications and natural graphite was the main raw material for battery anode materials.

However, batteries for electrical vehicles require different specifications (battery life & fast charging, lower swelling, environment conscious production process, better product consistency, etc …). On each of these dimensions, synthetic graphite performs better than natural graphite and is therefore better suited to produce high quality batteries for Electrical vehicle. Synthetic graphite offers a much longer life cycle, a lower swelling (critical to increase capacity with Si add-on) and an excellent uniformity due to rigorous control of raw materials and synthesis processes.

Contrary to the Asian market that is driven by both Electrical vehicle and consumer electronic markets, the European LiB market will be mainly driven by the Electrical Vehicle markets. As a result, experts considers that the mix between natural graphite and synthetic graphite will be different in Europe, compared to Asia. Anode material in Europe will be composed of more than 80%[[3]](#footnote-4) of synthetic graphite by 2025.

In 2018, 90%3 of synthetic graphite for LiB was produced in Asia, mainly in China (+80% of market share). Key Asian players (Zichen, BTR, Shanshan, Hitachi Chemicals…) have been working for years on improving graphite performance into batteries.

As an innovative leader on the highly demanding specialties graphite markets, Carbone Savoie is ideally placed to leverage its expertise and develop innovative and highly performing anode materials and production processes.

Carbone Savoie’s activities in the IPCEI on Batteries will contribute to the strategic objectives of the European Commission and help building an innovative, competitive and integrated European anode materials supply chain. Carbone Savoie activities in the IPCEI on Batteries are part of Work Stream 1 *Raw Materials & Advanced Materials.*

Research & Development has always played a significant role in Carbone Savoie. Today, more than 1.5% of the company’s turnover and 22 people (among them 6 engineers and PhD), work in its in-house synthetic graphite-dedicated R&D centre, located near Lyon, France. Carbone Savoie’s researchers have for decades devoted all their energy and know-how to innovate by rethinking and reinventing synthetic graphite solutions in order to improve final product performances, to reduce the environmental footprint and the ones of its customers.

Carbone Savoie is recognized as a reliable producer guaranteeing synthetic graphite with superior electrical and thermal conductivity, high purity and structure stability.

Carbone Savoie sees its clients and suppliers as long-term partners and has always looked for collaborative, win-win relationship with its partners. As of today, Carbone Savoie has three R&D framework agreements with its three most technologically advanced clients and four R&D framework agreements with suppliers and industrial partners. Naturally, in such a technologically advanced field, research and development is carried out in close co-operation with technical departments of universities, academic laboratories and other research organizations like R&D Carbon in Switzerland or Hydro Aluminium in Norway.

It is Carbone Savoie’s vision to let its actions be directed by respect for the environment at all levels, to become the most reliable company operating in the market today, and to be the manufacturer of the best products that money can buy. Some of the company’s profits will continue to be directed back into research and into environmental protection. This is what its customers expect from Carbone Savoie in a constantly changing world.

* 1. Objectives of the company in the IPCEI in all technical fields it’s involved

The Carbone Savoie project is only focusing on the Work Stream 1: Raw Materials & Advanced materials.

In order to understand the objective of Carbone Savoie in the IPCEI on Batteries, it is critical to understand first the current mainstream technology used by the Asian anode materials producers (refer to section 1.4 for further details).

*Description of the current mainstream technology:* 87% of the current production process of synthetic graphite for anode materials for batteries is made by first milling coke into very fine powders, then graphitizing these powders in crucibles placed in so-called “Acheson” graphitization furnaces. Such a production process, even though mainstream today, is not sustainable for the following reasons:

* The energy consumption of the Acheson furnace is twice that of the so-called “Castner/LWG” furnaces (3MWh / ton for Caster-LWG technology versus 6MWh / ton for Acheson technology). Graphitization is an electric-intensive production process. Therefore, the Acheson processes generate much higher CO2 emissions, especially in countries where electricity production significantly relies on from coal (i.e. China, Poland).
* This process generates about three times more contaminated pet coke (with carbide issued from the pack/insulation materials) than good graphite anode materials for LiB (meaning that 10,000 tons of anode materials generate 30,000 tons of contaminated pet coke). This contaminated coke is then sold to casting foundries and to the steel industry as a carburizer. A sustainable industry cannot generate three times more waste than good product.
* The mainstream Asian production process (using Acheson furnace) requires consumable crucibles made of synthetic graphite. A crucible is a rounded graphite block (20’’ diameter, 1.2 meter long) with a 16’’ hole into it (such as a tube). However, the crucibles lifetime is today limited to only four graphitization cycles. In other words, producing 10,000 tons of anode materials for LiB requires not only producing an enormous quantity of consumables (4,500 tons of consumables for 10,000 tons of finished product - 45%) but also using extruded graphite consumables (only material capable of supporting such high temperature), whose production is highly energy intensive and generates lot of CO2 emissions.
* The mainstream Asian production process (using Acheson furnaces) is very unstable and generates frequent explosions. The powder is so fine (~20µm) that it can explode during the graphitization. A sustainable process does not generate neither explosion, nor risks for employees and local communities, nor noise pollution.
* The Acheson process is batch-driven and not continuous nor semi-continuous. While such a batch process was adapted to small volumes required by the production of LiB for consumer electronics, this process cannot sustainability support volumes of production reaching about a million tons by 2030. Such a non-sustainable production process cannot be transposed into the European Union for standards, norms as well as regulatory purposes. Therefore, Asian anode materials suppliers plans to continue producing as such in China and to ship Anode materials for LiB to the European located cell manufacturers. With the installation of cell manufacturers in Europe, the European strategic dependency will be now on advanced materials. Carbone Savoie’s responsibility is however not to close the eyes on production process of such materials in China and make sure that it develop an industrial process that is not only sustainable but also guarantee EU strategic & technological independence.
* The mainstream Asian suppliers do not take into account the recycling of the product once the battery life is over. Considering the millions of lithium ion batteries that will be built in the next couple of years, it is Carbone Savoie’s responsibility to design advanced materials that are more easily recycled at the end of the battery life.

**Carbone Savoie’s objective in the IPCEI on Batteries is to leverage its expertise and experience in the production of synthetic graphite in order to develop a production process that:**

* **is scalable, energy-efficient, sustainable from an environmental point of view (energy-efficient, waste generation, less consumable products and easy recycling);**
* **meets the current expectation of the market in term of product performance and is not limited to certain battery applications;**
* **is much cheaper to produce than the state-of-the-art process used in Asia.**

**While current Asian cost of production is about 8.5$/kg (non-coated, non-spheroidized), Carbone Savoie targets a cost of production of only 5.5$/kg (-35%) for non-coated, non spheoridized anode materials.**

The experience of Carbone Savoie in synthetic graphite production allows the company not to start from scratch.

Firstly, Carbone Savoie, is recognized as a reliable producer guaranteeing synthetic graphite with high purity and structure stability.

Secondly, Carbone Savoie has developed fifteen years ago such innovative sustainable production process for the Aluminium industry (very energy-efficient, very limited consumable product, 95% internal recycling of byproducts, etc...). In addition, CEA Liten, an independent public R&D Lab in France specialized in Lithium ion battery, has tested existing synthetic graphite grades produced by Carbone Savoie and has confirmed the potential of Carbone Savoie process for battery application, conditional on an important R&D program.

* 1. R&D Projects Before IPCEI

Research & Development has always played a significant role in Carbone Savoie. Today, more than 1.5% of the company’s turnover is dedicated to R&D. 22 employees (among them 6 engineers and PhD, work in its in-house R&D centre SP2Lab. Carbone Savoie SP2Lab is equipped with state-of-the-art equipment: morphogranulometer, differential scanning calorimetric, gravimetric thermo analysis, mechanical press, electrolysis, shearing box, thermal conductivity with temperature, finite element analysis and simulation as well as a pilot line including extrusion, baking, graphitization and jet mill. Carbone Savoie’s R&D efforts have always been dedicated to developing specific synthetic graphite grades that meets customer expectations and to reducing energy consumption and waste by improving the internal recycling of its production process.

Carbone Savoie has showed interest in the emerging LiB markets since 2016. From 2016 to mid-2018, Carbone Savoie has devoted resources to developing a better understanding of the current anode material market for LiB: size of the market, underlying demand drivers, customer expectations, natural versus synthetic graphite, current Asian competition, advantage and drawbacks of the state-of-the-art production process, patent analysis, etc.

Mid 2018, Carbone Savoie has considered that the synthetic graphite anode materials for LiB market could support an additional competitor, located in Europe, if this new player succeeds not only in leapfrogging Asian product performance from a technical point of view but also in developing a more sustainable process, taking into account energy-efficiency, process scalability, waste reduction and product recycling.

In order to evaluate the potential of Carbone Savoie in this respect, the company has prepared some samples of its current industrial graphite grades and asked[[4]](#footnote-5) an independent French public RTO, CEA Liten, to evaluate their performance for battery application:

* External analysis to make an evaluation of the material itself: XRay diffraction, Purity, BET, granulometry…
* Test as a Li-ion anode to define whether or not there is a possibility to fit with the battery application

Results were received in October 2018 and have shown that even though the main Carbone Savoie synthetic graphite industrial grade was relatively far from customer expectation with a capacity of only 330mAh/g (for customer expectation of min 353 mAh/g), this product presented encouraging performance in terms of first time discharge, charge/discharge resistance and impurities. Therefore, addressing the LiB market would require an ambitious R&D program in order to design and develop a highly innovative dedicated new graphite grade, the associated innovative production process and go through a rigorous qualification process.

In this respect, in January 2019, Carbone Savoie has applied to the IPCEI on Batteries call for manifestation of interest organized by the French government.

Since February 2019, Carbone Savoie has started committing limited internal R&D resources to develop a more highly innovative and more sustainable production process, to design a dedicated synthetic graphite formulation to anode materials for LiB and to test different semi-industrial milling equipment in order to get the right shape and particle distribution for its graphite. Carbone Savoie has also outsourced some preliminary coin cell tests to the CEA Liten (a public RTO) at market prices. All costs associated to these early R&D efforts have been financially supported by Carbone Savoie on its cash reserve.

* 1. Technology and Challenges of R&D phase
     1. State of Art

As of today, there are several technical routes regarding the production of synthetic graphite Anode materials for batteries (120 000 tons in 2018). These different routes are summarized in the table below:

|  |  |  |
| --- | --- | --- |
|  | **Coke powders -> graphite powders** | **Coke powder -> graphite Blocks -> graphite powders** |
| **Acheson graphitization furnaces making “soft graphite”** | Mainstream concept   * Process mainly driven by Chinese players (Shanshan, Zichen, BTR, …) * 87% of the 2018 production (~104 000 tons in 2018[[5]](#footnote-6)) | Alternative concept   * Process mainly driven by Hitachi Chemicals (Japan) and used today at SGL Carbon (Poland)[[6]](#footnote-7) * 11% of the 2018 production (~14 000 tons in 2018[[7]](#footnote-8)1) |
| **LWG graphitization furnaces making “hard graphite”** | Concept tested between 2012 and 2015 but finally abandoned by Chinese players because the concept was combining drawbacks | Innovative concept   * Process studied by SGL Carbon in Morganton (USA) in collaboration with Hitachi Chemicals (Japan). * 2 % of the 2018 production (~2 000 tons in 2018[[8]](#footnote-9)1). * **Process is restricted to certain applications because of performance issues.** |

Table 1 Technical routes for the production of synthetic graphite Anode materials for batteries

EVs applications require not only capacity and long life but also a fast charging (for supercharger) and a fast discharge (equiv. to power, currently available for 'sport' driving)

Anode materials produced with the Acheson technology produces ‘soft’ graphite whose performance in cells fits well with the above-mentioned expectations for Electrical vehicles. Until today, anode materials produced with the LWG technology are 'hard' graphite, so called HPG (Hard Particle Graphite) by Hitachi Chemicals. Therefore, the anode material produced with this innovative LWG technology is for now limited to certain applications that are less demanding.

The R&D program that is described in the coming sections aims at addressing the technical locks that limit the production of “soft” graphite with LWG graphitation process. Carbone Savoie aims at developing a softer graphite with the LWG technology by developing operating conditions on the LWG furnaces that replicate the operating conditions of the Acheson furnaces (i.e reducing product density, maintaining high temperature for a longer period, etc…). Thus, with Carbone Savoie strong knowhow and innovation, anode materials made of LWG technology will not anymore be limited to less demanding application. Progressively, the battery application addressable with LWG technology will expand.

To Carbone Savoie’s best available knowledge, until today, no company has been able to obtain “soft” graphite at industrial scale with a LWG graphitization process. **Therefore, Carbone Savoie activities in the IPCEI on Batteries go beyond state of the art.**

* Understanding the two different graphitization technologies

For the Acheson furnace, packing coke surrounding the carbonized block (or powders placed in crucibles) acts as the resistor. Current is driven by the packing, heating of the resistor through Joule effect (resistive effect), and then heating the coke powders by conduction. This technology was invented at the beginning of the 20th century and remained the leading graphitization technology until the 80’s.

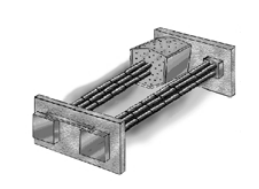
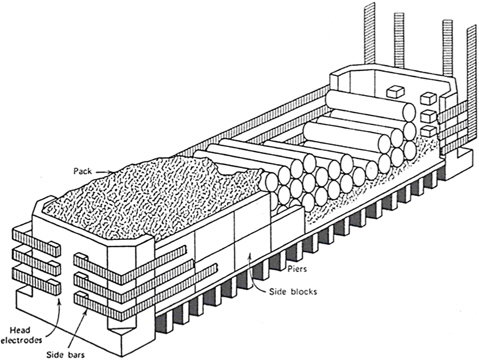


Figure 1 Acheson furnace design Figure 2 Castner/LWG furnace design

In the 60’s, a much more energy-efficient graphitization technology, called lengthwise graphitization (LWG /Castner), was developed for the graphite electrode[[9]](#footnote-10) industry. This technology consists in heating directly, and only, the carbonized blocks to be graphitized by Joule effect (high intensity current passing through the blocks themselves). The LWG furnace provides direct heat to the carbonized block, and the surrounding packing coke contributes to heat insulation and prevents oxidation.

Due to this difference in heating technology and the volume of packing, it had possible to greatly fasten the cooling cycle of the LWG technology. Today, when it takes one month of cooling for the Acheson furnace, cooling takes only eight days for the typical LWG furnace. This shorter cycle improves equipment utilization and allows for semi-automatization. The LWG technology is therefore superior in terms of thermal efficiency, scalability of production and operating environment and has quickly been adopted as the mainstream technology for the graphite electrode market.

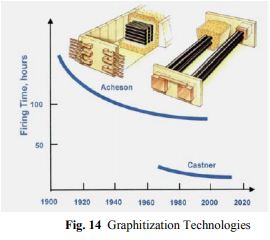


Figure 3 Graphitization technology adoption chart in the graphite electrode market

By process design, the LWG technology requires carbonized blocks to build a column to be heated through Joule effect with very high intensity current, the parts being themselves part of the electric circuit. The choice to graphitize directly powders by mainstream Chinese producers makes therefore impossible the use of the LWG graphitization technology, despite its much improved energy efficiency. Therefore, the indirect heating technology (Acheson) remains the mainstream production process used for direct graphitization of coke powders.

|  | Acheson graphitization technology | LWG/Castner graphitization technology |
| --- | --- | --- |
| Advantage of the process | * Product performance: The heating is indirect; therefore, it is possible to maintain the temperature of the product above 3,000°C for a long time. * Flexibility: Acheson technology allows the graphitization of both powders (in crucibles) and blocks. | * Cost and sustainable advantage: The LWG technology (~3kWh/kg) is 50% more energy efficient that the Acheson process (~6kWh/kg). The LWG process optimizes the CO2 footprint. * Cost advantage: The LWG technology is more compact and scalable. Once optimized LWG furnace produce 50t tons per week (200 tons per month), while one Acheson furnace produces only 30-40 tons per month. * Product performance: The energy received by the product is under better control, therefore improving product homogeneity |
| Drawback of the process | * Cost: the mounting and dismantling of the furnace is a manual handling process that can be organized only once the furnace has cooled off. * Sustainability; The quantity of packing materials and insulating materials is 6 times higher than that of the LWG technology because of the resistor heats conductive agent and because of higher insulation required due to longer cycles * Product homogeneity: The location of the crucible in the furnace drives the quantity of energy received by the coke powder, therefore affecting the homogeneity of the products. In order to counter this effect a lot of efforts has to be made in the mounting scheme of the furnace (optimizing insulating/resistor position and volumes increasing) | * Product performance: The heating is direct. Once the block reaches 3,000°C and is transformed into graphite, the resistivity of the block drops and it becomes difficult to maintain the temperature above 3,000°C (requires very high intensity which standard transformers/power supplies are not able to deliver). * Flexibility: LWG technology requires using blocks. It is not possible to graphitize directly coke powders. |

Table 2 Advantages and drawbacks of the different graphitization technology

* Understanding the two different manufacturing processes (powders and blocks) for synthetic graphite anode materials

The manufacturing of synthetic graphite anode materials for LiB called “powders to powders” process is relatively straightforward:

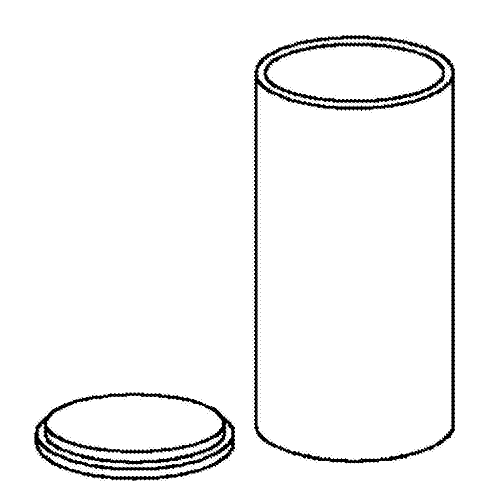


Figure 4 Design of a graphite crucible (500mm internal diameter x1300 mm, ~100kg of powder)

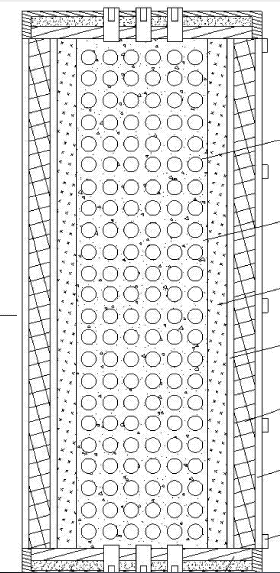
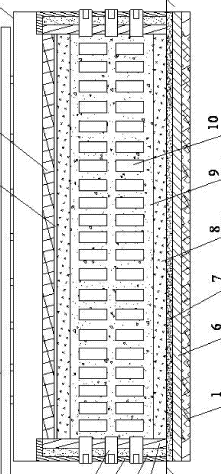


Figure 5 Mounting plan of an Acheson furnace “powders to powders” ~ 276 crucibles by furnace on two layers ~25t of powder/furnace

*Figure 6 Picture of a half-loaded Chinese Acheson furnace used to produce BAM “powders to powders”*

*(June 2019)*



Figure 7 Picture of consumable graphite crucibles used by a Chinese BAM producer

(June 2019)

The “powder to powder” process requires a crucible in graphite. Considering the successive extraordinary heats (above + 3000°C) supported by the crucibles, crucibles can only support four heating cycles. This process requires costly consumables produced from an energy-intensive manufacturing process.

