Sahara Wind Clean Hydrogen Water Purification System

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ABSTRACT

The 'Sahara Wind Clean HyWater' Project consists in coupling wind turbine sets to electrolyzers to produce chlorine derivatives while integrating renewable hydrogen by-products within Morocco's main water treatment facilities. This project demonstrates that clean water technologies can enhance the uptake of intermittent sources of renewable energies such as wind power in weaker grid infrastructures found on the Sahara/Sahel region and most of the African continent. Indeed, local generation of water treatment chemicals, integrated to ONEP desalination plants operating under windy conditions in the southern part of Morocco are likely to reduce overall drinking water production costs. By engaging simultaneous demonstrative and capacity-building objectives within an industrial application to access endogenous renewable resources, this project highlights the role of stand-alone fully integrated water treatment processes. To that end, the development of a green corporate-campus introduced within Morocco's Water Utilities headquarters will demonstrate the importance of integrative industrial processes when accessing renewable energies. Variable load wind-electrolysis for grid stabilization will be tested in a setting where by-products can be integrated on-site within relevant applications. Co-generated hydrogen will be used as spinning reserve, emergency backup power and as fuel in local eco-mobility applications. Hence, the issue of renewable energy access is addressed through a broader synergetic context focusing on drinking water and multiple uses of green hydrogen.

1. GENERAL DESCRIPTION:

a. Overall regional context

The trade winds that blow along the Atlantic coast from Morocco to Senegal represent one of the largest and most productive wind potentials available on earth. Because of the erratic nature of winds however, wind electricity is difficult to integrate on any significant scale, unless local mechanisms are developed to improve access to these intermittent renewable energies.

b. Combining wind energy and electrolyzer technologies

Acting as a stabilizing variable electric load in a high wind penetration system, electrolyzer technologies can enhance access to intermittent sources of renewable energies such as wind power in weaker grid infrastructures. These conditions are found in most parts of the African continent and in particular the Saharan/Sahel regions. Chlorine, generated by electrolysis is an indispensable elements in water treatment solutions for producing clean, potable water. Chlorine and its derivatives represent the main commodity operational expense of ONEP, the water utilities of Morocco. The 'Sahara Wind Clean HyWater' Project looks at developing a comprehensive approach aimed at solving both energy access and water treatment solutions within a demonstrative setting with capacity-building objectives. The site selected for the introductory phase of the 'Sahara Wind Clean HyWater' Project is located on the grounds of Morocco's main water treatment facility which is also ONEP's corporate headquarters. By coupling electrolyzers with wind turbine sets to produce chlorine derivatives within Morocco's main water treatment facilities renewable hydrogen is generated. Hydrogen as a feedstock and energy carrier has multiple applications. It can be considered as a renewable energy storage medium and can be used backup when fed through a fuel cell or even as a clean fuel in clean mobility applications.

