HYCELTEC 2019

PAST, CURRENT AND FUTURE OF FUEL CELL TECHNOLOGIES: A BIBLIOMETRIC ANALYSIS OF THE RESEARCH PUBLISHED DURING THE 1968-2018 PERIOD

VII SYMPOSIUM ON HYDROGEN, FUEL CELLS AND ADVANCED BATTERIES

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1. INTRODUCTION

CONTEXT
- Fuel-Cell technologies have evolved from being an emerging topic to a growing research area in business, science and education fields.
- The Fuel-Cell technologies have a multidimensional approach. This research presents a comprehensive review of different fuel cell technologies with their working principle, evolution, relationship and suitability of applications for transportation.
- The professionals and researches involved in this area of knowledge are seeking to uncover the conceptual structure and define a roadmap to reduce the time of research, development, testing/validation and industrialization.

OBJECTIVE
- The main aim of this contribution is to develop a bibliometric analysis to evaluate the performance and conceptual evolution of the Fuel-Cell technologies from 1968 to 2018.
- The analysis is developed using SciMAT.
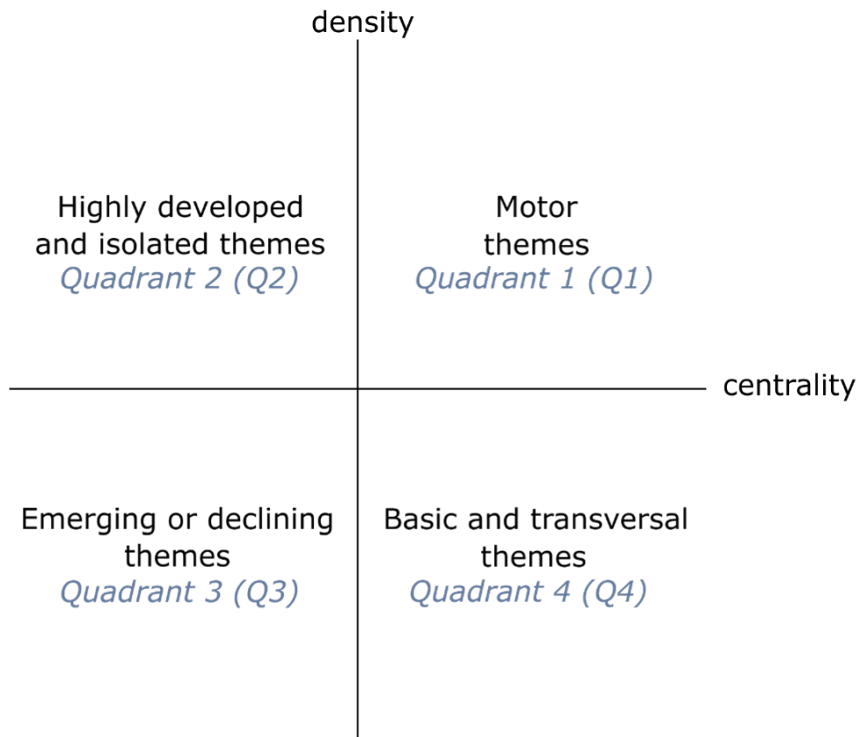
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2. METHODOLOGY

SOFTWARE TOOL
SciMAT was employed to develop a longitudinal conceptual science mapping analysis based on co-words bibliographic networks.

METHODOLOGY STAGES
1. **Detection of the research themes.** Co-word analysis, followed by a clustering of keywords to topics/themes. The similarity between the keywords is assessed using the equivalence index.
2. **Visualizing research themes and thematic network.** Strategic diagram and thematic network (centrality and density). Research themes mapped in a two-dimensional strategic diagram and classified into four groups (Figure 1): i) motor, ii) basic/transversal, iii) highly developed-isolated, and iv) emerging/declining
3. **Performance analysis.** Relative contribution of the research themes to the whole research field: number of published documents, number of citations, and different types of bibliometric indices (h-index).