In addition, the “powder to powder” process requires a very large quantity of packing and insulating materials to go all around the crucibles. This material, made of coke, will be contaminated during the process (by silicon catalyst for example) and will be sold out at carburizer to the foundries and special steel industries. Quantity of packing and insulating materials with the Acheson “powder to powders” process is 6 times more than the quantity of coke required by the LWG process that Carbone Savoie masters.

The manufacturing of synthetic graphite anode materials for batteries using block is more complex:

|  | Powders -> powders process | Powders -> Blocks -> powders |
| --- | --- | --- |
| Advantage of the process | * Simplicity: The process is very straightforward and easily replicable. Milling is done only once. | * Scalability: Using blocks simplifies the handling of product, allows automatization, doubles graphitization process capacity and greatly improves the material yield. * Sustainability: Using blocks allow higher density of product in the furnace. Using blocks requires up to 6 times less packing and insulation materials per kg of anode materials than using powders with LWG process. Because the packing is contaminated by catalyst during the graphitization process, this packing must be considered as a by-product. |
| Drawback of the process | * Unsustainable process:   + Graphitizing powders requires to put the powders into graphite crucibles (consumables that support only four cycles). To produce 10,000 tons of anode materials, 4,500 tons of extruded graphite consumable must be produced   + Coke powders are very fine (~15µm). During graphitization, the product goes up to 3,000°C. The process is very unstable and generates regular explosions. * Cost: the process is very labor intensive as crucibles have to be handled individually and the packing/insulating material scheme is quite complex in order to counter-effect the heterogeneity of this process. In order to manage properly the different layers of packing/insulating material the furnace has to be manually dismantled | * Complexity:   + The process requires specific know-how in extrusion and baking.   + Control of milling yield of blocks is mandatory to preserve all the cost advantages of the block route * Product performance: Milling and grinding blocks up to 15µm can affect the performance of the powders. |

Table 3 Advantages and drawbacks of two existing different production methods

* Combining the different elements discussed above

The following charts aims at explaining how the different technological routes for synthetic graphite anode materials positions themselves on three macro-dimensions:

* Product performance (PP)
* Cost of production: (CoP)
* Sustainability of production (SoP)

**Mainstream concept**

Powder to powder

with Acheson graphitization

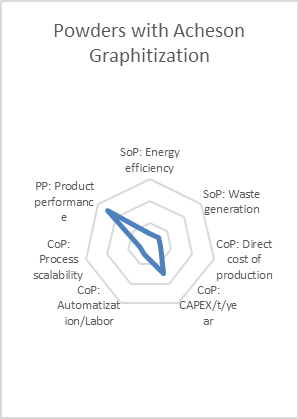
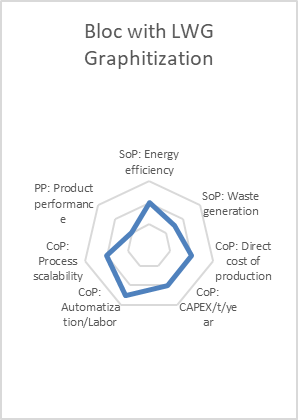
* Best for performance
* High cost of production (~8.5 usd/kg in China)
* Process absolutely not sustainable (batch process, no scalability, bad energy efficiency, lot of waste, energy-intensive production of consumables, no recycling, …)

**Alternative concept**

Block with Acheson

graphitization

* Good performance
* Improved but not optimum cost of production (~7 usd/kg in Europe)
* Improved but not optimum sustainable process

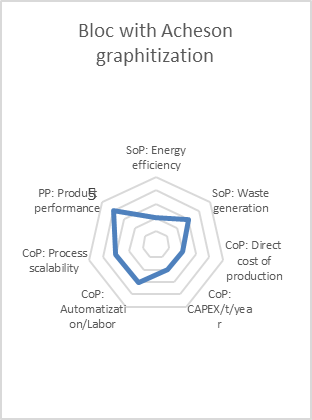


**Innovative concept**

Block with LWG

graphitization

* Optimum cost of production (~5.5 usd/kg in Europe)
* Optimum sustainable, scalable process
* Product currently limited to certain battery applications due to performance issue (hard graphite only with the current know-how)



**Carbone Savoie’s objectives in the IPCEI on batteries are to:**

* **leverage its expertise and experience in the production of synthetic graphite with LWG graphitization technology in order to develop the innovative concept “block with LWG graphitization”, to go beyond the state-of-the-art studied by SGL Carbon and address battery application currently addressed only with Acheson graphitization technology;**
* **increase significantly its fundamental R&D and R&D in FID, beyond the means that Carbone Savoie could support alone, considering the risk of the project ;**
* **share with European RTOs, universities and companies the knowledge accumulated during the IPCEI on Batteries;**
* **contribute to the European Commission project, particularly in term of economic development and reduction of CO2 emission (estimated saving of 600,000 tons of CO2 emission per year) and waste.**

**In term of cost, the Carbone Savoie innovative project aims at producing anode material for a 5.5$/kg (non-coated, non- spheoridized), when the Chinese mainstream process cost of production is 8.5$/kg (non-coated, non-spheoridized). Carbone Savoie innovation represents 35% savings compared with current Chinese production cost. Considering anode material cost of 6% of the battery cost, this project could decrease total battery cost by 2.5% in case of success. For a battery cost of 10,000 euros, this innovation represents a saving of 250 euros per battery.**

Note on SGL Carbon Acheson preferred technology:

This is important to understand that SGL Carbon (Germany & Poland) has studied the LWG graphitization option (with its partner Hitachi Chemicals) at its Morganton plant (USA), on a very limited scale (only 1,500-2,000 tons per year produced at its Morganton plant, only 1.5% of worldwide production). Because of technical locks and challenges that will be discussed in section 1.4.2 and 1.4.3, this SGL Carbon LWG project has not gained market traction and is not the preferred technology of SGL Carbon.

As an illustration of the SGL Carbon decision to develop the well-known Acheson technology rather than the LWG project for batteries, SGL Carbon has recently invested $60m to import the Acheson technology in Morganton (USA) rather than investing in an industrial development of the LWG project.

Therefore, the SGL Carbon LWG project cannot be considered state of the art.

* + 1. Technical locks

This innovative technology using “blocks with LWG graphitization” offers great advantage in term of cost and sustainability of production. However, several severe technical locks affect the product performance. This technology could become mainstream in the medium term only if one succeeds in overcoming the current technical locks:

**First technical lock**: Maintaining the temperature with LWG graphitization technology

The Acheson graphitization technology heats the product indirectly. The packing around the product is heated by Joule effect, then heating the product itself. It is therefore possible by continuing heating the packing to maintain the temperature of the product itself above 3000°C.

Maintaining this temperature above 3000°C is critical to:

* get good crystallinity of the product
* generate a soft graphite that will be easier to mill and grind later in the process.
* ensure a total elimination of the catalyst[[10]](#footnote-11). If the catalyzer is not fully eliminated, the product will be contaminated and will not have the required purity.

The LWG graphitization is 50% more energy efficient because the product is heated directly. Thus, there is therefore much less energy losses. Concretely, electric current goes through the product, along the column of blocks and heats the product. Maintaining current intensity increases temperature. As soon as you stop the current, the product starts to cool down. The challenge comes from the following technical locks:

* when the block reaches high temperature and transforms into graphite, the resistance of the blocks decreases dramatically, requiring very high intensity to maintain temperature (through controlled level of power injected). Furthermore, the resistance continues to evolve at very high temperatures (~3000°C). It is therefore very difficult at that level of current intensity and with standard equipment to maintain this level of temperature without attaining sublimation of graphite temperature (slightly above 3000°C).
* if we remain for a long time at very high temperature, the heat will be conducted to all the peripheral elements of the graphitization furnace (refractories, walls...) and will strongly damage equipment. The insulating capacity of packing or the heat resistance of the furnace has to be improved to sustain longer time at high temperature

**Second technical lock**: Protecting the graphite properties during the micronization

Compared to the “powders to powders” process, using block requires much more demanding milling, grinding or micronization process after graphitization of the blocks. These operations can alter the structure and the shape of synthetic graphite, leading to anode material bad performance in cells.

In order to avoid this difficulty, state of the art practice consists in preparing coke powders at the final expected particle size (~15µm) and then extruding a not-so-dense block. During baking and graphitization in Acheson furnaces so without pressure and with blocks indirectly heated by the pack, the binder and the catalyst will evaporate, then leaving a graphite block that is very light and fragile. The micronization will be made easier and not so traumatic for the final anode materials products.

The challenge comes from the following technical locks:

* Considering the exceptionally large quantity of pitch that will be cokefied during baking, the risk of pitch fume inflammation during baking is high.
* Low density goes with low mechanical properties, when to ensure the electric current conductivity the blocks must be put under high pressure in the LWG technology. It will be mandatory to establish new operating conditions to ensure that the current will be homogeneously distributed in the blocks and that the pressure will not mechanically damage the blocks.
* Developing milling and grinding technics of graphite blocks that would:
  + protect the cost advantage of the LWG technology up to the expected shape and particle size distribution of anode materials for LiB. The cost advantage of this innovative route to market requires a milling/grinding yield above 90%.
  + avoid the shaping (spheoridization) and coating operations mandatory with natural graphite and often implemented for synthetic graphite using the Acheson powder to powder route.

**Third technical lock**: Evacuation of the catalyst during the graphitization and recycling of the pack to reduce waste

In order to ensure good product performance, synthetic graphite for anode materials must be very homogeneous with a very high purity (>99.99%). Therefore, impurities are not accepted.

First of all, with the LWG technology, the product is heated by the center. The pack around the product is therefore cooler than the core product itself. The evacuation of the catalyst becomes difficult because the catalyst tends to evaporate from the center but re-condensates somewhere depending on the temperature isotherms either at the periphery of the product or more probably at a certain level in the cooler pack. The impurities are therefore higher on the block outskirts.

Second, the thermal balance of the furnace will cause reactions between the carbon of the pack and the exhausted catalyst. This will create hard agglomerates that pollute the pack, generate a tight crust in the pack and create potential gas pockets (generating therefore safety issues that will have to be overcome).

The challenge comes from the following technical locks:

* ensuring a complete elimination of the catalyst with a by-design thermal difference between product and pack.
* mastering the pack cleaning and recycling to ensure optimum thermal balance and cost control.
  + 1. Articulation between “R&D Phase” & “FID phase”

Carbone Savoie objective in the IPCEI on Batteries is to succeed in producing, at a large industrial scale with a LWG graphitization technology, anode materials for batteries that can only be produced today with Acheson graphitization technology. In addition, this industrial production must be competitive in terms of cost and sustainable with a very low CO2 footprint compatible with European standards and ambitions.

Therefore, Carbone Savoie objectives in the IPCEI on Batteries consist in:

* **First, a “R&D phase” (2019- Q12022) that contains both “foundation R&D phase” and “R&D validation phase”** 
  + **a “foundation R&D phase” that aims at developing soft graphite with LWG technology at a R&D lab.** The objective is to overcome the technical locks and challenges that are described in section 1.4.2 and 1.4.3. R&D teams lead this phase.
  + **a “R&D validation phase” that aims at validating the replication of R&D outcome with industrial equipment.** The objective is to succeed in obtaining the same performance with industrial equipment technologies that are different from that of the R&D labs. Trials (called “R&D loops”) are organized at the industrial plant to validate R&D findings usually per significant parameter highlighted during the foundation R&D phase with industrial equipment. R&D teams lead this phase, with the support of the plant quality control teams.
* **Second, a “FID phase” (2020-2022) that aims at overcoming industrialization challenges**. The objective of this phase is to stabilize the process, to obtain consistent product with cumulative effect of the different significant parameters already tested individually during the R&D validation phase and design the innovative adjustment to equipment and procedure that will give the opportunity to reach quality, volume and cost objectives with sustainable performances. Graphite manufacturing is a very complex process industry. Transposing R&D encouraging results into mass production has always raised challenges. Trials (called “FID loops”) are organized at the industrial plant to develop industrialization process.



Figure 8 High level planning between R&D, FID and Mass Production

Understanding the “R&D validation phase”:

The implementation of a “R&D validation phase” is unusual. In the chemistry industry, R&D teams usually work in the lab until the finalization of the formulation and then move directly to FID. However, this does not work in the graphite industry for two specific reasons:

* R&D replication challenge: Indeed, available R&D equipment use different technology than Carbone Savoie’s industrial equipment. For example, in the baking process: R&D baking furnace heats a maximum of 2 to 25 kg of product to expected temperature (~1000°C) using electricity. In industrial conditions, Carbone Savoie baking furnace uses gas associated with a continuous process (ring furnace technology). This technology is the most energy-efficient technology with heated fumes vacuumed into refractories. Quality of the refractories, fume aspiration speed into the refractories, packing cokes, etc. have an impact on the thermal heat transfer and thus on the final product properties as well as on the performance. Such impacts cannot be replicated in the R&D lab. Therefore, it is necessary, at each step of the R&D program, to validate the R&D work with the industrial equipment. Very often, recipes, heating temperature curve, standard process parameters and equipment have to be modified by the R&D teams to replicate the results of the “foundation R&D phase”.
* Product size challenge affecting R&D: Contrary to other industry, blocks are formed at the beginning of the production process and not at the end. The block will have to be transformed during the production process from a green (crude) block to a baked block and finally to a graphitized block. Everyone understands that it is very difficult to replicate exactly the baking and graphitizing conditions on a 2-ton block as compared to a few kg block in a R&D lab. R&D must therefore verify all along its progress, that the result obtained with small size block are the same as with large size blocks: this “scale effect” is particularly sensitive on the section of the product, bringing namely very large differences on heat transfer and chemical diffusion (all this physical mechanisms being related to the square of the section dimension).

Contrary to other industries, graphite industry is a process industry that is both science and art[[11]](#footnote-12). Trying to make R&D isolated in a R&D lab will generate results that will not be replicable with production equipment. This allows entering the right industrial input data in the company’s model in order to define the adjustments that have to be tested at the R&D scale before going back to the industrial R&D loops. This is the reason why there is always a “R&D validation phase”, in which the R&D teams validate step-by-step in industrial condition the R&D outcomes.

The start of the FID phase before the end of R&D phase:

Finalizing completely R&D work plan before moving to FID work plan would not make sense. Such a decision would increase significantly the project duration and therefore increase significantly the risk and cost of the project. FID requires to find ways to adapt the production equipment and the processes themselves at each step: milling, mixing, extrusion, baking and / or graphitization. None of Carbone Savoie’s equipment are on-the-shelves equipment. They cost millions and have been installed years ago. Therefore, Carbone Savoie cannot consider buying new equipment, but it must adapt the existing equipment. Adapting equipment takes months (engineering team to innovate and find a technical solution, consultation to engineering companies, work realization, installation, commissioning, test and new adaptation). Considering the number of equipment that needs to be adapted for the IPCEI on Batteries, it would not make sense to wait to completely finalize the “R&D phase” before starting the “FID phase”.

* + 1. Objectives and technical challenges in the “R&D phase[[12]](#footnote-13)”

Carbone Savoie R&D has defined the action plan below related to overcoming the technical locks. These three action plans related to technical locks are then ventilated in the four work plans described in chapter 1.8.1 (three work packages are R&D activities, one work package is FID activities).

The three tables below describe the objectives set out by Carbone Savoie in the IPCEI on Batteries. The activities that will be carried out to reach these objectives are describe in “1.6 Organisation of the different R&D loops and FID loops” and in “1.8 Work Plan”.

Related to first technical lock: Maintaining temperature above 3000°C with LWG graphitization technology

| Work | Action plan |
| --- | --- |
| Raw materials | * Fully understand the impact of the type of coke, coke production process and particle size of the coke on crystallinity (*R&D work made in collaboration with R&D of a major coke supplier*) * Fully understand the impact of the type of pitch on crystallinity (*R&D work made in collaboration with R&D of a major pitch supplier*) * Try new catalyst under different forms (carbide, metallic oxide, elementary) : Si, B, Ti , Fe, Ni … * Study impact of purification additives in the formulation |
| Baking process | * Better understand impact of final baking level on crystallinity. * Develop anode-designed baking curves (levels, duration, temperature) |
| LWG process | * Develop anode-designed graphitization curves (levels, duration, temperature) * Develop process to maintain final temperature as long as possible despite LWG process limitation by better managing energy and product resistance during graphitization * Develop optimum cooling curves and develop accordingly a new cooling system that improves crystallinity and length of crystallite. |
| From block to anode materials powders | * Develop anode material product portfolio with/without spheroidization and coating and synthetic/natural graphite blend (*R&D work made in collaboration with R&D of AMG Graphite (Germany), a specialist of spheroidization and coating for natural graphite*). |

Table 4 R&D action plan related to the first technical lock

Related to the second technical lock: Protecting the graphite properties through an efficient micronization step

| Work | Action plan |
| --- | --- |
| Raw materials | * Optimize the milling process regarding yield and cost (*R&D work made in collaboration with R&D of a CS Additive (Germany), a specialist of graphite powders*) * Optimize the recipe, mixing and extrusion process to get a product without defects and able to be baked efficiently (productivity, energy, yield) * Fully understand the impact of the type of coke, granulometry of cokes and additives, coke production process on extrusion (*R&D work made in collaboration with R&D of a major coke supplier*) on the low density and structure of the final graphite blocks |
| Baking process | * Learn to manage the cokefaction of pitch during the baking to get the right structure of product before graphitization while avoid inflammation. * Develop cleaning and recycling techniques for coke used as packing and contaminated by the catalyst. |
| LWG process | * Develop low density block graphitization curves (duration of holding temperature, ramp up) * Develop new in-pressure system to more fragile blocks designed for battery application. * Develop cleaning and recycling technics for coke used as pack and contaminated by catalyst. |
| From block to anode materials powders | * Develop energy-efficient technics to recover the original particle size from the graphite blocks with a yield above 90% (*R&D work made in collaboration with R&D of a CS additive, a specialist of graphite powders*) |

Table 5 R&D action plan related to the second technical lock

Related to the third technical lock: Evacuation of the catalyst and recycling of pack

|  |  |
| --- | --- |
| Work | Action plan |
| Raw materials | * Try new catalysts under different forms (carbide, metallic oxide, elementary) : Si, B, Ti , Fe, Ni …and see how it evaporates from the blocks to create hard agglomerate on the outside of the blocks. |
| Baking process | * Develop cleaning and recycling technics for coke used as pack and potentially contaminated by catalyst during baking. |
| LWG process | * Develop catalyst “*catch system*” to avoid polluting the coke used as pack. * Develop cleaning and recycling technics for coke used as pack and contaminated by catalyst during graphitization. * Look for other source of graphitization pack with specifications around the following themes: thermal exchange, permeability, catalyst evaporation, diffusion and reactivity. * Look for how to use SiC in a circular economy (internal or external consumption) |

Table 6 R&D action plan related to the third technical lock

* 1. Technology and Challenges of “FID phase”
     1. First Industrial development (FID) phase challenges

First industrial deployment (FID) refers to the upscaling of pilot facilities.

