

Hydrogen Fuel Cells for Electric Vehicles

Patent Landscape Analysis – October 2022

The growth in patenting activity among German vehicle manufacturers and the impressive IP recent developments of Chinese companies are indicative of renewed interest in hydrogen-based fuel cell electric vehicles (HFCEV) as one solution, along with battery electric vehicles (BEV), to tackle the issues faced by automakers.

REPORT OUTLINE

- Hydrogen Fuel Cells for Electric Vehicles
- Patent Landscape Analysis
- October 2022
- PDF >115 slides
- Excel file >30,000 patent families
- Reference: KM22005
- 4,990 EUR for a multi-user license



KEY FEATURES

- Describing the **global patenting trends**, including time evolution of patent publications, countries of patent filings, etc.
- Identifying the **main patent assignees** and the **IP newcomers** in the different segments of the supply chain.
- Determining the status of their **patenting activity** (active / inactive) and their **IP dynamics** (ramping up, slowing down, steady).
- Identifying the **IP collaborations** (patent co-filings) and **IP transfers** (changes of patent ownership).
- **Patents categorized** into more than 20 segments: **fuel cell technologies** (PEMFC, SOFC, MCFC, PAFC, AFC, etc.), **cell materials and components** (electrodes, membranes, catalysts, gas diffusion layer, bipolar plates, electrolytes, etc.), **stacking of fuel cells, fuel cell system, thermal management, pressure management**, etc.
- **IP profile of 15 key players:** patent portfolio overview (IP dynamics, segmentation, legal status, geographic coverage, etc.), **IP collaborations**, and **recent patenting activity**.
- **Excel database** containing all patents analyzed in the report, including patent segmentations and hyperlinks to an **updated online database**.

Context of the report

Nowadays, the global transportation sector represents about one quarter of all direct carbon dioxide emissions. To remedy this, during the past few years, several national and supranational governments around the world have instigated policy regulations and financial incentives regarding research and development programs in order to help green hydrogen production, hydrogen infrastructures and fuel cell-powered electric vehicles thrive in the future. Moreover, numerous R&D programs, strategic alliances and partnerships among vehicle manufacturers, equipment suppliers (OEM) and hydrogen- and fuel cell-related companies have blossomed, giving a strong insight into the structuring and strengthening of this specific market.

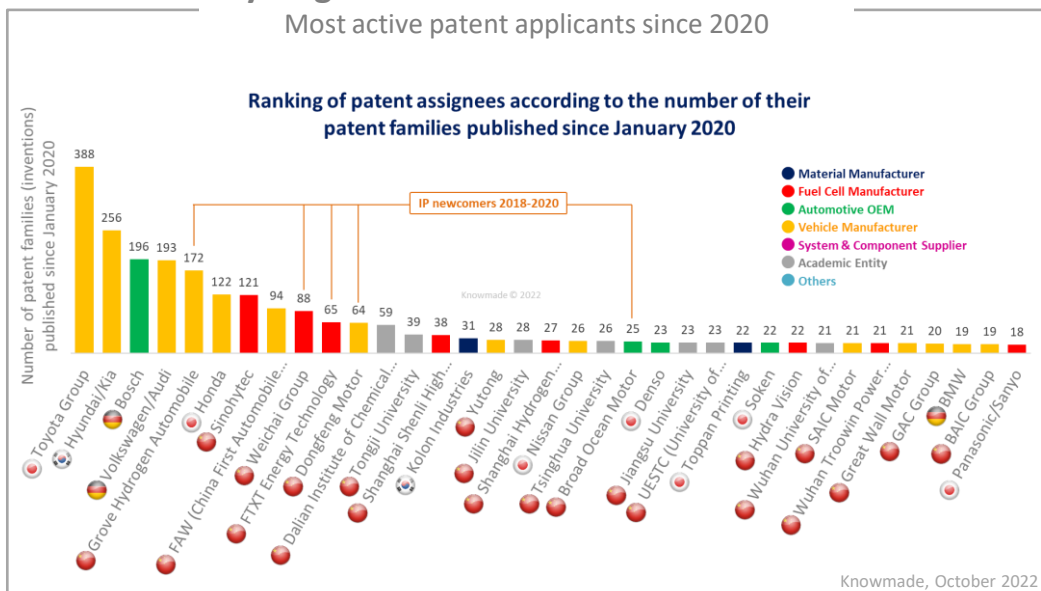
The last 10 years we witnessed a shift in technological interest in the automotive sector, with companies concentrating their R&D efforts and patenting activities on battery technologies. But with some as yet unresolved issues for electric vehicles (mileage autonomy, charging speed and safety to name a few), there was a revival in interest in fuel cell technology patent filings in the mid-2010s, with a CAGR of 18% between 2015 and 2021.

