National Research Council of Italy

A HYDROGEN-BASED TECHNOLOGIES: LIMITS AND POTENTIALS OF LIFE-CYCLE COST APPROACHES

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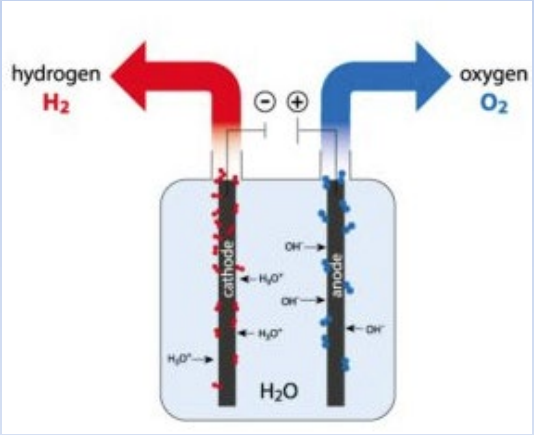
OBJECTIVE OF THE STUDY

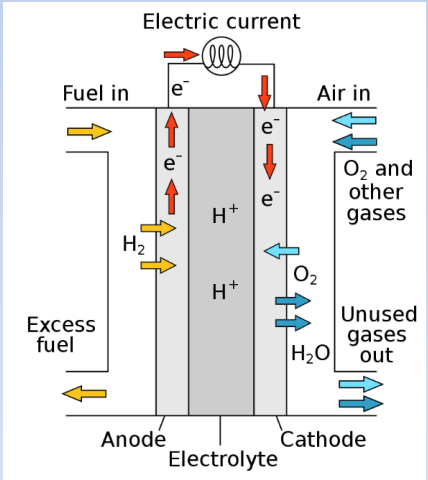
How can life-cycle cost or costing (LCC) be applied in technical-economic analyses of hydrogen technologies in this context of great dynamism and constant changes directed towards the realization of hydrogen economy?

