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Green hydrogen cooperation between Egypt and Europe: The perspective of locals in Suez and Port Said

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A R T I C L E I N F O

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A B S T R A C T

Hydrogen produced by renewable energy sources (green hydrogen) is at the centrepiece of European decarbonization strategies, necessitating large imports from third countries. Egypt potentially stands out as major production hub. While technical and economic viability are broadly discussed in literature, analyses of local acceptance are absent. This study closes this gap by surveying 505 locals in the Suez Canal Economic Zone (Port Said and Suez) regarding their attitudes towards renewable energy development and green hydrogen production. We find overall support for both national deployment and export to Europe. Respondents see a key benefit in rising income, thereby strongly underlying the economic argument. Improved trade relationships or improved political relationships are seen as potential benefits of export, but as less relevant for engaging in cooperation, putting a spotlight on local benefits. Our study suggests that the local population is more positive than negative towards the development and scaling up of green hydrogen projects in Egypt.

1. Introduction

Hydrogen produced by renewable energy sources (green hydrogen) has the potential to reduce emissions from industrial production processes significantly and thereby to decarbonize economies. According to Egypt's development strategy, Egypt's Vision 2030, the country aims to reach 42% renewables in its energy mix by 2030 supported by an ambitious action plan for green hydrogen production. As Egypt enjoys abundant solar and wind resources, that allows the production of green hydrogen at relatively low costs [1]. Egypt is also located within close proximity to markets where demand for green hydrogen is expected to grow the most, providing robust opportunity for export, notably the European Union. Here, especially Germany has forecasted high needs for importing green hydrogen [2,3].

As such, Egypt could become a major hub for green hydrogen production, targeting exports to various world regions such as Europe and Asia, and boosting the local industry. While several commercial projects are already running to test technical and economic viability [4–8], the comprehensive deployment of green hydrogen will rely on support from policymakers, experts, and the general public. As Blohm and Dettner [9] note, an assessment of hydrogen projects should not only focus on economic aspects, but needs to include environmental and social aspects as well. Social acceptance of hydrogen production and technologies has been widely researched. Literature reviews are provided by Emodi et al. [10] and Gordon et al. [11], while further works of Gordon et al. [12–15], De-León et al. [16] and D'Aquino et al. [17] aim to derive typologies and models for hydrogen acceptance. Further studies look into the acceptance of hydrogen production in the US [18], Norway [19], Spain [20], Australia [21,22], and Malaysia [23]. A clear takeaway is that local participation and the creation of economic benefits at local level is key for the successful deployment of hydrogen projects [24–26]. Furthermore, clear communication [26,27] and transparent public information seem to boost acceptance of hydrogen production [28,29].

These areas are so far not addressed by research and represent a gap in the literature regarding the case of Egypt. Taking Europe as an example export destination with Egypt as a case study of low carbon innovation, the aim of this contribution is to investigate aspects for the local acceptance of green hydrogen production and export. To this aim, we address the following research question:

How do locals in the Suez Canal Region perceive the plans to produce green hydrogen? Which factors facilitate local support for these projects?

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2. Background: the case for green hydrogen in Egypt

2.1. Economic and social situation in Egypt

The economic landscape in Egypt has been marked by fluctuations in recent years, with a GDP growth rate of 6.6% in 2022, before falling to 3.8% in 2023; this downturn was due in part to import restrictions that impacted domestic production and exports, as well as reduced purchasing power and slowed corporate activity, all of which had negative impacts on consumption and investment [30]. The country also faces challenges relating to human development: the average GDP per capita, at $4,295, is well below the global average of $12,687, and the country's Human Capital Index, which measures the amount of human capital a child born today can expect to attain by 18 given the state of health and education in the country, has a score of only 0.49 out of 1.0 [31]. Despite these challenges, the unemployment rate has steadily declined from 2014 to reach 6.4% in 2022, indicating an improvement in job opportunities in the country [31].

In the context of Egypt's energy landscape, natural gas is the largest source in the country (including all energy produced and imported, less any energy exported) at 55.1%, followed by oil (36.9%) and only 5.6% accounting for renewable sources [32]. Egypt has fluctuated between being a net energy importer and exporter but most recently had 4.8% of their total energy supply deriving from imports in 2021 [32]. In terms of final consumption of energy within the country, 47% is derived from oil products, 24% from natural gas, and 3.3% from renewable sources [32]. The sector that consumes the most energy in Egypt is transport (30.8%), followed by industry (24.5%) and residential (22.9%) [32]. Since 2016, Egypt has achieved universal electricity access [31], however, the country's energy production heavily relies on non-renewable sources, with 81% derived from gas and 7.5% from oil; the remaining 11.5% comes from hydro, wind, and solar sources [32]. In 2021, Egypt exported 1643 GWh of electricity, an increase of 401% from 2000 [32].

