

*A brief analysis of the physical requirements for
converting coal-fired power plants to hydrogen*

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The possibility of converting coal (and gas) power stations to use of hydrogen is often considered as a viable alternative in the efforts to decarbonise the power industry.

This brief proof of concept study aims to estimate some of the physical resources (electricity, land, water) needed for such a transformation. Mainly, it focusses on how much hydrogen is needed and where it would come from.

In this study, the considered transition of the coal power plants in the Maritza East coal basin in Bulgaria from lignite coal to hydrogen is taken as an example.

It is assumed that the electricity production at the coal-fired power plants of Maritsa East (3.1 GW), which produce about 17 TWh per year, will be replaced by hydrogen powered plants.

Bulgaria has relatively low potential for generation of renewable energy from wind in this region and with the case of low availability of other, industrial size renewable sources, the only realistically available resource is solar energy. For the purposes of this study, it is assumed that the necessary hydrogen will be produced by electricity obtained from photovoltaic power plants through electrolysis of water.

It is also assumed that 1MWp of installed solar PV power produces 1200 MWh¹ per year and occupies 24,000 m².

Theoretically, 1kg of H₂ (hydrogen) is produced from 39 kWh of electricity and requires 9 litres of water². Since the electrolyzers reach a maximum of 80% efficiency, in reality it

¹<https://globalsolaratlas.info/detail?c=42.275277,25.395584,10&s=42.287977,25.901642&m=site&pv=ground,180,33,1000> it has to be noted that despite the theoretical yield of 1350MWh/MW, a more conservative and realistic number of net generation available for electrolysis is assumed

²<http://www.renewableenergyfocus.com/view/3157/hydrogen-production-from-renewables/>

takes 49 kWh to produce 1 kg of H₂.

The theoretical thermal content (energy that can be produced by burning 1 kg of hydrogen) per 1 kg of H₂ is 36 kWh³. If it is used in existing condensing power plants with an efficiency of 30%, 1 kg of H₂ will produce about 11 kWh.

Assuming that the power plants operate approximately 2/3 of the time in the generation mode and 1/3 (during the day when the solar power plants will supply electricity to the system) in hot reserve, for the production of 17 TWh/y, it will be necessary to produce about 1 billion kg of H₂ per year.

For the production of 1 billion kg of H₂, approximately 52 TWh of electricity would be required (some losses are included here - from electrolysis, heat losses for conversion back to electricity, etc.). To produce this amount of electricity 43 GWp of photovoltaics would need to be installed.

The required land for the installation of such a number and size of photovoltaic power plants would be more than 1000 km², not including roads, substations - land on which more than 550,000 tons of wheat can be grown per year in the area around the existing power plants⁴.

It is important to note that the production of such an amount of hydrogen requires about 10 billion litres of clean water per year. The average consumption of clean water per capita in the region is 90 litres / day⁵. The needed for production of hydrogen water would be enough to provide drinking water for 290,000 people in a region which has low availability of clean water.

Additional energy and water costs must be added to ensure the liquefaction and storage of hydrogen to be used for fuel when there is no sun. To liquefy a kg of H₂, about 4 kWh⁶ is required, i.e. to liquefy the hydrogen required for the operation of the plants, additionally more than 4 TWh per year is required, which implies the installation of 3.5 GWp of additional photo solar stations. The size of the hydrogen storage facilities depends on the availability of solar energy in the winter season and on the expected number of consecutive days with a low solar radiation, in order to avoid situations with no hydrogen reserve to run the power plants in adverse conditions.

In conclusion: the transformation of coal-fired plants to hydrogen would require the construction of 47 GWp photo solar stations, which would occupy more than 1000 km² of land⁷

³<https://www.world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx>

⁴<https://nova.bg/news/view/2019/08/05/259005>

⁵<https://www.nsi.bg/en/content/5145/drinking-water-used-households-public-water-supply-average-capita-total-country>

⁶https://www.hydrogen.energy.gov/pdfs/9013_energy_requirements_for_hydrogen_gas_compression.pdf

⁷The territory of the country is 111 thousand km², from which 45% is agricultural land, the rest being mostly mountains and forests: https://www.mzh.government.bg/media/filer_public/2020/12/22/

and will use more than 10 billion litres of water per year, or the drinking water of 300,000 people from the area.

This brief study is not intended to calculate the exact parameters and requirements for such a transformation, nor the necessary infrastructure or technical solutions for balancing the electricity system.

The cost of one such transformation is not considered in this study, but it has to be mentioned that only the cost of photo solar power plants would exceed \$ 45 billion⁸, and they would need to be replaced at approximately every 20 years.

Furthermore, most of the technologies involved hardly exist in an industrial scale - namely electrolyzers able to produce billion kg of hydrogen, hydrogen storage facilities and pipelines able to store and transport such large volumes of difficult to contain and transport gas, conversion of coal fuelled boilers to use hydrogen.

The low round-trip efficiency of producing, storing and using hydrogen for electricity generation – less than 25% - along with the necessity of installation of very large solar PV installations, infrastructure, land and water needed, demonstrates that considering hydrogen path with the current state of technologies would be inefficient, physically challenging and potentially very expensive.

The purpose of this brief study is to identify the physical parameters of one such change and to bring awareness and realism to the discussion of the viability of replacing coal with hydrogen. The decision and policy makers should take into account the physical and cost constraints, before committing to potentially expensive, resource intensive, and ultimately harmful solutions.

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⁸<https://www.irena.org/publications/2020/Jun/Renewable-Power-Costs-in-2019>