In this context, **Knowmade** is releasing a new report which aims to provide a comprehensive view of the **patent landscape** related to **hydrogen-based fuel cells for terrestrial electric vehicles** (cars, trucks and buses), from **electrolyte** and **electrode materials** to the **fuel cell system** and **vehicle integration**, segmented into **fuel cell technologies** – such as proton exchange membrane (PEMFC), solid oxide (SOFC) and molten carbonate (MCFC).

Patent landscape analysis is a powerful tool to understand global hydrogen fuel cell electric vehicles competitive and technological environment. Overall, patenting activity (patent filings) reflects the level of R&D investment made by a country or player in a specific technology, while providing clues as to the technology readiness level reached by the main IP players. What's more, the technology coverage along the value chain and the geographical coverage of the patent portfolios are closely related to the business strategy of IP players.

Hydrogen Fuel Cells for Electric Vehicles

Most active patent applicants since 2020



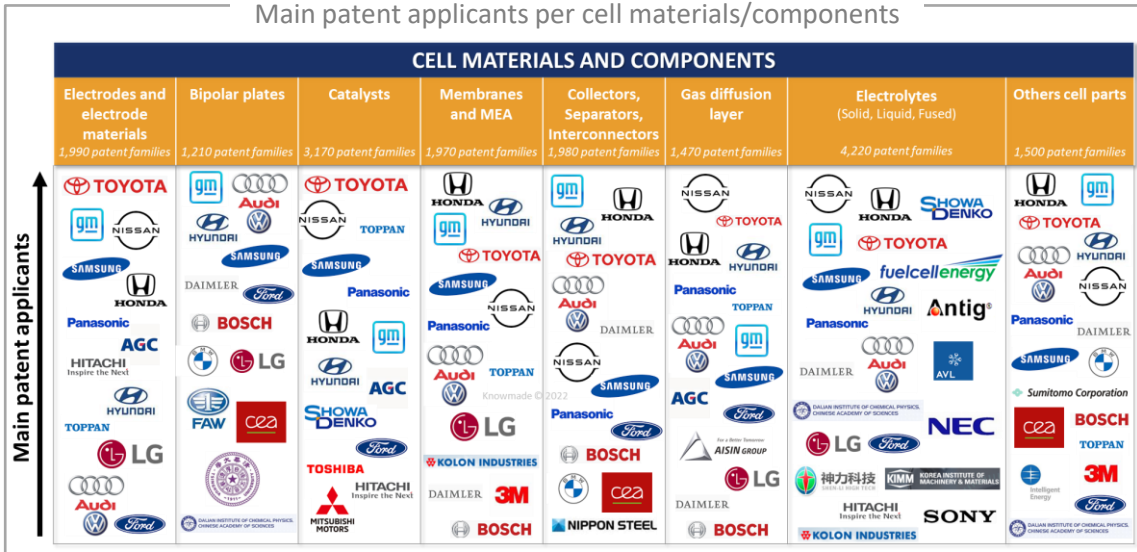
Knowmade, October 2022

A sector boosted by the emergence of newcomers

With more than 30,000 patent families published in the past 20 years, hydrogen-based fuel cell technologies for road transportation (cars, trucks, buses) is a sector that has caught the attention of a lot of companies around the world. As in a lot of innovation-led industry sectors, Japanese players historically took over the fuel cell-related technological field in the 2000s, taking a quantitative approach in patenting activity. Players such as car makers (**Toyota, Nissan, Honda, Mitsubishi**, etc.), equipment suppliers (**Aisin Seiki, Denso, Soken**, etc.), device manufacturers (**Panasonic/Sanyo, Hitachi, Toshiba, Murata/Sony**, etc.) or material suppliers (**Toppan Printing, Nippon Steel, Toray Industries, Sumitomo**, etc.) have