2.2. Green hydrogen in Egypt

To countries endowed with substantial natural gas resources and abundant renewable energy potential, exploring hydrogen production and utilization presents a promising opportunity for achieving energy security and reducing carbon emissions [33–36]. This is certainly the case for Egypt: Since COP27 in Sharm el-Sheikh, Egypt has confirmed its ambition for renewable energy and hydrogen production through the adoption of the Integrated Sustainable Energy Strategy (ISES) and signed over 19 Memoranda of Understanding (MoUs) to conduct feasibility studies on hydrogen production, with the aim to import to the European and Asian markets [37–39]. Egypt's hydrogen strategy is closely linked to its climate change policy and the development of renewable energies. Egypt's 2030 Plan aims for renewable energy to account for 42% of the country's total electricity generation by 2035. The government intends to establish Egypt as a green hydrogen hub and trade a portion of its produced hydrogen with other countries, including the European Union.

Varieties of studies assess the potential of green hydrogen production in the North Africa region [40–45] and more specifically in Egypt [46–48]. While all studies confirm a large technical potential for developing green hydrogen, the evaluation of the economic potential remains inconclusive.

Al-Orabi [49] assesses the potential of green hydrogen as a medium for storing Egypt's renewable electrical energy and fuel. The study explores the feasibility of green hydrogen production at three potential locations: Benban-Aswan, Ras Ghareb, and Edko City. Each site offers unique advantages in terms of solar and wind resources, water availability, and export infrastructure. A techno-economic analysis using HOMER software evaluates various configurations for green hydrogen production at these sites, considering factors such as net present value (NPV), levelized cost of hydrogen (LCOH), carbon emissions, and cost of energy (COE). The findings reveal that the configuration utilizing wind turbines at Ras Ghareb emerges as the most cost-effective option, with the lowest NPV, LCOH, and COE. Similarly, Sadiq et al. [50] highlight the promising potential of green hydrogen (H_2) by a review of Egypt projects that includes significant developments in the sector, such as the hydrogen project plants in the Suez Canal Economic Zone (SCZONE) and Ain Sokhna's economic zone, in partnership with international firms [51,52]. These initiatives represent significant advancements in the region's hydrogen production and underscore the growing interest in green and blue hydrogen technologies.

Finally, a recent study conducted by the United Nations Industrial Development Organization [53], in partnership with the Politecnico di Milano, provides the most comprehensive assessment of the current state of hydrogen and prospective development of hydrogen production in Egypt. They find that electrolysis-based hydrogen production in Egypt could have relatively low costs compared to other countries and they advocate for a public-private partnership model with a short-term focus on producing green ammonia and methanol for international export, a medium-term emphasis on green and low-carbon hydrogen production for decarbonization in challenging industries, and a long-term strategic plan centred around infrastructure development, including hydrogen and renewable energy exports and expanding local hydrogen demand.

As pointed out in this report, Egypt benefits from a dominant position in the production and the export of ammonia, largely obtained thanks to its abundant resources in natural gases, and the primary short-term goal is the greening of ammonia export and the production of blue hydrogen alongside carbon capture and storage technology. Recent reports and studies that review the current hydrogen market in Egypt advocate similar developments, as pointed out by Heinemann et al. [47] and Habib and Ouki [54]. They estimate the price for hydrogen production in Egypt:

- High-level estimate of US$ 1.652 per kg H_2 for blue hydrogen
- Estimate of US$ 1.247 per kg H_2 for grey hydrogen
- Estimate between US$ 1.515 to US$ 4.364 per kg H_2, depending on the scenario, for green hydrogen.

According to Habib and Ouki [54], Egypt's approximate total use of hydrogen is estimated at 1,824,540 tons in 2019. The authors estimate that switching to green hydrogen would require 110,585 GWh of renewable electricity, a production of renewable energy that is not yet met. Thus, they conclude that "a substantial expansion of Egypt's renewable energy capacity would need to be developed with a dedicated capacity for green hydrogen production."

One challenge for Egypt's hydrogen production goals is the requirement for substantial renewable energy capacity, which would represent over 60% of its current total electricity-producing capacity [46,54,55]. However, the study provided by Moharram et al. [56] shows confidence in the potential for developing renewable energy in Egypt (see also [33,43,49]). Nonetheless, the literature raises concerns about the fact that diverting supplies of renewable energy to green hydrogen production could hinder the country's progress in achieving its renewable energy targets and reducing carbon emissions from fossil-fuel-based thermal power plants [46]. This study supports the transition through blue hydrogen, which relies on carbon capture and storage (CCS) facilities, which may be more feasible and cost-effective in the short and medium term. According to Rystad Energy, the total CO2 storage potential in Egypt ranges between 85 and 600 Gt of CO2, highlighting the potential for blue hydrogen in Egypt [53], although other studies raise concerns that most of the carbon stockage capacity of Egypt lies in depleted hydrocarbon reserves, which presents dangerous shortcomings [46,54].