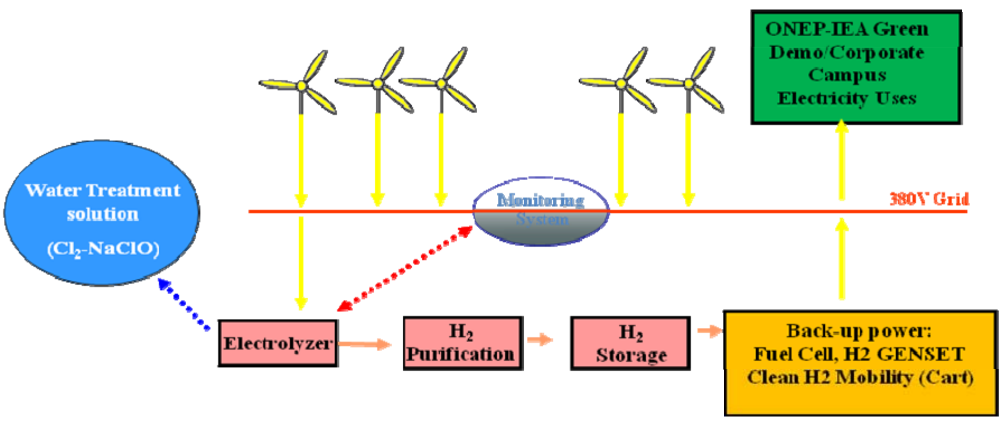

Figure 1: Integrated Wind-Electrolysis system with hydrogen recuperation

By addressing integrated water treatment alternatives the project seeks to demonstrate the potential for synergies emerging from sustainable, carbon-free hydrogen energy technologies and their related applications. The utilization of wind energy and electrolysis by-products are likely to enhance the access to potable water, particularly in the Sahara Desert where extended logistics and the safe transport of chlorine remain a delicate matter. On the Saharan coastline, where water is extracted via energy intensive desalination processes, trade wind-blown applications using wind-electrolysis can become even more relevant. Within such settings available on the African continent, collaborative partnerships will be extended into subsequent pilot projects with utilities and extractive mining industries. This collaboration has the potential to reinforce the environmental performance of the region's main extractive mining industries, and thereby facilitate access to a significant local renewable energy source: the Saharan trade winds.

By engaging simultaneous demonstrative and capacity-building objectives within an industrial application to access endogenous renewable resources, this project highlights the role of stand-alone fully integrated processes. To that end, the development of a green corporate-campus introduced within Morocco's Water and Electric Utilities headquarters will demonstrate the importance of integrative industrial processes when accessing renewable energies. Electrolysis for grid stabilization and variable load electrolysis will be tested in a setting where by-products can be integrated on-site within relevant applications. Spinning reserve in the form of electrochemical energy storage for grid optimization, or as emergency backup power can be generated and used as fuel in local eco-mobility applications. Hence, the issue of renewable energy access is addressed through a synergetic context focusing on multiple uses of green hydrogen. Indeed, the power for the administrative headquarters can be fed through small wind turbines stabilized by electrolyzers whose proceeds are applied to the nearby water treatment station. Grid stabilization as well as energy efficiency objectives are achieved with recuperation of hydrogen in a contained demonstration, training platform. This functional demo-installation will expand collaborative pilot project opportunities, where enhanced access to wind electricity and electrolysis by-products are integrated as energy or chemical feedstock within the region's industries, namely phosphates and iron-ore processing. In the future, plans are to partner with these industries which represent the main local energy loads to build an integrated energy system complementary to Sahara Wind's High Voltage DC Transmission Project. This Project, labeled within the IPHE's list of world hydrogen projects, will ultimately use hydrogen storage and hydrogen shipping via pipeline as well. By enhancing the local ownership of the trade winds on a regional basis to support cleaner, more sustainable industrial processing of mining resources, this system could potentially serve as a secondary power source to both North Africa and Europe.

2. INTEGRATING WIND ENERGY AND WATER TREATMENT TECHNOLOGIES:

In order to maximize the project's output, we are using a dual approach to test technologies in an industrial setting while demonstrating hydrogen's relevance in storing renewable energies within a green building concept. Coupling wind turbines and hydrogen in a green urban demonstration setting enables us to overcome the lack of functionality, energy efficiency and sustainability criteria currently impeding hydrogen technologies.

As the multiple uses of hydrogen will demonstrate, the most adequate processes for its intermittent production, filtration and pressurized storage represent the major challenges that will need to be addressed in this project. Innovative technological solutions are likely to require the evaluation of several options and an initial testing on a demonstration basis prior to considering a larger scale industrial deployment. ONEP/IEA's expertise, training and capacity building support within the compounds of Africa's second largest water treatment station provide an operational environment that will be most advantageous in that regard.

Several wind turbines will be fed into ONEP's power distribution grid at the International Institute for Water and Sanitation (IEA). This grid system will be stabilized by chlor-alkali electrolysers acting as dump loads that simultaneously generate hydrogen and hypochlorite. The electrolyser and small wind turbines (of 5 kW individual size) are designed for urban settings highlighting environmental and energy efficiency concerns within administrative buildings as well. Hydrogen will be stored in pressurized tanks and used as a fuel for electricity generation through fuel cells for power backup (emergency power), peak power shedding and in hydrogen eco-mobility applications (eco-karts). Chlorine/ hypochlorite will be used to support the IEA sanitation pilot plant's need. All components are connected to the local 380Volts power distribution grid of the water treatment station and the adjacent administrative headquarter complex. A 20 mA signal from the small wind turbine outputs is sent into the electrolyzer power setting in order to enable the electrolyser to act as a stabilizing 'base load' within the wind mini-grid system as if it ran in a stand-alone renewable energy setting. Due to lower wind resources at the site, the system will enable its wind, electrolyser, and hydrogen components to operate independently from each other as well, adding to the functionality and flexibility of the system. The reliability of the entire system is thereby reinforced, as a critical failure of any single component will not impact the functioning of the others. End-users will take advantage of the functionality of all individual components as for the benefits of the entire system to be compounded when operating together. These possibilities, a prerequisite in any industrial setting, will serve in the thorough analysis of the system.

