

# Hydrogen Fuel Cells for Electric Vehicles

Patent Landscape Analysis

October 2022



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		<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>	
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# THE 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](mailto:jonathan.dominici@knowmade.fr)



## Dr. Nicolas Baron

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

Contact: [nicolas.baron@knowmade.fr](mailto:nicolas.baron@knowmade.fr)

**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, Biotechnology, Medical Devices, Medical Imaging, Microfluidics, Pharmaceuticals, and Agri-Food.

# CONTEXT OF THE REPORT

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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.

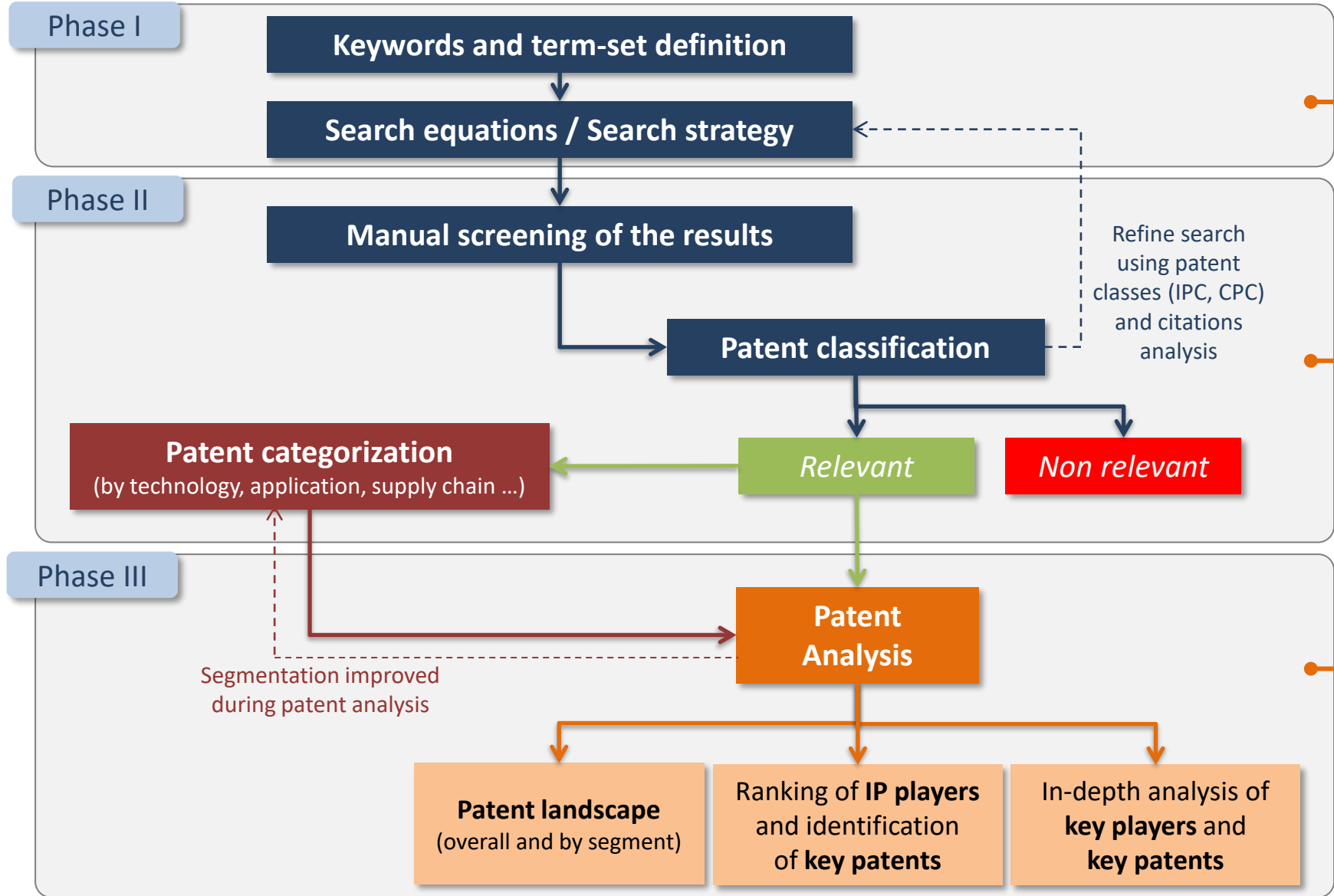
In this context, Knowmade is releasing a new report which aims to provide a comprehensive view of the patent landscape related to hydrogen-based fuel cells for terrestrial electric vehicles (cars, trucks and buses), from electrolyte and electrode materials to the fuel cell system and vehicle integration, 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.

