

LI-ION BATTERY PACKS FOR AUTOMOTIVE AND STATIONARY STORAGE APPLICATIONS 2020

Market & Technology Report - March 2020

The battery pack component market continues to be driven mainly by electric vehicles.

WHAT'S NEW

- Deeper insight into battery pack components such as battery management systems, safety devices and thermal management
- Deeper insight into different technologies currently used in battery packs and related technology trends and supply chain

KEY FEATURES

- 2019-2025 market in GWh, units, and \$B for lithium-ion battery packs in battery electric vehicles, plug-in hybrid electric vehicles electric buses and trucks and stationary battery applications
- 2019-2025 market in \$B for key battery pack components: Li-ion cells, battery management systems, thermal management components, safety components, electrical interconnects, housings and assembly
- Supply chain analysis for battery packs and their main components
- Insight into battery pack components, main technologies, and innovations
- Technology trends in Li-ion battery packs, cells and other pack components

THE BATTERY PACK MARKET IS DRIVEN BY EV DEMAND

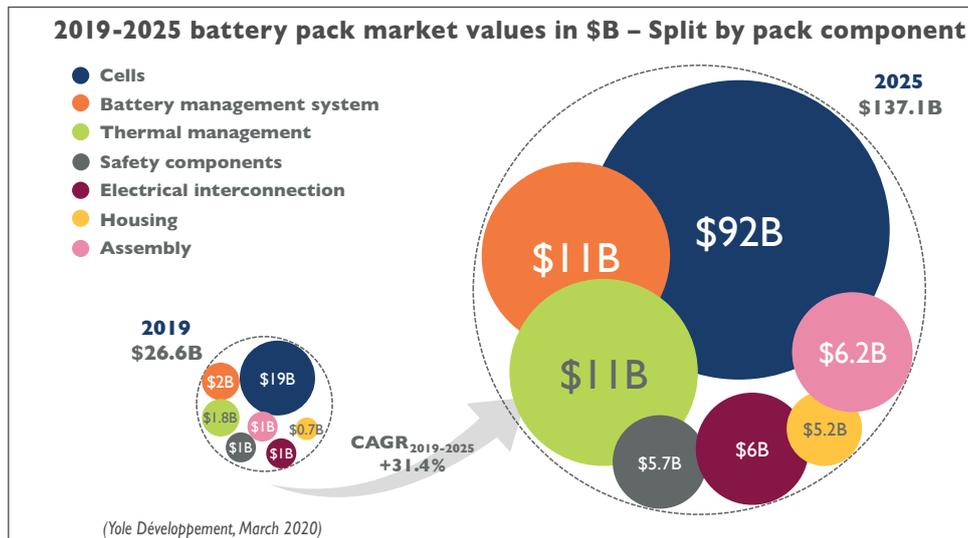
The main driver for battery pack applications is the growing electric vehicle (EV) market. This market is booming mainly due to the need to significantly reduce average vehicle fleet CO₂ emissions to match governments' strict CO₂ emission reduction targets and thus avoid heavy penalties. The end applications of battery packs analyzed in this report include plug-in hybrid electric vehicles (PHEVs), full battery vehicles (BEVs), electric buses and trucks, as well as stationary battery energy storage applications.

The total annual demand for battery packs for the aforementioned applications will grow from \$26.6B in 2019 to \$137.1B by 2025. The growth rate for different applications varies, as their market dynamics have different drivers. The demand will be mainly driven by full electric vehicles, specifically BEVs, which will represent 75.9% of the total demand in GWh by 2025. PHEVs enable big CO₂ emission reductions due to their electric engines, while keeping long driving ranges thanks to their Internal Combustion Engines (ICEs). They will take the

second place in our ranking of total demand measured in GWh by 2025.

The high level of air pollution in some big cities is driving deployment of electric buses. Buses stop frequently and can potentially charge at each stop or terminus station, making them well-suited for battery power. Electric trucks can then benefit from battery and charging station technology development for buses. The use of electric trucks in the urban environment helps further reduce air pollution.

