# RS and GIS Application for the Alternative Scenarios and Regions for Hydrogen Exploration

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*Abstract*: The Central Asian (CA) region is one of the regions most impacted by climate change and water shortages in the world. Some programs require the proper investigations, before implementation stage. Kazakhstan plans to use water from the Caspian Lake to produce and export hydrogen. As a part of the HYRASIA ONE cooperation program, Kazakhstan plans to construct a major "green" hydrogen production facility. This facility will be one of the largest in the world, and will desalinate water drawn from the Caspian Lake, which is in the Mangistau Region. The Caspian Lake is already shrinking, feeding concerns that it will have the same fate as the Aral Lake. As of now, proper scientific investigation that accounts for alternative scenarios and includes hydrogen producing regions is missing. In the transboundary Moselle-Saar River basin, a former coal mining district, researchers found significant reserves of "white" hydrogen, totalling up to 250 million tons. Like the previously mentioned regions, Central Asia is very rich with mineral resources, including iron-rich, uranium minerals, which produce hydrogen through serpentinization and radiolysis from underground water. Researching water replenishment in Central Asia, including carrying out precipitation analysis and hydrological data collection, is critical to understanding the situation. This paper will address the current effort to apply RS and GIS for alternative scenarios and exploring potentially hydrogen rich regions.

*Keywords*: geological hydrogen; Kazakhstan; Moselle-Saar; green hydrogen.

## 1 Introduction

In 2023, Kazakhstan faced severe droughts, which were then followed by devastating floods in 2024. Other impacts of climate change include changes in precipitation patterns, more frequent temperature extremes. These changes have a negative impact on Kazakhstan's agricultural production. This then threatens Kazakhstan's food and environmental security (UNECE 2023). To mitigate climate change and other challenges that impact water resources, many countries invest in foresight adaption programs, sustainable engineering for emergency events, and plans on how to deal with more frequent floods and droughts in advance (Millennium 2023). In the past, man-made intensive agricultural activities diminished the soil sustainability, increasing desertification (Hassani et al. 2021). Foresight research works are getting important, with some organisations starting to support such efforts. In Kazakhstan, challenges facing the study of water resources include weak scientific support for professional project management of water resources with a scientifically based financial forecast of expenses, and the lack of cooperation among ministries (emergency agencies, water, agriculture, internal affairs) and industry. For example, Kazakhstan is targeted to continue the industrial water extraction from the Caspian Lake to produce hydrogen and export through HYRASIA ONE project, along with continuing current intensive oil and gas extraction from the Caspian Lake area (UN 2023). Namibia has a project like Kazakhstan's Mangistau hydrogen program (DW 2023). It will be reasonable to adapt, review more comparison studies, how similar projects are in development, what issues they may cause. The challenge in executing Kazakhstan's HYRASIA ONE project stems from issues regarding water resource availability and the high electricity costs in the West Kazakhstan. It would be prudent to explore alternative solutions that are cost-effective and environmentally friendly, thus avoiding any adverse impact on nature.

## 2 Materials and methods

The research group employs a comparative-descriptive methodology to analyse more sustainable regions and alternative technologies for hydrogen exploration. This involves synthesising insights from literature reviews and collaborative brainstorming sessions among research groups. This allows the research group to identify the alternatives solutions for further investigation (Figure 1).

Research questions: 1) Is it sustainable to expand the HYRASIA ONE project in the Caspian Lake area? How can this project disrupt the Caspian Lake?; 2) Are there alternative regions and technologies for hydrogen explorations in Kazakhstan?; 3) What would be reasonable measures to adopt for more sustainable hydrogen exploration programs?

It is important to investigate Kazakhstan's hydrogen production plan for sustainability. This will require proper scientific investigations, surveys taken among the local people, and support from the Mangistau Region's inhabitants. Hydrogen production in the Caspian region will require much effort with approvals. At the same time, it will be reasonable to prepare alternative, more sustainable scenarios, where it will be reasonable to