(a) The strategic diagram
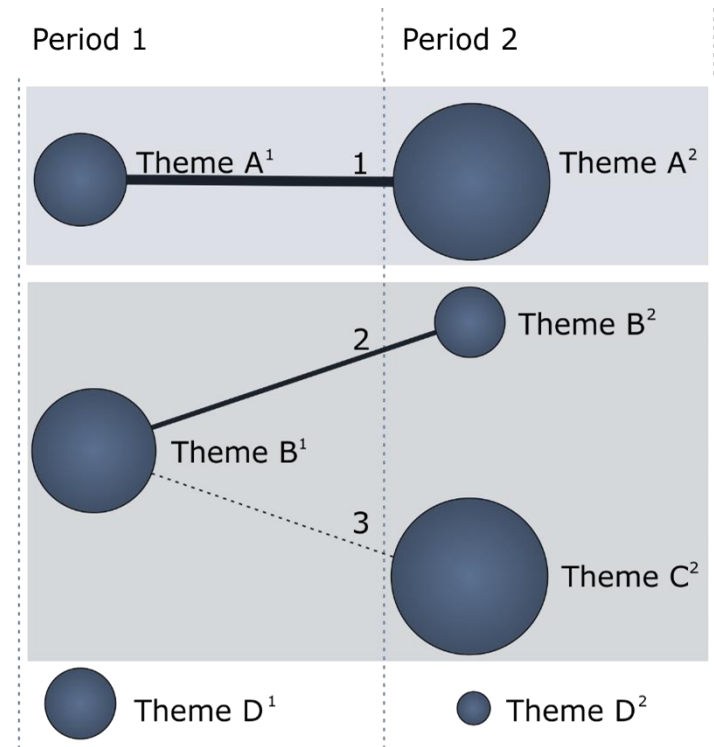
(b) Thematic evolution

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3. DATASET

CORPUS AND DATABASE
- Fuel-Cell technologies documents published in the WoS Core Collection.

QUERY
- TS=("fuel cell" OR "fuel-cell") AND TS=("transport" OR "automotive" OR "vehicle" OR "automobile") AND PY=1968-2018

TIME PERIOD
- 1968-2018 divided in three period: 1968-1999, 2000-2009 and 2010-2018.

CORPUS SIZE
- 14,446 documents (articles, proceedings, reviews…), 378,719 citations and 143,522 keywords (26,224 research terms).
- 378,179 citations count up to 3rd January 2019.
- 1968-1999: 369 documents, 28,657 citations and 1,724 keywords.
- 2000-2009: 4,562 documents, 208,968 citations and 38,796 keywords.
- 2010-2018: 9,535 documents, 141,094 citations and 103,002 keywords.
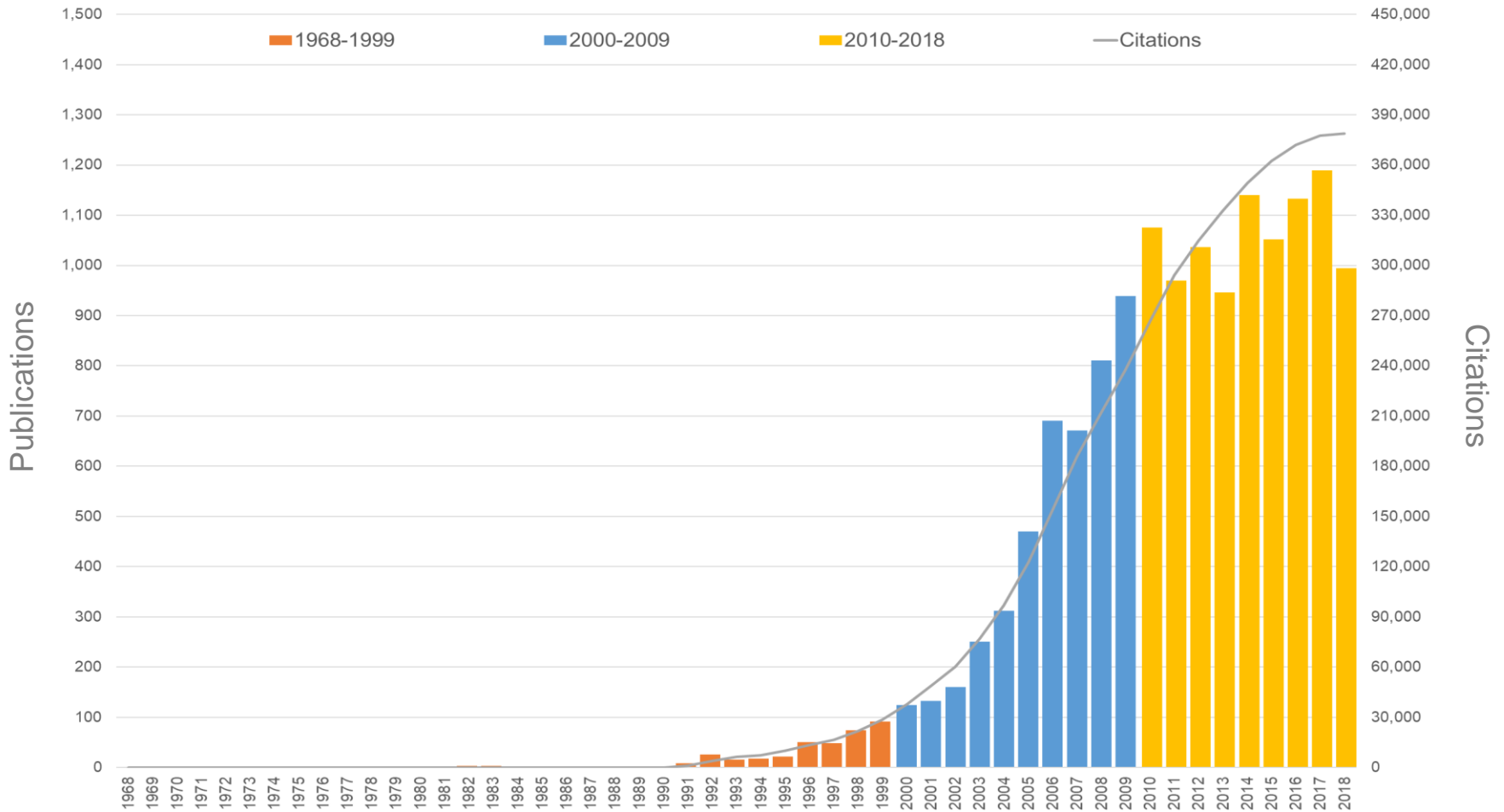
DOCUMENTS AND CITATIONS BY YEAR AND PERIOD