Stationary battery energy business is not the first priority of most battery manufacturers that are focusing today mainly on electric mobility. The market growth for stationary battery systems is growing and is mainly driven by renewable energy sources, mainly photovoltaics and wind, and electricity grid regulation. EV/PHEV charging stations have emerged as a new interesting market driver for stationary battery energy storage solutions to "smooth" strong electricity demand peaks while charging many EV/PHEVs at the same time.



THE MARKET FOR EACH BATTERY PACK COMPONENT IS GROWING

Battery cells form the main part of the global battery pack market studied in this report, 71.2% in 2019 and 67% by 2025. Although the cell price in \$/kWh will decrease further, the overall cell capacity per pack will increase, thus keeping the cell share within a battery pack at a high level.

The second largest part of the battery pack market will be the thermal management,

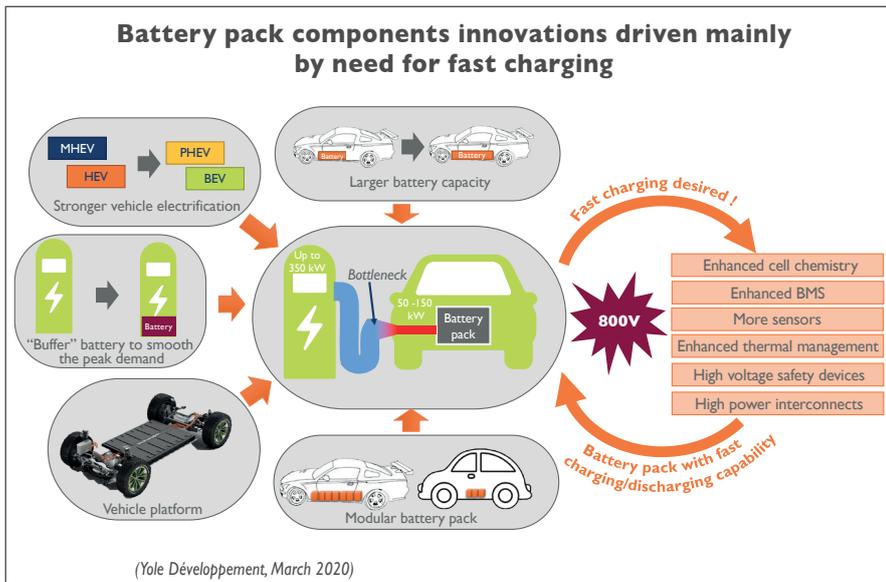
followed by Battery Management System (BMS). The importance of better thermal management is growing with the increasing cell energy density and battery pack energy capacity as well as growing needs for batteries compatible with very fast charging. As fast charging leads to high energy generation in a battery pack, an enhanced heat dissipation and temperature regulation become crucial. The importance of

BMSs is growing with increasing requirements to accurately determine remaining battery capacity, and with increasing cell and pack energy capacities.

An enhanced BMS also allows better using of the energy stored in a battery pack, thus reducing needs for battery pack capacity increase.

According to Yole Développement's (Yole) analysis, there is no big technology breakthrough expected in coming years regarding battery cells and other battery pack components. The main trends will involve existing technology solutions, which will be further improved and more widely deployed. Technology and cost improvement will be steady.

Our market forecast has been made during the outbreak of coronavirus disease 2019 (COVID-19). The impact of this virus on automotive and battery industry is significant. It is hard to evaluate how long this crisis will last and how its duration will negatively impact the manufactured volumes of conventional vehicles and EV/PHEV. The numbers presented in this report for 2020 might be thus reduced in the case of prolonged crisis due to coronavirus.



THE BATTERY PACK MARKET IS GROWING AND ATTRACTING MORE PLAYERS - WHO IS LOSING AND WINNING?