Another key challenge for the production of green hydrogen in Egypt is the ability to transport its production to the European market. While Egypt can rely on its experience in the export of liquefied gas and ammonia, particularly as studies have shown that it could be possible to transport hydrogen mixtures in one of Europe's gas import flows from North Africa [43,45,57], no direct pipeline exists between Egypt and Europe. Habib and Ouki [54] report that existing infrastructure may be repurposed to accommodate the potential hydrogen production but that they may not be available in the desired areas or region, as hydrogen production has been seen to be sensitive to local characteristics and conditions [58].

In this context, van Wijk et al. (2021) estimate that the implementation of a hydrogen "South-Nordstream" pipeline, spanning 2500 km from Egypt through Greece to Italy, and boasting a capacity of 66 GW, equivalent to the former Nordstream pipeline, would necessitate a total investment of € 16.5 billion. Thus, there is no doubt that an important challenge for the production of hydrogen in Egypt remains the condition of its transportation, as it has been found that investors will only invest into export pipelines for hydrogen if further distribution within the European grid is secured [47].

Finally, a last important challenge for the development of hydrogen production remains water scarcity, a problem shared with most of the contenders for regional leadership in hydrogen production in the MENA region [59]. Egypt is highly dependent on the Nile, which provides 98% of its available renewable water. For this reason, water desalination plays an important role in Egypt's hydrogen production. Currently, Egypt's daily desalinated water production stands at 1.4 million m^3, with plans to expand this capacity significantly to 8.8 million m^3 per day [60]. To encourage green hydrogen investments, Egypt initiated efforts in 2022 to prepare industrial areas like the Suez Canal Zone for desalination purposes [47,53]. However, water scarcity remains a challenge for hydrogen production, and although desalinated water can be used, it may restrict the locations of green hydrogen plants to coastal areas [46].

Despite facing difficulties, Egypt is experiencing a favorable momentum and attracting substantial investments in hydrogen development. The country actively engages in international collaborations on green hydrogen through partnerships involving governmental and private entities, focusing on pilot projects, feasibility studies, and scientific cooperation [53,61]. European countries like Germany or Norway, and more particularly the European Union, show keen interest in green hydrogen in Egypt, aiming to achieve a hydrogen electrolysis capacity of 40 GW by 2030. This aligns with Egypt's commitment to renewable hydrogen production, as demonstrated by the EU-Egypt Renewable Hydrogen Partnership, marked by a joint statement from their leaders during COP27 and the establishment of a hydrogen coordination group [39]. Several European countries such as Germany, France, Portugal, the Netherlands, and Spain also invest in hydrogen production to meet their carbon emission targets and explore hydrogen as a potential export resource. Nevertheless, potential Egyptian hydrogen exports to the EU may be subject to the Carbon Border Adjustment Mechanism (CBAM) tax, especially if the transition towards blue hydrogen is met first. This could be mitigated by adopting clean hydrogen usage, enabling enhanced trade without facing this tax [46].

In 2023, two key developments shed light on positive prospects of the development of green hydrogen in Egypt. First, the European Bank for Reconstruction and Development provides a US$ 80 million loan to Egypt Green Hydrogen S.A.E to support the funding and construction of a 100 MW electrolyser facility to produce green hydrogen in Egypt [7]. Although the project report highights the fact that the impact on groundwater does not align with the EU Water Framework Directive, this groundbreaking project in Egypt will demonstrate the potential of green hydrogen and ammonia industries and serve as a crucial milestone in the advancement of Egypt's green hydrogen.

Secondly, on May 17, 2023, a draft law was approved in Egypt to boost green hydrogen projects and related ventures, providing incentives for environmentally friendly initiatives. The law targets projects involved in green hydrogen production and its by-products, with agreements needing to be reached within five years of implementation. To qualify for incentives, projects must meet conditions such as relying on at least 70% foreign financing, using a minimum of 20% domestically manufactured components, transferring advanced technology, implementing training programs, and demonstrating social responsibility. The incentives comprise cash investment incentives, tax exemptions, zero tax on exports, and various financial benefits, with specific conditions to be met for qualification.

In sum, the adoption of green hydrogen aligns with Egypt's commitment to reducing carbon emissions and addressing climate change, as well as contributing to a greener and more sustainable energy future. The government's cooperation with international partners, such as the European Bank for Reconstruction and Development, underscores the potential for joint efforts in promoting green hydrogen production and global trade [62]. With the favorable assessment of green hydrogen production and the country's ambitious national strategy, Egypt stands poised to play a pivotal role in the future of green hydrogen technologies and international energy cooperation.

To completement political support for the development of renewable energies and green hydrogen, local acceptance is also critical. A previous survey identified a general awareness of the risks of climate change amongst a sample of the Egyptian population, as well as finding the majority of respondents in support of mitigation measures, including the provision of incentives for innovations that reduce greenhouse gas emissions and its effects [63]. Ensuring local support for the development and export of green hydrogen technologies may be fostered by highlighting the potential positive economic impacts. For example, as Egypt ambitiously aims to capture 8% of the global hydrogen market share, the Minister for Electricity and Renewable Energy estimated this would bring a GDP increase by $10–18 billion by 2025 along with the creation of 100,000 new jobs [64].