# METHODOLOGY

## Methodology for patent search, selection and analysis

SAMPLE



**Worldwide patent database (Questel-ORBIT)**  
Provides 100+ million patent documents from 100 offices (USA, Japan, Europe, China, Korea, Taiwan, Hong Kong, Singapore, etc.)

**IP analysts** with PhD degree combining **technical** and **patent expertise**. **Manual screening** of patent pools with patent classification between relevant & non relevant patent families based on their technical content & scope of the claims. **Categorization** of relevant patent families by technology, application or supply chain.

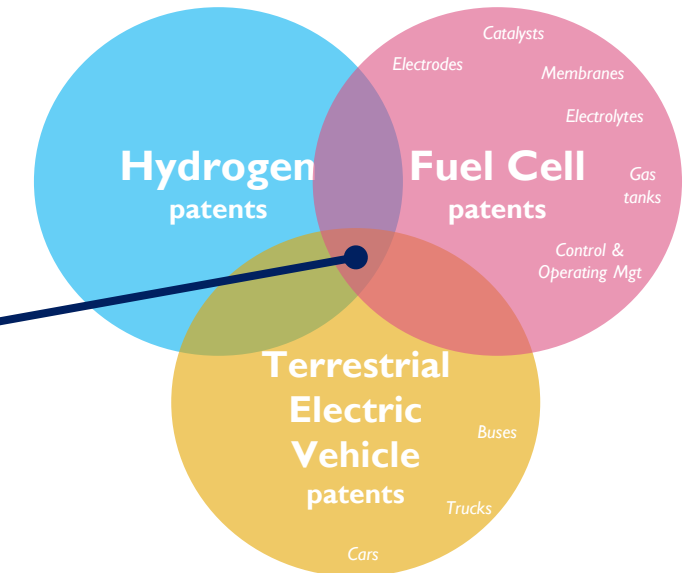
**Analytics tools** and **proprietary methodologies** dedicated to **IP business intelligence** including quantitative and qualitative analysis.

# METHODOLOGY

## Methodology for patent search, selection and analysis

SAMPLE

- The data were extracted from the **FamPat worldwide patent database** (Questel-ORBIT) which provides 100+ million patent documents from 100 patent offices (USA, Japan, Europe, China, Korea, Taiwan, Hong Kong, Singapore, etc.)
- The search for patents was completed in **January 2022**, hence patents published after this date are not available in this report.
- Both the **selection of relevant patents and their categorization in technical segments** are **manually** performed using **keywords and patent classes** (IPC, CPC), combined with **manual analysis** of each patent title, abstract, descriptions, illustrations and claims in conjunction with **expert review** of the subject-matter of the inventions.
- Some patents held by different entities are grouped considering the M&A history.
- The patents are grouped in **patent families**. A patent family is a set of patent applications filed in multiple countries to protect a single invention by a common inventor(s). A first patent application is filed in one country – the priority country – and is then extended to other countries.
- **Data analysis** is performed using the **Questel Orbit IP Business Intelligence analytics platform** combined with **Excel-based data processing** and will be supplemented by **expert analysis**.



We have selected and analyzed more than **52,000 patents and patent applications** grouped in more than **30,000 patent families** relevant to the scope of this report.



