Evaluation of Research in the Field of Energy Efficiency and MCA Methods Using Publications Databases

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Abstract—Energy is a fundamental component in sustainability, the access and use of this resource is related with economic growth, social improvements, and environmental impacts. In this sense, energy efficiency has been studied as a factor that enhances the positive impacts of energy in communities; however, the implementation of efficiency requires strong policy and strategies that usually rely on individual measures focused in independent dimensions. In this paper, the problem of energy efficiency as a multi-objective problem is studied, using scientometric analysis to discover trends and patterns that allow to identify the main variables and study approximations related with a further development of models to integrate energy efficiency and MCA into policy making for small communities.

Keywords—Energy efficiency, MCA, Scientometrics, trends.

I. INTRODUCTION

ENERGY is a fundamental factor in development. From an economic point of view, the use is closely related with the industrialization stage of the society, becoming energy an input not only for production but also a relevant variable in the observation of consumption patterns in society [1]. At this point, the energy demand changes according with the patterns of economic growth, production and lifestyle changes related with the levels of development in communities [2] where evidence shows that advanced industrialized societies tend to use more energy per unit of economic output and far more energy per capita than poorer societies, especially those still in a preindustrial state. [3].

II. METHOD

The main goals in this study covers:
- Analysis of trends and structure of Multi-Criteria Analysis (MCA) and Multi-Objective Decision making (MODM) applied to energy efficiency issues and its potential for policy and decision making applications in small communities
- Framework design of MCA applied to energy efficiency policy making
- Case study application

The designed methodology to cover these subjects is shown in Fig. 1. It must be noted, in this document, the results show the application of stages 1 to 3.

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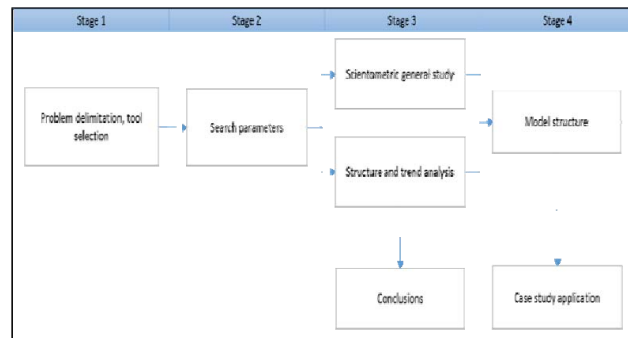
Fig. 1 Method applied in the study

A. Stage 1: Problem Delimitation

In the beginning of this project, the problem of energy efficiency planning and policy making was intended to be applied using strategic forecasting method in order to structure scenarios for small communities.

In the theoretical research, it was possible to identify the potential of MCA to cover the intention of policy making and evaluation of alternatives in the desired field.

Energy efficiency planning and policy making is a multi-objective problem [4] so for the study of this subject the main concerns recognized were:
- Identify the main trends and applications of MCA into the energy efficiency studies
- Identify general structure and dimensions involved in the application of MCA to Energy Efficiency.

To do so, the application of scientometric analysis to the field of interest (In this case: Energy efficiency and MCA) will provide knowledge about the structure and trends in the domain, according with the main concerns of the study.

B. Stage 2: Search Parameters

In order to conduct a scientometric study of MCA & EE, the search was designed to be done using Scopus as reference source due to its wide range of publications covered [5].

In order to recover the most accurate information, in this stage the principal activity was the design and test of the research algorithm that allows to get the bigger quantity of documents related with the study.

The delimitation of the search parameters includes:
- Time coverage: For the study of structure and evolution, no time delimitation was applied, however, in the 3rd stage, for the maps application (see stage 3) the time coverage was delimited to the last 5 years of production.

- Source limitation: The search was not limited by source type, in order to cover all publications related with the field of study
- In general, the search must include MCA and MODM methods applied to energy efficiency, there was no limitation about the sources (Journals) but the main concern was all papers must be related with EE applications

With these criteria, the search algorithm designed included the following keywords, and allowed to identify a total amount of 1274 documents for the analysis:

- energy efficiency, saving and management
- multicriteria, multi-criteria or multi criteria
- multiobjective, multi-objective or multi objective

C. Stage 3: Scientometric study

This stage includes two phases, the scientometric study to identify and co-word analysis to evaluate with statistical tools the structure and trends of the current research [6].