been active all along the value chain, from electrode materials and fuel cell stacks to system integration into vehicles. Other players have joined their Japanese counterparts in patent filings in that period, like US **General Motors** and **Ford**, German **Daimler, Volkswagen/Audi, Bosch** and **BMW**, and South Korean **Hyundai/Kia, Samsung** and **LG**. More recently, the patenting activity is led by German vehicle manufacturers and Chinese newcomers, as a way to develop and diversify their businesses, for the former – **Volkswagen/Audi, Bosch** or **BMW** – and to take some market shares and develop fuel cell technologies, for the latter – vehicle manufacturers **Grove Hydrogen Automotive, FAW China First Automotive Works, Dongfeng Motor, Yutong Bus** or **SAIC Group**, and product devices sellers **SinoHytec, Weichai Group, FTXT Energy Technology** or **Shanghai Shenli High Technology**.

Hydrogen Fuel Cells for Electric Vehicles

Main patent applicants per cell materials/components



Patent segmentation

The patent families have been categorized according to the **fuel cell technologies** (PEMFC, SOFC, MCFC, PAFC, AFC, etc.), **cell materials and components** (electrodes, membranes, catalysts, gas diffusion layer, bipolar plates, electrolytes, etc.), **management and control** (thermal management, pressure management, etc.), **stacking of fuel cells, fuel cell system, hydrogen storage, etc.**

IP profiles: focus on the top IP players' patent portfolios

The patent portfolio of 15 companies is analyzed: **Toyota, Honda, Nissan, Hyundai/Kia, General Motors, Panasonic, Volkswagen/Audi, Bosch, BMW, Grove Hydrogen Automotive, Shen-Li High Tech (SinoFuelCell), FAW, Weichai, Sunrise Power, Cellcentric**. For each player, the hydrogen fuel cell patent portfolio is analyzed to provide an overview of its strengths, its potential for reinforcement, the level of IP activity, IP collaborations and recent patenting activity.

