UPCOMING WATER DEFICIT IN CENTRAL ASIA RURAL REGIONS AND PERSPECTIVES OF GREEN HYDROGEN PRODUCTION

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Abstract. Due to the predicted water deficit by 2030, significant climate change should affect mostly rural regions of the southern part of Central Asia in such countries as the south of Kazakhstan, Kyrgyzstan, and others. The goal of our research is to analyse the influence of green hydrogen production on the upcoming water deficit in rural regions of Central Asia. We elaborated a simple mathematical model based on renewable energy and hydrogen production potential, giving numerical results about possibility of hydrogen production and water consumption. The article presents also an analysis of the current situation with the water-electricity balance in the region. We have concluded that hydrogen projects can have minimum impact on the water consumption by agriculture in the region and can be fully supplied with renewable energy sources.

Keywords: water deficit, hydrogen, climate change, water-electricity balance, rural regions, Central Asia.

Introduction

The upcoming water deficit could affect a significant part of the world's population. According to UNESCO research by 2050 up to 2.4 billion people should face water scarcity [1]. At the same time increasing hydrogen production and usage is a real worldwide trend. It reached 95 Mt in 2022, a nearly 3% increase year-on-year [2].

As water is the main source for hydrogen production there is a necessity for research on the impact of green hydrogen production and increasing water scarcity. Such studies are being carried out by some research teams [3,4]. One of the most detailed is IRENA's Water for hydrogen production report [5] showing that some of the realized projects could seriously affect the water deficit issue in different regions.

However, the region of Central Asia has not been deeply explored in that way. In our work, we conducted a study of the impact of green hydrogen production through projects that are being implemented in the region on water scarcity, which is especially sensitive in the Central Asia region.

We hope that the results will draw attention to the importance of a balanced approach to projects that affect aspects in different areas, such as the energy sector, agriculture, and water management.

1. Materials and methods

To model the impact of green hydrogen production on water deficit, we applied the following approach.

1. We used the literature research method, looking at both scientific literature, available policy documents and reviews, to find data for already predicted upcoming water deficit in Central Asia;
2. Also, literature research was conducted to clarify already existing projects concerning green hydrogen production;
3. A simple mathematical model was created, to calculate the amount of necessary water for production of hydrogen by electrolysis taking into account the renewable energy potential and considering existing projects in the region.

1.1. Upcoming water deficit in Central Asia

Climate change and continuous increase in water consumption will create a chronic water deficit in 2028-2029 in Central Asia countries [6,7]. The region of the Aral Sea is the most indicative in this regard (Fig. 1) [6]. Historically, this region is the most unfavorable in terms of water balance and this is even more significant because 81% of the population of Central Asian countries live in this region [8].