For the first phase, all documents obtained were analyzed, in order to have a general view of the research in MCA and EE over time. The variables studied were:
- Time evolution of production
- Geographic, institutional and author profiles

For the second phase, statistical analysis (Component analysis) was applied using NTsys software to get a graphical view of the structure of the research [6], [7].

D. Stage 4: Model and Case Study

Despite stage 4 is not covered in this document, the main objective is to develop a model based in the conclusion of stage 3, so, the conclusions part of this paper, will show the interaction of results and further developments.

The application of scientometric analysis to the field of interest (In this case: Energy efficiency and MCA) will provide knowledge about the structure and trends in the domain, according with the main concerns of the study.

III. RESULTS

The search allowed to identify 1274 results. Fig. 2 shows the distribution of the documents according with the type of publication.
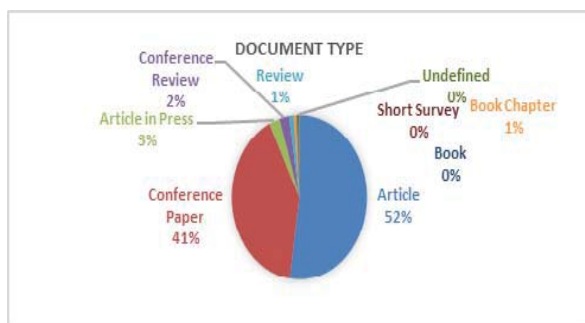

Fig. 2 Document type

In the next sections, the main results in the scientometric analysis will be shown.

The count of publications over time shows the evolution and status of the scientific activity in a field [8] and the study of the patterns of the production in time allows to identify not only the growing status of a research field, but also the maturity level of it, according with Price´s law. In this case, in the relationship between Energy Efficiency and MCA, Fig. 3 shows the evolution of the field from 1978 where the first document was found. The figure also shows an extra curve that represents a search intended to find only the relationship between "Energy" and MCA, excluding efficiency factors (6319 documents found).
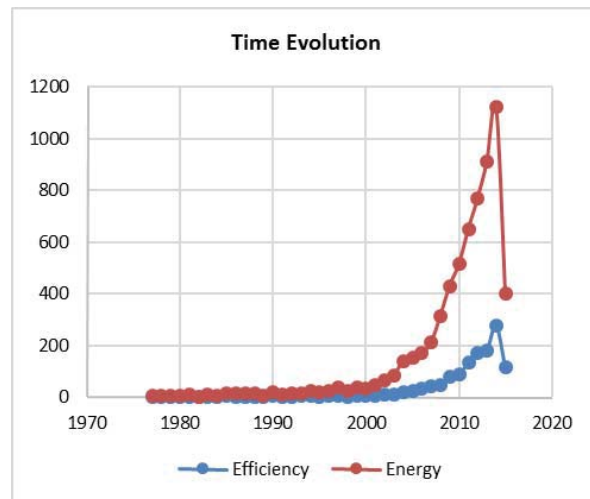

Fig. 3 Time evolution

According to Price law, and comparing the two curves obtained, Energy studies and MCA can be called a mature field (stage 2) showing that in this specific case, the use of MCA methods in energy studies has proved their value and applicability. Efficiency started its own development since 1978 in energy management across power distribution networks, and since that year, the evolution has not been as rapidly as energy studies, showing that in the combination of Energy efficiency and MCA, the field is in stage 1 (growing) but with a trend that shows it is close to reach maturity. Other applications developed during the evolution of studies in MCA and energy efficiency include: Energy use in agriculture, building design, sustainability issues in systems design and applications.

In policy making, that is a field of interest in this study, 16 documents were found, with applications of policy evaluation, planning and scenario studies, mainly related with climate change, where efficiency is one of the dimensions of measures and strategies.

The documents obtained have a total of 8438 citations (No endogenous citation analysis was done). Table I shows that China concentrate approximately 23% of the production, where the main subjects include (but not only) policy evaluation, case studies, bioenergy transition, local-level applications and sustainability assessment of energy related problems. First 10 countries in total represent 71.09% of the

research.