Technologies related to the production, use and storage of hydrogen are included

ELECTROLYSERS



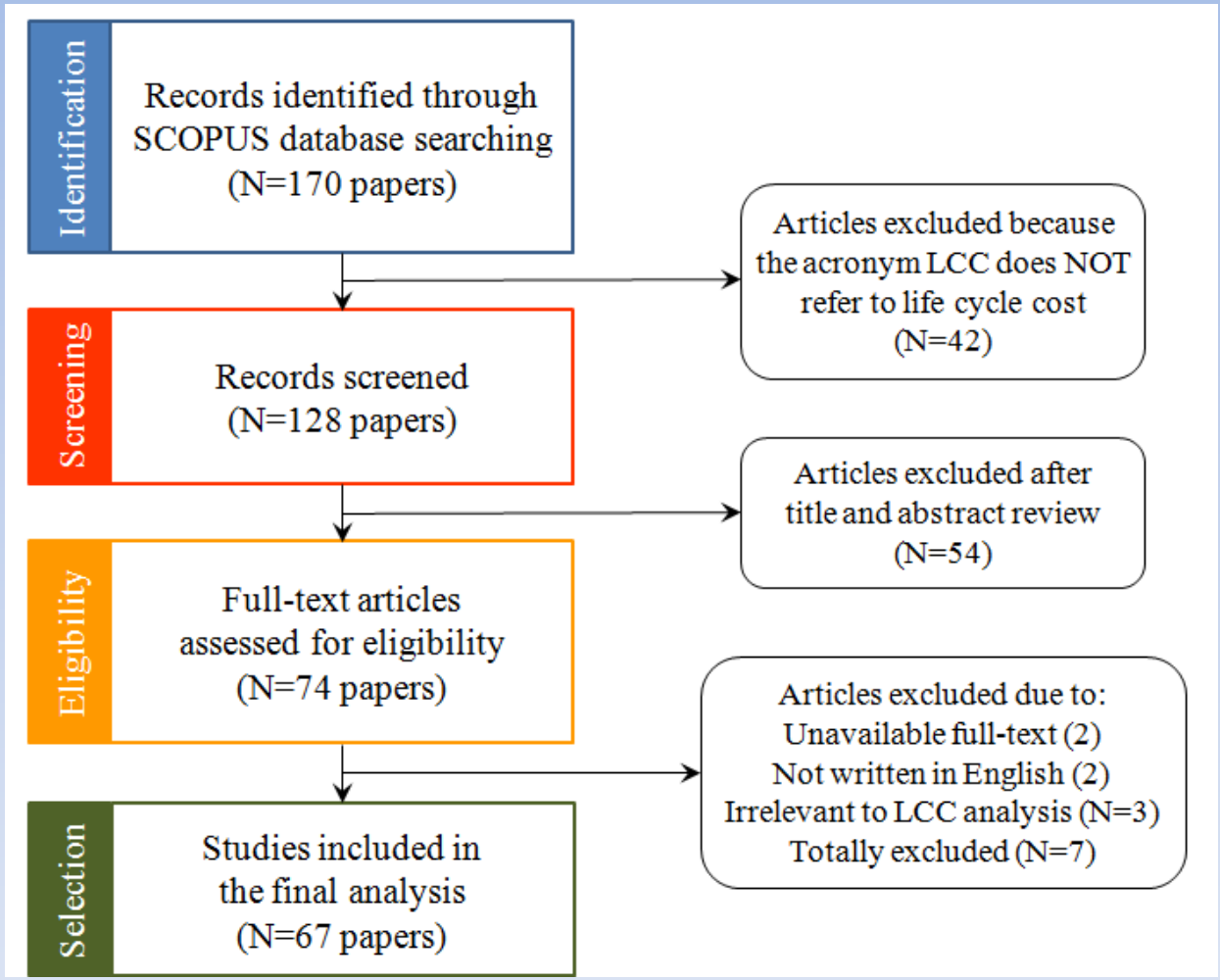
FUEL CELLS



H_2 STORAGE

"Life-cycle cost (LCC) applied to hydrogen technologies: A review",
A. NICITA, G. SQUADRITO, G. MAGGIO
***The International Journal of Life Cycle Assessment*, Vol. 29, pp. 46-79, January 2024.**

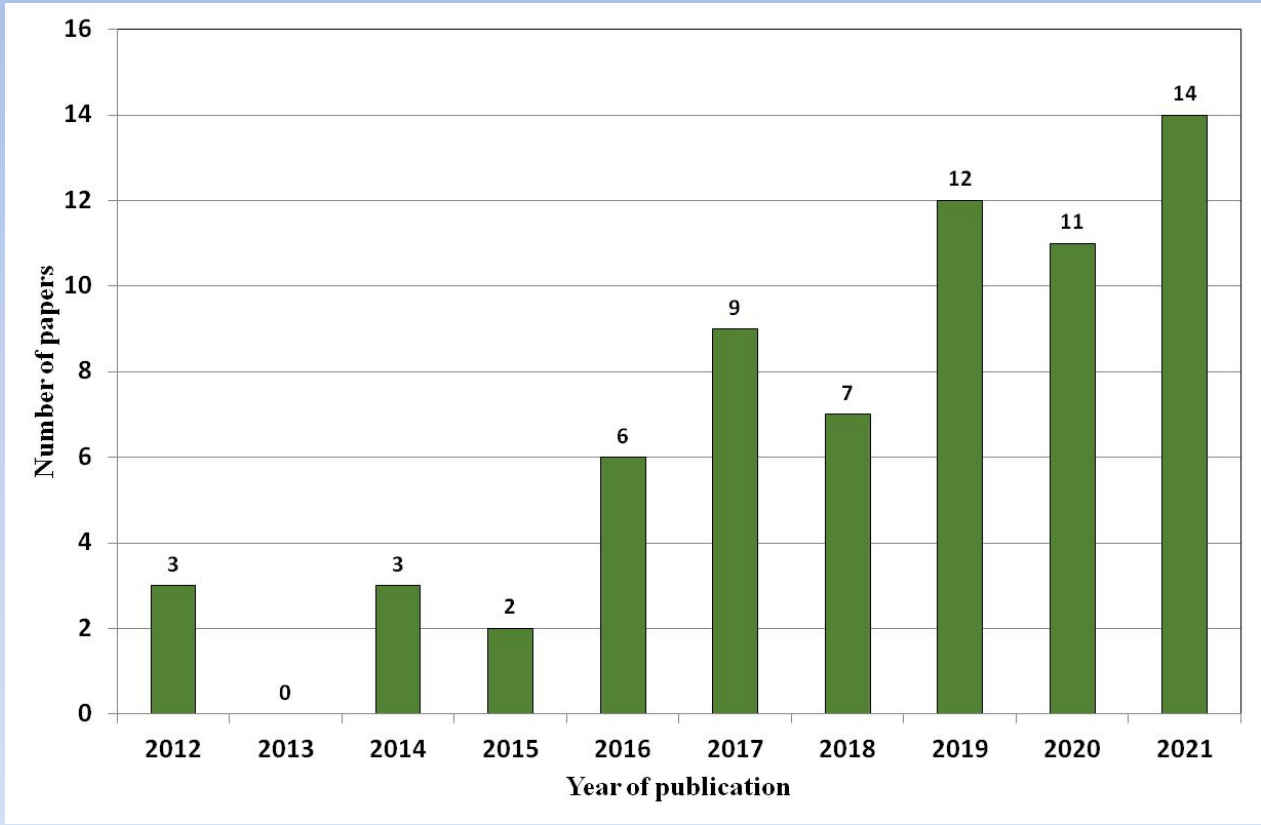
METHODOLOGY



Adopting the **SCOPUS** database we preliminarily identified **170 documents** in the period 2012-2021.

After applying inclusion/exclusion criteria, **67 papers** have been selected.