In order to convince cell manufacturer to qualify innovative anode material from a supplier, the anode materials manufacturer must demonstrate that:

* The anode materials perform well in the cell electrolyte and contribute to generate the expected cell performance in term of capacity, life duration and charge/discharge rate.
* He is capable of maintaining the consistency of the product, at industrial scale, over thousands of tons of production and during many years of production. It is therefore critical that the synthetic graphite manufacturers prove not only the availability of their raw materials for several years but also their ability to master the production process to replicate a very consistent product over time.

Therefore, to obtain qualification for anode materials and to move to mass production, Carbone Savoie must absolutely demonstrate its ability to industrialize its “R&D phase”. For Carbone Savoie, the IPCEI on Batteries aims at qualifying one LWG-driven graphite with one leading cell manufacturer for an application that is today addressed only with the Acheson process. This first anode material product could be either qualified for Electrical Vehicle application or for other application (ESS, forklift, e-bike, scooter...).

Overtime, building on the knowhow and experience accumulated with this first product, it is expected that Carbone Savoie will be able to develop enhanced graphite anode materials products that will meet more and more demanding applications. Such product improvement program will be launch after the completion of this IPCEI on Batteries.

The objective of this FID phase is to test the cumulative effects of all the new parameters, to stabilize the process, to obtain consistent product and to design the innovative adjustment to equipment and procedure to reach quality, volume and price objectives with sustainable results and very low dispersion. Graphite manufacturing is a very complex process industry. Transposing R&D encouraging results into mass production has always raised several challenges:

* Industrializing challenge:During the“R&D validation phase”, trials are organized during normal working hours, with a heavy support from the R&D and quality control teams. Lot of tests are made manually (*For example: injection of pre-weighted additives in the formulation*). Such trials aim at validating the replication of R&D findings into production. Very differently, the challenge of the FID industrialization phase is to identify and find technical solutions to all production issues in order to be able to produce a consistent quality, at a competitive economic cost, 24-hour a day. For example, anode materials formulation requires additives and catalysts that Carbone Savoie does not use today in its formulations. The addition of such additives during the “R&D validation” phase is made manually. However, finding a way to add automatically a very precise quantity of additives every 3 minutes inside a never-stopping closed mixers located 20 meters above the floor, on a 24-hour, 7 days a week basis, is a challenge that is only addressed during the FID phase.
* Production lead-time acquisition challenges: Contrary to other industries, synthetic graphite production requires a three-month lead-time production process. The two longest process steps are the baking (2 weeks) and the graphitization (one week). Unfortunately, the product performance can only be tested[[13]](#footnote-14) after the final graphitization step and therefore at the end of the 3-month production process. This challenge is very specific to this industry. To minimize the impact on product development, it requires accumulating as much learning as possible during each loop. For this reason, Carbone Savoie always produces loop batches of 150 to 300 tons (75 to 150 blocks), splitting each batch into baking and graphitizing sub-batch of 15-25 blocks, in order to evaluate the dispersion of the processes themselves over a given formulation. Each trial sub-batch will be prepared to test different process parameters innovation or different technical equipment innovation. Each sub-batch is closely monitored during the 3-month production lead-time.
* Product homogeneity FID challenge: Guaranteeing the product homogeneity and performance is therefore very challenging because contrary to other industry, blocks are formed at the beginning of the production process and not at the end. During the 3-month production process, more than 400 different production parameters[[14]](#footnote-15) have to be monitored and traced on each block. Each of these 400 different parameters has impact on the final product performance. R&D and quality control team must innovate to put these parameters under control, without human supervision. It therefore requires inventing control mechanism of key parameters.
* Scaling-up FID challenge: Carbone Savoie has a specific FID challenge. Carbone Savoie’s industrial equipment are very compact, fully automatized and capable of producing about 1,500 tons per week (equivalent of a very large and manual 60 Acheson graphitation furnaces plant in Asia). Therefore, Carbone Savoie will be the first-in-the-world to develop an industrial process adapted to the need for scalabity in the production of Graphite Battery Anode Materials.

*LWG graphitization technology applied to battery applications has been studied by SGL Carbon at Morganton but has never been industrialized to support the production of large quantities (current SGL Carbon production of ~ 1,500 tons/year ~ 4 tons/day). As an example of difference of scale, Carbone Savoie produces in Savoie (France) every week, about 1,500 tons of graphite blocks. This represents the annual anode production of SGL Carbon in Morganton. Carbone Savoie has therefore a unique, first-in-the-world challenge of scale before succeeding in the replication of its R&D findings and obtaining a consistent and industrial product.*

* Customer feedback integration challenge: Customers only request samples coming from the FID phase, not from the R&D phase. These samples will be transferred free to potential customers (cell manufacturers and/or OEMs) that will test them in their own innovation processes, and then send the results back to Carbone Savoie to analyze and run additional FID batches, and so on and so forth (innovation loops in qualification processes). This requires Carbone Savoie’s process control and R&D teams to innovate in real time and implement solution on its industrial production set-up.

Therefore, validating a first industrial deployment, meaning a semi-continuous production of consistent quality products, up to 200 tons per day, is a very difficult first industrial development challenge. It will require a minimum of five innovative FID loops, each of them containing a very important R&D component, which constitutes an integral and necessary element for the successful implementation of the project.

* + 1. Validation of the FID phase and start mass production:

In order to consider the FID phase completed and go to mass production, Carbone Savoie will use the following cumulative FID completion criteria:

* Reject rate < 10%;
* Cost of production < 5€/kg[[15]](#footnote-16) +/- 10%, at micronized powder stage (non-coated, non spheroidized);
* Full commercial qualification on a battery application requiring today soft graphite made with Acheson process;
* Delivery planning agreed with customer for the production and shipping of a minimum of 100 tons of production.

Carbone Savoie anticipates that these FID completion criteria will be reached after a minimum of five innovative FID loops over a three-year period (2020-2022).

*Note on commercial qualification process of cell manufacturer:*

*According to Carbone Savoie’s knowledge, there is no legal textbook describing the formal qualification process for Battery Anode Materials. Each cell manufacturer has its own qualification process, even if cell manufacturer seems to follow the same general rules:*

* *Qualification is tested on two completely different BAM industrial-scale batches in order to verify the capacity of the supplier to produce consistent products over time*
* *The qualification of the first batch takes 9 months and consists in accelerating the life cycle in order to test the performance of the cell over a long period.*
* *The 2nd batch is tested only if the first batch has passed the test, which makes a full 18-month qualification process before entering into production phase*
  1. Organization of the different R&D loops and FID loops

R&D loops are part of the “R&D validation phase”. R&D loops are organized at the industrial plant to validate R&D outcome with industrial equipment, focused for each of them on only one factor (either formulation or process).

FID loops are part of the “FID phase“. FID loops are organized at the industrial plant to develop industrialization process and integrate all the R&D loops made on a group of factors for a specific work plan.

“R&D loop” and “FID loop” should not be understood using classic definition. As already explained in section 1.4.3, no R&D lab equipment exists to replicate impact of large block size and impact of ring furnaces baking technology on product performances. Therefore, both R&D loop (only one factor) and FID loops (group of factors) require:

* First, a fundamental research in the lab to validate that choice of raw materials & advanced process parameters will meet product performance target.
* Second, a verification that the results obtain in the lab can be replicated with blocks of much larger size and using different equipment (i.e ring-baking technology).



*Figure 9 Detailed planning of the R&D phase and the FID Phase*

* + 1. Description of the 7 “R&D loops” and 5 “FID Phase” loops

Carbone Savoie anticipates a continuous loop process in order to progress in an agile mode and have the opportunity to validate R&D findings and progress in its FID efforts. A minimum of 12 R&D and FID loops will be required to:

* validate the feasibility of replicating R&D defined process on equipment parameters and procedures,
* evaluate the impact of equipment and industrial process parameters on final product,
* develop new innovative production processes on industrial equipment to succeed in the industrialization challenge, to guarantee product homogeneity, and obtain expected product performance.

Regarding the “R&D phase”, as already explained in section 1.4.3, Carbone Savoie needs to validate industrial replication of each of its R&D lab outcomes and recommendation, to validate the R&D work. Therefore, validating the process & equipment feasibility to LiB-dedicated synthetic graphite R&D formulation is as critical as the fundamental R&D development program in the R&D lab. The R&D validation phase requires a minimum of 7 loops involving production equipment and teams.

* Carbone Savoie usually starts with smaller batches of about 150 tons in order to validate only the final formulation. Therefore, the 4 first R&D loops related to WP 1 will be limited to 150 tons.
* Then, Carbone Savoie generally moves to its standard R&D batch size of 300 tons. Batch size must be larger because Carbone Savoie starts integrating the different R&D work plans together and it therefore needs more blocks to validate the different R&D outcomes. Therefore, each of the last 3 remaining R&D loops related to WP 2 and 3 will be based on 300 tons batches.

The “FID phase” requires a minimum of 5 FID loops of 300 tons batch. Carbone Savoie generally uses its standard FID batch size of 300 tons, testing different industrial conditions (equipment parameters, combination of process parameters on final product, …) whatever it is for mixing, extrusion, baking and / or graphitization.

In each of these 12 R&D loops or FID loops, the production batch is divided into different lots of 30 to 50 tons (15 to 25 blocks[[16]](#footnote-17)) to reflect either different formulations, different process parameters, different equipment or a combination of these.

Each trial represents the equivalent of 5 days of production (cleaning installation for trials, preparing for the trials, running trials, cleaning installation to restart). During that time, no side production is possible on Carbone Savoie’s industrial equipment.

| Loop number | Work Plan[[17]](#footnote-18) | Type of loop | Batch size | Objective of the R&D or FID loop | Completion target date | R&D associated with loop | KPI associated with the R&D or FID loop |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | WP1 | R&D Valid. Phase | 150t | Impact of the Raw Materials on advanced Materials: innovation linked with the production process of blocks based on new types of materials including type of cokes, binder and additives | Q2 2019 | As the recipes are brand new for an extruded graphite blocks process Carbone Savoie has to quantify the impact of this innovative recipe defined at R&D&I scale on the industrial performances (scrap, energy, yield).  The target is so to quantify the scale effect with the recipe chosen  Carbone Savoie has to make the comparison with pilot results mainly regarding final properties.  The first results on process and product will allow to go back to R&D&I. Based on its first R&D&I Carbone Savoie is able to adjust / fine tune the recipe regarding: quantities, types and may be choices of the different compounds. | Yield at each step of the process  Purity, crystallinity  Cell performance |
| 2 | WP1 | R&D Valid° Phase | 150t | Adjustment of the recipe and green (crude) process for the type of cokes, binder and additives | Q3 2019 | From the results got on the first trial and the adjustments defined during the R&D&I associated Carbone Savoie has to confirm with a second R&D validation phase trial | Yield at each step of the process  Purity, crystallinity  Cell performance |
| 3 | WP1 | R&D Valid. Phase | 150t | Impact of the Raw Materials on advanced Materials: innovation linked with the production process of blocks based on new granulometries | Q4 2019 | The granulometry and the binder content associated with will be very innovative for a usual graphite block extrusion/baking/graphitization process  Carbone Savoie has to make the comparison with pilot results mainly regarding final properties.  So the target is to quantify the scale effect | Yield at each step of the process  Hardness / grindability  Purity, crystallinity  Cell performance |
| 4 | WP1 | R&D Valid. Phase | 150t | Impact of the Raw Materials on advanced Materials: innovation linked with the production process of blocks with innovative additives | Q1 2020 | The additive that has been chosen has to be tested at a large scale to validate that the dispersion is well mastered and that the reactions during baking and graphitization are realized till the full removal of the catalyst in the final graphite block. | Yield at each step of the process  Purity, crystallinity  Cell performance |
| 5&6 | WP1 | FID Phase | 300t | Impact of the Raw Materials on advanced Materials: innovation linked with the production process of blocks with new raw materials and granulometries including additives and catalyst | Q2 2021 | After validation of the here above factors at a large scale and adjustment of the different levels by going back to the R&D&I process Carbone Savoie has to validate the full range of innovative solutions concerning the recipe of its innovative BAM products.  Carbone Savoie forecasts to double the trial to have an idea of the deviation linked to its process and so to mitigate as much as possible the final process parameters effects and the final properties of its innovative BAM products. | Yield at each step of the process  Hardness / grindability  Purity, crystallinity  Cost |
| 7&8 | WP2 | R&D Valid. Phase | 300t | Thermal Treatment impact on Advanced Materials | Q4 2020 | The thermal treatment has a great influence on the different reactions occurring with temperature (catalyst effect) , on the final grindability (texture) and purity linked with the evacuation of the catalyst and if necessary additives.  The first set of R&D validation phase trials 7 (baking) & 8 (graphitizing) allows to quantify the effects at a large scale as Carbone Savoie may have deviation due to the different thermal processes (baking and graphitization). From the results on yield, energy consumption, purity and crystallinity Carbone Savoie has to go back to R&D&I phase in order to adjust/ fine tune the process taking into account these results (product/process including packs analysis, modeling) and its R&D&I developed expertise. | Yield at each step of the process  Hardness / grindability  Purity, crystallinity  Energy consumption  Cost  Cell performance |
| 9 &10 | WP2 | FID phase | 300t | Thermal Treatment impact on Advanced Materials | Q2 2022 | From the adjusted process and product parameters re-defined thanks to the previous R&D&I validation phase Carbone Savoie finalizes the industrial possible deviation to anticipate as accurately as possible the final properties of the BAM graphite blocks. This continuous loop process is of importance to be sure to fix the right parameters allowing to guaranty the stability of the final innovative BAM graphite product. | Yield at each step of the process  Hardness / grindability  Purity, crystallinity  Energy consumption  Cost  Cell performance  Formal qualification launch (1st batch) |
| 11 | WP3 | R&D Valid. Phase | 300t | Preparation of the synthetic graphite powder | Q2 2021 | Directly linked with the previous results this phase must allow us to get the right final product at powder stage. The innovation is mainly in the fact that Carbone Savoie targets to get the right properties without having specific steps for spheroïdization and / or coating.  From the R&D&I results Carbone Savoie tests some selected milling process and conditions on a large scale in order to take into account the deviation linked to the milling process.  From the analysis of the final products, a second run with optimized parameters will allow to get sufficient confidence in order to master as much possible the final properties and the stability of Carbone Savoie’s innovative BAM product | Yield at each step of the process  Hardness / grindability /granulometry  Purity, Crystallinity  Energy consumption  Cost  Cell performance  Intermediate qualification results on 1st batch + launch of 2nd batch  First sales for prototype industrial cells |
| 12 | WP3 | FID phase | 300t | Preparation of the synthetic graphite powder | Q4 2022 | The innovation is mainly in the fact that Carbone Savoie targets to get the right properties without having specific steps for spheroïdization and / or coating.  From the R&D&I validation phase results Carbone Savoie tests the optimized selected milling process conditions on a large scale in order to take into account the deviation linked to the milling process.  This will allow to get sufficient confidence in order to master as much possible the final properties and the stability of the innovative BAM product | Yield at each step of the process  Hardness / grindability /granulometry  Purity, Crystallinity  Energy consumption  Cost  Cell performance  Intermediate qualification results on 1st batch + launch of 2nd batch  First sales for prototype industrial cells |

* + 1. Economic cost of R&D or FID loops

The R&D and FID loops will be performed with Carbone Savoie’s current equipment’s capacity, which are already fully loaded with current markets (aluminum cathode and specialty graphite blocks). From this point of view, these trials are a real investment in time and loss revenues for Carbone Savoie and generate not only direct cost but also substantial direct production/sales losses of opportunity: every ton of graphite product sold to currents markets generate about 1,600 euros per tons of EBITDA margin. Therefore, running trial for 5 days has an EBITDA negative impact of 650,000 euros.

Over the 4 years of R&D and FID development phase (2019-2022), Carbone Savoie will dedicate about 3.000 tons of production to loops required by the R&D phase and the FID phase (~2% of Carbone Savoie cumulated production between 2019 to 2023).

* 1. Intellectual Property Rights
     1. IP management principles

Carbone Savoie handles IP management internally, promoting close collaboration between the R&D team, the production team and its patent engineer, e.g. through the organization of patent committee meetings, performance of market intelligence, patent mappings, etc. IP strategy focuses on high performance synthetic graphite products and processes to enable sustainable growth.

* + 1. IP protections principles

Each IPCEI on Batteries’ partner will own the IP that it has developed itself as part of the project. In case of joint discovery, a co-ownership will be set up, reflecting the contributions of each partner to the invention. The details of the management, sharing and exploitation of intellectual property will be regulated in the partnership agreement to be established between the partners.

* + 1. IP exploitation principles

Regarding IP exploitation, each partner will in principle be free to exploit as it wishes its results which are protected by intellectual property rights, including the common new knowledge, without accounting to the other partners. In case of license agreements for exploitation of foreground owned exclusively by a partner, the licenses will be paid at the market price, on fair, reasonable and non-discriminatory conditions (FRAND), as a result of a negotiation between the owner of IP and the partner interested in the license.

Carbone Savoie’s technological vision on Li battery anode materials is to focus on secondary graphite production from raw materials selection, characterization, preparation and formulation, blending, mixing, extrusion (or any other forming process), baking, and graphitizing and bringing on the market secondary graphite blocks at the right level of intrinsic material quality ready for following operations.

From the IP point of view, Carbone Savoie intends to remain proprietary on the formulation and transformation processes from raw material to secondary synthetic graphite blocks, and therefore to exploit on its own facilities the know-how developed, by producing up to 15,000 tons per a year.

* 1. Work Plan
     1. R&D work plan

Carbone Savoie anticipates a three-year R&D&I program overlapping with also a three-year FID program from the 4 work plans below.