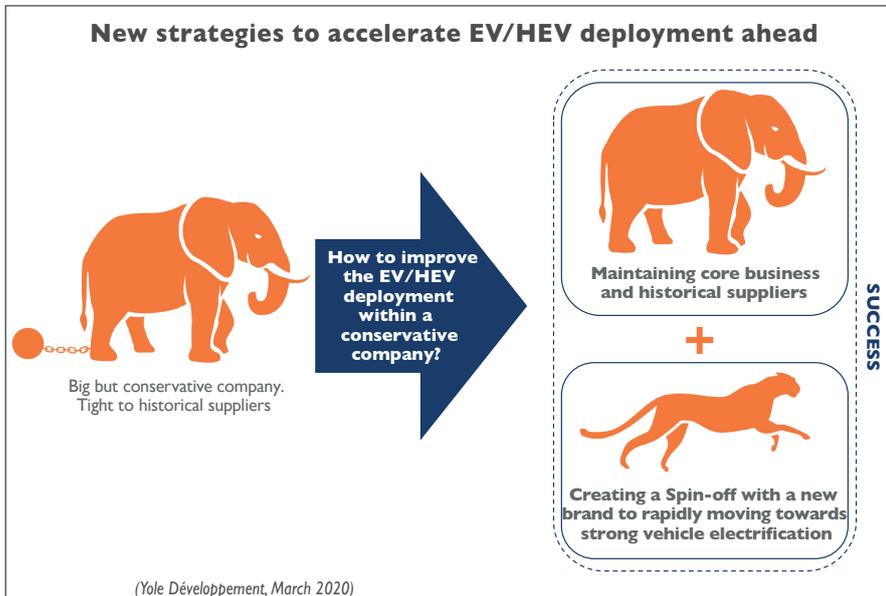
According to Yole analysis, battery pack suppliers face significant challenges from newcomers attracted by the fast-growing market, dominant position of some cell suppliers, and strong price pressure on all battery application segments.

Most battery pack suppliers are battery integrators, especially carmakers. They purchase battery cells mainly from leading suppliers like CATL, LG Chem, Panasonic and Samsung SDI, and build their battery pack using other components, including BMSs, heating/cooling systems, electrical interconnections, safety components, and housings. Carmakers are intruding ever more into battery cell design and in some cases also into cell manufacturing, as in the cases of Tesla and Daimler. Instead of purchasing cells, some battery integrators purchase battery modules directly and they just integrate modules into battery packs.

The modular battery pack approach enables further manufacturing cost reductions and keeps the design flexibility for battery packs. Battery integrators can increase the differentiating added value further by carefully designing the battery pack, and choosing components including the BMS, thermal management solutions, safety devices, electrical interconnects, housing and assembly.

Some carmakers have developed specific internal know-how and established tight supply chain partnerships. Therefore they might remain at least partially stuck with their historical technology and integration choices, while their competitors will move rapidly towards latest technologies and full vehicle electrification. The companies with tight technology and supplier partnerships may lose some business in the future, but not because their technology is bad. Instead they will not easily be able to adopt the latest innovations, reduce costs by choosing optimal suppliers and follow customer need evolution rapidly enough. A possible option for companies tight with their suppliers would be to spin-off a part of their activities into a new company, to create a new brand.

It is also crucial to shorten the development time for new products and reduce the development cost. Tesla has successfully demonstrated an extremely short development time for new car models. Other EV/HEV manufacturers should shorten their development time while maintaining product quality to avoid costly vehicle recalls. This can be enabled by an optimal development strategy, use of vehicle platforms like MEB and PPE from Volkswagen or E-GMP from Hyundai, and a modular approach in the battery pack design and assembly. As customers increasingly desire a choice of different electric car models, the platform approach would find further added value here.



There are many new partnerships, joint ventures and acquisitions ongoing within the supply chain. These reinforce companies' positions, secure access to strategic materials

such as lithium and cobalt and battery cells, ensure growth, and facilitate easier entries into new markets.