# Patent landscape overview

General trends, Key patent assignees, Newcomers, IP collaborations

SAMPLE







# Patent segmentation

By segment: IP dynamics, Key patent assignees, Newcomers, Key patents

SAMPLE

The patent families have been categorized into **20+ segments** 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.**

### PATENT SEGMENTATION OVERVIEW

Distribution and time evolution of patent publications (2/2)

Fuel cell systems and sub-systems & Management and control systems  
Time evolution of patent publications

### PATENT SEGMENTATION OVERVIEW

Key patents

Segmentation	Representative patent number	Title
Electrodes and electrode materials	US2018011111	Electrode and electrical component plate for a fuel cell stack
Membranes and MEA	US2018011111	Method for improved operability of a high-temperature fuel cell system
Stacking of fuel cell	US2018011111	Method of stacking fuel cells in a sulfide ion-free environment
Operation management	US2018011111	Method for two stacked proton exchange membrane fuel cell units
Catalysts	US2018011111	Method for assembling fuel cell comprising the

### PATENT SEGMENTATION OVERVIEW

Main patent assignees vs Supply chain segmentation (2/2)

Segmentation	Patent families
Stacking of fuel cells	3880 patent families
Fuel cell system	6250 patent families
Hydrogen storage	1670 patent families
Thermal management	1330 patent families
Pressure management	2360 patent families
Others parameters mgt (Humidity, fluid concentration, electric variables, others...)	2050 patent families

### PATENT SEGMENTATION OVERVIEW

Main patent assignees by segment – Cell materials and components (1/3)

Segmentation	Patent assignee	Headquarters	Patent families
Electrodes and electrode materials	Toyota	Japan	1000
	GM	USA	800
	Continental	Germany	600
	Hyundai	South Korea	500
	GM	USA	400
	GM	USA	300
	GM	USA	200
	GM	USA	100
	GM	USA	100
	GM	USA	100
Membranes and MEA	GM	USA	1000
	Continental	Germany	800
	GM	USA	600
	GM	USA	500
	GM	USA	400
	GM	USA	300
	GM	USA	200
	GM	USA	100
	GM	USA	100
	GM	USA	100
Catalysts	GM	USA	1000
	Continental	Germany	800
	GM	USA	600
	GM	USA	500
	GM	USA	400
	GM	USA	300
	GM	USA	200
	GM	USA	100
	GM	USA	100
	GM	USA	100

### HYDROGEN FUEL CELL FOR ELECTRIC VEHICLES

Temporal evolution of patent publications by types of fuel cells

Types of fuel cell	Number of patent families	1st publication year of patent families	Main patent assignees
Proton Exchange Membrane (PEMFC)	7533	2001	Toyota, GM, Continental, Hyundai, Bosch, etc.
Solid Oxide (SOFC)	1751	1967	GM, Continental, etc.
MCFC	326	1967	Continental, etc.
PAFC	1237	1967	Continental, etc.
AFC	448	1967	Continental, etc.
Other	1579	1967	Continental, etc.

Although all the types of fuel cells have seen a boost in filings lately, PEMFC technologies seem to still generate an intense activity.

### Focus on Proton Exchange Membrane Fuel Cells (PEMFC)

#### Key patents

Segmentation	Representative patent number	Title
Collectors, Separators, Interconnectors	US2018011111	Stacking of fuel cell
Operation management	US2018011111	Method for assembling fuel cell comprising the
Catalysts	US2018011111	Method for assembling fuel cell comprising the
Membranes and MEA	US2018011111	Method for assembling fuel cell comprising the
Stacking of fuel cell	US2018011111	Method for assembling fuel cell comprising the
Electrodes and electrode materials	US2018011111	Method for assembling fuel cell comprising the
Membranes and MEA	US2018011111	Method for assembling fuel cell comprising the
Catalysts	US2018011111	Method for assembling fuel cell comprising the
Electrodes and electrode materials	US2018011111	Method for assembling fuel cell comprising the
Membranes and MEA	US2018011111	Method for assembling fuel cell comprising the

#### Time evolution of patent publications

14,600+ patent applications grouped in 7,500+ patent families, including 3,100+ granted patents and 3,900+ pending patent applications