All along the way, Carbone Savoie will have to partner with potential customer in order to evaluate the performance of the graphite powder from customer specification (crystallinity, BET specific area, granulometry, density, impurities) and test it as anode material in a cell (capacity, efficiency, cell life).

* **WP1:** Understanding & Optimization of raw materials properties and forming on advanced materials. Raw materials are critical to obtain the expected final properties. Carbone Savoie aims, with its partners, to develop an overall understanding of structures-to-properties all along the product transformation chain, starting with on raw materials. These are basically coke and coal tar pitch as a binder and in addition potential additives and catalysts in order to modify the final properties of the graphite. The first step starts with the selection of the right coke in order to get the required properties mainly crystallinity, purity and ability to be milled at the right grain size distribution and shape with an acceptable yield. This coke must also be available at a low price with a sufficient stability and quantity in order to guarantee the deliveries to Carbone Savoie’s customers. From its huge experience on cokes, Carbone Savoie will choose some candidates either already referenced in its data base or even new ones potentially fitting well with the targeted specifications for a good Anode materials product. Carbone Savoie will start with usual analysis such as densities, ash content, resistivity, hardness and it will have to take special care on full set of impurities (GDMS/ICP analysis) and XRayDiffraction. After analysis, these cokes will have to be milled at different sizes down to some µm in order to establish the influence of the grain size distribution on the final properties (Lc, d002, grindability) of the Anode materials and on the yield of the full process.

The binder (usually a coal tar pitch) will also be involved in the program as it has a significant influence on the impurities and on the interaction with the dry materials. The binder plays a significant role on the final structure of the graphite. The binder is first transformed during the first thermal treatment, typically at about 800 to 900°C, and then graphitized during the graphitization process. Binder’s type and specifications have an influence on the different chemicals involved in these different processes due to the reaction with coke and additives. Carbone Savoie will therefore test different types of binders referenced in its data base in order to evaluate the influence of the main properties: Mettler point, coke yield, density, viscosity, impurities, wettability, graphitability on the final properties targeted for the Anode materials product.

The third main components to be involved in the R&D program are the additives for improving the ability to get a better graphite regarding crystallinity (Lc, d002 XRD or Raman) and potentially to have an effect on the final structure of the graphite to be efficiently milled at the right shape. Carbone Savoie will have to include different chemical elements at different amount, level of purity and granulometry.

As Carbone Savoie has different raw materials at different levels of properties, it intends to work with a design of experiment process in order to optimize the efficiency of the WP1. After the full analysis of these raw materials, Carbone Savoie will produce laboratory and then fine-tuned pilot samples through the DOE to include the different factors, the samples will be shaped, baked and graphitized at pilot scale. At this stage Carbone Savoie will analyze the graphite it gets mainly for impurities (GDMS, ICP), XRD (Lc, d002), grindability (yield) and then specific area (BET) and cell performance (capacity, efficiency, cell life).

Finally, from the previous pilot results Carbone Savoie will choose some specific defined parameters in order to check the main effects at the industrial scales thanks to a series of industrial trials with basically about 150 to 300 tons of shaped green product each time. This will involve the preparation, characterization of the raw material including micronization and the full process till the characterization of the final synthetic graphite as already described for the pilot samples.

* **WP2:** Optimization of an innovative Upstream (baking, graphitizing) process for advanced materials. As already mentioned the thermal treatments (baking, graphitization) have a significant impact on the physicochemistry of the process and so on the different species, mainly with the presence of additives, developed and transformed all along the process up to the final temperature at 3000°C. Carbone Savoie will take the advantage of the samples shaped at the WP1 in order to work on the baking and graphitization process. The first step will be from modelling of the process to define different thermal curves to be tested in order to influence the kinetics of transformation.. These curves will be tested at pilot and then at industrial scale. The final graphite products will be analyzed as already described hereabove as well as different analysis at the different step to follow the evolution of the physicochemicals species (including SEM)

As discussed in the section 1.4 on technical locks, one of the main technical lock is related to the difficulty to maintain temperature at 3,000°C to increase crystallinity during graphitization. Carbone Savoie will focus on that process and baking will also be also studied. Regarding the thermal curve, Carbone Savoie will start with the modelling of the process considering product and coke packing. Starting from the thermal balance the company will define the kinetics of transformation of the products considering the transformation to graphite and transformation / diffusion with temperature for the physicochemical species. The tested curved will included the temperature ramp up section and also the time and level at final temperature. The final graphite products will be analyzed as already described hereabove as well as different analysis at the different step to follow the evolution of the physicochemical specifications.

A special care will be dedicated to packing itself as Carbone Savoie forecasts to have chemical reaction with the different catalyzers improving the crystallinity. Carbone Savoie will test different type of packing, at different particle size distribution in order to optimize the cleaning and recycling process. The pack will be analyzed for particle size distribution and impurities / hardness.

* **WP3**: Optimization of an innovative Downstream (milling, micronizing, shaping, coating) process on advanced materials: Basically, the content of this third WP is to recover the right particle size distribution from a block. Optimizing the yield and protecting targeted properties during micronization process is today a technical lock. Carbone Savoie has already mentioned the study of the influence of different factors on the physicochemical species all along the process including the raw materials, which is of great importance on the final structure of the synthetic graphite products as well as the graphitization process parameters. Taking advantage of the samples prepared in WP1, Carbone Savoie will test at pilot and then at industrial scale different graphitization final conditions in order to determine the optimum - including raw materials and process - to get the structure allowing to get the targeted properties and the best yield at the end. That will include also the test of different types of milling with Carbone Savoie’s milling and grinding expert (outside the IPCEI on Batteries). In order to simplify the characterization on pilot and first industrial equipment Carbone Savoie will focus here on the product structure (porosity, pores size distribution, permeability, grindability, hardness, micro granular distribution).
* **WP4**: Integrated industrial production Upstream & Downstream scale up (FID): In the meantime, Carbone Savoie will start industrial trials in order to validate the R&D findings in operational conditions and develop innovative solutions to scale up these new processes to 500-time larger equipment. As already mentioned, Carbone Savoie will start with 4 batches of about 150 tons for the R&D&I phase until the right formulation has been determined. Then, from FID loop number 5 Carbone Savoie will increase batch size to 300 tons for the FID in order to be as representative as possible from the industrial conditions and to assess the dispersion of upstream processes (baking and graphitization). Carbone Savoie forecasts at least twelve (12) industrial development trials all along the three years of the FID period[[18]](#footnote-19). The scheduled overlapping between R&D&I and FID periods allows Carbone Savoie to take into account the scale up trials and errors and so to readjust if necessary some factors and effects in the R&D lab program. For the FID, Carbone Savoie will have again to include all the different characterization from the raw materials to the final products including impurities (FluoX, GDMS or ICP), crystallinity (Lc d002 XRD, Raman), structure (pores distribution, permeability), yield (grindability, hardness, granular distribution), and cell performance (capacity, efficiency, cell life)

| **WS** | **No. of WP** | **Title - Main objective of the work plan** | **Person Months (R&D&I)**  **2019-2021** | **Person Months (FID)**  **2021-2026** |
| --- | --- | --- | --- | --- |
| 1 | WP1 | Understanding & Optimization of raw materials properties and forming on advanced materials: determine the right formulation to get the product specifications and cell performance with consistent RM costs | 92 |  |
| 1 | WP2 | Optimization of an innovative Upstream (baking, graphitizing) process for advanced materials: develop an industrial process to get a graphite block capable of the product specifications and cell performance target with consistent upstream costs | 72 |  |
| 1 | WP3 | Optimization of an innovative Downstream (milling, micronizing, shaping, coating) process on advanced materials: develop an industrial process to get a finished powder fitting with specifications and the cell performance target, with consistent downstream costs | 36 |  |
| 1 | WP4 | FID: Integrated industrial production Upstream & Downstream scale up   * Safety/security of the processes * Routes, Investments * Capacity/productivity/Packing management * Equipment design / modification * Quality and yields * CO2 footprint: specific energy consumption |  | 81 |
|  |  | Total Person Month | 200 | 81 |

**Table 7: Work Plans (WP) vs. Person Months (PM)**

*Overlapping of R&D and FID Phase:*



Figure 10 Illustrative Gant chart of the 4 work Plans (WP)

Our process is agile and help reducing project risk along the way, fueling progressively work plan 1-3 (R&D work plans) with feedback from work plan 4 (FID).

* + 1. R&D collaboration plan inside and outside IPCEI on Batteries

High capacity lithium-ion batteries for Electrical Vehicles require high performing anode materials. Considering the knowhow that Asian anode manufacturers have acquired over the last fifteen years, only a pan-European collaborative and very ambitious R&D program will allow a European consortium to bring quickly to market European-designed highly innovative anode materials.

Carbone Savoie aims at coordinating a large pan-european collaborative R&D program ranging from leading raw materials suppliers (coke, pitch & silicon) to cell manufacturers in order to improve the overall understanding of structures-to-properties all along the product transformation chain, thus reducing product development time in the medium term. Carbone Savoie and its partners aim at developing highly innovative products that offer benefits to cell manufacturers in term of performance, cost and independence of supply.

Based on its extensive knowhow in designing synthetic graphite solutions and processes for different applications, Carbone Savoie aims at developing a world class graphite anode production with an innovative manufacturing process that is more scalable, more sustainable and deliver better cost than state-of-the-art processes developed in Asia. Carbone Savoie’s R&D and FID activities in this IPCEI on Batteries aim at designing, testing and validating the industrialization of an innovative production processes for battery application in order to have a quick ramp-up when a product is qualified by cell manufacturers.

In parallel, Carbone Savoie has joined forces with milling/grinding and spheroidization /coating specialists based in the European Union (outside of the IPCEI on Batteries), in order to leverage their experience, knowhow and equipment in their respective fields. This initiative will not only increase consortium chance of success by building on Carbone Savoie’s partners experience in obtaining the optimum shape, in optimizing yield and therefore in reducing product cost but it will also accelerate the production ramp-up of qualified products.

The operations of micronizing coke blocks to graphite powder at the right grain size distribution and shape will be performed by specialized companies such as Carbone Savoie’s partner CS Additive (D). The final transformation of micronized powders (purifying, coating, blending, …) and assembly of the Li battery anode will be performed by specialized European companies such as AMG Graphite (D).

Carbone Savoie has organized its collaboration in two ways:

* Partnership: In the partnership program, each company performs independent R&D under a collaborative agreement. R&D cost of the partner is supported by the partner. Carbone Savoie and the partner agree on sharing information that will help both companies to develop jointly better product. The partner keeps the Intellectual Property related to its innovation.
* Outsourcing: In the outsourcing program, Carbone Savoie outsources a portion of its R&D effort to the partner and supports the cost associated to the work made by the partner. As a result, Carbone Savoie holds the Intellectual Property of his own research and that made by the outsourcing partner. In the case of public RTO such as CEA Liten and Fraunhofer institutes, Carbone Savoie will contract the R&D fees at market price.

Strategic supplier (outside EU)

Coke

Carbone Savoie (F)

Graphite anode Manufacturing

Rain Carbon (B)

Pitch

CS Additive (D)

Grinding and milling

AMG Graphite (D) – spheroidization and coating

Ferroglobe (E)

Silicon

**Raw materials**

**Graphite anode**

**Cell manufacturing**

FAAM (I)

Cell manufacturing

SAFT (F)

Cell manufacturing

Nanocyl (B)

Carbon nanotubes

Fraunhofer institutes (D)

**Research organization**

CEA Liten (F)

IPCEI direct partner

**Legends**

Indirect partner - Partnership

Indirect partner - Outsourcing



Figure 11 Pan-European collaboration cluster around Carbone Savoie anode material project

| Name of partner | Country | Direct or indirect IPCEI partner | Main activities contributed to collaboration clusters | SME or LE or RTO | Type of collaboration fir indirect partner |
| --- | --- | --- | --- | --- | --- |
| Rain Carbon | B | Indirect partner | Contribution to materials selection and design | SME | Partnership |
| Coke supplier (conf.) | Conf. | N/A | Contribution to materials selection and design | LE | Partnership |
| Ferroglobe | E | IPCEI direct partner (Autumn IPCEI) | Development of Si contents in the Graphite anodes: use of micrometric silicon (or silicon-based products) in upstream processes as a catalyst. Use of nanometric silicon in downstream processes as an additive to dope the capacity of the final advanced material | LE | N/A |
| Nanocyl | B | IPCEI direct partner (Summer IPCEI) | Test of Nanocyl product with anode materials, use of carbone nanotubes as catalysts/precursors in upstream processes. | SME | N/A |
| CS additive | D | Indirect partner | Milling and grinding expertise | SME | Outsourcing |
| AMG Graphite | D | Indirect partner | Milling, spheroidization and coating expertise for post treatment | SME | Outsourcing |
| Fraunhofer Institutes (ISC, HLT, IWS) | D | Indirect partner | Specific expertise to complement CS knowhow | RTO | Outsourcing |
| FAAM | I | IPCEI direct partner (Summer IPCEI) | Process test on cell | SME | N/A |
| CEA LITEN | F | Indirect partner | Process test on cell. | RTO | Outsourcing |
| SAFT | F | IPCEI direct partner (Summer IPCEI) | Process test on cell | LE | N/A |

Table 8 List of direct or indirect IPCEI partner in the Carbone Savoie IPCEI project

**Note concerning the confidential coke partner from outside the European Union.**

Coke is the essential raw material to produce synthetic graphite. Coke properties come from coke origin of production (needle coke, petroleum coke …) and whether the coke has been issued from pitch or coal primary production. Not all coke can deliver synthetic graphite that meet the expectations for high capacity electrical vehicles batteries.

There are many coke sources in Europe. However, a key challenge for Carbone Savoie was to find a coke partner that had:

* sufficient R&D resources to support such an ambitious project;
* desire to serve the anode material market in the long term and develop therefore a dedicated product;
* capacity to fine-tune its production process;
* sufficient quantities with an even quality to meet the production objective of Carbone Savoie;
* willingness to go into long-term supply agreement with Carbone Savoie.

Finally, Carbone Savoie has made the choice to collaborate with a coke supplier located outside Europe (and not in Asia) with whom Carbone Savoie has more than 10 years of partnership.

* 1. Investment
     1. Tools and Equipment

*Important note*: the following information, giving the detail of the investments planned is strictly confidential and should in any case not be communicated by any means without Carbone Savoie prior explicit authorization.

| **Phase** | **Tech.**  **Class.** | **No. of tools** | **Examples of Tools** | **Invest. Cost [k€]** | **Year\*** | **Eligib. cost** | **WS** | **WP** |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| R&D | Extrusion | 2 | Preparation and testing of new raw materials   * Specific silo and weighing management system for catalyst with very fine grain size and very precise/low content) * Development of new automatism and on line measurement to manage new materials (catalyst) in formulas | 600 | 2019 - 2020 | Yes | 1 | 1 |
| R&D | Graphitization | 2 | Pilot furnaces at EP[[19]](#footnote-20) (1 four/20) & NR[[20]](#footnote-21) (1 four/10) workshop to test cooling optimization and pack management. These furnaces will have to be fine- tuned depending on the different tests and associated results | 2.200 | 2020 | Yes | 1 | 2 |
|  | Equipment for labs | 3 | Mills, sieving, graphitization LWG equipment at lab scale to be adapted to the specific raw materials for innovation in the processes required by the very different BAM products specifications | 1.010 | 2019 - 2021 | Yes | 1 | 1-2-3 |
| FID | Extrusion | 3 | Raw material preparation pilot equipments   * Jet mill technology for milling fine coke powders (20µm) to be adapted at the different raw materials tested * Silo management of very fine coke powders (current silos not adapted to powders lower than 100µm). Flowability of the fines will be hugely depending on the tested materials.   - Developing a new preheating of materials technology to allow mixing trials of pitch with ultra-fine powders having different heat transfer | 2.900 | 2020 - 2021 | Yes | 1 | 4 |
| FID | Baking | 2 | Handling capacity in the batch baking workshop (Republic) to adapt to the specific size of the BAM blocks during FID phase | 575 | 2020 - 2022 | Yes | 1 | 4 |
| FID | Graphitization | 1 | High amperage management system in order to test maintaining high temperature levels at the end of graphitization. This will require a lot of measurements (intensity, voltage, resistance, temperatures) in order to adjust step by step.  *Nota : during the R&D phase the size of the blocks will be adapted (downsized in section to get higher intensity with current transformer) in order to have the possibility to make the first trials without requiring a specific transformer. However during the FID phase, Carbone Savoie will have to test the scale effect at the final size of the blocks foreseen for qualification tests* | 2.000 | 2021 - 2022 | Yes | 1 | 4 |
| FID | Equipment | 4 | Equipment necessary to do internal analysis of anode materials products (XRD, BET, MEB, Fluorescence X or equivalent) | 380 | 2020 - 2022 | Yes | 1 | 4 |
| Mass prod. | Extrusion | 1 | Increase of storage capacity | 800 | 2022 - 2023 | No | NA | NA |
| Mass prod. | Baking | 1 | Refurbishment of furnace 12 | 16.000 | 2022 - 2023 | No | NA | NA |
| Mass prod. | Graphitization | 19 | Generalization of EP pilot furnace to the 19 remaining furnaces [[21]](#footnote-22) with cooling optimization, better yield of operations (progressive according to ramp-up) and packing management | 6.000 | 2022 - 2023 | No | NA | NA |
|  |  |  | **Total** | **32.465** | **2019-2023** |  |  |  |

\*investment year

**Table 9: Overview of investment in tools and equipment**

**Note concerning the investment considered in the R&D and FID phases:**

The modifications on existing equipment and new equipment necessary during the R&D and FID phases are very specific to the BAM products and cannot be used for our current graphitized cathode & specialty graphite production.

Indeed, these modifications and new equipment will extend the technical range of our current processes (lower grain sizes, specific additions of additives not used in our standard formulations, handling devices adapted to specific formats, higher temperature for a longer time, lab equipment and measures) in order to match the specific characteristics of BAM materials. This extended technical range is required only by the very high technicity of BAM products, does not provide additional production capacity on historical markets and is useless to Carbone Savoie’s current graphitized cathode & specialty graphite production. Therefore, these R&D and FID investments can not be amortized on our current productions.

In addition, all the modifications are limited to R&D and pilot FID equipment. If validated, Carbone Savoie will have to generalize or industrialize these innovations on its mass production equipment, requiring massive additional investment (23 million Euros identified so far). The additional investments related to mass production have not been included in the eligible costs.

* + 1. Construction of Buildings/Laboratory

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Technology**  **Classification** | **No. of Tools** | **Examples of Tools** | **Investment Cost [kEUR]** | **Year\*** | **Eligible cots** | **WS** | **WP** |
| Building | 1 | Hall 200m² | 500 | 2020 | Yes | 2 | 1-2 |
|  |  | **Total** | **500** |  |  |  |  |

\*investment year

**Table 10: Overview of investment in buildings or laboratories**

1. Budget
   1. Eligible Costs

The project started in February 2019 and will terminate end of 2022, which is the date for the end of the FID phase.