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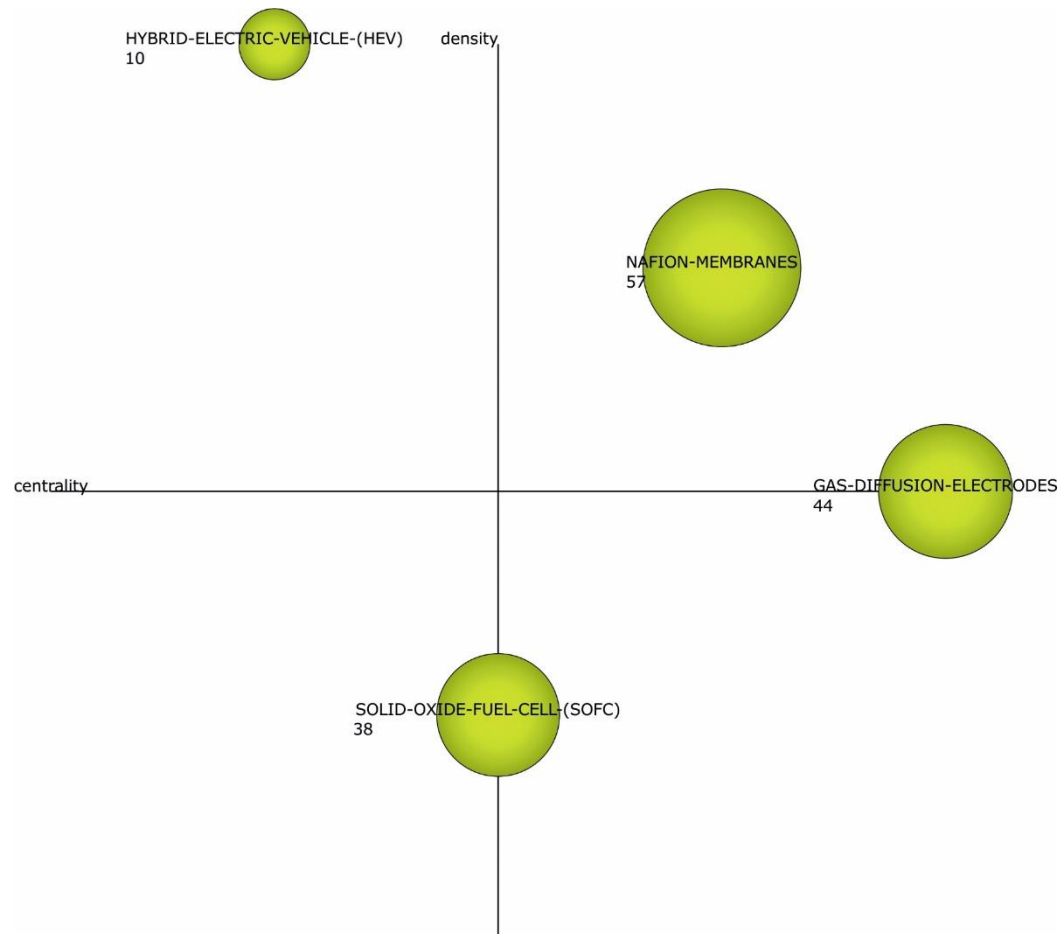# 4. CONCEPTUAL ANALYSIS