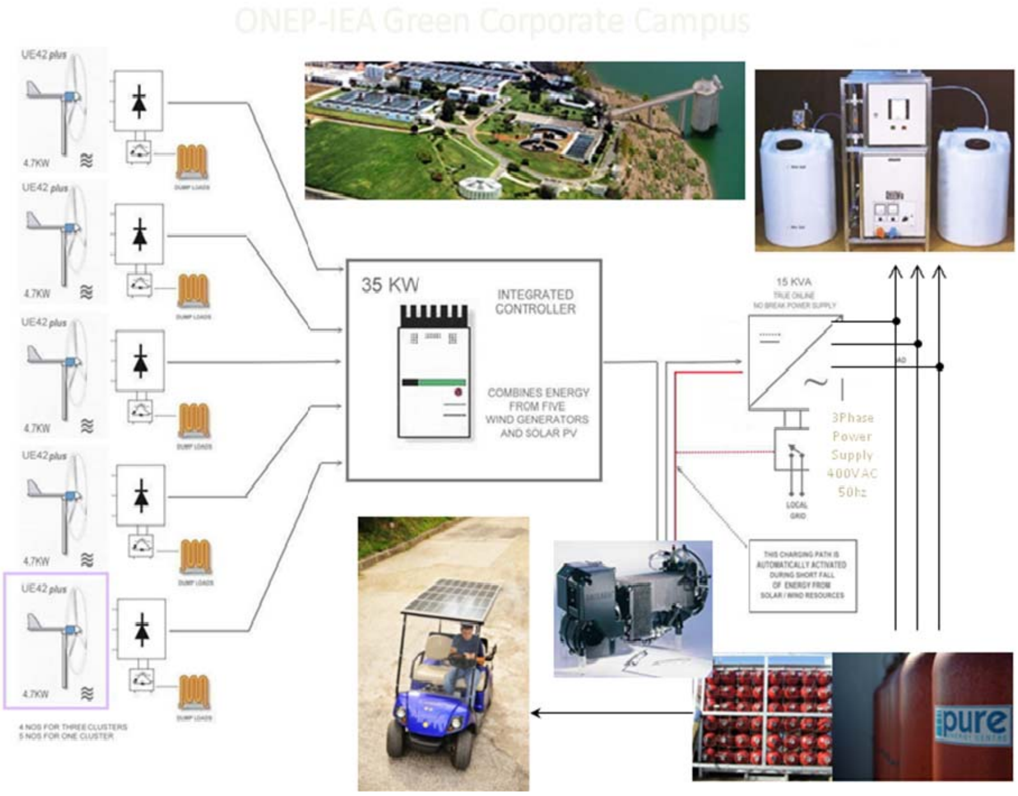

Figure 2: Outline of the functionalities of the green-corporate center of ONEP

The ONEP Green Corporate Center described above will serve as a demonstration and training grounds for similar systems to be dispatched among ONEP’s water facilities. This collaboration will be also extended regionally to other countries via ONEP’s International Institute for Water Sanitation (IEA). Carrying out such smart/flexible grid applications (with hydrogen storage) with an eco-mobility solution is an important element to initiate and demonstrate within Morocco’s water utility headquarters. With the lowest Well-to-Wheel CO2-emissions of Different Propulsion Concepts (according to IPHE’s latest REH2 report), hydrogen out of wind power coupled with Fuel Cells could be easily developed and demonstrated within such setting. Indeed, fuel cell vehicles prototypes built by the region’s engineering schools in partnership with locally established automobile manufacturers through their relevant foundations, will open complementary alternatives for clean mobility solutions. In terms of clean mobility this would represents one the most environmentally friendly technology available.

This project, ambitious and far-reaching is developed within a synergetic context through applied research partnerships with the region’s academia, in line with government policies. Its objective is aimed at building capacities and co-developing integrated green technology applications.