The more political and local support for the development of both renewable energies and green hydrogen is maintained at a high level, the easier it will be to fulfil this task.

3. Methodology

This study applies a survey-based approach to yield results that go beyond a pure description of the market status quo and capture local support or concerns against developing green hydrogen projects. For this, we conducted surveys in two locations of the Suez Canal Economic Zone (Suez and Port Said) to assess local support with $n = 505$.

3.1. Data

In March 2023, we conducted a standardized survey in two cities of the Suez Canal Economic Zone (Suez and Port Said) to assess local support for the production, export and domestic use of green hydrogen. Suez (Port Said) is located in the south (north) of SCZONE and both locations have the geographical potential to be used for green hydrogen production in Egypt.

For the survey, we developed a questionnaire on attitudes in the fields of environment, climate change, renewable energy, and the production and export or domestic use of green hydrogen. Core elements of this questionnaire are, first, a scenario description of green hydrogen production in the SCZONE, which was presented in two versions (export vs domestic use) in a split-ballot design. This scenario description was followed by questions on attitudes towards certain implications of the respective scenario. The rationale for this is to deduce and compare attitudes towards export and domestic use to see what kind of difference the use type makes. The second core element are specific questions on attitudes towards green hydrogen production in the SCZONE and export to European countries. Adding on to mere attitude reports, a scale with potential benefits of green hydrogen export was developed in order to find explanatory effects of a range of beliefs, since it can be assumed that attitudes towards green hydrogen production and export differ by the extent of certain convictions. The questions and codings are presented in the following section.

The survey was fielded in cooperation with Ipsos research in the form of computer-assisted personal interviews (CAPI). For these interviews, a total of 12 interviewers approached locals in the two cities by sampling an active workforce population in crowded places. In total, 544 persons were recruited for the survey, with nearly half stemming from each Suez and Port Said. However, Ipsos discarded 39 participants due to incomplete survey responses or data quality concerns. This led to an analytical sample of 505 valid cases with 254 respondents from Suez and 251 respondents from Port Said.

The age group of survey respondents is 25–50, with the highest percentage being that of 25-year olds (15.98%) and lowest percentage of 39-year olds (0.99%). Other ages represent approximately 2–4% of the population each. Men comprised 66.27% of all respondents, while women made up 33.53%. The respondents reside in either Suez (50.10%) or Port Said (49.90%). The education level of all survey respondents is at the university level, whereas 497 respondents hold a degree from the public school system, 4 from the Al-Azhar school system and 7 from the private school system.

The survey respondents were asked about their attitudes towards climate change and other environmental problems and largely reported being worried about these issues: on a scale out of 5, with 5 indicating 'very worried', a majority of respondents (81.85%) assigned ratings of 4 or 5 concerning their concerns about climate change, 85.00% did so for air pollution, 86.59% for water pollution, 91.12% for water shortage, 70.22% for domestic waste disposal, 65.68% for industrial CO_2 emissions, and 91.12% for interruptions in the electrical supply. Concerning beliefs about the causes of climate change, survey respondents were divided: 135 (26.62%) recognised human activity as the primary driver of climate change, whereas 221 respondents (43.59%) agreed that climate change results from an equal combination of natural processes and human activity, and 138 participants (27.22%) attributed climate change predominantly to natural processes. When surveyed on how bad or good they think the impacts of climate change will be on the world, the majority of respondents (60.36%) selected an 8 or 9 out of 10 (with 10 indicating that the impacts of climate change will be extremely good).

3.2. *Questions & codings*

The questionnaire was pretested in three consecutive rounds by both members of the research team and external experts from the Arabic German Young Academy. Experts from Egypt were included in the testing to safeguard that the questions were understandable given different cultural backgrounds. Interviewees were asked to reply based on their personal situation and experience.

The survey comprised 38 questions that were presented to both participants from Suez and Port Said and took about 45 min to complete. Among other things, the questionnaire included questions on the following issues which are of interest for this study:

1) Green hydrogen production scenario
2) Benefit evaluation of green hydrogen export
3) Attitudes towards green hydrogen production in the SCZONE and export
4) Social Desirability Scale

Items were to be rated on 5-point or 7-point rating scales to allow for clear positioning [65]. However, participants were given the option to opt out by replying "have no opinion", as some aspects of the subject of green hydrogen development may be politically sensitive to some respondents.

The following section gives an overview of relevant survey questions and their codings according to the above-listed issues.

1) Green hydrogen production scenario (*production scenario*)

We specified two scenarios on green hydrogen production that started equally, but differed in their endings:

"*The Suez Canal Region shall be used to generate electricity from solar and wind power. This electricity shall be used to run electrolyzers, which take fresh water to produce hydrogen. This so-called green hydrogen shall be …*"

- Scenario 1: "*entirely shipped to European countries*"
- Scenario 2: "*used entirely in Egypt*".