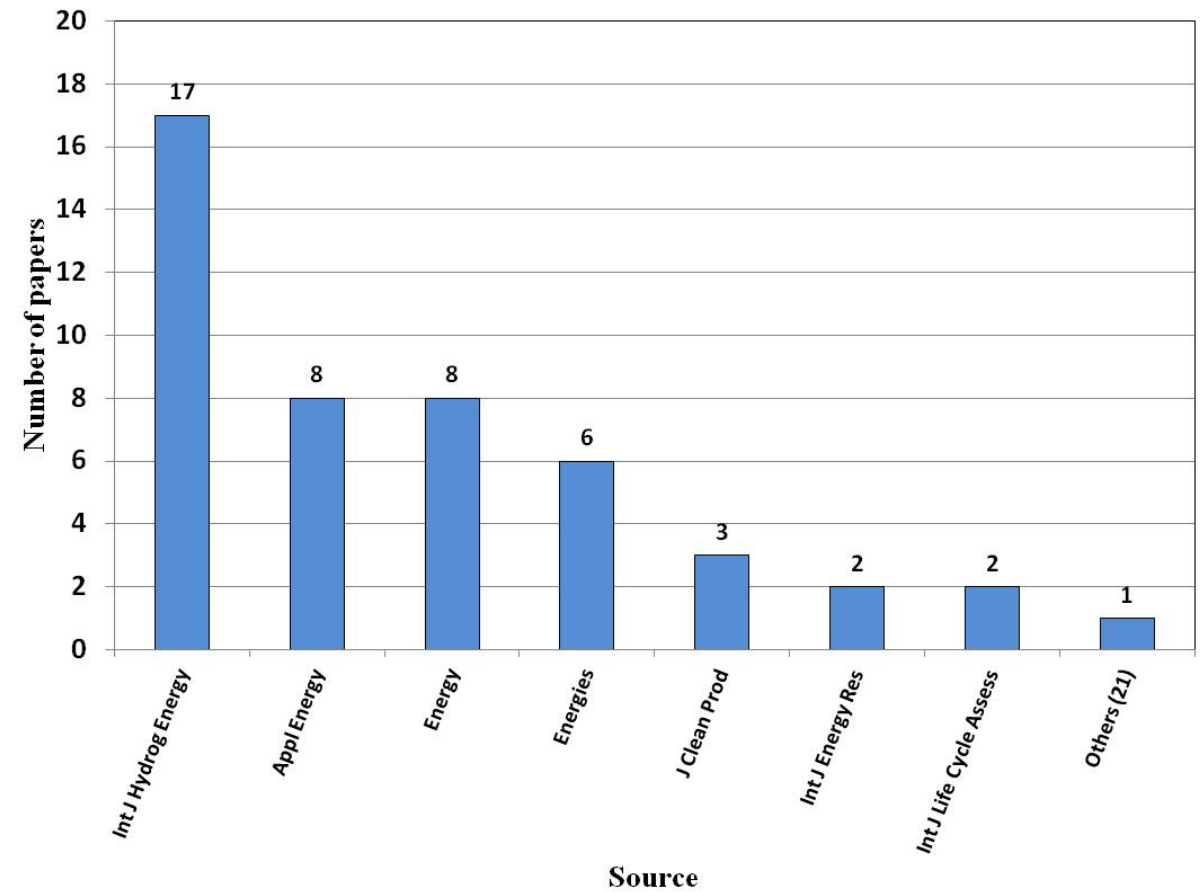
MAIN RESULTS
Number of publications by year



The **number of LCC studies** applied to hydrogen technologies **has increased** in the period examined.

