# *A GREEN ALLIANCE WITH THE BLACK CONTINENT: REQUIREMENTS TO EFFICIENTLY IMPLEMENT A JOINT HYDROGEN ECONOMY VIA PPP*

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## Overview (Research Scope and Motivation)

The adherence to the 1.5°C goal, re-confirmed during the 2021 COP26, requires the immediate implementation of a sustainable economy and thus massive investments into a low-carbon energy system and infrastructure globally. Also, at the latest after the Russian invasion of Ukraine, the criticality for the European Union (EU) of setting up a more diversified energy supply system not too heavily relying on energy imports from few major economies has become evident. Both aspects re-inforce the need to rapidly explore options for, and to realize the set-up of, an energy system essentially based on renewable energy sources (RES) and a diversified partner supplier landscape in order to achieve global decarbonization, *inter alia* in the industry, as well as security of energy supply.

The deployment of green hydrogen ($H_2$) has beed widely discussed as a promising means to store and transport energy, and has been integrated as a key pillar into the European Green Deal. The goal laid down in the EU's 2020 Hydrogen Strategy, specifying the magnitude and the way in which $H_2$ is planned to be part of the decarbonization effort, is to install at least 40 GW of green $H_2$ electrolysers in economies neighboring the EU and exhibiting more advantageous geographical and climatic characteristics—such as higher solar energy intensity, stronger and more steady winds, and more surface area to install RES facilities—until the year 2030. Due to its favorable conditions, a high proportion of those green $H_2$ generation facilities is discussed to be installed in African countries, implemented within the framework of an EU-African Energy, resp. Hydrogen, Partnership (e.g., Bghatwat and Olczak, 2020)[1].

Despite these ambitious plans and promising advantages it remains unclear, how the setup of green $H_2$ facilities and infrastructure—e.g., to transport the $H_2$ from the generation sites to the load centers—can be effectively realized. Different options to implement and finance green $H_2$ projects are discussed[2], including, e.g., equity or debt finance, or alternative financing vehicles. The most widely discussed approach, which also has already been implemented, is to set up Public-Private Partnerships (PPP) (APAC/OECD, 2019). Of these, governments promise themselves to achieve, *inter alia*, increased efficiency in construction and operation, effects of scale and scope, more efficient risk allocation and stronger incentives for research and development (R&D) activities (e.g., Estache et al., 2014; Roumboutsos et al., 2014). Indeed, most $H_2$ projects, which have been so far initiated in Africa, are realized via some form of PPP.

In order to exploit the full potential of PPPs, however, the framework conditions must be right. A key determinant of the success of a PPP is a sound design of the PPP incl. its contractual design, as well as a regulatory and institutional environment setting incentives for efficiency, *inter alia* regarding risk allocation and the enforceability of the PPP contracts (Saussier and de Brux, 2018; APAC/OECD, 2019).

However, within the context of an EU-African Hydrogen Partnership, both the assessment of which design of the PPPs themselves and favorable framework conditions, particularly in the wider geopolitical context, remain widely unexplored. The paper we intend to present at the 17th IAEE Conference sheds light on the following research questions (RQ): Firstly, which investments would be necessary to realize the EU-African Hydrogen Partnership's targets? Secondly, how can these investments be realized via PPPs, i.e., which different design options exist given the current institutional setup? Thirdly, which of the design options is the most efficient one, best exploiting potential advantages of PPPs—such as making use of expertise and economies of scale and scope—taking into account the different interests and goals of the stakeholders involved? And, finally, how does the institutional setup impact the efficiency of the differently designed PPPs, particularly regarding the distribution of the benefits gained through cooperation, and which potential improvement levers exist?

## Methods (Approach)

To the end of answering the first two RQ, we firstly present a literature-based stocktake of different scenarios and identify investment needs, potential designs of PPPs for $H_2$ projects in Africa as well as specifications of the landscape

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[1] The frontrunner in this type of effort has been the German Federal Government, who has set up the global hydrogen import scheme and bilateral initiatives with African countries, including Morocco, Namibia and South Africa via an initiative called "H2 Global", which is backed by a public funding of €900 million, see here.

[2] Given that externalities arising from the emission of greenhouse gases (GHG) have not been fully internalized globally yet, and the likelihood is low that they will be quickly enough to achieve the goals of GHG reduction and security of supply at the intended time scale, the realization requires economic policy and regulatory intervention, e.g., in the form of public investment or an effective private sector incentivization.

of institutional setups, as obtained from an investigation of currently implemented $H_2$ projects and already existing first approaches to concrete frameworks, such as the above-mentioned $H_2$ Global.

To answer RQ three and four, we then present a game theoretical model approach. We aim at assessing the EU-Africa Hydrogen Partnership as a network of PPPs in a multi-objective evolutionary game, considering both non-cooperative and cooperative games to the end of identifying setups not only encouraging an efficient functioning of the PPP network (non-cooperative part of the model), but also incentivizing players to become and remain a part of the Partnership and a fair distribution of the cooperation benefits (cooperative part of the model). Furthermore, the evolutionary game is selected, since, firstly, the hydrogen projects themselves are long-term projects—with comparably long investment cycles, i.e., construction and life-times—Partnership is, ideally, of a long-lasting nature as well. In this setup, stakeholders take into consideration their experiences from previous rounds in the game. Thus, we determine the evolutionary stability strategy (ESS), referring to the equilibrium point within the game, wherein the stakeholders cannot improve their outcomes no matter how their strategies change.

We use the model to the end of comparing the different probable overall welfare and distribution outcomes of the distinct PPP design options within the respective institutional framework, and thus derive recommendations for an optimal setup. The assessment includes a comparison of the respective performances with regards to the incentive effects—and hence the incentivizable investment volumes—the efficiency achieved during construction and operation, as measured by the green $H_2$ production costs, as well as the implication on the incentivization of research and development (R&D) activities. The latter is particularly interesting to consider, since realizing $H_2$-based energy transportation or storage is not yest cost competitive, and the success of $H_2$ being an integral component of a low-carbon economy is highly dependent on cost reductions induced by technological progress (IRENA, 2018).

The parties involved are assumed to share the same project objectives, such as quick completion of the project as well as maximum basic payoffs, however, they pursue their own specific benefits. As the groups of players—respectively, the coalitions of players—within the game, we consider the different stakeholders, which are involved in the EU-Africa $H_2$ Partnership and the $H_2$ projects, which are (1) the African governments, i.e., public sectors, (2) the European governments, i.e., public sectors and (3) private sector investors. The three players

pursue their behavioral strategies between cooperation or non-cooperation, given the different assumed PPP designs and framework conditions, leading to a maximization of their respective utilities. Different payoffs of the players are considered: Basic payoffs, such as profits from the operation of the hydrogen production facilities, value-added payoffs, such as environmental benefits, security of energy supply, the reception of subsidies and social benefits (which are particularly relevant in the case of African economies), as well as costs, risks and enforcement mechanisms, such as transaction costs or penalties.

## Results

The final results of our research are currently being developed, and will be available at the time of the IAEE conference ($21^{st}$-$24^{th}$ September 2022).

## Conclusions

With our paper, we contribute to the politically highly relevant question, how to rapidly and efficiently advance a RES-based energy system and diversify the energy supply. From an academic perspective, we contribute to and advance the existing research on game theoretical investigations of infrastructure investment and finance, and, particularly, of PPPs, within the context of energy economics. Filling this lacuna in the literature is particularly interesting, since infrastructure investments in the energy context are marked by very specific characteristics, *inter alia* by the high significance of security of supply within the canon of objectives.

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