Respondents were randomly assigned to only one of these two scenarios (Scenario 1: $n = 232$; Scenario 2: $n = 273$) and then asked to rate six statements on a fully-verbalised 5-point rating scale ranging from "Agree strongly" to "Disagree strongly" (with exit option "Have no opinion"). For the analysis, the statements were taken together to form three indices by computing the mean-score values. This allows for comparison across topics. The *Scenario appreciation* index comprises the two statements "The scenario sounds fine to me" and "All in all, this seems not to be a good idea". The latter item was recoded such that its directionality corresponds to the first item of the Scenario appreciation index. The *Egyptian interests* index comprises the following three statements: "The renewable energy should be made accessible to Egyptian people rather than to European nations", "European countries should generate renewable energy in their own countries", "We must be careful not to be exploited by foreign investors". Lastly, the *No Suez Canal Energy* index addresses opposition to energy generation in the SCZONE regardless of their further usage and comprised one statement: "I don't like the idea of green hydrogen generation in the Suez Canal Region".

2) Benefit evaluation of green hydrogen export (*benefits battery*)

Respondents were asked to rate six statements on the benefits of green hydrogen export. Rating was done on a fully-verbalised 5-point rating scale with an exit option. The benefits statements were as follows:

- Exporting green hydrogen will raise people's income
- Exporting green hydrogen will improve political relationships
- Exporting green hydrogen will improve trade relationships
- Exporting green hydrogen will improve economic development in Egypt
- Exporting green hydrogen will attract further investments
- Exporting green hydrogen will improve Egyptian's energy access

For each statement, a mean value across all respondents was calculated. We refrained from formulating risk items for parsimonious reasons, since each statement also represents a risk component if worded reversely.

3) Attitudes towards green hydrogen production in the SCZONE and export (*attitude battery*)

To gain insight into people's attitudes towards different parts of the hypothetical scenario (such as the production of renewable energy in general or the use of the SCZONE for green hydrogen production), the following statements were presented to be rated on a 7-point rating scale with verbalised end- and midpoint (1 = "Oppose very much", 4 = "Neither oppose nor support", 7 = "Support very much", with the exit option "Can't say"):

- On a scale of 1–7, to what extent do you oppose or support renewable energy generation in general? Remember: Renewable energy generation means energy generation using wind, water, or solar power.
- On a scale of 1–7, to what extent do you oppose or support renewable energy generation in the Suez Canal Region?

- On a scale of 1–7, to what extent do you oppose or support using renewable energy to produce green hydrogen in the Suez Canal Region?
- On a scale of 1–7, to what extent do you oppose or support exporting green hydrogen produced in the Suez Canal Region to Europe?

For each statement, a mean value was calculated across all respondents.

The scale of these items was recoded (1 = "Support very much", 7 = "Oppose very much") in order to align the directionality with the remaining items and, hence, facilitate the interpretation of our results. Lastly, respondents were asked to decide between "it should mainly be exported" and "it should mainly be used inside Egypt" using the following question:

- If green hydrogen was produced in the Suez Canal Region, should it mainly be exported or should it mainly be used inside Egypt according to your personal opinion?

Here, also, the exit option "Can't say" was offered.

4) Social Desirability Scale

Since the survey was conducted via CAPI, we employed a short version of the Social Desirability Scale by Winkler et al. [66] to account for social-desirability bias in the responses. The short scale comprises six items, three of which form the dimension *self-deceptive enhancement* (SDE) and the other three form the dimension *impression management* (IM). Items (rated on a 7-point scale ranging from "absolutely not true" to "absolutely true") were:

- My first impression of people usually turns out to be right (SDE)
- I am often insecure in my judgment (SDE, recoded)
- I always know why I like things (SDE)
- I have received too much change from a salesperson without telling him or her (IM, recoded)
- I am always honest to other people (IM)
- There have been occasions when I have taken advantage of someone (IM, recoded)

According to Paulhus [67,68], sum scores of 18 and above per dimension can be interpreted as existing self-deceptive enhancement and impression management, respectively.

4. Results

The survey is targeted at the local population of Suez and Port Said in Egypt with the objective of better understanding the public sentiments regarding potential Green Hydrogen production in Egypt and its export possibilities.

4.1. Green hydrogen production scenario

As described in Section 3.2, we presented respondents with the scenario that the SCZONE should be used to generate electricity from solar and wind power to produce green hydrogen. This should be entirely shipped to European countries in Scenario 1, and be used entirely in Egypt in Scenario 2, respectively. Table 1 shows the mean values for each of the three mean-scores indices: *Scenario appreciation*, *Egyptian interests*, and *No Suez Canal Energy*. Interestingly, none of the three indices differs significantly between the two scenarios. Hence, irrespective of whether the scenario suggested that green hydrogen from the SCZONE should be entirely exported to European countries or whether it should be entirely used inside Egypt, scenario appreciation is fairly high (value: 2.1, with 1 being highest appreciation and 5 being lowest appreciation). Statements stressing Egyptian interests, such as the sentiment that European countries should generate renewable energy in their own countries, gained less agreement (for Scenario 1: $t = -3.59$, $p < 0.001$; for Scenario 2: $t = -3.18$, $p = 0.001$). The statement opposing green hydrogen production in the SCZONE was rated with a mean value of 4.4, which is close to total disagreement (value 5), meaning that the idea of green hydrogen generation in the SCZONE is generally seen positively. There is no significant difference between Suez respondents and Port Said respondents in the responses to any of these issues, all $t \leq |1.48|$, all $p \geq 0.141$.