A clear indication of the increasing interest in the subject

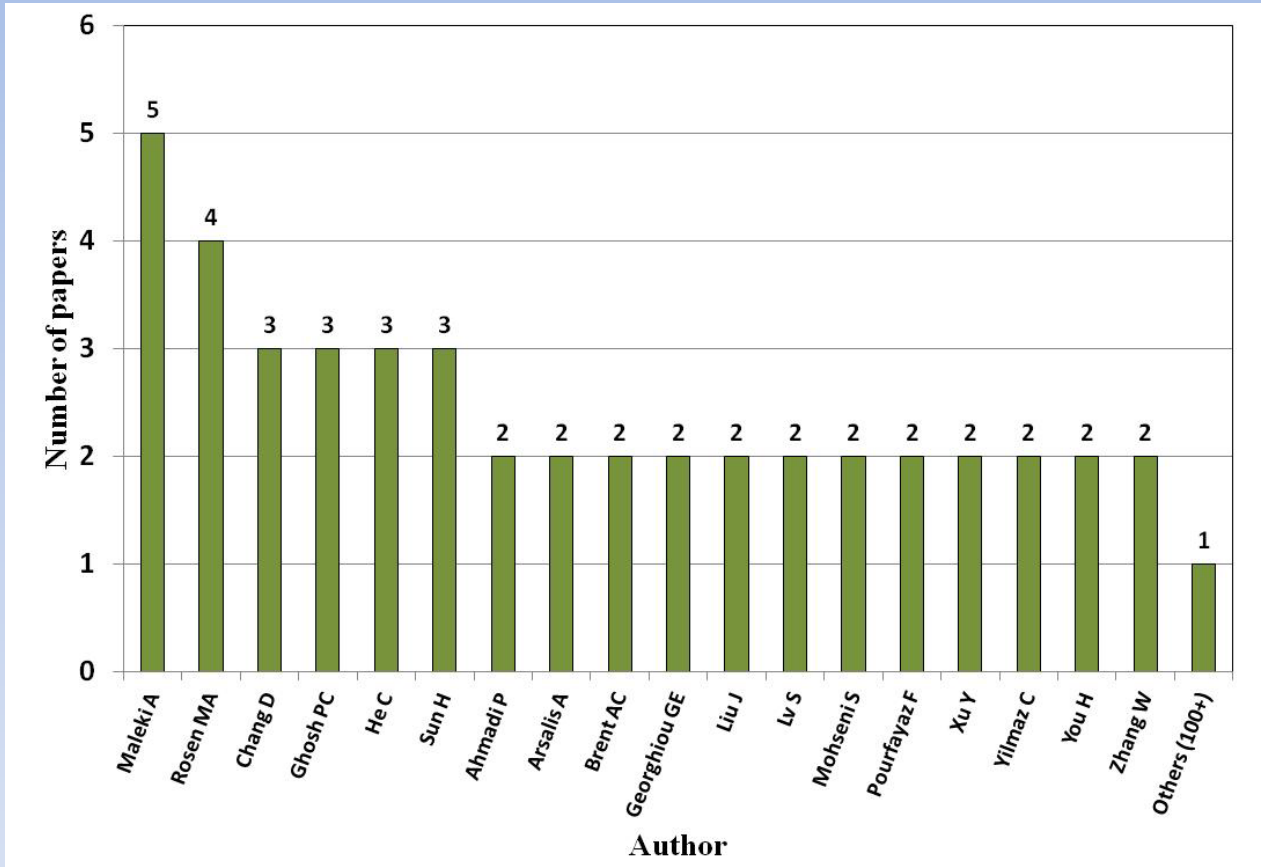
MAIN RESULTS
Number of publications by source



Int. J. Hydrogen Energy is the preferred journal (17 papers), followed by **Appl. Energy** and **Energy** (8).

Energy thematics are prevailing over the LCC ones

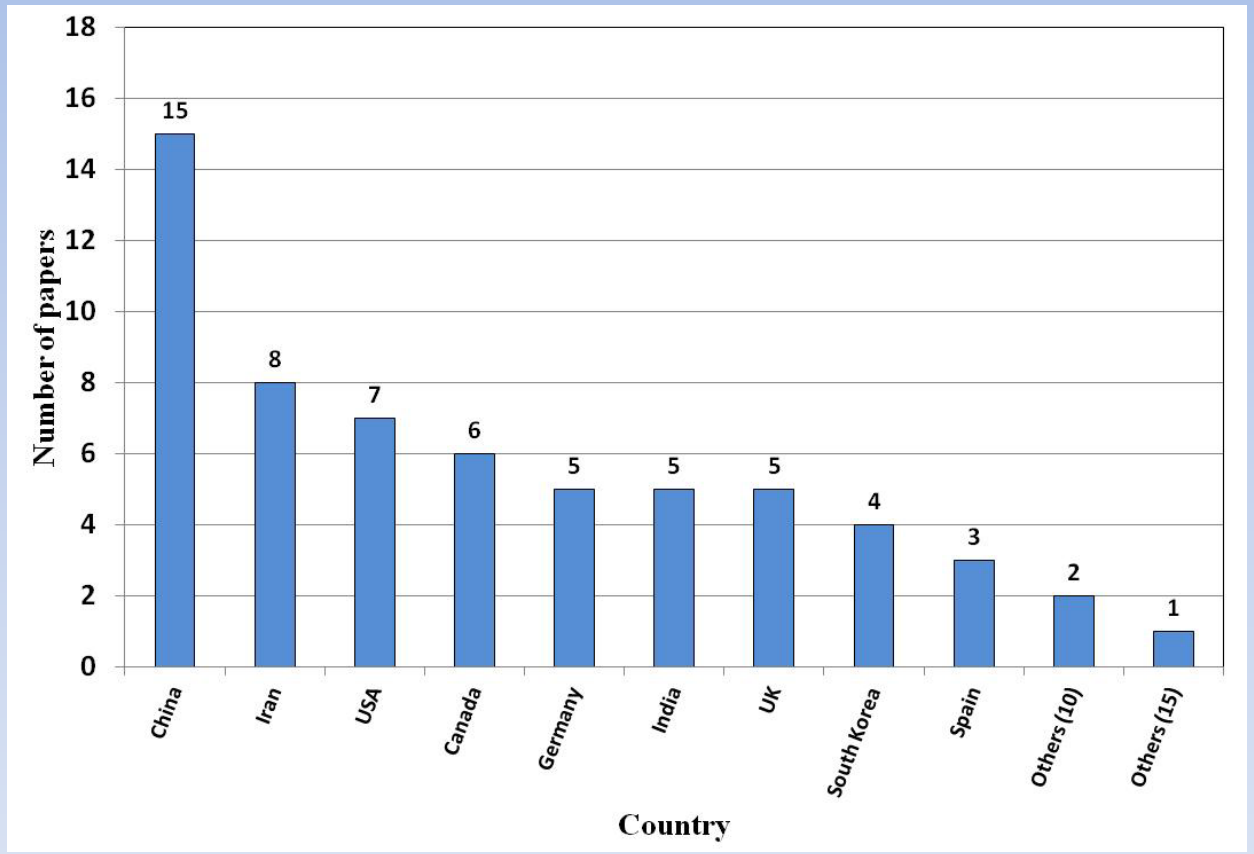
MAIN RESULTS
Number of publications by author