Strategic diagram 1968-1999

4. CONCEPTUAL ANALYSIS

Theme	Documents	Citations	h-index
NAFION-MEMBRANES	57	8,904	41
GAS-DIFFUSION-ELECTRODES	44	4,906	29
SOLID-OXIDE-FUEL-CELL-(SOFC)	38	3,151	24
HYBRID-ELECTRIC-VEHICLE-(HEV)	10	528	7

The first period has lower number of publications than the other periods, we could identify four themes related to the Fuel-Cell technologies research field. In this regard, we could highlight three key themes (motor theme and basic and transversal themes) of the knowledge field: NAFION-MEMBRANES, GAS-DIFFUSION-ELECTRODES and SOLID-OXIDE-FUEL-CELL-(SOFC).
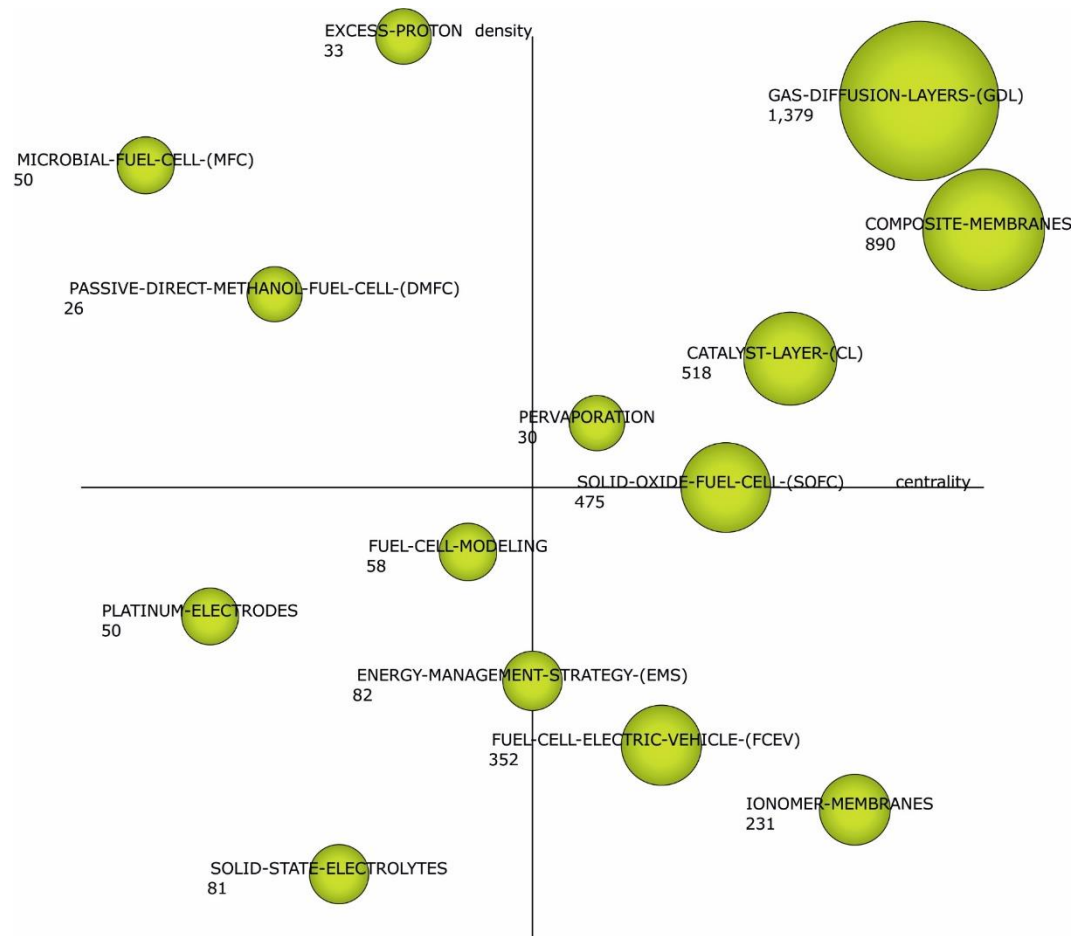
Strategic diagram 2000-2009
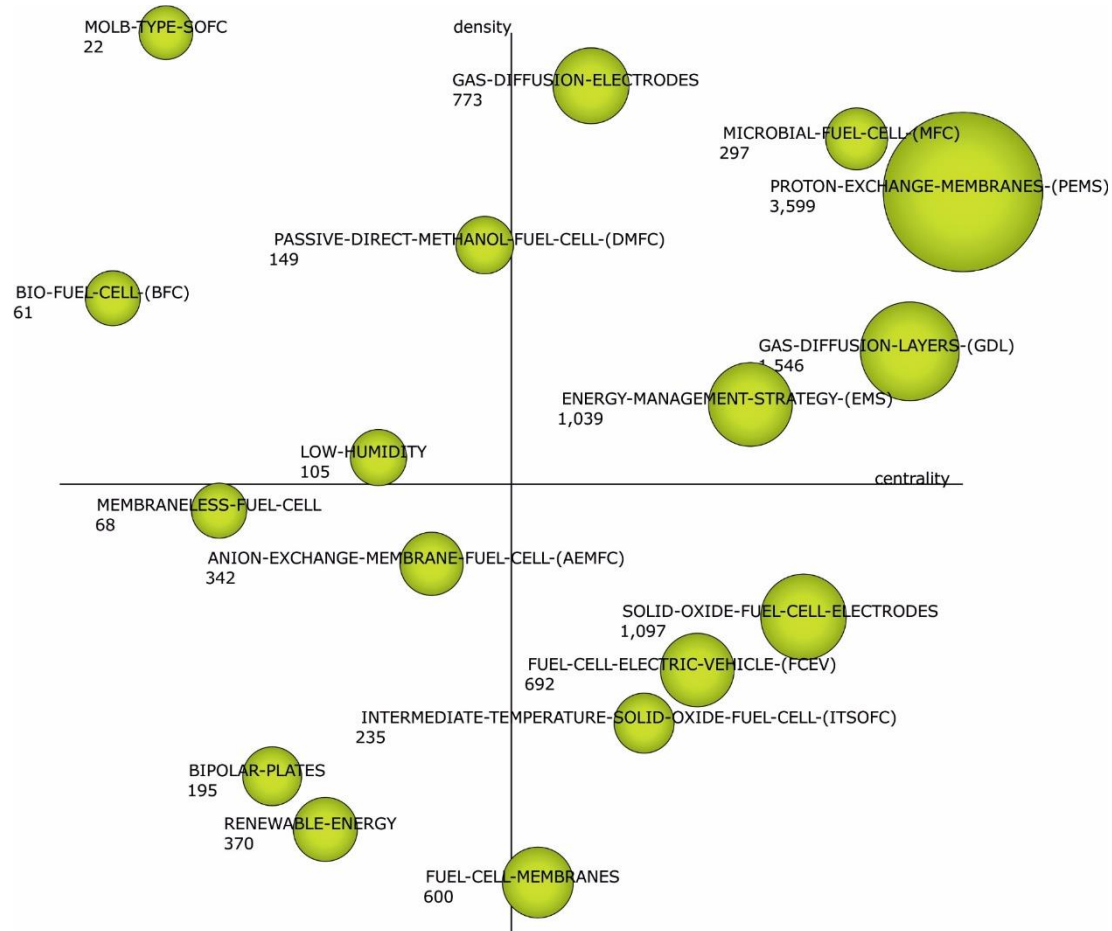
4. CONCEPTUAL ANALYSIS