Table 1
Descriptive results of mean agreement values to the presented scenarios.

Statement Topic	Scenario[a]	*N*	Mean	*SD*	Min-Max
Scenario appreciation (2 items)	1	228	2.13	0.74	1.00–4.50
	2	270	2.12	0.76	1.00–4.50
Egyptian interests (3 items)	1	227	2.37	0.69	1.00–4.33
	2	269	2.31	0.65	1.00–4.33
No Suez Canal Energy (1 item)	1	224	4.43	0.86	1.00–5.00
	2	268	4.39	0.92	1.00–5.00

[a] Scenario 1 = export to European countries; Scenario 2 = use inside Egypt (between-subject design). Note: low values indicate agreement; high values indicated objection.

4.2. Benefit evaluation of green hydrogen export

The part on benefit evaluation of green hydrogen export was designed to gain insights into beliefs associated with the export of green hydrogen, not with its production or the use of the SCZONE in particular. The rating of the six items is shown in Table 2. The rating of all statements circle around the value of 2, indicating general agreement. This shows that exporting green hydrogen is mostly associated with positive economic side effects both on individual level (people's income) and on national level (improved political/trade relationships and economic development). Even energy access is believed to improve due to exporting green hydrogen, whereas this statements finds least agreement, i.e., significantly less than the beliefs that the export would improve political relationships ($t = 4.50$, $p < 0.001$) and trade relationships ($t = 4.14$, $p < 0.001$), and that it would attract further investments ($t = 3.88$, $p < 0.001$). There is no difference between Suez respondents and Port Said respondents in the rating of any of these benefits, except for the first one. The belief that exporting green hydrogen will raise people's income is more agreed to among respondents in Suez ($M = 2.08$, $SD = 0.68$) than among those in Port Said ($M = 2.20$, $SD = 0.65$), $t = -1.96$, $p = 0.050$, however with a weak effect of Cohen's $d = 0.165$.

Table 2
Mean agreement values to statements concerning potential export benefits.

Item	*N*	Mean	*SD*	Min-Max
Exporting green hydrogen will raise people's income	489	2.14	0.66	1–5
Exporting green hydrogen will improve political relationships	490	1.93	0.81	1–5
Exporting green hydrogen will improve trade relationships	488	1.97	0.75	1–4
Exporting green hydrogen will improve economic development in Egypt	486	2.06	0.75	1–5
Exporting green hydrogen will attract further investments	489	1.98	0.78	1–5
Exporting green hydrogen will improve Egyptian's energy access	489	2.18	0.83	1–5

4.3. Attitudes towards green hydrogen production in the SCZONE and export

Table 3 shows mean values of the statement ratings regarding the production of green hydrogen in the SCZONE and its export. The results show general support (values close to 1 on a scale from 1 to 7) for renewable energy generation in general as well as in the SCZONE. The production of green hydrogen is also seen positively. The export of green hydrogen produced in the SCZONE yields slightly less support, which is, however, still between “Support very much” (1) and “Neither oppose nor support” (4), hence basically supported. These results do not differ significantly between Suez and Port Said respondents. To reveal the respondents’ preference between export and domestic use explicitly, we confronted them with the decision whether hypothetically produced green hydrogen from SCZONE should mainly be exported or used inside Egypt. As Fig. 1 shows, 63% ($n = 316$) of respondents preferred the use inside Egypt, while 14% ($n = 71$) preferred its export. Suez and Port Said respondents do not differ significantly in this question.

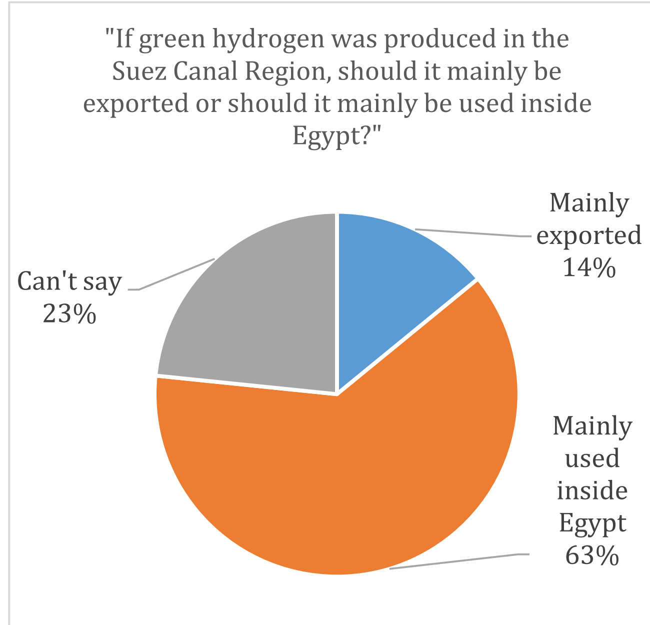

Fig. 1. Response behaviour to the forced-choice decision of green hydrogen export or domestic use.