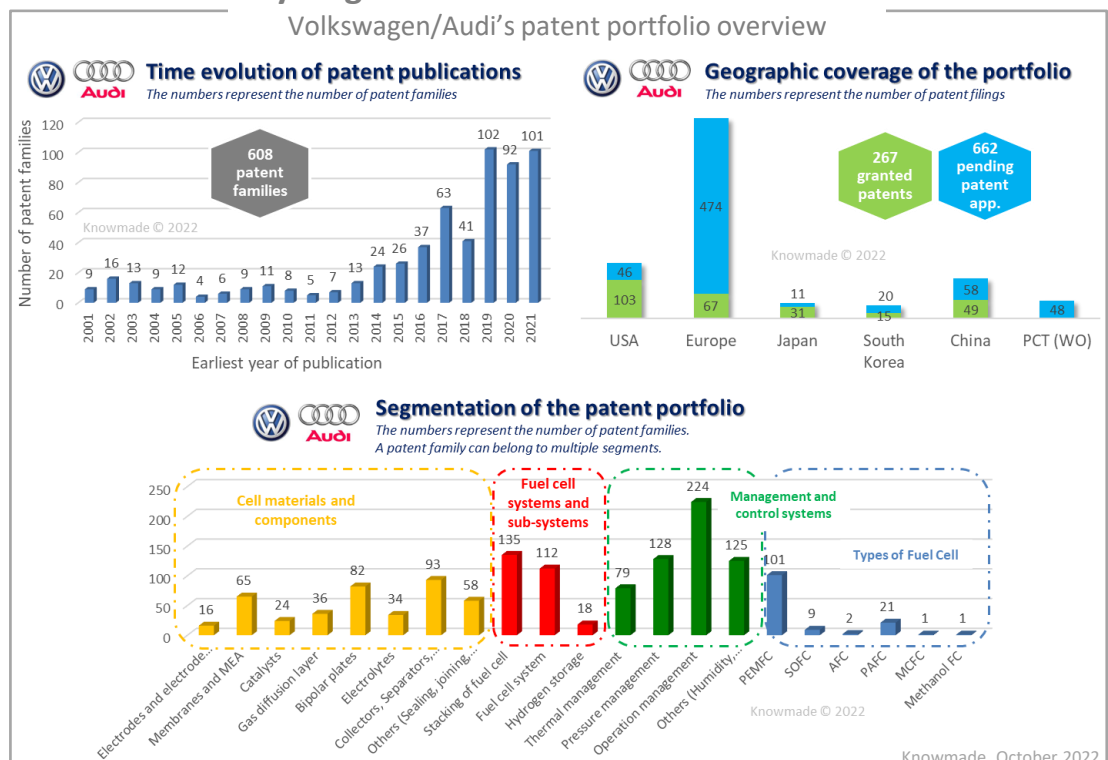
Useful Excel patent database



This report also includes an extensive **Excel database with the 30,000+ patent families** (inventions) analyzed in this study. This useful patent database allows for **multi-criteria searches** and includes patent publication numbers, **hyperlinks to an updated online database** (original documents, legal status, etc.), priority date, title, abstract, patent assignees, patent's current legal status, and **20+ segments** (PEMFC, SOFC, MCFC, AFC, electrodes, membranes, catalysts, gas diffusion layer, stacking of fuel cells, fuel cell system, hydrogen storage, thermal management, pressure management, etc.).

Hydrogen Fuel Cells for Electric Vehicles

Volkswagen/Audi's patent portfolio overview



Companies mentioned in the report (non-exhaustive)

Industrials: AGC, Aisin Seiki, Anderson Industries, Asahi Kasei, BAIC Group (Beijing Automotive), Blue World Technologies, BMW, Bosch, Canon, Cellcentric, Chery Automobile, Daimler, Denso, Dongfeng Motor, FAW (China First Automobile Works), Ford, FTXT Energy Technology, General Motors, Grove Hydrogen Automotive, Hitachi Group, Honda, Hylium Industries, Hyundai/Kia, J&L Tech, Kolon Industries, LG Group, Mitsubishi Group, Murata Manufacturing/Sony, New Keli Chemical, Nippon Steel, Nissan Group, Nuvoton, Panasonic/Sanyo, Refire Technology, Renault, Samsung Group, Schaeffler Technologies, S-FuelCell, Shanghai Shenli High Technology, Sinohytec, Soken, Sumitomo Group, Sunrise Power, Suzuki Group, Toppan Printing, Toray Industries, Toshiba Group, Toyota Group, Vitesco Technologies, Volkswagen/Audi, Weichai Group, Yutong, etc.

Research organizations: AIST (National Institute of Advanced Industrial Science & Technology), Beijing University, CEA (Alternative Energies and Atomic Energy Commission), Dalian Institute of Chemical Physics - CAS, Jilin University, KAIST (Korea Advanced Institute of Science & Technology), KIER (Korea Institute of Energy Research), Seoul National University, Shanghai Jiao Tong University, South China University of Technology, Tongji University, Tsinghua University, Wuhan University of Technology, Zhejiang University, etc.