3. EXPECTED RESULTS

Small wind turbines, wind electrolysis, hypochlorite, hydrogen storage, and hydrogen end-uses will be tested separately and collectively in a synergetic context under a variety of conditions and applications. Economic analysis with system performances will be thoroughly evaluated with respect to ONEP's Hypochlorite/chlorine needs opening new integrated hydrogen applications. Hydrogen for electricity production through fuel cell will be evaluated under different conditions and uses namely as back-up power, peak load shedding and eco-mobility applications. Configurations for system optimisations and technology validations will be aimed at dispatching systems within project partners in order to expand regional collaboration and support early industrial scale deployments. A pilot project application in the trade wind region of Tarfaya will be developed in order to supply amongst others, local water processing plants to support the region's needs for water treatment solutions. The Green Corporate Center Demo platform will be used for the local and international training and sensitization activities of ONEP-IEA. This platform could be introduced within Morocco-UNIDO's Country program on automotive industry.

As electrolysis processes recuperating hydrogen are costly and hard to downscale, initial test trials and experiences will be needed before considering any industrial scale approach. This is particularly relevant as the access to a large renewable energy source -the trade winds- although abundant, remains intermittent. Hence, estimated cost savings are likely to be achieved through a demonstrator system, due to the fact that this technology would certainly not have been initially envisioned without due test trials

4. DEPLOYING FIELD APPLICATIONS

The Green Corporate Center Demo platform will be used for the local and international training and sensitization activities of ONEP-IEA. This platform and its collaboration with Morocco's engineering universities could be introduced within Morocco-UNIDO's Country program on automotive industry.

In order to supply the local water processing plant and the surrounding Saharan region with integrated water treatment solutions, a pilot project in the trade windblown region of Tarfaya will be installed. Responding to a specific need, the project will assess centralized as well as decentralized applications in a demonstration for a regional dispatch. The integrated applications partnerships codeveloped with other industrial activities will be effectively tested to be expanded into subsequent frameworks involving the project partners.

a. Tarfaya wind-electrolysis pilot project

For that matter, a larger wind-electrolysis pilot project in the area of Tarfaya will be developed within this proposal to support Chlorine/Hypochlorite needs in the Saharan trade wind region. Similar to the previous system, the pilot project in Tarfaya, will have a larger capacity optimized for industrial scale, remote applications. This will be carried out with the support of our project partners' complementary funding frameworks (NATO SfP-982620 Sahara-Hydrogen, bilateral partnership funding, UNIDO-ICHET, UNDP/UNIDO-GEF, WB Clean Technology Fund, etc.). Building upon experience drawn from the first system installed at the ONEP/IEA pilot plant, the later, larger pilot project will consider expanding the use of hydrogen into grid support and back-up systems, industrial clean-mobility as well as chemical feedstock applications in partnership with relevant industries.

b. Wind resource assessment:

The integration of other electrolysis by-products such as oxygen, chlorine and caustic soda within local industries will rely on wind-measurements carried out on-site regionally through the NATO SfP-982620 Sahara-Hydrogen network of project partners in Morocco and Mauritania. The wind resource assessment for the proposed larger scale pilot project in Tarfaya relies on ongoing academia-industry partnerships with telecom operators (and distributed energy end-users). This project involving the 'Sahara Wind Clean HyWater' project partners is funded under the NATO Science for Peace Project SfP-982620 Sahara Trade winds to hydrogen (Sahara-Hydrogen) framework. The availability of mast tower infrastructures enables accurate wind measurements for the 'Sahara Wind Clean HyWater' pilot project to be implemented.

c. Equipment selection and design

The selection of small wind turbine technologies, electrolyser and systems integration will draw from the experience gained through systems deployed at the Sahara-Hydrogen project partnering universities. These include ongoing industrial engineering programs on small wind turbine component designs, integration and maintenance, as well as electrolyser planning, configuration and site design with hydrogen storage and fuel cell systems. As a result, project costs and technology deployment risks are likely to be reduced as design and maintenance issues will benefit from experiences of previously deployed systems.

5. PROSPECTS OF TECHNICAL AND ECONOMIC VIABILITY

A full economic study will analyse the project's outcome based upon the Value of hypochlorite needs of ONEP and avoided costs (maximization of the systems for the production of hypochlorite versus investment costs depreciation). The study will assess the use of wind energy for desalination integrated to the production of hypochlorite, the access to wind in a stand-alone energy autonomous system and the costs impact analysis in specific low wind speed context. The wind-desalination and water treatment economics in higher wind speed (Morocco and Mauritania windier sites) contexts will analysed as well. The mixing between wind and grid electricity with different utilisation ratios are aimed at optimizing systems outputs.