Theme	Documents	Citations	h-index
GAS-DIFFUSION-LAYERS-(GDL)	1,379	71,544	120
COMPOSITE-MEMBRANES	890	50,444	104
CATALYST-LAYER-(CL)	518	28,576	87
SOLID-OXIDE-FUEL-CELL-(SOFC)	475	22,215	75
FUEL-CELL-ELECTRIC-VEHICLE-(FCEV)	352	17,630	67
IONOMER-MEMBRANES	231	15,511	67
ENERGY-MANAGEMENT-STRATEGY-(EMS)	82	4,093	35
SOLID-STATE-ELECTROLYTES	81	4,809	36
FUEL-CELL-MODELING	58	3,253	30
MICROBIAL-FUEL-CELL-(MFC)	50	4,840	31
PLATINUM-ELECTRODES	50	3,820	30
EXCESS-PROTON	33	4,189	25
PERVAPORATION	30	1,745	22
PASSIVE-DIRECT-METHANOL-FUEL-CELL-(DMFC)	26	1,203	19

During the second period we could identify fourteen themes related to the Fuel-Cell technologies research field. Consistent with the last period, eight themes are considered keys in the knowledge field: GAS-DIFFUSION-LAYERS-(GDL), COMPOSITE-MEMBRANES, CATALYST-LAYER-(CL), PERVAPORATION, SOLID-OXIDE-FUEL-CELL-(SOFC), ENERGY-MANAGEMENT-STRATEGY-(EMS), FUEL-CELL-ELECTRIC-VEHICLE-(FCEV) and IONOMER-MEMBRANES.

Strategic diagram 2010-2018

4. CONCEPTUAL ANALYSIS

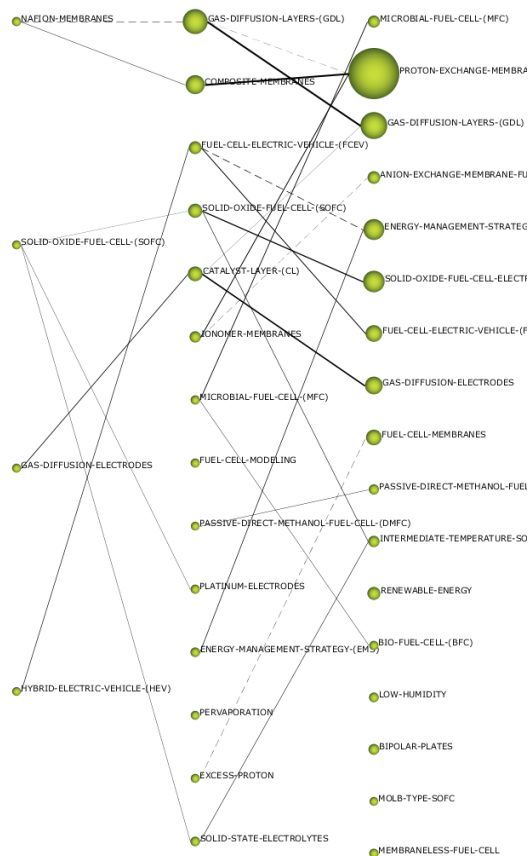| Theme	Documents	Citations	h-index
PROTON-EXCHANGE-MEMBRANES-(PEMS)	3,599	57,511	83
GAS-DIFFUSION-LAYERS-(GDL)	1,546	23,134	57
SOLID-OXIDE-FUEL-CELL-ELECTRODES	1,097	15,812	51
ENERGY-MANAGEMENT-STRATEGY-(EMS)	1,039	17,168	61
GAS-DIFFUSION-ELECTRODES	773	13,112	51
FUEL-CELL-ELECTRIC-VEHICLE-(FCEV)	692	12,715	57
FUEL-CELL-MEMBRANES	600	9,934	45
RENEWABLE-ENERGY	370	9,113	45
ANION-EXCHANGE-MEMBRANE-FUEL-CELL-(AEMFC)	342	9,127	46
MICROBIAL-FUEL-CELL-(MFC)	297	5,981	40
INTERMEDIATE-TEMPERATURE-SOLID-OXIDE-FUEL-CELL-(ITSOFC)	235	4,346	31
BIPOLAR-PLATES	195	2,152	23
PASSIVE-DIRECT-METHANOL-FUEL-CELL-(DMFC)	149	2,480	27
LOW-HUMIDITY	105	2,020	24
MEMBRANELESS-FUEL-CELL	68	934	17
BIO-FUEL-CELL-(BFC)	61	789	16
MOLB-TYPE-SOFC	22	167	8