TABLE OF CONTENTS

INTRODUCTION	6	IP COLLABORATIONS	74
<ul style="list-style-type: none"> • Context • Hydrogen fuel cells: advantage and drawbacks • Types of fuel cells: PEMFC, SOFC, MCFC, PAFC, etc. • Fuel cells in transportation • Incentives & Policies worldwide • Latest news 		IP LITIGATIONS AND OPPOSITIONS	76
SCOPE OF THE REPORT AND METHODOLOGY	22	PATENT SEGMENTATION	80
<ul style="list-style-type: none"> • Key features of the report • Methodology for patent search, selection and analysis • Key IP players & Key patents • Terminology 		<ul style="list-style-type: none"> • Distribution of patent families by segment • Time evolution of patent publications by segment • Main patent assignees vs. Segments • Ranking of patent assignees for each segment 	
HIGHLIGHTS AND KEY INSIGHTS	39	FOCUS ON PEMFC	96
PATENT LANDSCAPE OVERVIEW	55	<ul style="list-style-type: none"> • Time evolution of patent publications • Main patent assignees • IP leadership of patent assignees • Key patents 	
<ul style="list-style-type: none"> • Timeline of patent publications • Time evolution of company headquarters • Main patent assignees • Most active patent applicants since January 2020 • Main patent assignees by company type • Patent assignees time evolution of patent publications • IP newcomers • Current legal status of patents • IP leadership of patent assignees • IP blocking potential of patent assignees • Geographical distribution of alive patents • Patent assignees geographical coverage of portfolio • IP strategy of main Chinese players 		IP PROFILES OF KEY PLAYERS	103
		<p><u>Selected IP players:</u> Toyota, Honda, Nissan, Hyundai/Kia, General Motors, Panasonic, Volkswagen/Audi, Bosch, BMW, Grove Hydrogen Automotive, Shen-Li High Tech (SinoFuelCell), FAW, Weichai, Sunrise Power, Cellcentric</p> <p><u>For each player:</u> Overview of its strength, its potential for reinforcement, the player's IP dynamics, its IP collaborations and its recent patenting activity</p>	
		KNOWMADE PRESENTATION	119

AUTHORS**Jonathan Dominici**

Jonathan works for Knowmade as a Technology and Patent Analyst in the field of Material Chemistry and Energy Storage. He holds a Master's degree in Materials Science and Engineering from the Grenoble Institute of Technology (France) with a specialization in Technological Innovation Management. He previously worked in Competitive Intelligence and IP Strategy within a research institute and a consulting firm.

Contact: jonathan.dominici@knowmade.fr

**Dr. Nicolas Baron**

Nicolas is CEO and co-founder of Knowmade. He manages the development and strategic orientations of the company and personally leads the Electronics department. He holds a PhD in Physics from the University of Nice Sophia-Antipolis, and a Master of Intellectual Property Strategies and Innovation from the European Institute for Enterprise and Intellectual Property (IEEPI) in Strasbourg, France.

Contact: nicolas.baron@knowmade.fr

ABOUT KNOWMADE

Knowmade is a Technology Intelligence and IP Strategy consulting company specialized in analyzing patents and scientific publications. The company helps innovative companies, investors, and R&D organizations to understand their competitive landscape, follow technological evolutions, reduce uncertainties, and identify opportunities and risks in terms of technology and intellectual property.

Knowmade's analysts combine their strong technology expertise and in-depth knowledge of patents with powerful analytics tools and methodologies to turn patent information and scientific literature into actionable insights, providing high added value reports for decision makers working in R&D, innovation strategy, intellectual property, and marketing. Our experts provide prior art search, patent landscape analysis, freedom-to-operate analysis, IP due diligence, and monitoring services.

Knowmade has a solid expertise in Compound Semiconductors, Power Electronics, Batteries, RF Technologies & Wireless Communications, Solid-State Lighting & Display, Photonics, Memories, MEMS & Sensors, Semiconductor Packaging, Medical Devices, Medical Imaging, Microfluidics, Biotechnology, Pharmaceuticals, and Agri-Food.

ORDER FORM

Hydrogen Fuel Cells for Electric Vehicles

Patent Landscape Analysis – October 2022

Ref.:KM22005

SHIP TO

Name (Mr/Ms/Dr/Pr):

Job Title:

Company:

Address:

City:

State:

Postcode/Zip:

Country:

VAT ID Number for EU members:

Tel:

Email:

Date:

PAYMENT METHODS

Order online: Click [here](#)

Check

To pay your invoice using a check, please mail your check to the following address:

KnowMade S.A.R.L.
2405 route des Dolines, Le Drakkar
06560 Valbonne Sophia Antipolis
FRANCE

Money Transfer

To pay your invoice using a bank money wire transfer, please contact your bank to complete the process. Here is the information you will need to submit the payment:

Payee: KnowMade S.A.R.L.
Bank: Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var
IBAN: FR76 1460 7003 6360 6214 5695 139
SWIFT: CCBPFRPPMAR

Paypal

To pay your invoice via PayPal, you must first register at www.paypal.com. You can then send money to KnowMade S.A.R.L. by entering our email address contact@knowmade.fr as the recipient and entering the invoice amount.