**The total Eligible costs amount to 24 966 k€.**

**The R&D Eligible costs amount to 15 778 k€** and they are distributed among the various cost categories according to the **Table 11** below:



**Table 11: R&D&I Eligible Costs**

The gross FID Eligible costs amount to 9 188 k€ and they are distributed among the various cost categories according to the table below:



**Table 12: FID Eligible Costs**

FID phase costs at 9 188 K Eur. 750 K Eur revenues generated from the sale of unsuccessful samples as by products (see section 6.1.1) has not been deducted.

* 1. State Aid

Without public funding, a positive NPV for the project would not be met for Carbone Savoie’s project: there is a negative funding gap of 13 962 k€ with a post-tax WACC of 9.2 % (see below chapter 6).

To compensate for the negative NPV of the project, the maximum required State aid from France is a grant of 23 592 k€. Total eligible costs amount to 24 966 k€. The State aid intensity would therefore amount to 94 % of eligible costs.

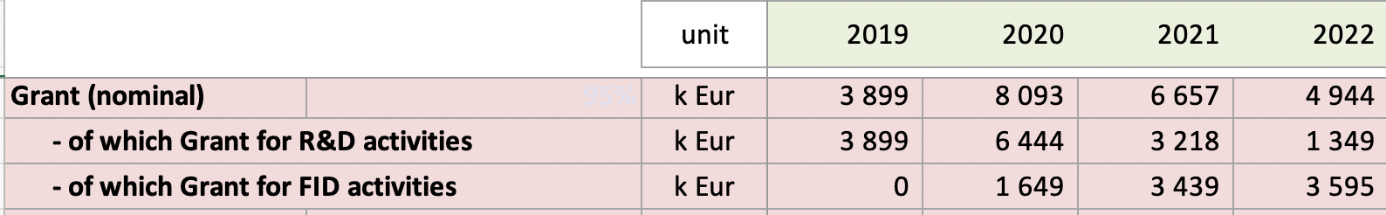
The anticipated instalments of the grant, calculated as 94 % of the eligible costs every year as requested by the beneficiary, is shown in the following table:

Table 13 Anticipated instalments of the grant as a percentage of eligible costs every year

The pre-tax discounted value of the grant is 19 226 k€ at 9.2 %.

Consequently, the tab of the annex "funding gap questionnaire presenting the NPV of the project with State aid" is provided for information only insofar as the financing to be allocated by the French authorities to the project has not yet been decided. However, the French authorities undertake that the nominal amount of aid discounted at the company’s WACC value (9.2%) over the project period will not exceed the funding gap.

1. Spill-over Effects
   1. Spill-over by non-protected results diffusion

Different dissemination levels, ranging from awareness to exploitation, are proposed to ensure the translation of developments and outputs into new findings and market opportunities. The objective is to reach the fullest range of potential users and uses among research, social, investment and policy makers.

Carbone Savoie commits to undertake the dissemination actions of non-protected results from IPCEI on Batteries (among the participating companies and Member states) presented below:

|  |  |  |  |
| --- | --- | --- | --- |
| **Targeted audience** | **Purpose** | **Dissemination material vehicle** | **Target (KPI)** |
| **General Public** | To communicate to the general public of IPCEI objectives, timelines and expected outputs | Press Releases  Interviews | 5 articles/interviews or press releases  (~1 per year during 5 years 2020-2025) |
| **Employees and stakeholders** | To communicate on objectives, on the expected outputs and on results | Internal conferences and newsletters (published via regular email and regular meeting with stakeholders) | 24 different communications with all stakeholders (employees, suppliers, unions, local authorities, …)  (~4 per year during 6 years 2020-2026) |
| **Scientific communities** (Universities, Engineering Schools, Professors, National Laboratory, Research Institute, R&D teams of industrial companies) | To exchange with other scientists in the field (inside and outside IPCEI)  To coordinate with ongoing and future program to maximize impact and create synergies | Presentation on relevant congresses and conferences  Project presentation at the European Commission  Project presentation at relevant agencies and schools (PhD thesis) | 3 joint publications (post project) in 2022, 2023 and 2024 in journals such as *Ceramics International, Carbon, Technique de l’ingénieur Journal of Applied Electrochemistry*  10 conferences as speaker or visitor over the duration of the IPCEI (2020-2023) in conference such as *Graphite Conference, The Battery Show (Europe), EV Battery Tech, SFEC, Carbon conference* |

***Table 14: Dissemination strategy of non-protected results***

**Publication, Conferences, Events, Roadshows**

Overall dissemination outside IPCEI on batteries will be performed thanks to conferences, external workshops and publications. The table below shows some actions that Carbone Savoie commits to undertake during the IPCEI on Batteries:

|  |  |
| --- | --- |
| **IP\* (new patent files – first filing)** | To be defined based on R&D work  *Possible patent:*   * *BAM graphitization catalysis: additives choices, choice and granulometry of the raw materials* * *Thermal treatment process parameters allowing to get the right properties for BAM* |
| **Conferences / Papers** | One conference/paper per year  *Example of possible publication or conference:*   * *Influence of some specific raw materials on the cristallinity of graphite battery anode materials* * *Influence of the thermal treatment process parameters on the texture on the crystallinity of graphite battery anode materials* * *Mastering of the milling yield depending on the texture of graphite battery anode materials*   *Papers: Ceramics International, Carbon, Technique de l’Ingénieur, Journal of Applied Electrochemistry*  *Conferences: Graphite Conference, The Battery Show (Europe), EV Battery Tech, SFEC, Carbon conference.* |
| **Workshops and actions in industry association** | One workshop on graphite production process and properties and an illustrative visit of the production site with two downstream or upstream battery value chain players per year.  *Association: ECGA[[22]](#footnote-23), European Battery Alliance, EMIRI* |
| **Education (bachelor, masters theses, PhD)** | One PhD thesis, possibly two  *Example of potential PhD thesis:*   * *Graphitization catalysis: saving energy while mastering the cristallinity of graphite* * *Thermodynamic of the reactivity between carbon and metallic /metalloid compounds at high temperature* |

(\*) Portion of patents, publications, PhDs and press releases will be done in common with other industrial partners

Carbone Savoie commits to reinforce its cooperation with French research organizations in the IPCEI on Batteries, such as the CEA Liten, and also European research organizations such as Fraunhofer Institutes in Germany (Fraunhofer ISC (specialized in advanced Materials LiB), Fraunhofer HLT (specialized in high temperature furnaces) and IWS (specialized in powders)

The company’s strong implantation in Auvergne-Rhone-Alpes will attract many actors such as research labs, SMEs, start-ups… in the context of innovation proposals around advanced materials for batteries and more generally carbon-related businesses.

Thanks to IPCEI on Batteries, academic partners which collaborate with the company will be free to disseminate results that will not be protected by intellectual property rights, through scientific publications, conference communications, etc. All academic partners have an excellent reputation and their high-level publications have a significant influence within the European scientific and technological community. IPCEI on Batteries will also lead to the completion of a large number of doctoral thesis and post-doctoral contracts, the results of which will be widely disseminated. From the license (bachelor), masters, and PhD theses co-supervised by the company, it is estimated that over the duration of the IPCEI one to two thesis could be started (in addition to trainees). It is also planned to attract students coming from universities outside France.

As a result, Public Research Organisations will be strong vectors in terms of knowledge dissemination in Europe, achieved through both the R&D and the FID phases.

The activities of diffusion of non-protected results from IPCEI on Batteries will reinforce cooperation with European Public Research Organizations (PROs), the overwhelming mission of which is knowledge dissemination in France and all over Europe. A powerful way to achieve this will be through R&D and FID feedbacks, meaning R&D activities that PROs will carry out following new results from IPCEI on Batteries. Such R&D and FID feedbacks will happen after a new process, a new material, a new technology brick has been transferred as a result of IPCEI on Batteries. Therefore, PROs new knowledge and background will be strongly consolidated over time and possibly disseminated outside IPCEI on Batteries. It will also help PROs to generate additional private resources, which can be allocated to future independent research, in particular to other scientific fields.

**EU programs**

IPCEI on Batteries will clearly be the enabler of a larger European cooperation relying on the instruments supporting the European industry for innovative lithium-ion batteries. IPCEI on batteries is providing the backbone needed to structure this European industry. A significant number of countries are involved in the IPCEI on Batteries to set the roots for cooperation. As the European eco-system needs to be much larger than the actual ecosystem, Carbone Savoie commits to follow the two following paths:

* Involve more countries and partners from the European industry even though they are not part of the ICPEI.
  + RTO - Outsourcing collaboration model:
    - Carbone Savoie is also in discussion with CEA Liten (<http://liten.cea.fr>), a well-known French RTO specialized on Lithium ion batteries.
    - Carbone Savoie is also in discussion with several institutes of Fraunhofer (<https://www.fraunhofer.de/en.html>) a well-known German RTO.
  + Upstream (raw materials) – Partnership collaboration model:
    - Carbone Savoie is also in discussion with Rain Carbon (<https://www.raincarbon.com/>), a pitch manufacturer to develop a specifically dedicated LiB pitch with very low impurities.
  + Downstream (from graphite block to powder) – Outsourcing collaboration model:
    - Carbone Savoie will develop partnership with *CS Additive GMBH* ([https://www.cs-additive.de/en/#](https://www.cs-additive.de/en/)), a German company specialized in grinding and molding carbon products (for both coke grains and graphite grains)
    - Carbone Savoie will develop partnership with *AMG Graphite* (<https://www.gk-graphite.com/en/home/>), a natural graphite mining company located in Germany who has developed a knowhow on shaping and coating of natural graphite but not synthetic graphite.
* Involve other partners (such as forklift manufacturers, ESS storage business companies …) located elsewhere in the value chain and strongly aiming at / relying on performing batteries solutions.
  1. Spill-over by IP protected results diffusion

The IPCEI on Batteries is about the development of a complete supply chain on batteries from raw materials to recycling, each IPCEI partner bring a building block to this supply chain. Only a very low number of exclusive IP licenses[[23]](#footnote-24) deriving from the IPCEI on Batteries results is expected. Indeed, the patents that will be licensed will be related mainly to generic technological building block; therefore, they will not be blocking for the final product because alternative process and solutions could be implemented. Dissemination policies will also be implemented in order to promote and stimulate new approaches regarding the licensing of generic scientific IP building block (avoiding any blocking issues for final product), with a view to serve other application fields through different value chains in order to get wider societal impacts.

In the exceptional case of a request for an exclusive license for possible commercial exploitation of results from the IPCEI on Batteries, the domain and the duration of the exclusivity will be limited. In addition, in case of non-exploitation of the technologies for the application purposes provided for in the license within a reasonable contractual period (in the light of the tests to be carried out), the exclusivity will fall automatically in order not to block the diffusion of new technologies in the involved domain.

Regarding IP, all participants are committed to develop Intellectual Property (IP) such as patents. IP creation will range from process technology, new material, general architecture, software and hardware development. The IP will be generated with the intent to be as open as possible in order to facilitate the best possible uptake of new technologies from the IPCEI on Batteries. The table below shows the actions that Carbone Savoie commits to undertake during the IPCEI on Batteries.

|  |  |  |  |
| --- | --- | --- | --- |
| **IPR, dissemination** | **Develop “Proof of Concept” for LWG graphitation for all graphite application**   * Offer to all European Union start-ups or SME to license the IP at FRAND conditions | Start-ups, SMEs willing to expand their activity to new markets | one start-up/SME by the end of the project |
| **Start-ups on post treatment (usual distribution channels)**   * + Commitment to sell blocks of LWG graphite at competitive price to milling/grinding start-up from European Union developing post treatment technology that optimize yield. | Start-ups, SMEs willing to innovate and expand their activity | Proposal made to at least one SME/start-up every two years. |
| **Tutoring of SMEs willing to introduce next generation synthetic graphite anode material in their products. Can be tackled at an IPCEI consortium level**   * + Use European Battery Alliance network to allow consulting by public laboratories, preferably in same region, in different Member States | Cell manufacturers such as SAFT, FAAM, BMZ, VARTA, etc. | 2 contracts  2022: launch, legal setup, announcement  Definition of yearly KPI target |

***Table 15: Dissemination strategy of IP-protected results***

* 1. Spill-over in FID phases

Within the project timeframe, FID activities in the IPCEI on Batteries will lead to significant spill-over effects in downstream markets, among IPCEI partners but also beyond them. In general words, downstream markets parties, especially cell manufacturers, will benefit in many ways from the FID phase. IPCEI on Batteries will enable them to develop cells using clean, sustainable synthetic graphite made of LWG technology for application that are today addressed by the polluting, energy inefficient Acheson technology. They will acquire a better understanding of how graphite characteristics affected the performance of lithium ion batteries and how to develop synthetic graphite grade that can easily be recycle at the end of the battery life. Such knowledge will be used in cooperation with third parties (inside or outside IPCEI on Batteries).

A key asset of IPCEI on Batteries is to embed many players from all along the battery value chain. Cooperation programs will bring even more players inside and outside the Members States which are committed to fund the IPCEI on batteries. This is definitely a strategic advantage that will make easier access to them inside EU.

Some examples of how IPCEI FID activities will leverage R&D&I activities from downstream markets parties within and outside IPCEI on Batteries are described below:

* Downstream market players tend to be the main contributors initiating new battery developments: new technology, new product, new capacity and sometime even line upgrade. Once the need is known by an OEM, through market studies or direct market request, a feasibility study is launched. Eventually, a decision is made in order to start R&D&I phase.
* During the R&D&I phase, technologies are not reliable enough. Downstream market is usually not interested to test new anode material technologies at this stage. When entering FID phase, technologies have demonstrated their intrinsic value: functionality and reliability and a minimum level of repeatability, then, some prototypes of innovative anode material for graphite can be translated to downstream markets.
* Sampling of raw materials, while sharing the risks between the potential end user and the technology provider, can start and continuously involve R&D&I phase in downstream markets: conception, testing in independent labs, additional specification request to graphite manufacturer, data gathering and processing, several generations of prototyping and sampling, reliability at application level… are some examples of typical R&D&I activities of downstream market partners.

The FID activity from the graphite manufacturer and the R&D&I from the downstream markets progress in the same time. This is a decisive phase to assess the technologies and make the downstream markets ready to use them. A successful final stage is when downstream markets initiate their own FID with the graphite manufacturer’s new technologies.

IPCEI on Batteries will provide access to next generation batteries, as well as to new technologies issued from FID phase to partners, large companies, SMEs and RTOs. This will be very helpful for SMEs and PROs that want to develop new knowledge and applications considering the entire lifecycle of this high-performance batteries. These partners will benefit of an early access to the latest technologies available and will be able to shorten their development time.

The FID phase will also generate spill-over effects to other industrial partners such as equipment manufacturers present all over Europe. Indeed, in order to support the FID phase, some technological progress will be needed from these industries. Therefore, they will benefit from their own “Feedback R&D” improving their own equipment, materials and processes. This spill-over will be reinforced since the scope of IPCEI on Batteries is very large.

Thus, the benefits of the FID phase are clearly not limited to the company itself but will also spill-over to the project partners and expand to many EU high-tech industries, businesses and research organisations. IPCEI on Batteries will create positive spill-over effects on multiple levels of the value chain.

**Open Fab**

Carbone Savoie commits to share its specific lab equipment (replicating extrusion, baking, graphitization…) for RDI purposes with European PROs and SMEs beyond its usual partners and beyond IPCEI beneficiaries. The idea is to foster cross-fertilization to other scientific or technological fields. It commits to give access to European PROs and SMEs to the R&D toolset and scientific knowledge acquired by the company during the IPCEI. The company commits to process for them on its lab equipment disruptive prototypes upon their request at fair and reasonable pricing and in accordance with the trade secret and provided that their materials are compliant with the company’s technical and environmental specifications. The timing will depend on the developments required and should typically be in the range of 10 % of the installed lab equipment capacity. So far, the company has never opened its lab equipment to other parties. With the IPCEI on Batteries, it will be a first.

In order to inform the European scientific community about this new opportunity, the company commits to communicate through press releases and media tools during the inauguration of the new equipment and during workshops, as well as to actively approach at least one European SMEs and PROs from non-IPCEI Member States each year to check whether they could be interested.

1. Other positive effect on the market
   1. Impact of the Project on Employment and New Investments in Europe

Carbone Savoie is forecasting the net creation of **50 direct jobs** over the 7-year period of 2019-2026, according to the table below. This includes only the production steps between raw material and graphitized block, ready for milling.

An **additional 50 direct jobs** will be necessary for the milling, and possibly spheroidization and coating steps. However, these steps will not necessarily be made by Carbone Savoie itself, but most probably by one of its downstream indirect partners already identified in this IPCEI file (CS additive (D) and AMG Graphite (D))

***Table 16: Jobs net creation forecast at Carbone Savoie***

Most of these jobs are operational jobs and should be created in Savoie (between Albertville and Moutiers), in a rural environment with limited activity of process industry. Therefore, the development of this activity will require specific training of local manpower. In that perspective, Carbone Savoie has already a long tradition of training of its workforce, based on an internal school adapted to its specificity (‘contrat de professionnalisation’), suiting well the company’s replacement rate (10 to 15 trainee/year). Given the additional number of trainees per year required by this specific project, it could be necessary to develop a local national training dedicated to process industry.

Regarding indirect impact of the project, the major investment plan (32 M€ over the period 2019-2026, mainly on industrial assets), should have large impact on local and European companies specialized in this kind of facility. A rough estimation gives 200 men x year for the design, manufacturing, erection and commissioning of these equipment, most of them being based in Europe.

Also, the development of downstream transformation operations of secondary synthetic for milling and grinding (in cooperation with CS additive) and/or spheroidization and coating (in cooperation with AMG graphite) will require additional jobs and investments. For instance, the CS additive operations of micronization of the 15.000 tons of blocks produced by Carbone Savoie require an additional investment of 6 million euros in jet-mill capacities.

* 1. Environmental protection and energy dependence

At the core of the Carbone Savoie project is the development a new industrial process for the production of anode materials for batteries that is at least 50% more energy-efficient and overall more sustainable than the current mainstream industrial process developed in Asia. Considering the enormous quantities of anode materials that are required by cell manufacturers and the energy-intensive process of synthetizing graphite, developing a more energy-efficient industrial process contributes greatly to the environmental protection and energy dependence of European Union. The CO2 emission saving will therefore come from:

* An energy saving of 3MWh per ton of anode material due to the innovation
* A cleaner source of energy in France (75% nuclear, 25% hydroelectricity) compared to the coal-based source of energy in China (~1 ton of CO2 / MW.h for coal-based power station).