4.4. Social Desirability Scale

Table 4 shows the sample’s response behaviour of Winkler’s Social Desirability Scale. The two dimensions of yielded mean scores of $M = 4.98$, $SD = 0.76$ for self-deceptive enhancement (SDE) and $M = 4.09$, $SD = 0.85$ for impression management (IM). These did not differ between Suez and Port Said respondents.

As mentioned in Section 3.2, sum scores of 18 and above per dimension can be interpreted as existing self-deceptive enhancement or impression management, respectively. In our sample, 7.9% of respondents meet this requirement for SDE and 0.4% for IM. Hence, other results of the questionnaire should be interpreted with this in mind. However, correlating the two SD dimensions with other responses in the survey can hint towards social desirability tendencies in certain items. Table A1 in the appendix shows pairwise correlation coefficients between the two SD dimensions and the other relevant variables. As can be seen in Table A1, most correlations are significantly different from zero ($\alpha = 0.05$) and 12 out of 32 coefficients amount to $|0.3|$ or larger. This speaks in favour of controlling for social desirability in the upcoming regression analysis.

Table 4
Mean response values to the Social Desirability Scale.

Item	Dimension	*N*	Mean	SD	Min-Max
My first impression of people usually turns out to be right.	SDE	505	5.62	1.15	2–7
I am often insecure in my judgment. (inverted)	SDE	505	4.18	1.83	1–7
I always know why I like things.	SDE	505	5.15	1.10	2–7
I have received too much change from a salesperson without telling him or her. (inverted)	IM	505	3.68	1.72	1–7
I am always honest to other people.	IM	505	5.21	1.12	2–7
There have been occasions when I have taken advantage of someone. (inverted)	IM	505	3.39	1.54	1–6

4.5. Regression model “export of green hydrogen from SCZONE”

We performed a multiple regression analysis to find out what explanatory effect the benefit evaluation has on the degree of support and opposition regarding the export of green hydrogen produced in the SCZONE to Europe. Further predictors were the two dimensions of the Social Desirability Scale (SDE and IM) as well as age and gender. The analysis of the Suez sample on $N = 242$ shows that the extent of green hydrogen export from the SCZONE to Europe can be predicted with $F(10, 231) = 3.33, p < 0.001$, 12.6% of variance in the dependent variable can be explained. The coefficients are displayed in Table 5. The analysis of the Port Said sample on $N = 238$ shows that the extent of green hydrogen export from the SCZONE to Europe can be predicted with $F(10, 227) = 8.25, p < 0.001$, 26.7% of variance in the dependent variable can be explained. The coefficients are displayed in Table 6.

Table 3
Mean values of the attitude-battery items regarding renewable energy generation and green hydrogen production in SCZONE as well as its export to Europe.

	N	Mean	*SD*	Min-Max
Renewable energy generation in general	493	2.24	0.90	1–6
Renewable energy generation in the Suez Canal Region	495	2.20	0.91	1–5
Using renewable energy to produce green hydrogen in the Suez Canal Region	491	2.32	0.90	1–5
Exporting green hydrogen produced in the Suez Canal Region to Europe	493	2.69	0.93	1–6

Table 5
Regression coefficients of the multiple regression model on the Suez sample.

Predictor	*β*	*SE*	*t*	*p*
Raise people’s income	0.41	0.10	3.98	<0.001
Improve political relationships	0.20	0.10	2.11	0.036
Improve trade relationships	−0.13	0.09	−1.43	0.153
Economic development in Egypt	−0.07	0.09	−0.74	0.458
Attract further investments	−0.11	0.10	−1.16	0.248
Improve Egyptians’ energy access	0.06	0.10	0.63	0.527
SDE	0.02	0.03	0.59	0.555
IM	−0.01	0.02	−0.44	0.658
Age	−0.01	0.13	−0.08	0.933
Gender	−0.00	0.01	−0.71	0.480
Constant	1.98	0.67	2.94	0.004

Among Suez respondents, *raise people’s income* and *improve political relationships* had a positive effect, meaning that supporting green hydrogen export from SCZONE is predicted by the belief that exporting it will raise people’s income and by the belief that it will improve political relationships. Among Port Said respondents, *raise people’s income,*

Table 6
Regression coefficients of the multiple regression model on the Port Said sample.