#### Legal state of patents

#### Main patent assignees

#### Time evolution of patent publications by country of filings

#### IP leadership of patent assignees

Patent families

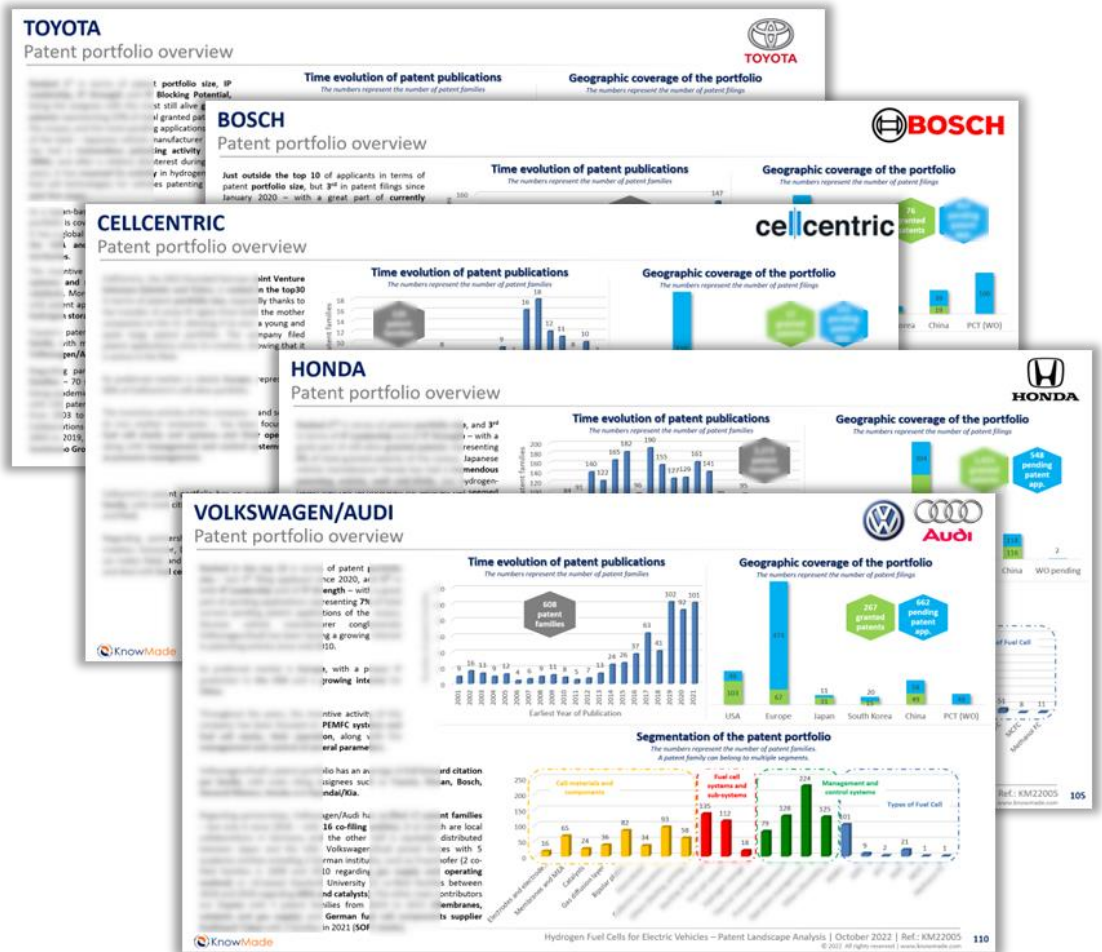
Regarding the IP leadership of assignees when only patents mentioning PEMFC are selected, a change of hierarchy can be observed.

# IP profile of key players

IP portfolio summary, IP strategy, IP collaborations and recent IP activity

SAMPLE

A focus on the 15 key IP players is provided in a dedicated section. 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.