REPORT OBJECTIVES

- Determine the market value for lithium-ion (Li-ion) battery packs and their components including battery management system, thermal management, safety components for plug-in hybrid electric vehicles (PHEV), battery electric vehicles (BEV), electric trucks and buses, and stationary battery energy storage systems
- Demonstrate the strong, consistently-growing potential for power electronics players including suppliers of power ICs, fuses, sensors, and thermal management solutions, in the energy storage business, based on Li-ion battery technologies
- Describe the battery pack supply chain landscape, including the key players for battery cells, battery packs, and battery pack components and associated business models
- Discuss market opportunities for players that can supply materials, devices, or technology solutions to the Li-ion battery pack industry
- Provide insights into different technologies currently used in battery packs and related technology trends

COMPANIES CITED IN THE REPORT (non exhaustive list)

ABB, AllCell Technologies, Amada, Anhui Ankai Automobile Co., Ltd, Anhui Jianghuai Sinoev Battery System Co. Ltd Arrival, Ashok Leyland, Audi, AUTOLIV, Bitrode, BMW, BMZ, BYD, CALB, CATL, Calienté, Calsonic Kansei, Carling Technologies, Dana, Daimler, EATON, EC Power, Efen GmbH, Electrovaya, Elithion, Eska, ETI Elektroelement, Ewert Energy Systems, Henkel, Hesse Mechatronics, Hitachi, ION, Hyundai, Infineon, Iron Edison, Iveco, JTT, Kokam, Kulicke & Soffa, Laird, Leclanché, LG Chem, Lishen, Littelfuse, Lithium Balance, Lithiumwerks, MAHLE, Manz, Marelli, Mersen, Modine, NEC Corporation, New Flyer, Nissan, NXP, Octillion, OEZ, Pacific Engineering Corporation (PEC), Panasonic, Phase Change Material Products Ltd. (PCM Products), Polytec PT, Porsche, Preh GmbH, Protterra, Renault Trucks, Renesas, Rogers, Saft, Saint-Gobain, Samsung SDI, Scania, SCLE SFE, Schneider Electric, Schunk Sonosystems, SIBA, Solaris Bus & Coach, SK Innovation, SNAM, SIBA, Skoda, SOC, Sovema, Stäubli, STMicroelectronics, Sunstone, TE Connectivity, Tesla, Tesvolt, Texas Instruments, Toshiba, Van Hool, Ventec, Volkswagen, Volvo, Wanxiang, Workhorse, Xiamen SET Electronics, Yutong, Zhong Tong Bus, and more...

TABLE OF CONTENTS (complete content on i-Micronews.com)

| | | | |
|-----------------------------------------------------|-----|------------------------------------------------------------|-----|
| Table of contents | 5 | Technology trends - BMS | 195 |
| Report objectives | 10 | Technology trends - Thermal management system | 213 |
| What we got right, what we got wrong | 15 | Technology trends - Fuses, circuit breakers and contactors | 230 |
| Who should be interested by this report | 16 | Technology trends - Electrical interconnects | 245 |
| Executive summary | 18 | Technology trends - Battery pack housing | 259 |
| Market forecasts | 54 | Technology trends - Battery pack manufacturing | 264 |
| Market trends | 74 | > Take away and outlook | |
| Business model and supply chain analysis | 95 | > Appendix – Li-ion battery safety issues | |
| Technology trends in Li-ion battery cells and packs | 154 | Yole Développement presentation | |
| Technology trends - Battery cell | 165 | | |
| Technology trends - Battery pack | 176 | | |

RELATED REPORTS & MONITORS



- Power Electronics for Electric & Hybrid Electric Vehicles 2020
- Status of Rechargeable Li-ion Battery Industry 2019

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ABOUT YOLE DEVELOPPEMENT

Founded in 1998, Yole Développement (Yole) has grown to become a group of companies providing marketing, technology and strategy consulting, media and corporate finance services, reverse engineering and reverse costing services. With a strong focus on emerging applications using silicon and/or micro manufacturing, the Yole group of companies has expanded to include more than 120 collaborators worldwide covering MEMS and Image Sensors, Compound Semiconductors, RF Electronics, Solid-state Lighting, Displays, Software, Optoelectronics, Microfluidics & Medical, Advanced Packaging, Manufacturing, Power Electronics, Batteries & Energy Management and Memory.