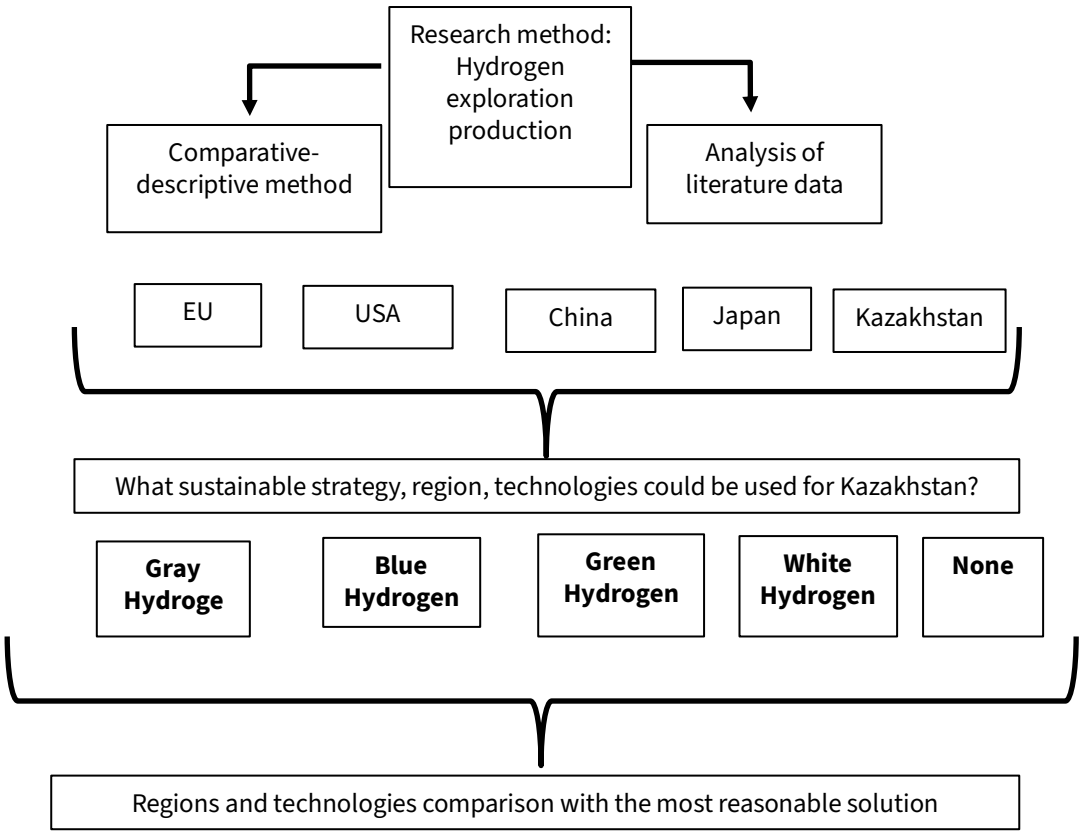


*Figure 1. Block diagram of research methods for sustainable hydrogen.*

produce hydrogen without harming the environment. Moreover, the HYRASIA ONE project is solely designed to export hydrogen, without developing Kazakhstan's internal usage.

## 3 Results

Most countries are targeted to set up their own internal hydrogen hubs with intensive investment hydrogen research programs. An extensive examination of patents associated with hydrogen production was conducted spanning the years 2018 to 2023. This analysis utilised the Derwent World Patents Index (DWPI) from Web of Science, Clarivate Analytics (Derwent 2023). An examination of the International Patent Classification (IPC) codes indicates that electrolysis has emerged as the predominant method for hydrogen production, with a total of 611 patents published over the span of 10 years (IPC 2023). This surpasses other methods such as thermal decomposition and photolysis, which collectively garnered 464 patents during the same period. The USA is intensively supporting the scientific work of academic researchers in cooperation with the Hydrogen Hubs Industry, increasing publications and patents on hydrogen. This is to develop their domestic market for the use of hydrogen, including for use by agricultural corporations, in irrigation, and for transport (Gonzalez 2023). China is recognized as the world leader in hydrogen production with a production of 33 million tons of hydrogen per year, which is 1/3 of world production. Production occurs primarily in oil or coal-fired units of oil refineries or chemical plants. It is still cheaper to produce hydrogen using coal than through electrolysis of natural gas or water, costing around 0.7–1.2 Chinese Yuan (CNY) (US$0.1–0.19) per cubic metre of hydrogen production. There are plans to increase hydrogen production to 120 million tons by the year 2060 (Gong et al. 2022). The China Hydrogen Alliance anticipates that hydrogen production derived from renewable energy sources could potentially reach 100 million tons by the year 2060.

Instead, the Caspian Lake, a potential alternative region for hydrogen production can be in the north of Kazakhstan, in cooperation with Russia and China. Here, Russia can provide inexpensive water resources, natural gas, and coal to produce hydrogen. Annually, 16.5 cubic kilometres of water from Kazakhstan flow into the Arctic Ocean through Russia (Figure 2). Using this water for hydrogen production could be a viable option. The generated hydrogen could then be used in the southern regions of Kazakhstan for agriculture.