TABLE I
COUNTRY LEADERS

Country	No. Docs	Percentage
China	294	23,08%
United States	141	11,07%
Italy	85	6,67%
United Kingdom	69	5,42%
France	67	5,26%
Spain	54	4,24%
Iran	54	4,24%
Germany	51	4,00%
India	51	4,00%
Canada	50	3,92%

At institutional level, the first 10 institutions represent close the 12% of the total production; is interesting to notice how for example the Ecole Polytechnique Federale de Lausanne with 26 documents concentrate almost 50% of the total production of Canada (one of the top 10 countries) however, Switzerland is not listed in the top 10. The other universities listed, also show research groups in Brazil, Poland and Iran, showing that in their countries.

The areas of study represent what knowledge and research disciplines are involved in the evolution of the field "Engineering" represents 34% of the participation, which suggest a strong relationship in the study and development of applications in energy using MCA. Environmental sciences with 10% also suggest that these studies have a strong component on research and development intended to find solutions to climate change challenges.

TABLE II
INSTITUTION LEADERS

Institution	No. Docs
Ecole Polytechnique Federale de Lausanne	26
North China Electric Power University	21
Tsinghua University	19
Harbin Institute of Technology	15
Ethniko Metsovio Polytechnico	14
Universidade de Coimbra	14
University of Tehran	12
Shanghai Jiaotong University	12
Tongji University	12
Southeast University	11

In order to establish the structure and content in the documents analyzed, every paper retrieved was classified into one category, to identify the distribution of issues and main applications in the study.

Fig. 4 shows the results obtained.

In this search, computer and networks is the issue with more applications, the subjects studied in this area include wireless networks, cloud computing and server configurations, showing a special orientation in the use of MCA methods to evaluate and improve the energy efficiency, the quality of service and the configuration design of devices and solutions in computer sciences. Other areas are Power systems, Vehicles

and transportation, industry and production system analysis, renewable energy and Buildings, which cover 60% of the total production during the time of study.
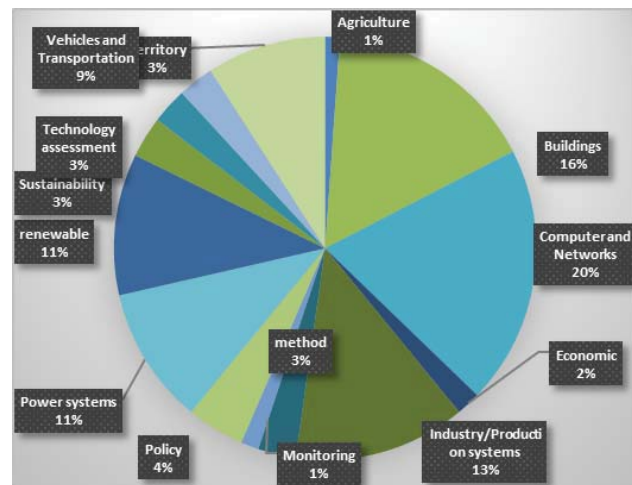

Fig. 4 Areas of application

The general structure of the documents, obtained with the application of NJOIN analysis using NTSYS software. In order to evaluate this problem, 169 words were analyzed (The most common words from 990 documents) identifying the next four clusters:

- Methods and models for the optimization of efficiency in systems
- Consideration of environmental and economic variables in the study, evaluation and improvement of energetic systems
- Application of MCA and MODM methods in power plants, energy production and logistics
- Evaluation of alternatives for decision making

IV. CONCLUSIONS

Time evolution shows that the use of MCA methods applied to energy and energy efficiency is a research field in stages of maturity and growing, where the applications include the search for solutions in problems like energy planning, energy consumption reduction in industry, transport and buildings, development of models and methods to decision making in policy applications, between other subjects.

Research application in Energy efficiency and MCA includes uses in planning, agriculture, building, sustainability issues, product design, industrial applications and other fields. The closes relationship is in the subject of buildings, where the research shows studies intended to improve energy usage and saving in old buildings and develop methods and knowledge for the applications in new constructions.

In the field of policy making, energy efficiency has not been studied directly in relationship with MCA methods, and is more intended to be part of the variables analyzed in the planning of policies related with climate change mitigation.

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