Combining the two above-mentioned effects and assuming the innovation developed by Carbone Savoie becomes the mainstream technology to supply anode materials for the European demand (~200 GWh of battery cell by 2025), the Carbone Savoie innovation represents a saving of 600,000 tons of CO2 emission per year.

On the environment side, all the foreseen equipment will be equipped with Best Available Technology, as all the rest of Carbone Savoie’s existing equipment, reducing by design the emissions at the lowest possible level.

On the energy performance point of view, the industrial investment planed in this project will benefit of all the knowledge available and improvements already made in Carbone Savoie. Over the last 3 years, the company’s specific energy performance has improved by more than 10% with the optimization of the company’s baking and graphitizing operations. Furthermore, the on-going modernization of Carbone Savoie’s bigger furnace in Venissieux (already decided and not included in the battery IPCEI project, start-up end of 2019) should bring another 20% improvement of its baking specific energy performance, reaching world-class. Of course, the furnace included in the investment plan for the battery project will benefit of this experience, and will embed all the technology to reach the same level of energy performance, reducing drastically the carbon footprint.

Carbone Savoie has also a long experience of recycling internally its co-products in its main processes and masters the formulations in order to optimize the utilization of the raw materials, reducing the end waste close to zero. The Li battery graphite products will of course be developed taking into account this optimization and will benefit of the available co-products of other production lines of Carbone Savoie in its formulations.

Finally, supporting the development of European-based anode materials will greatly reduce transportation of anode materials from Asia to Europe and therefore reduce CO2 emission related to the transportation.

* 1. Market failure: Coordination problems
     1. Coordination failures between companies and research organizations

The very large number of public and private initiatives to define a mainstream trend to develop the next generation batteries creates important coordination problems. Academia and businesses differ greatly in many aspects. The goal of scientists’ activities is the growth of knowledge, while for companies the principal motivation is profits. Each one tends to underestimate or even discard the objective that the other pursues. Reward modes are also orthogonal: an important scientific discovery will contribute to the reputation of the team that makes it, while a significant innovation will enrich the company that develops it. Finally, scientific results acquire their value when they are shared through scientific publications, while businesses’ R&D&I results get their value if they are patented. The reconciliation of the two approaches is possible but often causes misunderstandings and conflicts.

The difficulties that companies and research organizations face when trying to work together are well documented. In particular, these relations are known to be much more complicated in Europe than in the United States. A lack of investment by public and private actors inhibits knowledge transfer by directly limiting the transfer capacity between public research organizations and companies, leading to limited communication and increases in coordination failures.

In the case of the European next generation batteries sector, this lack of coordination between research organizations and companies in most Member States is a major systemic failure. Its outcome is a deficit of growth and competitiveness as compared to other parts of the world, particularly Asia and North America. This is reflected in the loss of momentum of European players in research and innovation capacity, particularly visible in the low impact of their patents worldwide.

In addition, partnerships between research organizations and companies tend to be set up only at a local dimension. They prefer to collaborate when they know each other well and are close, which leads to neglecting other partnership opportunities that could be more productive from the scientific and technological points of view. The lack of cross-frontier public funding leads some public research organizations to focus solely on local companies for partnerships, or rather the opposite, to develop fully open business models where the benefits of European research efforts, particularly within cooperative projects.

The IPCEI on Batteries will promote an intense cooperation between academic partners and industrial partners from five different Member States. Market forces alone cannot lead to such cooperation. This major European R&D&I partnership will significantly intensify scientific and technological exchanges between European players from academia and from next generation battery industry. As part of the IPCEI on Batteries, the research agendas of academic laboratories and companies will be much better aligned, and exchanges will transcend the borders established by local tropisms. Thus, the ambition of R&D&I activities can be of a much higher level.

The IPCEI on Batteries initiative will foster new trans-border collaborations between EU companies. Without the IPCEI on Batteries, such collaboration would probably not have happen. For example,

Carbone Savoie (F) and Ferroglobe (E) will collaborate on the integration of Si additives in order to be able to optimize end product cost and performance

Carbone Savoie (F) and FAAM (I) will start soon preliminary characterization of the Carbone Savoie graphite for niche battery applications.

* + 1. Coordination failures between European research organizations themselves

Most European research organizations suffer from sub-critical size to engage in advanced research in next generation batteries. Such research activities require heavy resources in manufacturing equipment and characterization. No European public research laboratories owns the full set of equipment included a complete production line to carry out their research activities.

The sub-critical size of European research organizations, particularly compared to the United States, combined with a lack of coordination between them, leads to dispersion and redundancy. Important efforts are made on some research topics without exchange of information, leading to a deteriorated scientific productivity, while other topics are neglected. The setting up of in-depth discussions within each technological field of next generation batteries.

The IPCEI on Batteries will mobilize and bring together many European research laboratories, thus making it possible to overcome the lack of coordination that characterizes them. As part of the project, the redundancies will be removed, synergies and exchanges will be developed to pursue common R&D&I objectives in the field of advanced materials for batteries and next generation batteries, considered to be strategic for Europe.

* + 1. Coordination failures between SMEs and industry leaders

The IPCEI on Batteries will provide SMEs with access to R&D&I activities and high-level infrastructure that they would not have accessed in the absence of the project. Without State aid, Carbone Savoie would work with some of these SMEs in a "client-supplier" logic, rather than associate them as partners and allow them to anticipate technological breakthroughs. Thus, most of these SMEs simply would not have the ability to be working on these technological areas.

The State aid encourages many European SMEs (more than 80 in total are direct or indirect partners of IPCEI on Batteries) to collaborate and invest in R&D&I, by pooling and sharing risks. The project will enable the actors to achieve collectively the critical size that is needed to carry out advanced next generation batteries R&D&I activities. European SMEs in the batteries sector will coordinate R&D&I activities with high levels of ambition and risk.

* + 1. Coordination failures between European clusters

European next generation batteries clusters are limited in size as compared to other clusters in the world. They are insufficiently coordinated to compete globally. The weakness of cross-frontier public funding for large projects leads each cluster’s actors to carry out their R&D&I activities in a logic of hermetic silos. The weakness of cooperation between European clusters leads to redundancies, neglecting synergies and significant complementarities, and finally to significant losses in terms of scientific and technological productivity.

The scientific and technological objectives of the IPCEI on Batteries, particularly for the development of new technology platforms as well as pilot lines, constitutes a major scientific, technological and organizational challenge. All players in the European next generation batteries industry must engage in closely coordinated R&D&I activities to achieve this development, reducing redundancies, developing synergies and complementarities.

* + 1. Coordination failures of a very large-scale R&D project

The scope, scale and the scientific and technological complexity level of IPCEI on Batteries require joint work amongst a very large number of actors (53 direct partners in the Summer IPCEI), most of them industrial companies and some being public research organizations and university laboratories.

The intensity of collaboration inside IPCEI on Batteries is very important, program partners will work in a very strong interdisciplinary sense, which could not be mobilized without the State aid. The results obtained by each partner will impact the other partners' actions. The collaboration must be coordinated in a very close and dynamic way, in order to get the best results from trials and error experiences of R&D&I activities, as well as to reorient all work packages as a result of the progress of each partner, so that the R&D&I program can achieve its objectives. Round trips will be necessary between the different partners to coordinate their work, in order to remove the technological barriers that will be identified.

State aid to partners of the project IPCEI on Batteries deeply strengthens the coordination of the consortium. The disbursement of the public funding will be spread over the four years lifetime of the project, thus necessitating a very close monitoring by public authorities through progress reports, semi-annual milestones, etc. All partners know that they must progress together towards the achievement of IPCEI on Batteries objectives to get the public funding. Thus, the State aid gives each partner very strong dynamic incentives to overcome the difficulties of such a large-scale and long-lasting project. It makes it possible to set up a very large European R&D partnership which constitutes an efficient and responsive mode of organization, able to catalyse synergies between partners and ensure gathering and coordination of the broad spectrum of necessary sector skills for the realization of such an ambitious project. Major European players in the batteries field will all work together for the first time in a collaborative approach around a major unifying R&D&I program, lowering the technical and economic barriers.

* + 1. Coordination failures associated with contractual incompleteness

The State aid will also limit the coordination difficulties related to the contractual incompleteness of major collaborative R&D&I programs. It is well known that R&D&I contracts are incomplete, that is, they cannot anticipate or take into account all possible situations and all future contingencies. Indeed, R&D&I programs are characterized by high uncertainty: not all results can be determined in advance ("serendipity"), unanticipated scientific and technological hurdles can arise, with a potentially strong impact on the program's calendar or costs, successes or failures can come from where they were not expected, etc.

Contractual incompleteness may encourage opportunistic partners' behaviours, reducing their commitment to the collaborative R&D&I project. In such context, cooperation is rendered very unstable by the alternative opportunities that are offered to the partners. The occurrence of an unforeseen event in the contract can lead to a chain of reactions from the partners, putting at risk the primary purpose of the partnership. Naturally, this risk is all the more important as the number of partners grows and the research is of a high level of complexity, which is very clearly the case for the project IPCEI on Batteries.

A very large collaborative R&D&I project like IPCEI on Batteries is characterized by a high uncertainty, which means the occurrence of unpredictable events during the project. A partner could invoke the occurrence of an unforeseen contingency in the contract to defend opportunistically his interests. The collaboration contract cannot therefore prevent these behaviours. Sanctions or penalties cannot solve this problem: a sanction can only apply over a behaviour considered as deviant by reference to foreseeable configurations provided for in the contract.

Secondly, the interests of the partners may diverge over the content of the program, or its objectives, or even its costs, as it progresses. This is common in a very large collaborative R&D&I program like IPCEI on Batteries, since project developments are very likely to deviate from the initial plan. Therefore, each of the partners would tend to influence the program in such a way as to favour its interests to the detriment of the common interest of the consortium, while it would be hardly possible to invoke the contract to prevent it (in particular, through penalties provided for in the contract). This may for example involve renegotiating the allocation of costs between the partners, to the detriment of the effectiveness of the project.

Thirdly, it is very difficult, if not impossible, to anticipate and define in an exhaustive way the totality of the results of a very large R&D&I program. Thus, one of the partners might be tempted to appropriate some unanticipated results of the program by claiming that they would result from R&D&I activity outside the program. Here again, applying fines could not address anything, because of the intrinsic uncertainty of the very large collaborative R&D&I programs and the resulting contractual incompleteness.

The examples above, where a partner might be interested in adopting opportunistic behaviour, are not exhaustive. However, they provide an overview of the wide range of opportunities for partners in a very large collaborative R&D&I program like IPCEI on Batteries to derive a profit from the program at the expense of the common interest of the partners. Thus, although collaborative R&D&I contracts are essential for framing partnership relations, they may reveal a limited effectiveness in managing the divergences of interests that do not fail to appear, especially in the context of a program as expensive, long and complex as IPCEI on Batteries. Since it is very difficult to anticipate all situations in which a partner might have an interest in opportunistic behaviour, or even to prove this type of behaviour, it is impossible to provide for an appropriate system of sanctions.

State aid makes it possible to reduce a priori the opportunistic behaviour that may result from contractual incompleteness, and thus facilitates the coordination of IPCEI on Batteries partners. Indeed, for each partner, the risk related to the implementation of the program will be shared with the public authorities, limiting its potential financial losses in case of failure. This sharing of risks reduces each partner's incentives to use opportunistically contractual incompleteness to his advantage.

For example, without state aid, neither Carbone Savoie (F), nor Ferroglobe (E) could afford to develop their battery related R&D & FID programs. Instead, Ferroglobe (E) will develop Si solution for the anode materials and Carbone Savoie will develop high capacity anode materials boosted by Si. Therefore, the IPCEI on Batteries’ partnership foster synergies between partners.

* 1. Market failure: Imperfect and asymmetric information
     1. Risks affecting the project
        1. Technological risk

The European Commission generally recognizes that a greater technicality of a R&D project goes along with a greater probability of failure. R&D and innovation are highly complex and challenging in the batteries sector, and therefore they inherently carry a very high level of risk.

In the specific context of the IPCEI on Batteries, Carbone Savoie will undertake RDI activities in order to explore scientific and technological paths that are very risky. Carbone Savoie is focusing on developing an innovative energy-efficient, cost-efficient, more sustainable anode materials production process. As the manufacturer of graphite blocks for the Aluminum Pots and for the Specialty Business, Carbone Savoie knows the importance of technological risk with long technical lead times inherent to the process of making Graphite from Coke.

It is well understood that all these very innovative R&D and innovation pathways that will be explored as part of the IPCEI on Batteries may not be performing as anticipated. The technologies developed by Carbone Savoie are characterized by a very high level of complexity and there is a high risk that the work undertaken in the project will not achieve all the expected results, or not in the anticipated planning. For each technical objective, there are indeed several paths that can be explored in parallel, and the paths chosen within the project may not produce the expected performances.

Furthermore, there is a risk of non-compatibility of the solutions developed in IPCEI on Batteries in FID and large-scale industrialization or with the equipment available on the market. High-performance technology may be difficult to exploit in order to produce operational finished products. For example, maintaining very high temperature is critical to the development of long crystallite that improve anode materials product performance. When graphitizing coke with the Acheson technology, it is easier to maintain the temperature above 3,000 °C as the heat is indirect. The LWG technology is much more energy-efficient because electrical current goes directly into the product and there is limited heating loss. However, as the coke/graphite reach 3,000 °C, resistivity lowers, electrical current does not go though as easily, temperature lowers and crystallite development stops.

The technological risks are essentially linked to technical issues that can occur during the project. The technological risks are considered by Carbone Savoie as exceeding the level of risks usually observed in more standard developments. A large number of potentially cumulative technological hazards could quickly lead to an unacceptable failure in performance which could require unforeseen additional work (studies, modifications, tests) in order to reach the initial objective, hence leading to significant delays and additional costs.

* + - 1. Economic risk

Regarding the economic risks, the technologies developed under the IPCEI on Batteries are positioned upstream of the products that will could ultimately be marketed by Carbone Savoie. Therefore, the risk is very high that Carbone Savoie would not be able to exploit commercially as expected the results of the project.

In particular, given learning curves in competing technologies for synthetic graphite production, there is a risk that not only Carbone Savoie products be introduced too late on the market but also that the anode material prices decrease a lot under the pressure of OEM and cell manufacturer. Thus, a significant economic risk is attached to the innovative application of synthetic graphite production for batteries.

Finally, hundreds of R&D teams are investing time in the development of Gen4 battery (Solid State batteries not using graphite in the anode). Hundreds of millions have been committed to the development of this technology. Every day, the press reports breakthroughs (even though no one really knows if these breakthroughs are real and aiming at raising capital). There is an clear economic risk that solid state batteries comes to the market earlier than expected and cannibalizes a large portion of lithium-ion battery business, thus affecting the demand forecast for graphite anode materials.

* + - 1. Partnership risk

The risk of partnership of a very large R&D program such as the IPCEI on Batteries results from the difficulties to organize the coordination and the synergies between such a large number of actors and centers of competences that are culturally very different, as well as to maintain the cohesion of the partnership in the long run.

The R&D partnership set up in the project IPCEI on Batteries involves a very large number of partners coming from various sectors, they also have different sizes and institutional origins. Indeed, the IPCEI on Batteries requires academic research laboratories and companies to work together on common scientific and technological objectives. Given the strong interdependence between their activities, it will be very difficult to coordinate their numerous contributions to the project. It is clearly the case regarding the contributions of the numerous public research laboratories, which will work in parallel on multiple tasks of scientific modelling and development of basic technological building block.

* + - 1. Risk associated with major R&D programs

Major R&D programs such as IPCEI on Batteries, which extend over several years and aim at many technological breakthroughs, are generally exposed to numerous and significant risks that are not all identified and even less quantified. For example, it is common for nominal objectives not to be achieved, also there may be defects at the interfaces, delays in the availability of the results of a subsystem, failures of partners during the program, technical and functional problems, etc. This is why significant uncertainty often weighs on the respect of the initial schedule, as well as on the forecasted estimation of R&D and FID expenditures. The two risks are associated to the extent that each year of delay generally induces significant additional costs.

Moreover, it is reasonable to consider that the more elementary building block are included in the objectives of the program, the more these risks intensify and the chances of failure multiply exponentially. In the IPCEI on Batteries, Carbone Savoie plans to work on several technological building blocks, as well as on their integration, which has an adverse impact on its chances of success.

* + - 1. Regulatory risk

European regulations such as the RoHS directive prohibit the use of certain components, and the REACH regulation requires the registration and evaluation of any new chemical used. European regulations introduce regulatory constraints for European manufacturers that have not, or not yet, been imposed to their Asian or American competitors.

These regulations apply in particular to manufacturing processes that use substances banned only in Europe, which may limit the operation of European factories. For the purposes of the IPCEI on Batteries, it is important to focus attention to comply with these European regulations, which are often more stringent than those in force in the United States and Asia.

Complying with such regulations may have severe consequences on FID investments by increasing the costs and slowing down the industrialisation process from a competitive point of view.

* + - 1. Strategic and organizational risk

The strategic and organizational risks are those associated with Carbone Savoie strategic dependence on a specific sector, i.e. graphite manufacturing. They also include the risks associated with the availability of raw materials, especially needle and regular pet coke, potential market power of one or more of Carbone Savoie customers (giant cell manufacturers), the geopolitical risk in the manufacturing of chemical components or the mastering of the technologies and their ecosystems.

* + 1. Difficulty to recruit highly qualified personnel

At global level, the batteries sector suffers from an important difficulty for the recruitment of highly qualified profiles, a problem that hinders the development and commercialization of innovative technologies. This shortage is a result of mismatches between needed skills and available skills on the labor market. The qualifications proposed by the education system, university formations or training programs lag behind the fast-changing specific highly qualified profiles required in the batteries sector. This problem is well documented in numerous studies, reports and research publications.

One key problem is that training programs fail to include several scientific disciplines under one technological field, while companies in the batteries sector are demanding profiles with strong interdisciplinary skills.

One of the main objectives of the public support for the IPCEI on Batteries is precisely to foster university – industry collaboration and to enhance the attractiveness of the European batteries clusters regarding the highly qualified labor market, thus supporting the evolution of academia to train and supply to the market these highly qualified profiles. For that purpose, thanks to public funding, the IPCEI on Batteries will implement the following features at a very large European level: a strengthening of partnerships, a better circulation of ideas and people and a better mutual understanding between public research organizations and companies.

* + 1. Strategic independence of supply

The current development of the cell manufacturing in Europe is particularly weak, exposing the EU to Asian supplier’s dependence. Europe must therefore try to be as independent as possible not only in the production of batteries cells but also on associated raw materials.

Until recently, press and policy makers have been concerned by availability and strategic dependence on lithium, nickel, cobalt and manganese. However, with the recent shift from natural graphite (with many mines all over the world) to synthetic graphite (with 80% of the production coming from China), availability of graphite for batteries has also become a strategic dependence issue.