The most prolific author is **Akbar Maleki** (5 papers) from University of Teheran, **Iran**; followed by **Marc A. Rosen** (4) from Ontario Tech University, **Canada**.

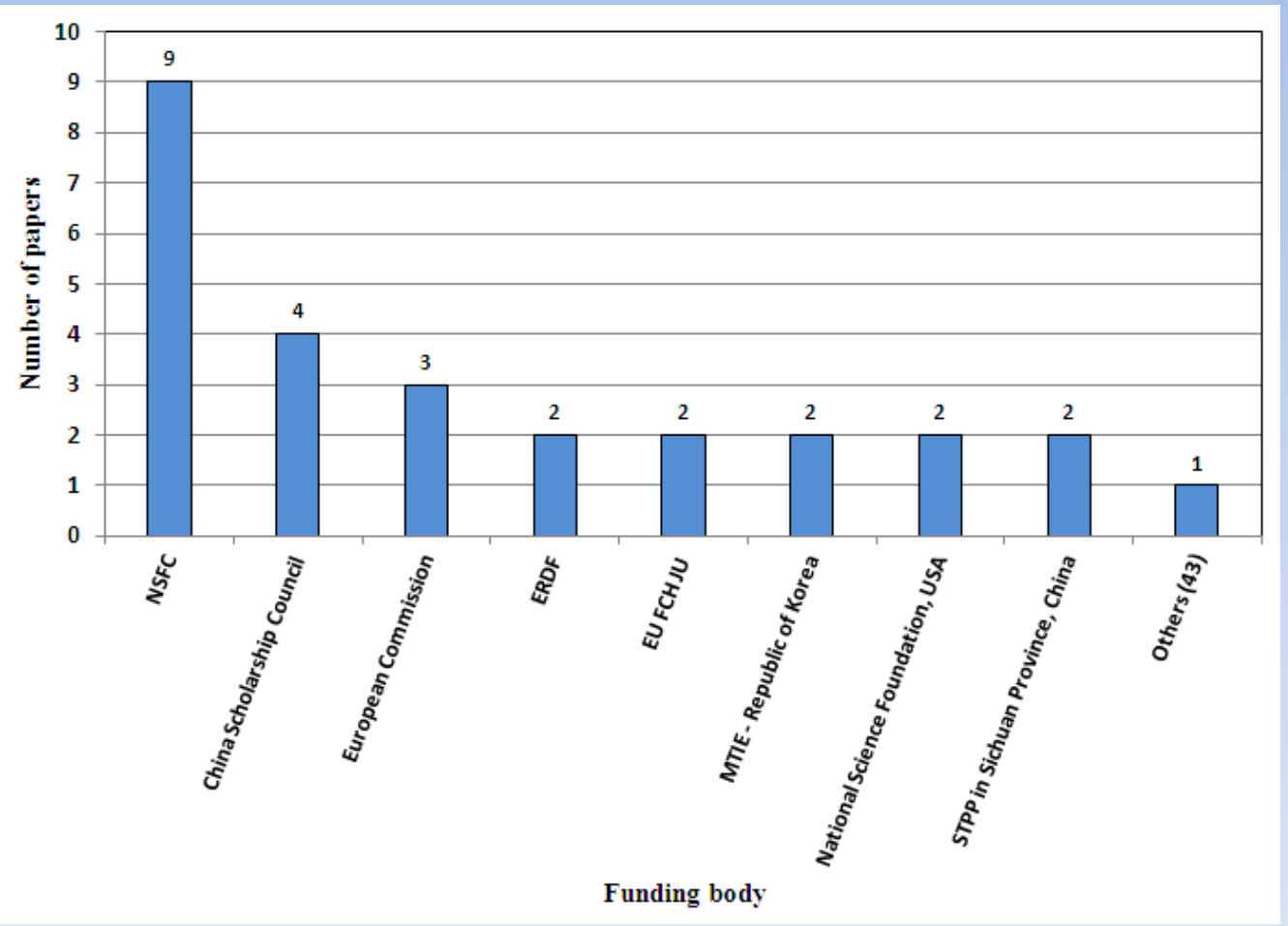
University of Teheran (6 papers) and Ontario Tech University (4) – together with Southwest Jiaotong University (SWJTU), China – are the top affiliations.