The “More than Moore” market research, technology and strategy consulting company Yole Développement, along with its partners System Plus Consulting, PISEO and Blumorpho, supports industrial companies, investors and R&D organizations worldwide to help them understand markets and follow technology trends to grow their business.

CONSULTING AND ANALYSIS

- Market data & research, marketing analysis
- Technology analysis
- Strategy consulting
- Reverse engineering & costing
- Design and characterization of innovative optical systems
- Financial services (due diligence, M&A with our partner)

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Definitions: **“Acceptance”**: Action by which the Buyer accepts these General Terms and Conditions of Sale in their entirety. It is done by signing the purchase order which states “I hereby accept Yole Développement’s General Terms and Conditions of Sale”.

“Buyer”: Any business user (i.e. any person acting in the course of its business activities for its business needs) placing an order pursuant to these General Terms and Conditions of Sale, with the exclusion of any individual consumer acting for his/her sole personal interest.

“Seller”: Headquartered in Villeurbanne (France), Yole Développement provides marketing, technology and strategy consulting, media and corporate finance services, reverse engineering/costing services as well as IP and patent analysis. With dedicated teams of technology & market analysts, Yole Développement operates worldwide with the key industrial companies, R&D institutes and investors to help them understand the market and technology trends.

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“Products”

Our products can be bought either on a unit basis or as a bundled offer (i.e. subscription for a period of 12 calendar months).

“Report”

Reports are established in PowerPoint and delivered in a PDF format with an additional Excel file. 30 min of Q&A session with an analyst/author can be included for all purchased reports (except the ones bought as a one user license). More time can be allocated on a fee basis.

“Monitor”

Monitors are established and delivered in Excel. An additional PDF can also be added. Q&A with an Analyst is possible for each monitor (except where specified otherwise). Frequency of the release vary according to the monitor or service (quarterly and monthly). All monitor products are eligible for a Corporate License.

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Yearly subscription to access a web-based interactive portal to view features and specs of a device or component based on a complete turnaround process.

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1. SCOPE

1.1 Both Contracting Parties undertake to comply with these General Terms and Conditions of Sale.

ANY ADDITIONAL, DIFFERENT, OR CONFLICTING TERMS AND CONDITIONS IN ANY OTHER DOCUMENTS ISSUED BY THE BUYER AT ANY TIME ARE HEREBY OBJECTED TO BY THE SELLER, ARE DEEMED WHOLLY INAPPLICABLE TO ANY SALE MADE HEREUNDER, AND SHALL NOT BE BINDING IN ANY WAY ON THE SELLER.

1.2 These General Terms and Conditions of Sale shall be deemed valid and enforceable between the Contracting Parties after acceptance of an order from the Buyer by the Seller pursuant to Article 1.3 below. For such purpose, the Buyer, when signing the purchase order which mentions “I hereby accept Yole Développement’s Terms and Conditions of Sale” is deemed to have fully and unequivocally accepted these Terms and Conditions of Sale.

1.3 Orders are deemed to be accepted only upon written acceptance and confirmation by the Seller, within [7 days] from the date of order, to be sent either by email. In the absence of any confirmation in writing, no order shall be deemed to have been accepted.

2. MAILING OF THE PRODUCTS

2.1 Products are sent by email to the Buyer after Seller’s confirmation:

- Within a few days from the Seller’s confirmation of the order for Products already released and paid; or
- Within a reasonable time for Products ordered prior to their effective release. In this case, the Seller shall use its best endeavours to inform the Buyer of an indicative release date and the evolution of the work in progress.

2.2 The Seller shall by no means be responsible for any delay pursuant to Article 2.1 above, in particular in cases where a new event or access to new contradictory information would require the Seller analyst to dedicate extra time to compute or compare the data in order to enable the Seller to deliver a high quality Product.

2.3 The mailing of the Product will occur only upon payment by the Buyer, in accordance with the conditions contained in Article 3 above.