* Report from the US Senate commission on batteries (February 2019) <https://www.energy.senate.gov/public/index.cfm/files/serve?File_id=9BAC3577-C7A4-4D6D-A5AA-33ACDB97C233>

*« Considering China’s position across the entire graphite to EV value chain, secure supply of anode material is as big a risk as cobalt for US to consider.”*

* European commission: R*eport from the european commission (april 2019): Overcoming Europe’s energy and raw material dependency – a strategic opportunity*

<https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1554816272501&uri=COM:2019:176:FIN>

*« This dependency is not only limited to battery cell production; access to the five essential battery raw materials (lithium, nickel, cobalt, manganese and graphite) is also a major challenge for Europe’s security of supply as they are only available from a small number of countries.  Battery-grade refining and processing facilities for almost all these materials are also currently concentrated in China, which consequently dominates the lithium-ion battery supply chain. »*

Graphite is not only one critical advanced materials for battery. It is also required in enormous quantity and is the only materials that can be synthetically produced in Europe. Supporting the development of anode materials manufacturing knowhow is critical to guarantee the long-term strategic independence of EU.

* 1. Appropriateness of the policy / aid instrument
     1. Appropriateness among alternative policy instruments

There is no other less distortive policy instrument than State aid which would make it possible to achieve the same result for the IPCEI on Batteries.

* + - 1. The regulation

Regulation is a standard and widely used public policy instrument. The use of regulation to implement the IPCEI on Batteries has little practical consistency. In theory only, Member States could impose to companies in the industry to develop the innovations proposed in the IPCEI on batteries, based on full technical specifications. However, because of the numerous technological uncertainties weighing on the technological building blocks and integrated systems to be developed, such regulation does not seem to be realistic. For example, it is very likely that due to deficient information from the State regarding the evolution of the batteries market, regarding the technological state of the art, regarding the strategies of the different actors, etc., the choice to impose the development of such an innovation rather than another would be inefficient.

It is much more efficient to trust the strategies and technological choices of companies to decide on their R&D projects. This is the option retained in the IPCEI on Batteries.

* + - 1. A better funding of public research

The IPCEI on Batteries aims at removing technological barriers and demonstrating the technical and economic viability of many industrial innovations in the field of batteries. The project must therefore have a strong technological and industrial component, on top of its scientific dimension. To this end, R&D activities must be carried out simultaneously in public research organisations (which will contribute, with their advanced knowledge, to the development of scientific models, generic technological building blocks,) and in companies, which have the essential role to ensure the development of new technologies and their industrial and commercial deployment. A very important gap (in terms of time, cost, and risk) separates the concepts studied in PROs from the demonstration of the technico-economic viability of an innovation, carried out in companies.

A better funding of public research would not achieve the same effect as the State aid from France for the IPCEI on Batteries, meaning the structuration of a sustainable ecosystem of research and innovation around a very large R&D partnership between many public and private actors from 10 EU Member States.

* + - 1. The research tax credit

In order to succeed, the project IPCEI on Batteries must implement a strong collaborative logic between multiple public and private European actors.

A general tax measure in favour of R&D, such as the research tax credit (Crédit Impôt Recherche in French) implemented since 2008 by the French government, may lead French companies to boost their individual R&D efforts. However, it is not oriented towards the deployment of the European collaborative logic of the project that is a necessary condition for its success.

* + - 1. The innovation tax credit

The innovation tax credit is a French tax measure reserved for SMEs to stimulate their innovation activities, such as building a prototype or a pilot installation of a new product. In concrete terms, a SME having incurred innovation expenses of up to € 400,000 will be able to receive a 20 % reduction in the cost of the expenses incurred in favor of the innovation.

However, the project IPCEI on Batteries is not carried out only by SMEs, but its partners also include SMEs located elsewhere in the European Union (in particular in Germany) and public research organizations. Moreover, some key partners, including Carbone Savoie, will have expenditures far above the 400,000 euros ceiling of the innovation tax credit. Hence, this fiscal measure does not constitute an appropriate policy instrument in the case of the project IPCEI on Batteries.

* + 1. Appropriateness among different State aid instruments

In the context of the IPCEI on Batteries, the main market and systemic failures come from spillovers, coordination problems and Europe’s strategic dependence. To address these failures, a grant is the most appropriate State aid instrument.

The market failure or other important systemic failure which the State aids from Germany and Italy seek to address is neither lack of access to finance nor to provide Manz with a certain degree of risk-sharing. Therefore, a public soft loan, a State guarantee or a repayable advance are not taken into account.

The grant is intended to compensate for the low profitability of the project for Carbone Savoie without State aid, induced by the very high level of spillovers (see Section 3). It is well known in economic theory that such positive externality is corrected by granting a so-called Pigouvian subsidy to the economic agent who is at the origin of the externality, namely Carbone Savoie who carries out the R&D and FID activities which will benefit to third parties.

The simulation of a repayable advance in the business plan can only have a marginal impact on the project’s profitability: public money is received in the first hand but reimbursed including interests in the nominal scenario of success. Only a direct grant has the potential to have the profitability reach the company’s hurdle rate by filling the funding gap.

The grant also addresses the coordination problems (see Section 4.3), being a cement of the coordination of the partnership. The grant will encourage partners to commit to the project although it is exposed to a high degree of uncertainty and to returns that will materialize only in the long term. Indeed, the payment of the grant, spread over the four years of the project and closely monitored by French public authorities (progress reports, key milestones, decision-making milestones), offers dynamic incentives for the partners (including Carbone Savoie) to overcome the difficulties of coordinating the very large research partnership, and to progress together towards the achievement of the project objectives.

The payment of the grant also limits the potential financial losses of the partners in case of project failure, which reduces their incentives to opportunistically use contractual incompleteness to their advantage. Repayable advances have a major drawback in this respect: they provide an additional incentive to opportunistically use contractual incompleteness, since putting the project in a situation of failure from the contractual point of view makes it possible to avoid repayment of the advance (while the project could be a success from the technical and commercial point of view). The grant to Carbone Savoie is therefore the appropriate aid instrument to address the coordination problems in IPCEI on Batteries.

The EuBatIn IPCEI is designed to bring together public and private sectors to undertake a very large-scale project that provide significant benefits to the Union and its citizens. It is very clear that the huge coordination challenge rooted in the IPCEI on Batteries could not be addressed by providing a public soft loan, a State guarantee or a repayable advance to the IPCEI’s partners. Only a direct grant can adequately address such market or systemic failure.

However, the grant provided by France to Carbone Savoie could be backed upon a claw-back mechanism that shall be targeted on the FID activities and related costs / State aid (they are closest to the market). The principles of this claw back mechanism are considered and developed in the Chapeau text of the EuBatIn IPCEI.

1. Incentive Effect
   1. Absence of similar projects

According to Carbone Savoie’s and French Authority’s best knowledge and to public information, no similar project exists today in Europe.

* 1. Counterfactual scenario

Carbone Savoie did not consider an alternative project nor a clearly defined and sufficiently predictable alternative project in its internal decision-making process (point 29. of IPCEI Communication). Thus, **there is no counterfactual scenario**.

The company’s “business as usual” R&D and FID activities in the field of battery materials in the past three years can be roughly described as follows:

* Carbone Savoie will continue to dedicate most of its R&D efforts to meet the expectation of its current customers in the aluminum and specialty graphite market.
* Carbone Savoie will continue to commit limited time and money (~ 100,000 euros per year) on market intelligence of new potential markets such as anode materials.
* Carbone Savoie would only consider investing in this anode material market if Carbone Savoie receives a binding, and financially supported, partnership proposal from a cell manufacturer. As of today, cell manufacturers from Asia are relying on anode manufacturers from Asia and have so many internal challenges to overcome that it seems very unlikely that they turn to Carbone Savoie or other European graphite manufacturer for financially supported R&D partnership.

As a result, the counterfactual scenario will have zero investments in people and plants in France related to the graphite anode opportunity. Carbone Savoie will simply continue to invest its current R&D budget in addressing its current markets (aluminum and specialty graphite). Without the State aid, Carbone Savoie will not be able to develop its knowhow to address the anode material.

* 1. Start date of the project

Carbone Savoie has submitted a demand for public funding to French public authorities on 2019/01/30. Carbone Savoie had not undertaken any R&D or FID activity in the scope of IPCEI on Batteries before this date. Carbone Savoie started its activities in the IPCEI on Batteries in February 2019. Thus, the incentive effect of the State aid under notification cannot be presumed to be null.

* 1. Increase in R&D and FID efforts

Over the period 2019-2025 the state aid on this project would allow an increase of R&D and FID efforts of Carbone Savoie from 13.6 M€ to 42.5 M€, as indicated in the table below.



***Table 17: Increase in R&D and FID efforts***

1. Elaboration on Terms of the Funding Gap Questionnaire

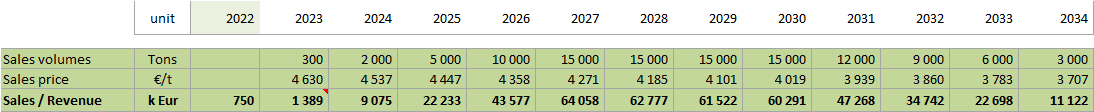
   2. Main hypothesis of the business plan

Annex B describes precisely the different assumptions made in the Business Plan and demonstrates that Carbone Savoie’s assumptions are reasonable.

Due to technology evolution toward 4th generation of batteries (solid-state batteries), graphite will probably not be the next anode material for batteries. Considering that 4th generation of batteries will start mass production in 10 years from now, new standards for Electrical Vehicle will progressively turn toward 4th generation batteries. Therefore, the business case is limited to the period 2019-2034.

*Revenues*

* + **Volume:** Volumes starts in 2023 with 300 kg of sales of BAM products. Progressive production ramp-up increases sales from 2 000 tons in 2024 to 15 000 tons per year in 2027. Sales assumed to remain stable from 2027 to 2030. Considering that 4th generation of batteries will start mass production in 10 years from now, new standards for Electrical Vehicle will progressively turn toward 4th generation batteries and result in the replacement of lithium-ion technology by solid-state battery technology. Therefore Carbone Savoie has assumed a 3 000 tons per year decline of battery anode materials sales volumes from 2031 till 2034. Therefore, volumes is limited to 3 000 tons in 2034 and null in 2035.
  + **Selling price**: BAM sale price assumed at 6 000 $/t in 2023. This price is based on the sale price of BAM graphite blocks (and not powders) according to research of the consulting firm, Avicenne Energy and indicative prices provided by a leading Asian anode manufacturer, which outsources the production of blocks to high-quality suppliers, and focuses mainly on micronizing and post treatment. Due to not only the OEM pressure to reduce battery costs of electrical vehicles but also the race to expand capacity, Carbone Savoie anticipates a decrease of -2% per year in the price (from 2024 to 2034).
  + **Additional revenues from the sale of by-products**: On top of the above-mentioned BAM sale plan (2023-2034), Carbone Savoie has assumed, in 2022 during the FID phase, revenues of 750 k€. These revenues come from the sale of unsuccessful FID batch samples as by-product for recarburizing applications (66% of R&D/FID trials ie ~2 000 tons) at current byproduct selling price (375 €/t for recarburizing application).



*Variable costs*

Variable costs are estimated on current raw materials costs and central scenario for recipients and production costs taking into account the existing experience of processes and future complexity of the BAM products.

*Terminal value*

The funding gap questionnaire has been set in accordance with the lithium-ion product life cycle in order to grab all the value generated by the investment. So, terminal value is only limited to trade working capital recovery.

*Inflation*

All revenues and costs are not inflated and expressed on 2019 basis, idem WACC is without inflation impact.

*WACC*

Carbone Savoie is a privately-owned company. Therefore, there is no public WACC calculation. The WACC of Carbone Savoie has been computed by a leading investment banks in France (DC Advisory). The WACC has been calculated post-tax to be consistent with the funding gap (also calculated post tax). On May 7th 2019, Kepler Chevreux has publicly disclosed its calculation of the WACC of SGL Carbon, a competitor of Carbone Savoie. SGL Carbon WACC has been calculated at 9.1%, therefore very close from Carbone Savoie own WACC calculation (9.2%).

* 2. Proportionality of state aid
     1. Firm’s hurdle rate

According to point 30 of the IPCEI Communication, in the absence of an alternative project, the Commission will verify that the aid amount does not exceed the minimum necessary for the aided project to be sufficiently profitable, for example by making possible to achieve an IRR corresponding to the firm’s hurdle rate.

Carbone Savoie’s Internal Rate of Return for the project IPCEI taking into account a 23 592 k€ State aid from France would be 9,2 %. This happens to be the value of the company’s WACC20. Thus, the State aid required would provide the necessary incentive to enable Carbone Savoie to launch these highly ambitious and long-term R&D and FID activities, by raising the IRR just at the level of the WACC. The State aid does not confer extra profits for the company, it is proportionate.

* + 1. Project’s funding gap

According to point 31 of the IPCEI Communication, the maximum aid level will be determined with regard to the identified funding gap in relation to the eligible costs. The funding gap refers to the difference between the positive and negative cash flows over the lifetime of the investment, discounted to their current value on the basis of an appropriate discount factor reflecting the rate of return necessary for the beneficiary to carry out the project notably in view of the risks involved.

Carbone Savoie’s funding gap, calculated as the discounted difference between the positive and negative cash flows over the lifetime of the IPCEI on Batteries, amounts to -13 962 k€ (with a discount rate of 9,2 % equal to the company’s WACC).

The State aid granted to Carbone Savoie, in the form of a direct grant amounting to 23 592 k€ nominal, has a post-tax Net Present Value of 13 962 k€. Thus, it is exactly equal to the funding gap; the State aid is proportionate.

* + 1. State aid intensity

The eligible costs to carry out the proposed activities are calculated only to the level necessary for achieving the project objectives. They consist in personnel costs (technicians, engineers and other supports mandatory for the project completion), materials costs and equipment costs the details of which are provided in section 1.8. For equipment, only the part of the cost prorated with the usage in the IPCEI on Batteries is considered.

The total amount of eligible R&D and FID costs is 24 966 k€.

Thus, the required State aid is limited to 94 % of the eligible costs, which is below the threshold of 100 % set by the Community guidelines for IPCEI.

* + 1. State aid cumulation

In the light of the beneficiary's declarations and to the knowledge of the French authorities, Carbone Savoie does not receive any State aid other than that indicated in point 2.2 of this notification to finance its share of work under the IPCEI on Batteries.

This state aid may come from the state budget or local authorities as well as from the structural funds.

* + 1. Open selection proceeding

The selection of Carbone Savoie as a partner for the IPCEI on Batteries and as a beneficiary of public support in France was done in the context of an open call for manifestation on interest in January 2019, based on objective criteria which are neither discretionary nor discriminatory. Twenty-nine companies applied, among which Carbone Savoie was selected. This contribute to reinforcing the proportionate nature of the State aid.

1. Limitation of distortion of competition and trade
   1. Market affected by the State aid

Carbone Savoie is a French industrial company producing speciality graphite materials, graphitized cathodes products for aluminium and ramming pastes. Carbone-Savoie has one production facility and one R&D facility dedicated to synthetic graphite, both of them located in France.

Annex C presents the production value of Carbone Savoie by Prodcom from 2014 to 2018.

The vast majority of lithium-ion batteries use graphite powder as an anode material. Graphite materials are either synthetically-produced (synthetic graphite) or mined from the ground (natural graphite). Natural graphite and synthetic graphite can be identified as substitute goods when it comes to the graphite-based battery anode material, one being able to replace the other.

Silicon has a number of advantages over graphite as an anode material and it is likely become a material of choice for the anode, as it increases the capacity of the battery. Silicon-based anodes are still under development they could be in commercial use by 2023 for small size batteries. Due to the important swelling of silicon-based anode materials and its subsequent risk of explosion, Silicon-based anodes are unlikely to develop for Electricle vehicles in the short term. The other anode materials used in Li-ion batteries are lithium titane oxyde (LTO) and carbon.

Within the IPCEI on Batteries framework, Carbone Savoie intends to develop two innovative products. Firstly, battery designed synthetic graphite blocks obtained with the energy efficient, sustainable LWG technology; and secondly, synthetic graphite powders, made from these blocks, for anode application in Lithium ion cells for electric mobility.

The core of Carbone Savoie’s innovative project is to apply the LWG graphitization technology to Battery Anode Material (BAM). Today, this technology has been used and regularly improved for other applications such as the production of graphite electrode for the steel industry or the production of cathode for the aluminium industry. Only a very small percentage (<5%) of anode material for battery application is produced with a combination of blocks and LWG graphitization technology. The only graphite manufacturer that uses such technology is SGL Carbon (tolling for Hitachi Chemicals) but for less than 2,000 tons per year. It is a competing technology, called Acheson, that has the lion share for the production of battery anode material. Asian manufacturers, in particular, use the Acheson technology.

Thus, as of today, the main road to the market of graphite powders for anode application in Lithium-ion electrolytes is the usage of Acheson graphitization technology. In the IPCEI on Batteries, Carbone Savoie wants to innovate by producing high-quality, low-cost, low-CO2 powders from LWG graphitized blocks and by improving the yield and therefore reducing cost with innovative methods of milling, grinding, shaping and coating of graphite blocks.

Carbone Savoie intends to sell battery designed synthetic graphite blocks to graphite powders experts (including backward integrated cell manufacturers such as Hitachi) and the anode material for battery (synthetic graphite powders) directly to cell manufacturers.

Both innovative products are destined to battery anode material. Therefore, the relevant product market that could be potentially affected by the State aid from France to Carbone Savoie is the market for battery anode material.

These products can be imported in Europe from Asia as it is today to serve the battery industry. There are limited logistical obstacles to the transportation of material and no specific barrier to the entry on the European market (such as custom duties or standards). Cell manufacturers will organize their supply chain based on Battery Anode Material cost and product performance looking at all options available across the globe.

Therefore, the relevant product market that could be potentially affected by the State aid from France to Carbone Savoie is the global market for battery anode material.

* 1. No creation nor strengthening of market power

In 2018, Avicenne Energy, a consulting company specialized in the battery supply chain, considered that the world sales of graphite powders for lithium-ion batteries applications accounted to 180,000 tons per year. As described in the table below, the battery anode material market is exclusively addressed by Chinese (80%) and Japanese suppliers (20%).