Climate change's rising temperatures are leading to melting glaciers and rising ocean levels. Coastal zones and islands are going under water (Harlan 2023). Desalination and industrial use of water from the landlocked endorheic basins and lakes, such as the Caspian and Aral Lakes, are ultimately unsustainable. These activities are so destructive to the environment, that it would be reasonable to prohibit them. Instead, it is more rational to stimulate the development of technologies for the use of water from the rivers flowing into oceans (Yapiyev et al. 2017). Northern Kazakhstan will be more reasonable to produce electricity, including water and electricity availability at reasonable costs.

As a result, it would be reasonable to investigate the application of Russian and Chinese hydrogen producing technologies in Northern Kazakhstan. This includes


*Figure 2. Kazakhstan's transboundary rivers with North region, realising 16.5 km³ into Arctic Ocean through Russia.*

technologies that produce hydrogen and ammonia, including from coal (Gray Hydrogen), natural gas (Blue Hydrogen) and water (Green Hydrogen). In Northern Kazakhstan's case, electricity, and resources (water, natural gas, and coal) will be relatively inexpensive and production technologies are more interconnected and efficient for hydrogen-ammonia facilities. Ammonia is widely used in the production of agricultural fertilisers and is currently the best solution for the fertiliser industry (UN 2023).

## 4 Discussion

Transporting hydrogen from Northern Kazakhstan to regions those facing water resource challenges near the Aral Sea region, would be a viable solution. In this scenario, hydrogen transportation costs would be comparable to those of energy resources like oil, gas, gasoline, and diesel, making it economically feasible. Hydrogen would be classified as an energy resource, which would garner greater respect from local communities compared to the current perception of water resources as inexpensive or free. This perception often complicates the implementation of water-saving and efficiency measures in Kazakhstan (Adenova et al. 2023). Achieving a balanced utilisation of natural resources and adopting sustainable practices for mineral fertilisers necessitates a foundation of comprehensive knowledge and the deployment of advanced irrigation technologies with support from scientific and Technical Vocational Education and Training (TVET). The introduction of the hydrogen market in Kazakhstan has the potential to revolutionise people's perspectives and enhance efficiency in water resource management. The connected opportunities are related to the potential exploration of geological "white" hydrogen (Figure 3).

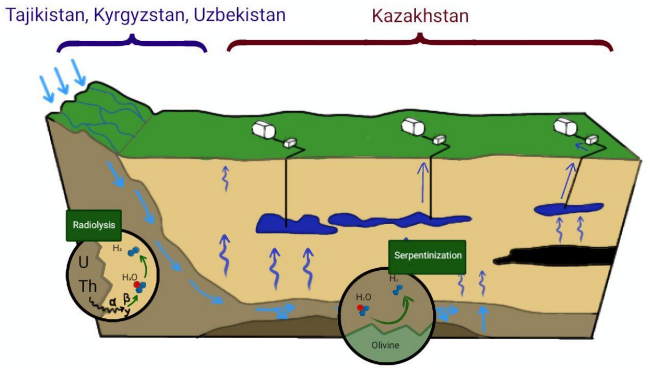


*Figure 3. The diagram exhibits a potential of Central Asian countries for cooperation in groundwater resource use to prospect natural geological "white" hydrogen production, modified from Hand (2024).*

Numerous countries are currently engaged in "white" hydrogen exploration, which has been compared to a modern-day gold rush. This fervour extends to regions like the German French border, which boasts the world's largest underground reserves of "white" hydrogen. On the territory of the transboundary Moselle-Saar River basin, a former coal mining district, are large volumes of natural geological "white" hydrogen, with an estimated volume of up to 250 million tons (Bettayeb 2023). Kazakhstan does not have "white" hydrogen exploration activities and programs dedicated to identifying underground geological "factories." This program can relate to the NEXUS-water, food, energy activities. RS and GIS technologies combined with geophysical studies would be reasonable to expand in applications for the alternative scenarios and regions for hydrogen exploration.

## 5 Conclusions

Combining RS and GIS technologies with geophysical studies is a viable approach to investigating alternative scenarios and potential hydrogen-rich regions. Efforts like

these require support for research and the development of TVET programs that include a connected chain of colleges and universities. Improving educational programs is essential for expanding Kazakhstan's hydrogen programs.

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