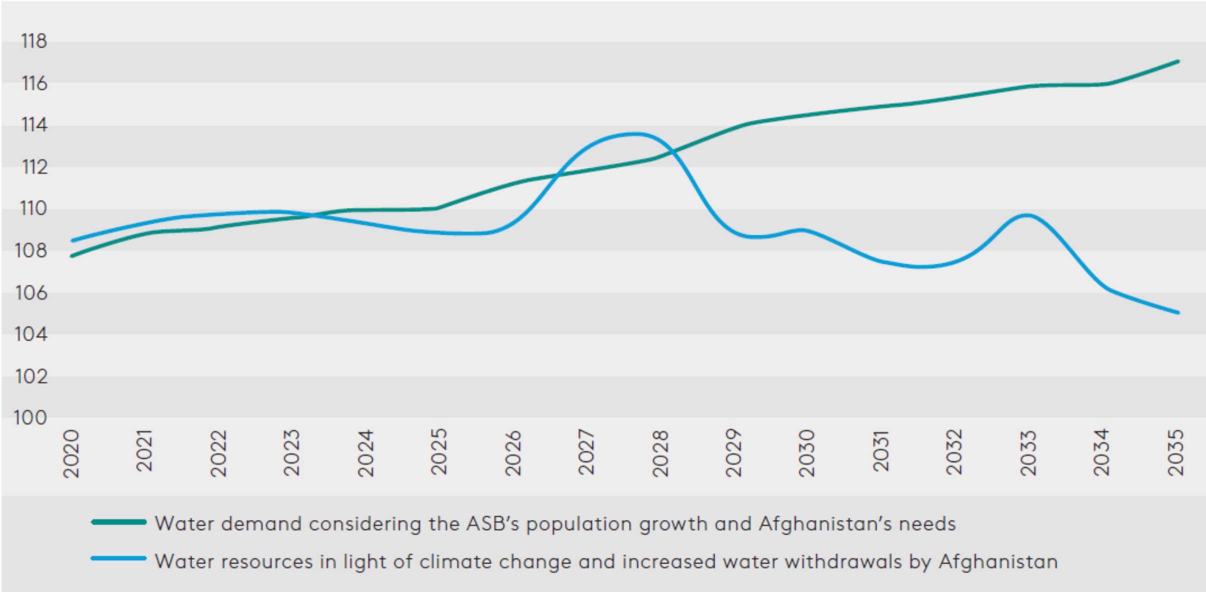

Fig. 1. **Aral Sea basin (ASB) water balance forecast by 2035, km^3 [6]**

The current world situation and upcoming changes in the structure of energy production create a good possibility for green hydrogen production [9]. According to the IEA research, the annual production of hydrogen could reach 38 Mt in 2030 based on a rapidly growing number of announced projects (Fig. 2) [2].

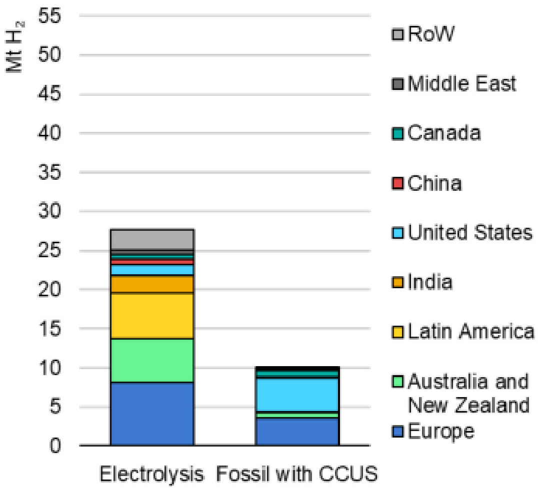

Fig. 2. **Low-emission hydrogen production by region, 2030 [2]**

Central Asia region has a good possibility of green hydrogen production due to the renewable energy potential and expected cost reduction of its production (Fig. 3) [2].

Considering electricity generation at hydropower plants of Central Asia countries in 2022 it increased by 882.0 million kWh compared to 2021 and totalled 21452.2 million kWh or 20.9% of the total electricity generation of Central Asia [10].

Shardara is one of the most important reservoirs in the Aral Sea basin with a full capacity of 5,200 million m^3 at a normal operating level of 252.0 m as well as the Shardara hydropower plant. The reservoir was designed mostly to accumulate winter runoff and re-regulate it in summer for irrigation and agriculture needs in the rural regions of the South of Kazakhstan. [10] Water balance in the years 2021-2022 is shown in Table 1.

For comparison, water consumption by agriculture in the South Kazakhstan region reaches 2 million m^3 per day [11].

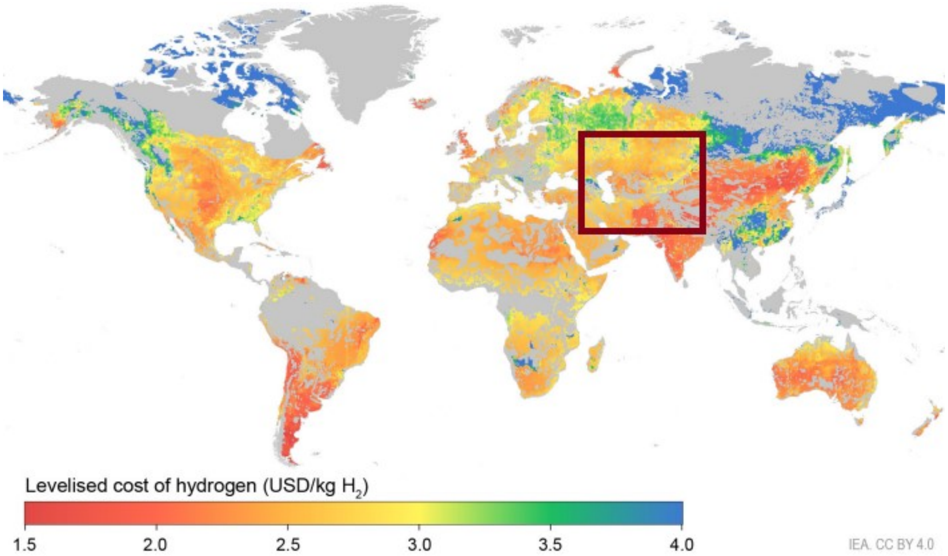

Fig. 3. **Hydrogen production costs and share of solar PV from hybrid solar PV and onshore wind generation, 2030 [2]**