The third period is the most productive and hosts seventeen themes. In this regard, nine of the total themes are considered key: GAS-DIFFUSION-ELECTRODES, MICROBIAL-FUEL-CELL-(MFC), PROTON-EXCHANGE-MEMBRANES-(PEMS), GAS-DIFFUSION-LAYERS-(GDL), ENERGY-MANAGEMENT-STRATEGY-(EMS), SOLID-OXIDE-FUEL-CELL-ELECTRODES, FUEL-CELL-ELECTRIC-VEHICLES-(FCEV), INTERMEDIATE-TEMPERATURE-SOLID-OXIDE-FUEL-CELL-(ITSOFC) and FUEL-CELL-MEMBRANES.

CONCEPTUAL EVOLUTION MAP
FUEL-CELL RESEARCH THEMES AND THEMATIC AREAS

Theme	Periods	Documents	Citations
GAS-DIFFUSION-LAYERS-(GDL)	P2; P3	2,925	94,678
ENERGY-MANAGEMENT-STRATEGY-(EMS)	P2; P3	1,121	21,261
FUEL-CELL-ELECTRIC-VEHICLE-(FCEV)	P2; P3	1,044	30,345
GAS-DIFFUSION-ELECTRODES	P1; P3	817	18,018
SOLID-OXIDE-FUEL-CELL-(SOFC)	P1; P2	513	25,366
MICROBIAL-FUEL-CELL-(MFC)	P2; P3	347	10,821
PASSIVE-DIRECT-METHANOL-FUEL-CELL-(DMFC)	P2; P3	175	3683

In the Fuel-Cell technologies evolution map we can identify four kinds of topics: Membranes, Fuel-Cell Technology, Fuel-Cell Components and Technology Applications. Accordingly, GAS-DIFUSSION-LAYERS-(GDL) is the most representative research theme in the period evaluated followed by ENERGY-MANAGEMENT-STRATEGY-(EMS) and FUEL-CELL-ELECTRIC-VEHICLES-(FCEV).

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CONCLUSIONS

SUMMMARY

- An amount of 14,446 documents (articles, proceedings and reviews) were retrieved from the Web of Science Core Collection.

- The corpus was divided in three period: 1968-1999, 2000-2009 and 2010-2018
- 1968-1999: 369 documents, 28,657 citations and 1,724 keywords.
- 2000-2009: 4,562 documents, 208,968 citations and 38,796 keywords.
- 2010-2018: 9,535 documents, 141,094 citations and 103,002 keywords.

- The impact achieved is summarized in the following indicators:
- Average citations per publication: 105.03
- Sum of Times Cited (without self-citations): 378,915 (312,102 -82.37%-)
- Citing articles (without self-citations): 150,558 (140,430 -93.27%-)

CONCLUSIONS

MAIN CONCLUSION
- The size of literature related to Fuel-Cell technologies research field showed a noticeable increase in the past decade (2010-2018). Given the large volume of publications and citations received in this field, it is expected that the use of these will be seen as part of other knowledge fields.
- The main themes used in the Fuel-Cell technologies literature are: PROTON-EXCHANGE-MEMBRANES-(PEMS), GAS-DIFFUSION-LAYERS-(GDL), GAS-DIFFUSION-LAYERS-(GDL), SOLID-OXIDE-FUEL-CELL-ELECTRODES, ENERGY-MANAGEMENT-STRATEGY-(EMS), COMPOSITE-MEMBRANES, GAS-DIFFUSION-ELECTRODES, FUEL-CELL-ELECTRIC-VEHICLE-(FCEV), FUEL-CELL-MEMBRANES and CATALYST-LAYER-(CL).

FUTURE WORKS
- Evaluate the evolution of the research themes across the consecutive time periods.
- Study the relationship to other industries and scientific disciplines.

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THANK YOU

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