RETURN ORDER BY

E-mail: contact@knowmade.fr

Mail: KnowMade S.A.R.L. 2405 route des Dolines, Le Drakkar, 06560 Valbonne Sophia Antipolis, FRANCE

PRODUCT ORDER

4,990 EUR – Multi user license*

For price in dollars, please use the day's exchange rate.
For French customer, add 20% for VAT.
All reports are delivered electronically in pdf format at payment reception.

**The report can be shared with the employees of the company purchasing the report. Subsidiaries and joint-ventures are excluded. Please be aware that the report is watermarked on each page, with the name of the recipient and the organization (the name mentioned in the PO). This watermark also reaffirms that report sharing is not allowed.*

I hereby accept Knowmade's Terms and Conditions of Sale

Signature:

TERMS AND CONDITIONS OF SALES

Definitions

“Acceptance”: Action by which the Buyer accepts the terms and conditions of sale in their entirety. It is done by signing the purchase order which mentions “I hereby accept Knowmade’s 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) entering into the following general conditions to the exclusion of consumers acting in their personal interests.

“Contracting Parties” or “Parties”: The Seller on the one hand and the Buyer on the other hand.

“Intellectual Property Rights” (“IPR”) means any rights held by the Seller in its Products, including any patents, trademarks, registered models, designs, copyrights, inventions, commercial secrets and know-how, technical information, company or trading names and any other intellectual property rights or similar in any part of the world, notwithstanding the fact that they have been registered or not and including any pending registration of one of the above mentioned rights.

“License”: For the reports and databases, 2 different licenses are proposed. The buyer has to choose one license:

1. Single user license: a single individual at the company can use the report.
2. Multi user license: the report can be used by unlimited users within the company. Subsidiaries and Joint Ventures are not included.

“Products”: Reports are established in PowerPoint and delivered on a PDF format and the database may include Excel files.

“Seller”: Based in Sophia Antipolis (France headquarters), Knowmade is a technology intelligence company specialized in the research and analysis of scientific and technical information. We provide patent landscapes and scientific state of the art with high added value to businesses and research laboratories. Our intelligence digests play a key role to define your innovation and development strategy.

1. Scope

1.1 The Contracting Parties undertake to observe the following general conditions when agreed by the Buyer and the Seller. 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, shall be wholly inapplicable to any sale made hereunder and shall not be binding in any way on the seller.

1.2 This agreement becomes valid and enforceable between the Contracting Parties after clear and non-equivocal consent by any duly authorized person representing the Buyer. For these purposes, the Buyer accepts these conditions of sales when signing the purchase order which mentions “I hereby accept Knowmade’s Terms and Conditions of Sale”. This results in acceptance by the Buyer.

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 or to the Buyer’s address. In the absence of any confirmation in writing, orders shall be deemed to have been accepted.

2. Mailing of the Products

2.1 Products are sent by email to the Buyer:

- within [1] month from the order for Products already released; 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 Some weeks prior to the release date the Seller can propose a pre-release discount to the Buyer.

The Seller shall by no means be responsible for any delay in respect of article 2.2 above, and including in cases where a new event or access to new contradictory information would require for the analyst extra time to compute or compare the data in order to enable the Seller to deliver a high quality Products.

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

2.4 The mailing is operated through electronic means either by email via the sales department. If the Product’s electronic delivery format is defective, the Seller undertakes to replace it at no charge to the Buyer provided that it 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 to 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 information to the Seller, even in case of delayed delivery. Any Product returned to the Seller without providing prior information to the Seller as required under article 2.5 shall remain at the Buyer’s risk.

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 expressed to be inclusive of all taxes. The prices may be reevaluated from time to time. 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 Knowmade, PayPal, or by electronic transfer to the following account:

Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var

BIC or SWIFT code: CCBPFRPPMAR

IBAN: : FR76 1460 7003 6360 6214 5695 139

To ensure the payments, the Seller reserves the right to request down payments from the Buyer. In this case, the need of down payments will be mentioned on the order.