Table 1

Water balance of the Shardara reservoir in 2021-2022 [10]

Parameter	**I**		**II**		**III**		**IV**		**Year**	
	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021
Inflow, $m^3 \cdot s^{-1}$	699	679	358	221	147	78	702	328	477	326
Outflow, $m^3 \cdot s^{-1}$	282 T.205 x.77	399	412 T.400 x.12	273	310	244	380 T.349 x.31	143	346 T.316 x.30	265
Level at the beginning of the period, m	246.93	248.74	251.72	251.83	250.03	249.28	245.13	242.81	End-year level	End-year level
Volume, m^3	2069	3008	4994	5074	3773	3327	1333	665	250.17 V-3874	246.93 V-2069

1.2. Green hydrogen projects in Central Asia

Based on the recent available data provided by IEA [12] there are only 3 (three) announced projects (Figure 4) with a total hydrogen production capacity of 3465 kt $H_2 \cdot y^{-1}$. The biggest one is a 'Hyrasia one' project with a capacity of 3465 kt $H_2 \cdot y^{-1}$.

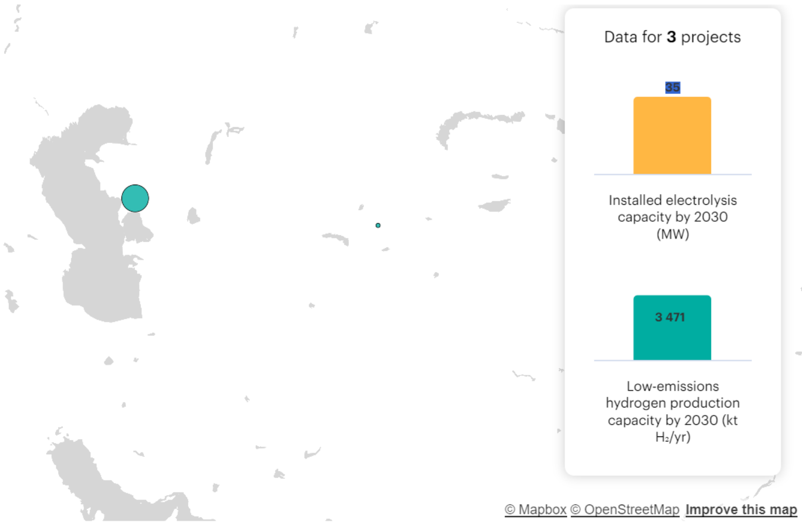

Fig. 4. **Hydrogen production costs and share of solar PV from hybrid solar PV and onshore wind generation, 2030 [2]**

Only two countries: Kazakhstan and Uzbekistan joint a "hydrogen club". The required electric power for these projects is 35 MW.

1.3. Required water resources for hydrogen production in Central Asia

Using electrolysis method for hydrogen production, we are performing a water splitting process which can be simply described with a formula:

$$2H_2O \rightarrow 2H_2 + O_2, \quad (1)$$

That means that 9 liters of water are required to produce 1 kilogram of hydrogen using the electrolysis process. However, we have to consider the water needs for a cooling process and the losses. Thus, to produce 1 kg of hydrogen about 20-30 liters of water is needed [13]. Thereby, to find out the required amount of water we can use the formula:

$$Q = QH_2 \cdot K, \quad (2)$$

where Q – required water quantity, million tons;
QH_2 –hydrogen production, million tons;
K – production coefficient, 30.

For all three upcoming projects in Central Asia, 104.13 million tons of water per year are required. The largest share falls on the 'Hyrasia One' project in Kazakhstan. For the project in Uzbekistan, just 0.18 million tons of water per year are needed.

2. Results and discussion

According to our calculations using the methodology described above (1, 2), it appears that to cover the needs for the announced hydrogen projects in the region about 104.13 million tons of water are required.