MAIN RESULTS
Number of publications by country



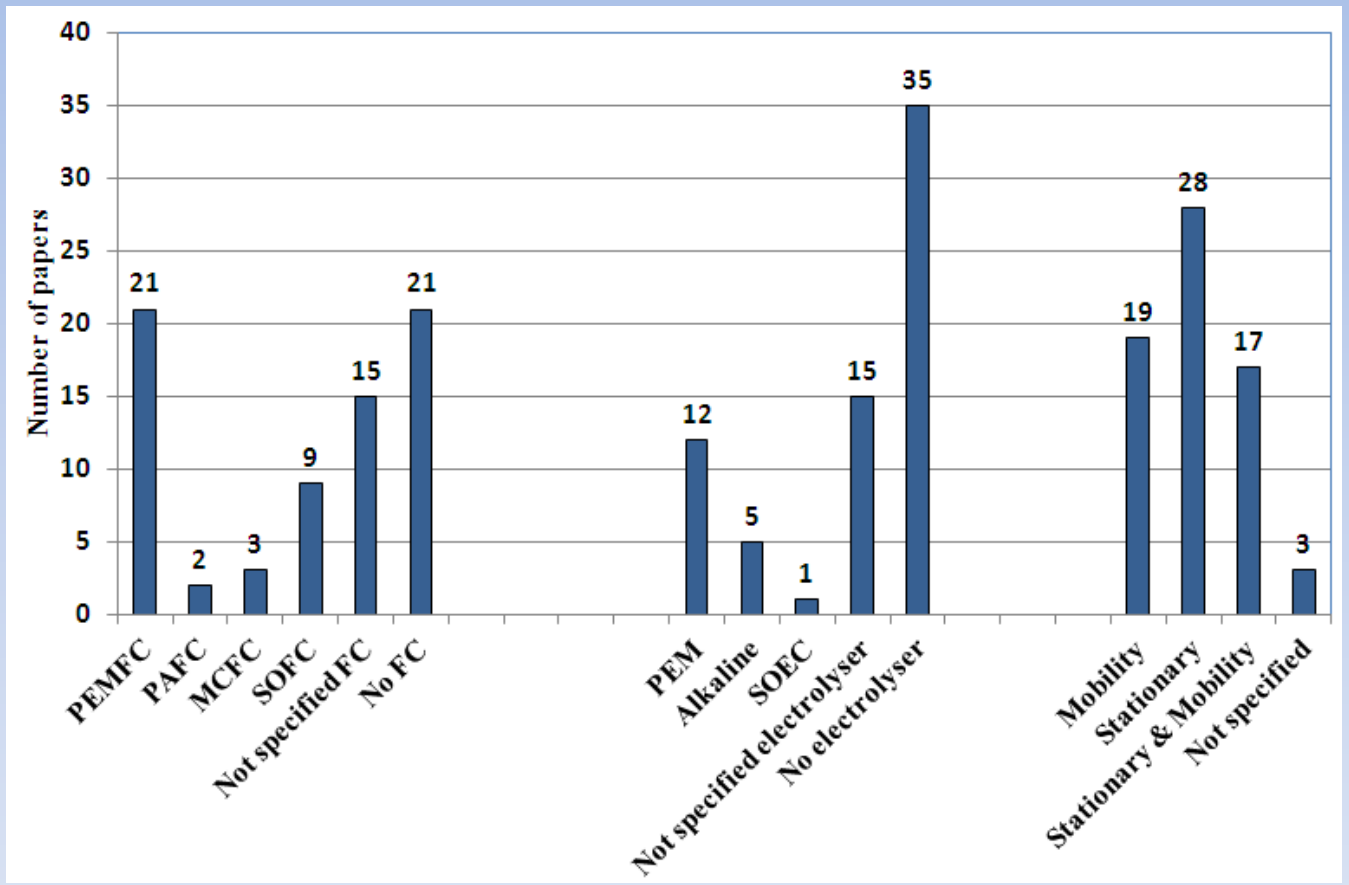
China holds the leadership for number of papers published (15), followed by Iran (8), USA (7), and Canada (6).

MAIN RESULTS
Number of publications by funding body



The two leader funders are Chinese: the National Natural Science Foundation of China (NSFC) and the China Scholarship Council, followed by 3 European institutions and other relevant organisations.