The aforementioned economic analysis will be made with simulation of wind resource assessments, integrated in the system to indentify impact of investment operational costs, system sizing, potential sites (wind curves-resource assessment from the Sahara-Hydrogen project) with applications. As in any electrochemical application, energy represents a high proportion of the systems overall costs. Hence, the wind electrolysis demonstrator design will consider meeting several operational objectives namely, how to enhance the access to renewable energies with flow optimisations, electrolyzer output maximizations and electrolysis by-products integrated applications.

The synergies developed through the demo/system will integrate several departments (water production and chemical poles) of ONEP, and involve inputs from an academic network teaming up with industrial partners.

Transport & logistics costs of ONEP for the dispatching of hypochlorite will be considered, along with the risk assessments of chlorine transport, which will need to be evaluated with real costs of safety and regulatory transport criteria.

Electrolyser manufacturers will be associated possibly in the design, testing and optimization of these processes on a range of issues involving variable load operations, intermittent maximized outputs, chlorine storage and safety and hydrogen recuperation with treatment, storage and fuel cell applications. As carried out in the Sahara-Hydrogen project; co-development of solutions with manufacturers of the electrolysers will be envisioned. They represent key players in the conception of integrated solutions, in order to establish an effective Equipment Manufacturer/Industrial End-User collaboration.

With support from partnering institutions such as the UNIDO-ICHET, the ‘Sahara Wind Clean HyWater’ project will seek to expand the aforementioned operational platform and industrial collaboration with end-user groups into subsequent plant designs. The size of the industries involved and their importance is a key asset for this approach to succeed, as large potential markets with integrated renewable energy applications will be opened. This is likely to enhance interests and facilitate the joint collaboration between electrolyser manufacturers and end users on the design of specific applications as a follow up on our project’s findings.

Support from the Sahara-Hydrogen project partners is needed to evaluate the access to alternative sources of clean electricity (from wind), that otherwise may not have been easy to get to in the Sahara desert. This represents a significant gain, in securing the access to drinking water as well as the development of integrated processing solutions of local raw minerals into higher value-added refined derivatives.

Financial and environmental benefits associated to clean development mechanisms (CDM) under the terms of the Kyoto protocol and other carbon mitigation support mechanisms will be resorted to. As mentioned before, the involvement of UNIDO-GEF, the Clean Technology Funds from the World Bank with support from other institutions are likely to complement the prospects of technical and economic viability of the project's outcomes. This will facilitate the industrial scale replication and commercial exploitation of the technological knowledge acquired, highlighted and developed during the course of the project.

6. CONCLUSIONS

With the exception of wind and plentiful seawater to desalinate (for use as electrolytic feedstock) this alternative is environmentally clean (no carbon cycle involved) and totally endogenous. The enhanced access to safe drinking water will also help address local sanitation needs of hospitals, food processing plants and other industrial applications located in remote areas. Such integrated applications could facilitate the scaling up of renewable energy technologies and lead to the establishment of economic clusters. These could gradually support the deployment of industries which could be introduced as a result of an enhanced access to the wind resource. This can be particularly relevant in the context of larger projects as envisioned by Sahara Wind. In reinforcing the integration of water sanitation chemicals production on-site in water treatment plants, we are disseminating electrolyzer technologies within a synergetic context. This approach may be critical in the stabilization of weak grids, when high wind penetration rates are sought. The involvement of local industries that can be sensitized on both renewable energy access and environmental issues is an essential step toward the development of integrated solutions. The environmental benefits associated to these are likely to be significant, as they are transverse encompassing energy, water, mineral processing and even clean-mobility applications. Although more difficult to implement due to an effect of scale, the aforementioned distributed solution aimed at enhancing wind energy access are likely to become relevant within larger grids as well. Indeed within such settings, stabilization through electrolysis processes could provide a long term alternative to excess wind power curtailments.

Electricity for industrial uses can be very difficult to secure particularly in remote areas. If abundant wind resources can provide a stable, buffered source of electricity in weaker grids, costly alternative electricity generation options can be mitigated through integrated cogeneration systems. These can make use of electrolysis technologies with integrated by-products. Local industries, such as mine processing, also consume a lot of fresh water, a rare commodity in the Sahara Desert. Introducing these technologies within electric utilities and water treatment industries provides a favourable setting for this project to succeed. This could be particularly relevant as this work is supported by a regional academic/end-user applied research network already active on the theme in Morocco and Mauritania through the Sahara-Hydrogen project.

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