3.3 Payment is due by the Buyer to the Seller within 30 days from invoice date, except in the case of a particular written agreement. If the Buyer fails to pay within this time and fails to contact the Seller, 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. Our publications (report, database, tool...) are delivered only after reception of the payment.

3.4 In the event of termination of the contract, or of misconduct, during the contract, the Seller will have the right to invoice at the stage in progress, 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 choosing the Products and for the use and interpretations he makes of the documents it purchases, of the results he obtains, and of the advice and acts it deduces thereof.

4.2 The Seller shall only be liable for (i) direct and (ii) foreseeable pecuniary loss, caused by the Products or arising from a material breach of this agreement

4.3 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 or inability to use the Seller's website or the Products, or any information provided on the website, or in the Products;

b) any claim attributable to errors, omissions or other inaccuracies in the Product or interpretations thereof.

4.4 All the information contained in the Products has been obtained from sources believed to be reliable. The Seller does not warrant the accuracy, completeness adequacy or reliability of such information, which cannot be guaranteed to be free from errors.

4.5 All the Products that the Seller sells may, upon prior notice to the Buyer from time to time be modified by or substituted with similar Products meeting the needs of the Buyer. This modification shall not lead to the liability of the Seller, provided that the Seller ensures the substituted Product is similar to the Product initially ordered.

4.6 In the case where, after inspection, it is acknowledged that the Products contain defects, the Seller undertakes to replace the defective products as far as the supplies allow and without indemnities or compensation of any kind for labor costs, delays, loss caused or any other reason. The replacement is guaranteed for a maximum of two months starting from the delivery date. Any replacement is excluded for any event as set out in article 5 below.

4.7 The deadlines that the Seller is asked to state for the mailing of the Products are given for information only and are not guaranteed. If such deadlines are not met, it shall not lead to any damages or cancellation of the orders, except for non-acceptable delays exceeding [4] months from the stated deadline, without information from the Seller. In such case only, the Buyer shall be entitled to ask for a reimbursement of its first down payment to the exclusion of any further damages.

4.8 The Seller does not make any warranties, express or implied, including, without limitation, those of saleability and fitness for a particular purpose, with respect to the 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 the 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, labor difficulties, equipment failure, late deliveries by suppliers or other difficulties which are beyond the control, and not 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 the Product, or any part of it to any other party other than employees of its company. The Buyer shall have the right to use the Products solely for its own internal information purposes. In particular, the Buyer shall therefore not use the Product for purposes such as:

- Information storage and retrieval systems;
- Recordings and re-transmittals over any network (including any local area network);
- 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 the Product.

6.3 The Buyer shall be solely responsible towards the Seller of all infringements of this obligation, whether this infringement comes from its employees or any person to whom the Buyer has sent the Products and shall personally take care of any related proceedings, and the Buyer shall bear related financial consequences in their entirety.

6.4 The Buyer shall define within its company point of contact for the needs of the contract. This person will be the recipient of each new report in PDF format. This person shall also be responsible for respect of the copyrights and will guaranty that the Products are not disseminated out of the company.

7. Termination

7.1 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 borne by the Seller, following this decision.

7.2 In the event of breach by one Party under these conditions or the order, the non-breaching Party may send a notification to the other by recorded delivery letter upon which, after a period of thirty (30) days without solving the problem, the non-breaching Party shall be entitled to terminate all the pending orders, without being liable for any compensation.

8. Miscellaneous

All the provisions of these Terms and Conditions are for the benefit of the Seller itself, but also for its licensors, employees and agents. Each of them is entitled to assert and enforce those provisions against the Buyer.

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

The Seller may, from time to time, update these Terms and Conditions and the Buyer, is deemed to have accepted the latest version of these terms and conditions, provided they have been communicated to him in due time.

9. Governing law and jurisdiction

9.1 Any dispute arising out or linked to these Terms and Conditions or to any contract (orders) entered into in application of these Terms and Conditions shall be settled by the French Commercial Courts of Grasse, which shall have exclusive jurisdiction upon such issues.

9.2 French law shall govern the relation between the Buyer and the Seller, in accordance with these Terms and Conditions.