Research Grants for PhD students from China Scholarship Council

Design, optimization and scalability of the hydrogen supply chain

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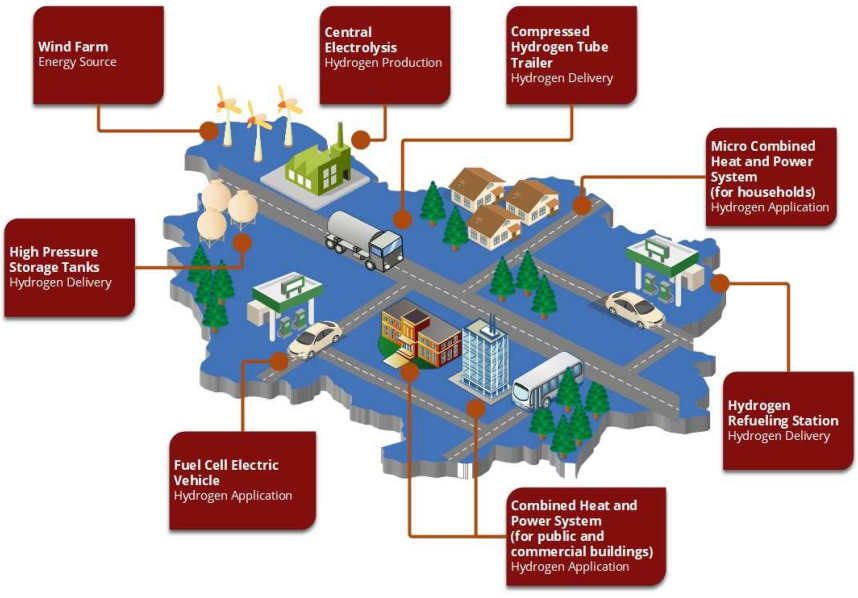
Research environment:

In the axis Transport and Mobility of the OMNI team, the proposed topic fits into the Logistics field. In this area, we are working particularly in Operations Research, around exact methods, metaheuristics and multi-objective optimization for transport integration in the supply chain, at various levels.

Context

Today, hydrogen is a promising energy carrier in a context of sustainable development. It begins to be used as energy storage for photovoltaic energy, as fuel for forklifts, light vehicles and locomotives, as heating energy ... But the development of a market for hydrogen energy involves the deployment of the infrastructure for the production, storage, transport and distribution of hydrogen. The proposed thesis is concerned with the design of the hydrogen supply chain, from production to distribution. It will follow a first PhD thesis work in which we have applied a mono-objective optimization approach. Indeed, in a sustainable context, it is essential to measure the impact of the global chain on the environment. But to ensure the full development of the hydrogen option, it is also important to control the costs of the global supply chain, in order to ensure such a competitive price compared to other energy sources.
The design of this supply chain (also known as facility location problem) is relatively complex in the considered context. Indeed, hydrogen can be produced from diverse primary energy sources, such as hydrocarbons, wind, biomass, water, or solar energy…The hydrogen can be transported in gas or liquid form at different pressures, which requires pressurizing and liquefaction units. Then, to ensure good service quality, it is necessary to locate storage and distribution units as near as possible from customers. So, the hydrogen supply chain (HSC) is a network of integrated facilities, i.e. nodes which are mutually connected and which interact in a specific way. These nodes include: (1) sources of energy, (2) production technologies, (3) storage facilities, (4) transportation modes, and (5) dispensing (fueling) stations. To design such a network, there are many design and operational decisions to make. These ones include: (1) the number, location, size, and capacity of hydrogen production and storage facilities, (2) the necessary transportation links for establishing the network, (3) the flow rates of hydrogen and energy sources, and (4) the production rates and the average inventory of materials.



Moreover, a further difficulty of this work is to locate and quantify the customer demands. Indeed, as the hydrogen sector is booming, it is impossible to rely on past data which cannot be collected. It is therefore essential to make predictions in the form of different deployment scenarios.
Our goal is to overcome some scientific and practical locks identified in the optimization models and algorithms in the literature. Indeed, most of the existing studies do not consider the entire supply chain and the associated challenges. For example, previous papers do not consider the location and the types of hydrogen fueling stations which impact on the flow capture rate. It is the same for the way the demand is considered in the models…Our innovative and comprehensive HSC network design methodology has been deduced from a deep analysis of the literature and it results from the conclusions of this state of the art. These ones can be found through the link given in reference [4].

Objectives/ Expected contributions

In a previous PhD thesis work, we have first developed a Mixed Integer Linear Programming model of HSC. The MILP model was tested on a given region of a country. Now scaling up this model is essential to enable it to address the problem merging several regions considered as components of a grid, where the grid may cover a whole country. It will request the elaboration of new deployment scenarios along several periods, and new optimization algorithms to simulate them. These algorithms will be based on approached method (metaheuristics), all the more as the problem involves a multi-criteria approach where at least three objectives have to be optimized simultaneously, i.e. the cost, the service quality and the environmental impact. Solutions to be searched consist in a Pareto front, corresponding to various design strategies in the associated variable space. Multiple choices decision making analysis will be selected to find the best compromise.
This work clearly featured within a sustainable context. But in all the solutions obtained, to propose the best solution, it is necessary to develop tools for multi-criteria decision. Another part of the work would be to develop a demonstrator with the adequate interface in which the various optimization algorithms will be implemented, coupled with a simulator with varying parameters, ensuring a visualization of the problem and the results, in order to facilitate the final decision making.
This work could be particularly valued by projects with territories wishing to develop their use of renewable energies and make optimal gain.

Skills and job profile

A solid foundation in algorithms and combinatorial optimization are needed (operations research methods). Some past practice of solvers like Cplex, Gurobi …would be appreciated.
Serious programming skills are essential. In particular, good practice of object-oriented language like C^{++} would be much appreciated, as well as a strong background in logistics.

Keywords:

Supply chain, hydrogen, scalability, operations research, multi-objective optimization, multi-criteria decision.

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