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**Project Title:** A Future Study of Nanotechnology Application in Fuel cells and Hydrogen Technologies Development

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### Project Necessity:

Amongst different types of renewable energy, hydrogen and fuel cells technology can be coupled with other renewable energies like solar and biomass to produce clean and renewable energy. Hydrogen produce water when burning and therefore is the best candidate to substitute gasoline. Developed countries such as U.S, European countries, and Japan have a program plan to substitute hydrogen base fuel with fossil fuels by 2050. Therefore, European countries decided to invest 1.3 B\$ and DOE (U.S) put more than 120 M\$ in 2016 in hydrogen and fuelcells R&D to reach the aim by 2050. In 2014 more than 180 MW of electricity were supplied by fuel cells and the forecast for 2023 is more than 20000 MW, which shows a huge growth in this technology.

On the other hand, emerging nanotechnology in engineering fields leads to a much more rapid growth. For instance, nanomaterials increased the efficiency of the hydrogen storage in comparison with conventional materials. Nanotechnology has some advantages in hydrogen and fuel cells; however, the questions and challenges in this technology needs to be carefully considered in detail for future investments and directions. The developing and developed countries find out this necessity and they are working on these subjects for more than a decade. In Iran also there are some regulations and upstream documents, although, the trend of these works and funding need revision. This project focuses on these challenges and futures study of nanotechnology application in hydrogen and fuel cells to investigate the most probable futures or the sections of this field, which would be most influential by the nanotechnology.

### Project Goals:

In this project the main objective is to determine the trend of nanotechnology research in Fuel cell and hydrogen. The detailed aims are as follow:

- Determining the nanotechnology fields in hydrogen and fuel cells;
- Investigating the future of the nanotechnology in hydrogen and fuel cells and a value chain with higher efficiency;
- Planning of investment methods and sections for reducing the financial risks for hydrogen and fuel cells futures
- Distinguishing potential of nanotechnology application in fuel cell and hydrogen in Iran

### **Abstract:**

In this project the main goal was to determine the trend of nanotechnology applications in different types of production and storage of hydrogen and fuel cells regarding future study methodologies. First, different types of hydrogen production and storage were studied. Besides, different types of fuel cells from the aspect of advantages, disadvantages and performance were investigated. Afterward, comparative research were performed and road maps of developed countries and action plans were presented by details. On the other hand, upstream documents in Iran were evaluated regarding other countries road map and action plans. The results revealed that in developed countries, the hydrogen and fuel cells are growing fast and nanotechnology has been applied to grow these technologies. In the next step the bottlenecks of nanotechnology development in fuel cell and hydrogen technology were investigated and some solutions to these hurdles were presented.

Finally, technology frameworks and indexes were determined and for better understanding of research trends, recent papers in these field were evaluated. For instance, the result of solid oxide fuel cells (SOFCs) study revealed that there is no preference for nanotechnology appliance in different parts of SOFCs and these parts have all the same chance for improvement in future.

### **Steps and Methodologies:**

In this study first different types of production and storage of hydrogen and fuel cells were determined. Afterward, upstream documents and road maps of developing countries were studied to find out preferred technologies for further investigation. To reach this goal, challenges of nanotechnology usage in fuel cell and hydrogen were evaluated by observing different research articles, technical reports and other related documents. Finally, the Scopus were chosen for searching recent years' paper on these technologies with different approach as for researchers, countries, journals, institution etc. These results were plotted using VOSviewer and the selected researchers and trend of their work were presented.

### **Main Results (technical outputs, patents, papers, books, reports, etc.):**

As it was mentioned, using comparative researches and road maps of different countries, the trend of fuel cell and hydrogen technologies were presented. Moreover, the challenges and bottlenecks for introducing nanotechnologies in fuel cell and hydrogen were demonstrated and some solution were presented. Finally, technology frameworks were determined and for better understanding of research trends, the research papers in recent years were evaluated and categorized in different way such as researchers, countries etc. separately.

In addition to these results and technical reports, two scientific papers has been submitted to a conference and another one will be sent to international journals.