2.4. The mailing is operated through electronic means either by email via the sales department or automatically online via an email/password. The Buyer is responsible for ensuring that the Buyers platform has the required capacities and authorisations to receive the Product(s) emailed by the Seller. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that the Seller is informed of the defective formatting within 90 days from the date of the original download or receipt of the Product.

2.5 The person receiving the Products on behalf of the Buyer shall immediately verify the quality of the Products and their conformity with the order. Any claim for apparent defects or for non-conformity shall be sent in writing to the Seller within 8 days of receipt of the Products. For this purpose, the Buyer agrees to produce sufficient evidence of such defects.

2.6 No return of Products shall be accepted without prior written notification from the Buyer to the Seller, even in case of delayed delivery. Any Product returned to the Seller without the Buyer providing prior notification to the Seller as required under Article 2.5 above shall remain at the Buyer’s risk. In no event shall the Seller incur any liability for Products erroneously ordered by the Buyer, or for any request from the Buyer to replace a Product previously ordered by a different Product.

3. PRICE, INVOICING AND PAYMENT

3.1 Prices are given in the orders corresponding to each Product sold on a unit basis or corresponding to annual subscriptions. They are deemed to be inclusive of all taxes applicable in the country where the Seller is based (except for France where VAT will be added). The prices are re-evaluated from time to time by the Seller. The effective price is deemed to be the one applicable at the time of the order.

3.2 Payments due by the Buyer shall be sent by cheque payable to Yole Développement, or made by credit card or by electronic transfer to the following account:

HSBC, 1 place de la Bourse 69002 Lyon France
Bank code: 30056
Branch code: 00170
Account n°: 0170 200 1565 87
BIC or SWIFT code: CCFRFRPP
IBAN: FR76 3005 6001 7001 7020 0156 587

To secure the payments due to the Seller, the Seller reserves the right to request down payments from the Buyer. In such case, the need for a down payment will be mentioned on the corresponding order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except as otherwise specifically agreed in writing by the Buyer and the Seller. If the Buyer fails to pay at the due date and fails to request and obtain from the Seller a payment extension, the latter shall be entitled to invoice interest in arrears based on the annual rate Refi of the “BCE” + 7 points, in accordance with article L.441-6 of the French Commercial Code.

3.4 The Seller publications (reports, monitors, tracks...) are due for delivery only after receipt by the Seller of any payment due by the Buyer prior to delivery.

3.5 In the event of termination of the contract by the Seller attributable to Buyer misconduct during the contract, the Seller will have the right to invoice all work performed at the time of termination, and to take legal action for damages.

4. LIABILITIES

4.1 The Buyer or any other individual or legal person acting on its behalf, being a business user buying the Products for its business activities, shall be solely responsible for the choice of the Products purchased as well as for the use and interpretations the Buyer makes of the documents it purchases, of the results the Buyer obtains, and of the advice and acts the Buyer bases thereon .

4.2 In no event shall the Seller be liable for:

- a) Damages of any kind, including without limitation, incidental or consequential damages (including, but not limited to, damages for loss of profits, business interruption and loss of programs or information) arising out of the use of a Product or the use of or the inability by the Buyer to use the Seller’s website, or any information provided on the website, or contained in a Product;
- b) Any claim attributable to errors, omissions or other inaccuracies in a Product or interpretations thereof.

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4.4 Any Product that the Seller sells may, upon prior notice to the Buyer from time to time be modified by Seller or substituted with a similar Product meeting the needs of the Buyer. Such modification shall not lead to any liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

4.5 In the case where, after inspection, it is acknowledged that a Product contain defects, the Seller undertakes to replace the defective product to the extent reasonably feasible and without indemnification or compensation of any kind for labour costs, delays, loss caused or any other reason being due by the Buyer . This undertaking from the Seller shall be effective for a maximum of two months starting from the delivery date but shall not be applicable in the event of force majeure as described in Article 5 below.