MAIN RESULTS
Technologies & type of application

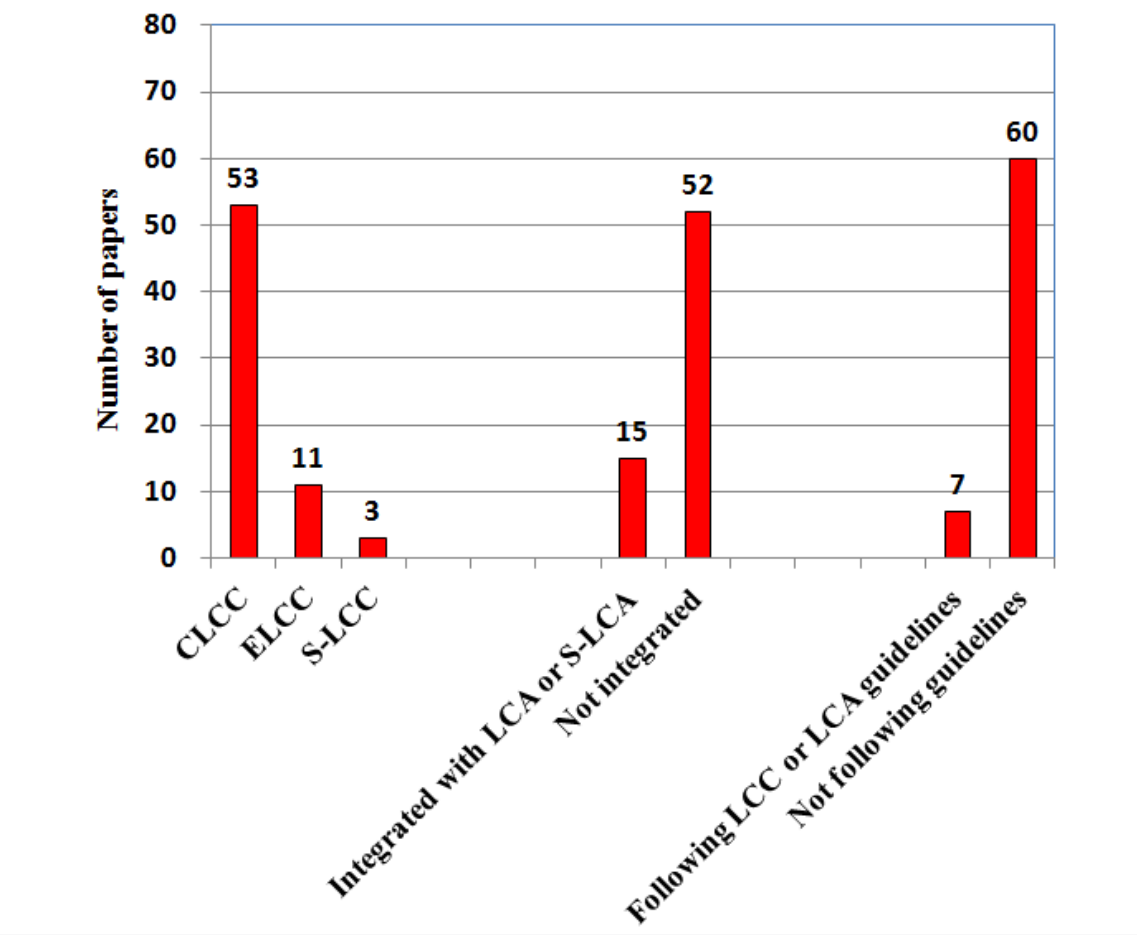


Most papers (82%) included FCs and/or ELs in the LCC analyses. The interest is mainly focused on those **based on polymer electrolyte membranes**.

Hydrogen storage (mainly compressed gas storage) is included in 51% of the selected studies; while only 27% of them included **hydrogen distribution**.

The majority of the papers (28) are oriented towards **stationary applications**.