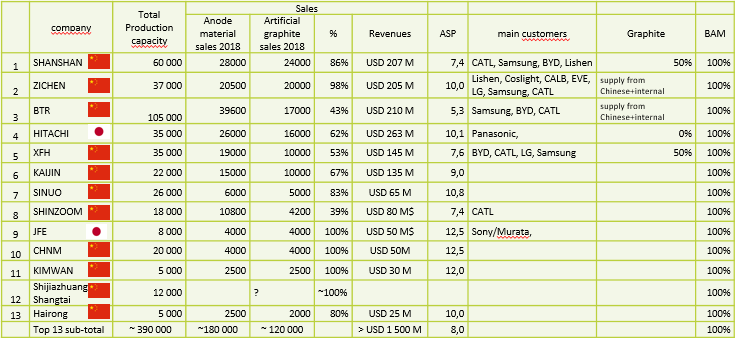


Table 1 Main players on the global market for Battery Anode Material (source: Avicenne Energy)

It appears from this table that there is no European company in the top 13. In particular, As of today, Carbone Savoie has no activity on this market. Moreover, the European battery anode material market is in its infancy.

In the IPCEI on Batteries, Carbone Savoie intends to build capacity of 15,000 tons, which corresponds to the minimum efficient scale. Avicenne Energy estimates that the market for battery anode material will reach 664,000 tons per year by 2025 and 1,030,000 tons per year by 2030. Therefore, assuming a full utilization of its capacity, Carbone Savoie could reach a market share of 1,5 % in 2030 on the global market of battery anode materials.

Moreover, Carbone Savoie’s future customers will mainly be giant battery cell manufacturers, with very strong buying power.

Carbone Savoie's actual and future market position, the presence of very strong established competitors, the anticipated growth of the market and the strong buying power of its future customers make it reasonable to assume that the State aid from France to the company will not create nor strengthen any market power. As a new entrant, Carbone Savoie will rather positively affect the competition at a European level by weakening the market concentration and providing an alternative to the currently Asian-dependant European cell manufacturers.

* 1. Limiting distortion of dynamic incentives

Being a potential new entrant in the battery anode material market, Carbone Savoie will have to face strong competition from well-established Asian competitiors. The later are already active and significantly more advanced in their development in comparison with Carbone Savoie.

The State aid required by Carbone Savoie for the IPCEI on Batteries amounts to 5,6 M€ per year on average (four year 2019-2023), that is approximately 6,7 M$ per year. It is very small compared to the size of the market (for example, less than 0,5 % of the 2018 sales of the top 13 Asian players reported in Table 1 above). Moreover, it will be dedicated to R&D funding for 2/3 approximately and to FID for only 1/3, which makes it less likely to distort dynamic incentives.

Moreover, according to Avicenne Energy, the anticipated average growth of the battery active material market is set at 14 % between 2018 and 2030.

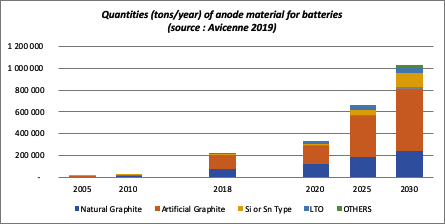




Figure 12 Estimated growth of the global market for battery anode material (2005-2030)

As a result of this forecasted market growth, there will remain ample opportunities to develop profitable business for Carbone Savoie’s competitors on the battery anode material market.

For all the above-mentioned reasons, the French State aid to Carbone Savoie for the IPCEI on Batteries is highly unlikely to deter the company’s competitors’ investments in R&D and FID to develop competing technologies.

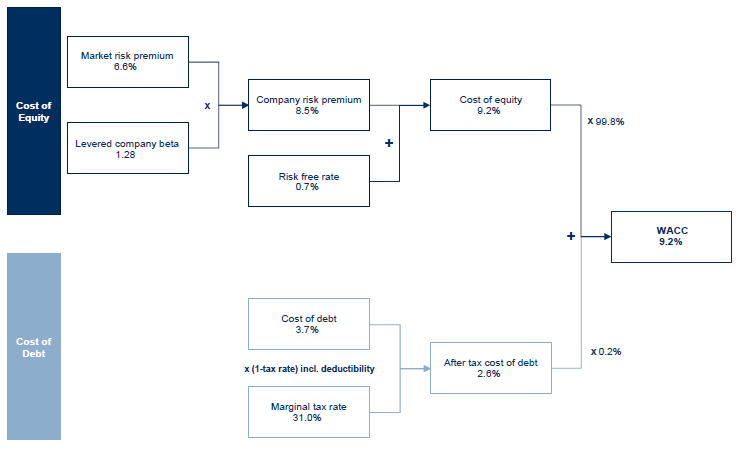
* 1. No maintaining of an inefficient market structure

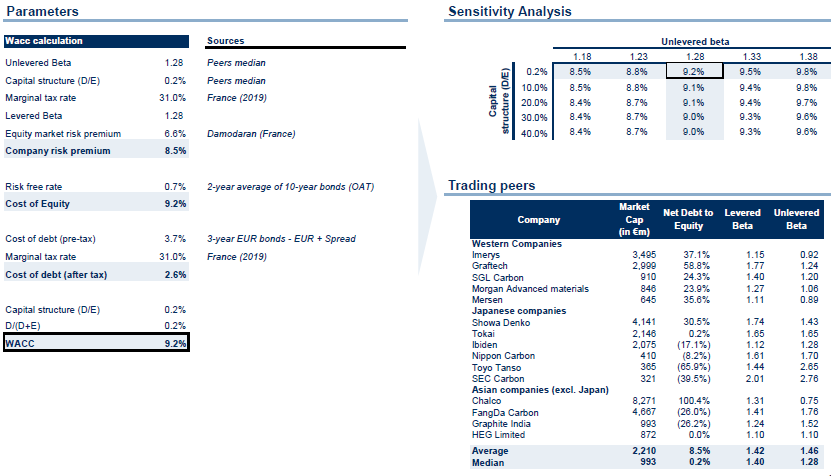
The State aid that is granted to Carbone Savoie in France for the development and first industrial deployment of innovations in the field of battery anode material will not adversely impact a market suffering from overcapacity nor a declining sector. The European anode material for battery market is still in its infancy and should experience an important growth in the coming decade, nurtured by strong innovations and competition. Moreover, the installed capacity in Europe is marginal, while the number of new entrants is expected to rise significantly. These features are typical of dynamic and efficient markets.

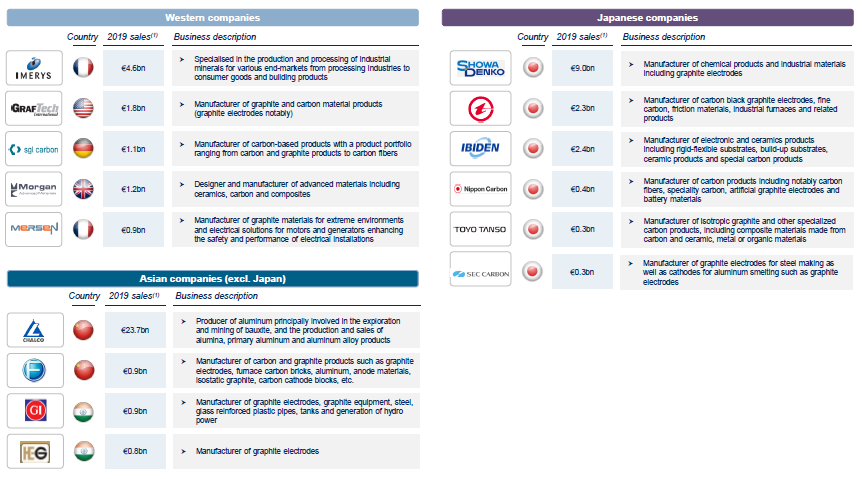
* 1. No effect on the location of activities

Carbone Savoie’s core industrial activities are located in France; it is also the case for its R&D and FID activities in the IPCEI on Batteries. The company did not consider locating its activities related to the IPCEI on batteries outside France, and it did not demand any public funding to another Member State for the same project.

Thus, there is no risk of a subsidy race between Member States that may arise in particular with respect to the choice of Carbone Savoie’s location for the IPCEI on Batteries.

1. Annex to the Portfolio
2. *Annex A: Carbone Savoie WACC calculation*
3. *Annex B : Funding gap assumptions*
4. *Funding Gap Questionnaire*
5. *(If necessary) Internal Company Documents substantiating the counterfactual scenario*
   1. Annex A : Carbone Savoie WACC calculation





* 1. Annex B : Funding gap detailed assumptions
* **Business plan horizon**: Business plan covers the period from 2019 to 2034 assuming R&D period in 2019-Q12022 and a FID period in 2020-2022, then mass production starting in 2023 with BAM volumes sold from 2023 to 2034. Terminal value consists in recovering trade working capital.
* **Revenues:** 
  + **Volume:** Volumes starts in 2023 with 300 kg of sales of BAM products. Progressive production ramp-up increases sales from 2 000 tons in 2024 to 15 000 tons per year in 2027. Sales assumed to remain stable from 2027 to 2030. Considering that 4th generation of batteries will start mass production in 10 years from now, new standards for Electrical Vehicle will progressively turn toward 4th generation batteries and result in the replacement of lithium-ion technology by solid-state battery technology. Therefore Carbone Savoie has assumed a 3 000 tons per year decline of battery anode materials sales volumes from 2031 to 2034. Therefore, volumes is limited to 3 000 tons in 2034 and null in 2035.
  + **Selling price**: BAM sale price assumed at 6 000 $/t in 2023. This price is based on the sale price of BAM graphite blocks (and not powders) according to research of the consulting firm, Avicenne Energy and indicative prices provided by a leading Asian anode manufacturer, which outsources the production of blocks to high-quality suppliers, and focuses mainly on micronizing and post treatment. Due to not only the OEM pressure to reduce battery costs of electrical vehicles but also the race to expand capacity, Carbone Savoie anticipates a decrease of -2% per year in the price (from 2024 to 2034).
  + **Additional revenues from the sale of by-products**: On top of the above-mentioned BAM sale plan (2023-2034), Carbone Savoie has assumed, during the FID phase, revenues of 750 k€. These revenues come from the sale of unsuccessful FID batch samples as by-product for recarburizing applications (66% of R&D/FID trials ie ~2 000 tons) at current byproduct selling price (375 €/t for recarburizing application).
* **Cost structure:** Eligible costs: According to R&D and FID programs, excluding revenues from by product (750 k€, see above), eligible costs are estimated at 24 966 K€ (R&D eligible costs at 15 778 K€ and FID eligible costs at 9 188 K€). Costs are based on production of BAM graphite blocks (and not powders) in order to be consistent with selling price assumptions.



* + **Depreciation of equipment and buildings:** Assumptions in number of years have been detailed below.

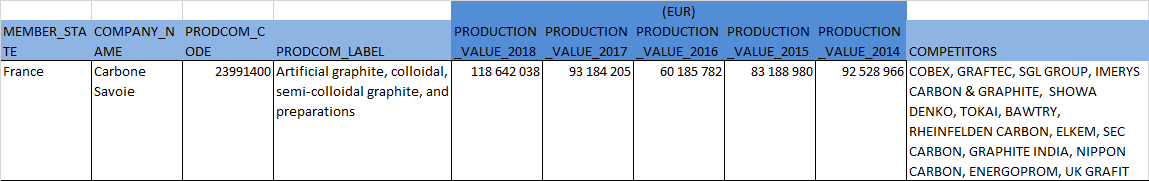


* + **Costs of materials** include raw materials and energies required to produce BAM materials for all trials and homologation process. Raw Materials costs (coke, pitch, graphite, additives…) and energy costs (natural gas and electricity) are based on current unit market prices and on targeted BAM recipes. These assumptions are optimistic as they include petroleum coke in the formulation (and not needle coke three time more expensive) and the manufacturing process is based on blocks (instead of powder) allowing therefore optimized energy consumptions per ton of product.
  + **Personnel costs** are based on:
    - During the 2019-2022 period for R&D and FID phases, personnel costs cover all internal costs of people involved within the project until the qualification of Carbone Savoie product: dedicated R&D team (see 1.8. Section Work Plan), production staff cost during the industrial trials, and dedicated managers on the project.
    - From 2023 onward, during the mass production period, personnel costs covers BAM production staff, additional administrative support related to the increase of activity and limited dedicated R&D resources to maintain product performance improvement.
      * *Production staff*: Productivity of the production staff has been optimized in the assumption by taking into account the benefits of working with blocks rather than powder
      * *Additional administrative support*: Due to the incremental activity (+45%) generated by BAM sales, additional administrative support resources are also included, in line with current Carbone Savoie ratio (~20% of direct labor costs).
      * *Limited dedicated R&D resources*: these R&D resources aims at maintaining competitive technical advantage of Carbone Savoie against its competitor through continuous improvement.
  + **Other costs** represent other production costs such as maintenance, consumables/ furniture/packing, internal transportation between the company’s two plants, equipment rentals (forklift…), insurance, local taxes, etc…
* **Investments:** Capital expenditures (see section 1.9) have been estimated by Carbone Savoie’s project engineering department. The project engineering department (6 people) manages all investment projects and have therefore a very deep knowledge of cost associated with project on Carbone Savoie premises. Their first estimations are systematically based on aggressive estimate with 30% contingencies budget. The same method has been used for this project.
* **Inflation**: No inflation has been assumed in the Business Plan, neither on revenues, nor on costs.
* **Weighted Average Cost of Capital (WACC)**: WACC has been calculated post-tax to be consistent with the funding gap (also calculated post tax) and to be aligned with inflation at 0%.

Carbone Savoie’s WACC has been estimated by DC Advisory (a leading investment bank in France) at 9.2%. On the 07th of May 2019, Kepler Chevreux has publicly disclosed its calculation of the WACC of SGL Carbon, Carbone Savoie’s close competitor. SGL Carbon WACC has been calculated at 9.1%, therefore very close from Carbone Savoie own WACC calculation (9.2%).

For detailed calculation: see section 8.1 Annex A: Carbone Savoie WACC calculation

* 1. Annex C : Production value of Carbone Savoie by Prodcom



1. These figures has been computed by Avicenne Energy, a consulting firm specialized in LiB supply chain after interviews of anode producers and anode customers for LiB. [↑](#footnote-ref-2)
2. REPORT FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE, THE COMMITTEE OF THE REGIONS AND THE EUROPEAN INVESTMENT BANK

   on the Implementation of the Strategic Action Plan on Batteries: Building a Strategic Battery Value Chain in Europe [↑](#footnote-ref-3)
3. These figures has been computed by Avicenne Energy, a consulting firm specialized in LiB supply chain after interviews of anode producers and anode customers for LiB. [↑](#footnote-ref-4)
4. This work has been priced at market conditions and paid fully by Carbone Savoie on its cash reserve [↑](#footnote-ref-5)
5. These figures has been computed by Avicenne Energy, a consulting firm specialized in LiB supply chain after interviews of anode producers and anode customers for LiB. [↑](#footnote-ref-6)
6. The SGL Carbon production in Poland, using Acheson Furnace is today dedicated to the Tesla plant in Arizona. Graphite powder made in Poland is shipped to the Hitachi Chemicals in Japan for post treatment and then shipped to Panasonic-Tesla plant in Arizona (USA). This supply chain is therefore generating a lot of CO2 emission. [↑](#footnote-ref-7)
7. [↑](#footnote-ref-8)
8. [↑](#footnote-ref-9)
9. Graphite electrode is a high value, needle coke based raw material primarily used in the electric arc furnaces (EAF) & blast oxygen furnace (BOF) for steelmaking, mine electric furnace for smelting ferrous alloys and electric discharge machining markets to enhance the production of fine surface finishes. [↑](#footnote-ref-10)
10. In order to improve crystallinity of the graphite and the length of the crystallites, a catalyst (usually Si carbide or Si) is mixed with the coke powder during the preparation of the raw materials in very precise and small quantities. During baking and graphitization, the catalyst must be eliminated. When using Si Carbide or Si as a catalyst, Si evaporates at high temperature and recondensates in the insulating packing (colder regions), creating hard agglomerates in the packing (“crust”). [↑](#footnote-ref-11)
11. Having the theoretical know-how, the best equipment and the best raw materials is not sufficient to produce high quality graphite. Each graphite plant has built on the collective know how of its employees to develop continuous improvement processes. Aside from the graphite plant of Banting (Malaysia) built by the SGL Carbon in 2007 [which technology does this plant use, Acheson or LWG?], no greenfield graphite plant has been built in the last 25 years outside of China. This project proved to be a nightmare for SGL Group. Despite SGL Carbon experience, knowhow and experts of SGL Carbon, the Banting plant has never performed as planned and was finally sold to Showa Denko in 2016 to repay the debt accumulated by the project. [↑](#footnote-ref-12)
12. The R&D phase includes the “foundation R&D phase“ and the “R&D validation phase“ [↑](#footnote-ref-13)
13. Testing must not be understood as complete product test (incl. control of capacity, 1st time discharge and resistance to 1000 cycles, etc.). Running complete product tests would add a minimum of 2-month to the 3-month production lead-time, further delaying the project. In many case, preliminary tests and observation of the internal structure of the graphite with a polarizing microscope provide a quick and accurate estimation of the success of the trial. [↑](#footnote-ref-14)
14. Each parameter has impact on the final performance of the product. For example, after extrusion, the block is cooled in a swimming pool. During this very simple and short phase, Carbone Savoie monitors not only the temperature of the water compared to the outside temperature but also the chemical additives in the water and the duration of this cooling. Only if these process procedures are strictly followed, the product will have the expected specifications two months later after graphitization. [↑](#footnote-ref-15)
15. At 1,1 exchange rate ~ 5.5USD/kg [↑](#footnote-ref-16)
16. At Carbone Savoie, each graphite block is assigned a unique identification number. This allows Carbone Savoie quality team to trace the block all along the production process and find correlation between process parameters and product performance. [↑](#footnote-ref-17)
17. For detail of the Work Plan, please refer to section 1.8.1 [↑](#footnote-ref-18)
18. The 12 FID loops have been described in section 1.5.2 [↑](#footnote-ref-19)
19. EP workshop is Carbone Savoie’s secondary, small size graphitation workshop with 20 small graphitization furnaces, graphitizing up to 20 tons per day. Annual graphitization capacity is more than 6,000 tons per year [↑](#footnote-ref-20)
20. NR workshop is Carbone Savoie’s main graphitization workshop. The shop is composed of 10 large graphitization furnaces, graphitizing up to 100 tons per day. Annual graphitization capacity is more than 30,000 tons per year. The NR workshop offers best-in-class energy consumptions profile. [↑](#footnote-ref-21)
21. EP workshop is Carbone Savoie’s secondary, small size graphitation workshop with 20 small graphitization furnace, graphitizing up to 20 tons per day. Annual graphitization capacity is more than 6,000 tons per year [↑](#footnote-ref-22)
22. ECGA (*European Carbon & graphite Association)* : <http://www.ecga.net/> [↑](#footnote-ref-23)
23. IP licence can only be linked to potential patents either on recipes allowing to get a catalysis during the graphitization or on process innovation during the thermal treatments (baking & graphitization) [↑](#footnote-ref-24)