4.6 The deadlines that the Seller is asked to provide for the mailing of a Product are given for information purposes only and are not guaranteed. If such deadlines are not met, this shall not, without the agreement of the Seller lead to any claim for damages or right of cancellation of one or more orders by the Buyer, except for non-acceptable delays exceeding [3] months from the stated deadline. In such case only i.e. only in the event of a delay exceeding (3) months from the stated deadline the Buyer shall be entitled to ask for a reimbursement of any down payment previously made to the Seller, to the exclusion of any other damages.

4.7 The Seller does not make any warranties, express or implied, including, without limitation, those of sale ability and fitness for a particular purpose, with respect to any Products. Although the Seller shall take reasonable steps to screen Products for infection of viruses, worms, Trojan horses or other codes containing contaminating or destructive properties before making Products available, the Seller cannot guarantee that any Product will be free from infection.

5. FORCE MAJEURE

The Seller shall not be liable for any delay in performance directly or indirectly caused by or resulting from acts of nature, fire, flood, accident, riot, war, government intervention, embargoes, strikes, labour difficulties, epidemics, major health event (e.g. Corona virus), equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not attributable to the fault of the Seller.

6. PROTECTION OF THE SELLER’S IPR

6.1 All the IPR attached to the Products are and remain the property of the Seller and are protected under French and international copyright law and conventions.

6.2 The Buyer agreed not to disclose, copy, reproduce, redistribute, resell or publish a Product, or any part of it to any other party other than employees of the Buyer Company (and only in the country of the Primary User for Multi-User Licenses). The Buyer shall have the right to use Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use any Product for purposes such as:

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- Use in any timesharing, service bureau, bulletin board or similar arrangement or public display;
- Posting any Product to any other online service (including bulletin boards or the Internet);
- Licensing, leasing, selling, offering for sale or assigning a Product or any derivative thereof.

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6.4 The Buyer shall be solely responsible towards the Seller for any infringement of the obligation described in Article 6.3 above, whether such infringement originates from the Buyer’s employees or any person to whom the Buyer has sent the Products. Furthermore, the Buyer shall initiate and personally take care of any related proceedings in coordination with the Seller, and the Buyer shall bear the related financial consequences in their entirety.

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6.6 It is acknowledged and accepted by the Buyer that whether purchased in the form of Bundles or Annual Subscription, all unselected reports will be deemed cancelled and lost after a period of 12 month following acceptance of the corresponding order by the Seller in accordance with provisions of Article 1.3 above .

6.7 It is further acknowledged and agreed by the Buyer that any investor in the Buyer Company, any external consultant of the Buyer Company or any joint venture done with a third party in which the Buyer Company is involved , is not entitled to use a Product, without paying to the Seller the full price for a license to the required Product..

7. TERMINATION

If the Buyer cancels the order in whole or in part or postpones the date of mailing, the Buyer shall indemnify the Seller for the entire costs that have been incurred as at the date of notification by the Buyer of such delay or cancellation. This may also apply for any other direct or indirect consequential loss that may be incurred by the Seller, pursuant to such cancellation or postponement.

8. MISCELLANEOUS

8.1 All the provisions of these General Terms and Conditions of Sale are for the benefit of the Seller, but also for that of its licensors, resellers and agents. Each of them is entitled to assert and enforce these provisions against the Buyer.

Any notices under these Terms and Conditions shall be given in writing and shall be effective upon receipt by the other Party.

8.2 The Seller may, from time to time, update these General Terms and Conditions of Sale, and the Buyer, shall be deemed to have accepted the latest version of such General Terms and Conditions of Sale, once they have been duly communicated to the Buyer by the Seller.

9. GOVERNING LAW AND JURISDICTION

9.1 Any dispute arising out or linked to these General Terms and Conditions of Sale or to any Licenses or Products purchased in application thereof shall be submitted to the French Commercial Court of Lyon, which shall have exclusive jurisdiction upon such issues.

9.2 French law (without reference to any applicable conflict of law provisions) shall apply to these General Terms and Conditions of sale and any agreement between the Buyer and the Seller made pursuant thereto.