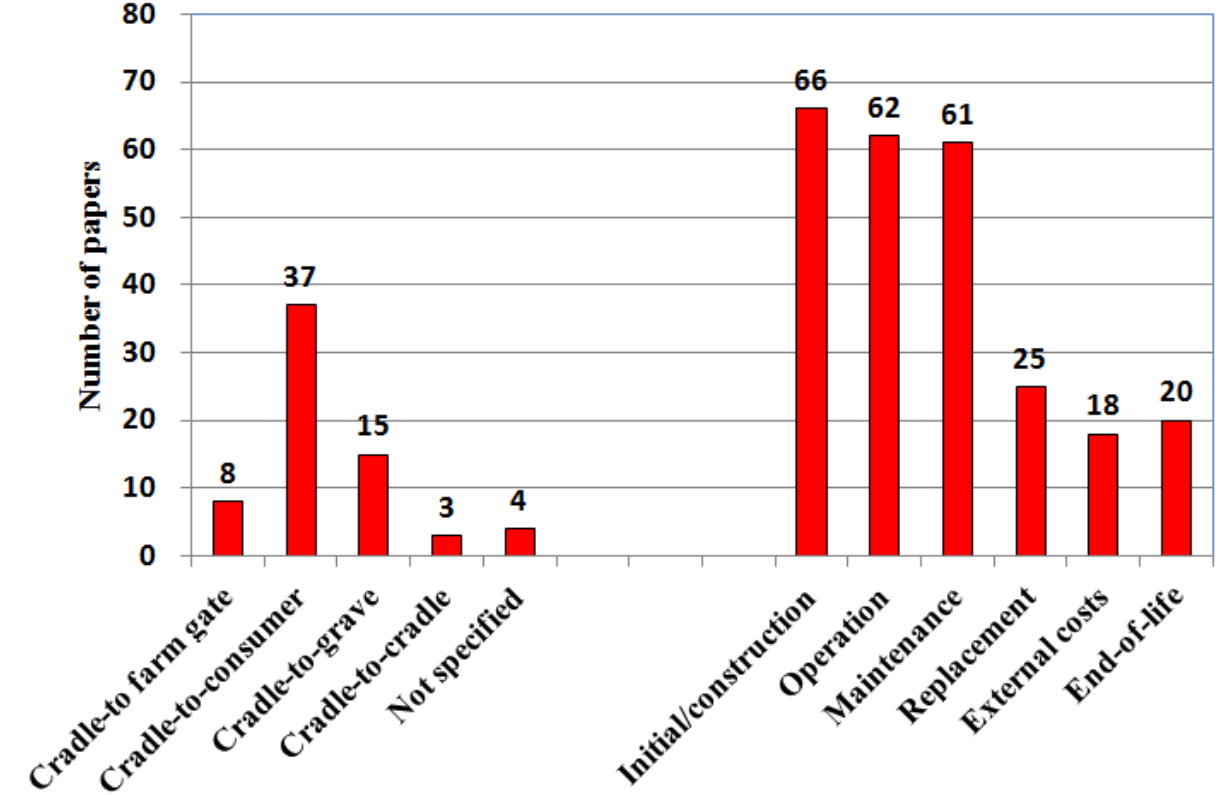
MAIN RESULTS
Characteristics of the LCC approaches



Conventional LCC is the most used approach.
15 studies **integrated LCC with LCA** (1 with S-LCA). LCC and LCA sometimes resulted in opposite conclusions (economic & environmental sustainability conflict).
A limited number of papers (7) explicitly **followed** LCC or LCA **guidelines** (e.g. ISO 14040 & ISO 14044 LCA standards)

Adoption and adherence to rigorous standards has increased over the years

MAIN RESULTS
Characteristics of the LCC approaches



The most widely used boundary approach is **cradle-to-consumer** (37 papers) followed by **cradle-to-grave** (15).
A compromise between increasing complexity of the approach and adequate description.
Almost all studies included initial, operation & maintenance costs.
Replacement costs are often disregarded; **external costs and EoL costs** are difficult to quantify.

External (environmental) costs are usually calculated by monetisation methods

OTHER FINDINGS

Lack of information on the functional unity and financial tools used

Most commonly used **functional units**:
1 kg H_2 and/or 1 kWh electricity

Most commonly used **financial metrics**:
NPV or the equivalent NPC and NPSV

Life spans range from **3 to 40 years**

The majority of the studies (25) used a **life span of 20 years**

A good **compromise** between short time horizons, that sometimes did not allow **economic benefit**, and long time periods that require evaluation of critical costs (e.g. replacement) and could make the estimates **unrealistic or not attractive**

MAIN CONCLUSIONS

A **literature review** on LCC applied to hydrogen technologies was conducted

67 relevant papers in the period **2012-2021** have been selected and analysed

Primary findings:

(i) **the number of LCC studies** applied to hydrogen technologies **has increased in the period** investigated.

(ii) **China is the leading country** for number of publications on the subject.

(iii) fuel cells and/or electrolysers **based on proton exchange membranes** are the most studied technologies.

(iv) **cradle-to-consumer** is the prevalent system boundary approach.

(v) almost all the studies included initial, operation and maintenance costs; while **other costs (replacement, external, end-of-life) are only included in a limited number of them**.

(vi) **net present value** (NPV) is the most used financial tool.

RECOMMENDATIONS

We suggest the following main **recommendations** for a more **comprehensive LCC analysis** of hydrogen technologies and to **facilitate comparison** among similar studies

Future studies should:

(i) Provide **more information on the hydrogen technologies** included in the LCC analyses.

(ii) Have greater **adherence to standard methodologies**.

(iii) Prefer the adoption of approaches covering the **whole life-cycle stages** (cradle-to-grave, or cradle-to-cradle).

(iv) Include **all cost categories**.

(v) Use **different financial tools** (NPV, IRR, PP) to complement LCC analyses.

(vi) Provide greater information and promote **uniformity on the use of functional units and financial tools**.

Thank you for your attention

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