If we consider the Aral Sea basin, this value seems to be significant, for instance, the volume of Shardara reservoir can fall to 2069 million m^3. But the biggest project in the region 'Hyrasia One' is located near the Caspian Sea, which has salt water that is not usable for agriculture needs and a water volume of 80 000 km^3 [14].

The ACWA Power project [12] in Uzbekistan will consume just 0.18 million tons of water which is not so critical.

The required electricity capacity for the hydrogen projects by 2030 is 35 MW. To evaluate the potential of renewable energy sources to produce the required electrical energy for hydrogen production in the region the Global Solar Atlas can be used (Figure 5) [15].

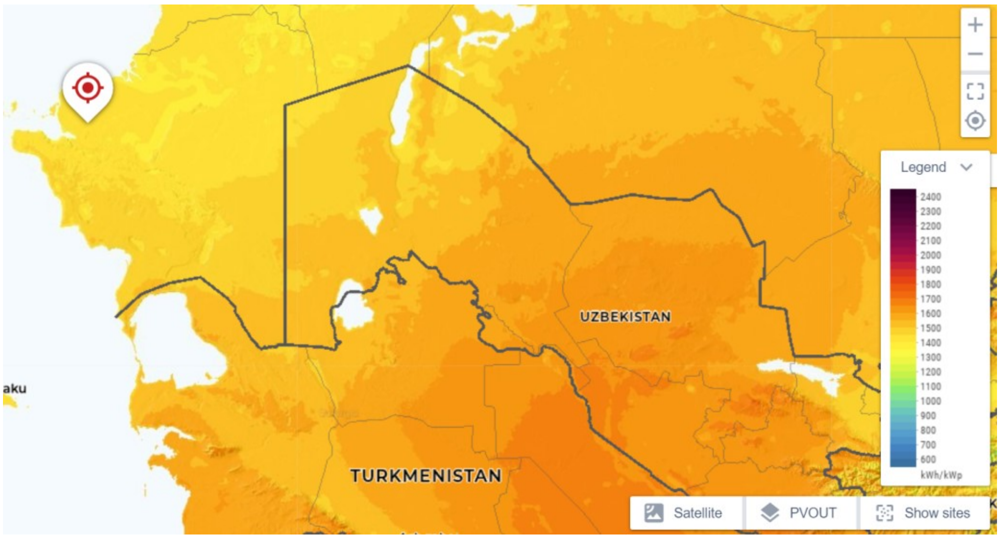

Fig. 5. **PV power output [15]**

Total average photovoltaic power output in the region is 1400 $W \cdot m^{-2}$ [15]. The theoretical area required for a solar farm, based on the obtained potential per square meter, is calculated using the following formula:

$$S = E/P_w, \tag{3}$$

where S – required area, sq. meters;
E – required electricity, W;
P_w – average solar potential, $W \cdot m^{-2}$.

With such output theoretically 0.025 square kilometers will be required for solar generation. Such values are the possible highest theoretical potential according to the used sources. According to the region's geographical location, solar energy seems the most promising to be used, but considering the unit commitment problem solving and using energy storage facilities [16].

Based on our analysis, hydrogen projects can have minimum impact on the water consumption by agriculture in the region and can be fully supplied with renewable energy sources.

Conclusions

Current trends show a rapid growth in the number of green hydrogen projects in the world. The Central Asia region despite its huge area, renewable energy potential, economy, and energy demand growth still has just a few green hydrogen projects. Water resources which are used for irrigation purposes in agriculture as well as for electricity generation on hydro power plants are used also for hydrogen production.

Based on our calculations, the announced green hydrogen projects should consume about 104.13 million tons of water per year. Thus, the biggest project 'Hyrasia one' is located in Kazakhstan, near the Caspian Sea in Mangystau region. As the Caspian Sea has a water volume of 80 000 km^3 and the Mangystau region is not used for agriculture on a wide scale, then installing hydrogen production facilities will not have a strong effect on upcoming water deficit and irrigation. The second project in Uzbekistan has just 0.18 million tons of water consumption per year and cannot have a serious impact.

The region's renewable energy potential could easily cover the power requirement of 35 MW with solar generation facilities which can occupy an area of only 0.025 square kilometers.

Thus, in Central Asia, it is possible to develop and increase the capacity for producing green hydrogen, however, less water-stressed areas should be chosen for this, or sea or wastewater should be used for hydrogen production.

Author contributions

Both authors have contributed equally to the study and preparation of this publication. Authors have read and agreed to the published version of the manuscript.

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