# Excel file with all patents analyzed in the report

Useful patent database allows multi-criteria searches

SAMPLE

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 **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 - Patent Landscape Analysis (October 2022)**

The data is presented in an Excel table with columns including:

- Family number (Country/Inventor/Company/Date)
- Patent number (Publication number)
- Current assignee
- Title
- Abstract
- Earliest application date (yyyy-mm)
- Earliest publication date (yyyy-mm)
- Earliest grant date (yyyy-mm)
- Expected expiry date (yyyy-mm)
- Legal status (Patent Granted/Revoked/Expired)
- Type of Fuel Cell (Proton Exchange Membrane (PEM), Solid Oxide (SOFC), Alkaline (AFC), Phosphoric Acid (PAFC), Molten Carbonate (MOC), Reformate-fed/Non-reformate-fed (RHFOA))
- Cell materials and components (Catalyst, Gas diffusion layer, Bipolar plates, Electrolyte, Membrane and H<sub>2</sub>, Collector, Separator, Other (metal joints), Stacking of fuel cells, Fuel cell system, Hydrogen storage, Thermal manage, Pressure manage, Operation)

**Patent information**  
**Dates and numbers of priority/application/publication/grant, Title, abstract, claims, patent assignees, Hyperlinks to an updated online database (original documents, legal status, etc.)**

**Segments**  
**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.**

# 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:

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#### 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

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Bank: Banque Populaire Méditerranée, CAP 3000 Quartier du lac, 06700 St Laurent du Var, France  
IBAN: FR76 1460 7003 6360 6214 5695 139  
BIC/SWIFT: CCBPFRPPMAR

#### Paypal

In order to pay your invoice via PAYPAL, you must first register at [www.paypal.com](http://www.paypal.com). Then you can send money to the KnowMade S.A.R.L. by entering our E-mail address [contact@knowmade.fr](mailto:contact@knowmade.fr) as the recipient and entering the invoice amount.

### RETURN ORDER BY

**E-mail:** [contact@knowmade.fr](mailto: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.

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*I hereby accept Knowmade's Terms and Conditions of Sale*  
**Signature:**



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“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.

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2.1 Products are sent by email to the Buyer:

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- 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, France

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

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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.

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- 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.

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Competitive landscape | Technology trends | Opportunities / Risks | R&D and IP strategy



## Intellectual Property

Patent your inventions  
Assert your patents and defend your position in case of licensing/litigation  
Evaluate the risks to infringe patents

*Prior art search, Freedom-to-operate analysis, Patent invalidation, Evidence of use, Patent valuation*

Understand, anticipate and evaluate the competitive landscape and current technology developments

*Patent landscape, Monitoring service, IP due diligence*

## Innovation Strategy

Improve your R&D and IP strategy  
Identify and get access to external innovation

*Technology scouting, Scientific literature analysis*



# MAIN FIELDS OF EXPERTISE

## Communication

- RF, microwave, mm-wave
- Datacom & Photonics
- Front end modules
- Antenna & Networks



Advanced Packaging  
Innovative Materials  
AI & Computing

## Energy

- Power electronics
- Batteries & Fuel-cell
- Power management
- PV



## MEMS, Sensors & Optoelectronics

- Micro-systems
- Sensors & Imaging
- Lighting & Display

## Life Sciences & Healthcare

- MedTech
- Microfluidics
- Biotech & Pharmaceuticals
- Agrifood



# KNOWMADE OFFER



**Patent Landscape Analysis**  
to give an overview on  
IP dynamics, IP trends and  
IP players



**Tailor-made  
analyses**

Meet customer's  
business needs and  
budgetary constraints

**Off-the-shelf  
Reports**



**Monitors**

**Patent Monitoring Service**  
to track current R&D activity and  
early detect weak signals,  
opportunities and risks



Monthly IP database | Quarterly report  
Access to IP analysts



KnowMade SARL  
2405 route des Dolines  
06902 Sophia Antipolis, France

[www.knowmade.com](http://www.knowmade.com)  
[contact@knowmade.fr](mailto:contact@knowmade.fr)