Predictor	β	SE	t	p
Raise people's income	0.40	0.10	3.91	<0.001
Improve political relationships	0.01	0.08	0.09	0.926
Improve trade relationships	−0.13	0.08	−1.58	0.115
Economic development in Egypt	0.00	0.08	0.02	0.985
Attract further investments	0.15	0.08	1.80	0.073
Improve Egyptians' energy access	0.32	0.08	4.07	<0.001
SDE	0.00	0.03	0.17	0.861
IM	−0.01	0.02	−0.33	0.739
Age	0.13	0.11	1.21	0.226
Gender	−0.00	0.01	−0.25	0.805
Constant	0.97	0.66	1.46	0.146

attract further investments, and *improve Egyptians' energy access* had a positive effect, meaning that supporting export is predicted here, too, by the belief in raised income, but also by the belief that exporting green hydrogen will attract further investments and that it will improve Egyptians' energy access.

5. Discussion

In this paper, we assessed the potential of green hydrogen production in SCZONE and potential export to Europe by focusing on the beliefs and attitudes of the local population in Suez and Port Said. In the following section, the above-reported results are interpreted and discussed.

5.1. Survey results

The survey revealed generally high agreement to the hypothetical production and export of green hydrogen from SCZONE to European countries. Specifically, we confronted respondents both in Suez and in Port Said with two different scenarios. Both scenarios described renewable energy generation from solar and wind power in the Suez Canal Region in order to produce green hydrogen. Scenario 1 postulated that this green hydrogen should be entirely shipped to European countries, Scenario 2 postulated that it should be entirely used in Egypt. Interestingly, both scenarios were equally positively rated in the statistical sense, implying that people are in favour of green hydrogen production in SCZONE, regardless of whether it is for export or for domestic use. When confronted with notions stressing Egyptian interests more than European ones (e.g., that SCZONE renewable energy should be made accessible to Egyptians rather than to Europeans), we find less agreement in both scenarios compared to notions appreciating the scenarios. For Scenario 1, it seems plausible that agreement to the appreciation of export differs significantly from agreement to the emphasis of Egyptian interests. However, for Scenario 2, the result is surprising and thus very interesting: Since Scenario 2 described the domestic use of hydrogen produced in SCZONE, agreement to the appreciation of this scenario could have been expected to be similarly high as agreement to the emphasis of Egyptian interests. However, this is not the case. When confronted with a hydrogen production scenario—no matter whether it is for export or domestic use—people seem to have the tendency to agree. On the other hand, when confronted with notions that sound minimally cooperative (e.g., "European countries should generate renewable energy in their own countries"), people do not agree to the same extent. This is plausible because appreciating hydrogen production and use in Egypt—especially if the question offers no alternative scenario—is far away from non-cooperative thinking. In summary, people tend to agree with the suggested scenarios but do not agree with non-cooperative or egoistic notions.

The presentation of various statements expressing different potential benefits of green hydrogen export found generally high agreement. This holds true for statements concerning political and trade benefits as well as personal benefits. However, statements concerning improved political and trade relationships yielded higher agreement values than statements concerning personal benefits, such as the beliefs in raised income and in improved energy access. Respondents in Suez do not differ from respondents in Port Said in this regard. The only detectable difference between the two subsamples' benefit evaluation could be determined in the belief of raised income as a consequence of green hydrogen export. People in Suez seem to believe more in raised income than people in Port Said. However, this result must be interpreted with great caution, since the difference's effect is particularly small [69].

In line with the positive evaluation of green hydrogen production in SCZONE and its export, attitudes towards renewable energy generation in general, in the Suez Canal Region, its use for green hydrogen production, and green hydrogen export are generally seen positively by the people (regardless of location). When confronted with the decision between mainly export and mainly domestic use, the majority chooses mainly domestic use. This makes sense, as using green hydrogen within Egypt has a number of advantages, such as improved economic conditions in Egypt or on the reduction of the carbon footprint of a country's industry. Surprisingly, almost one quarter of respondents refused to answer this question or could not decide. This can indicate limited knowledge of the topic, simply a lack of preference in this question or potential uncertainty concerning consequences of the answer. The latter may contribute to socially desirable response behavior. However, this was not the case according to our data.

By analyzing multiple regression models, we aimed to explain people's attitudes towards green hydrogen production in SCZONE and export to European countries. For this, we included potentially explanatory predictors, i.e., respondents' agreement to export benefits statements, age, and gender and controlled for socially desirable answer behavior. Results suggest that the attitude towards production and export of green hydrogen from SCZONE can be explained both among respondents in Suez and in Port Said to a considerable extent by the examined predictors. Especially the belief of raised income due to exporting hydrogen contributes to a positive attitude in both locations. Other predictors differed between the two locations. Among Suez respondents, the beliefs of improved political relationships had a significant effect, while among Port Said respondents, the beliefs of attracting further investments and an improved energy access for Egyptians had a positive effect on the attitude towards green hydrogen production in SCZONE and export to European countries. Interestingly, the regression analysis on the Port Said sample resulted in a higher explanation of the dependent variable's variance than the regression analysis on the Suez sample. This indicates that the same predictors could explain attitudes of people in Port Said better than in Suez. We have no evidence to explain these differences between Suez and Port Said, hence we cannot say whether the cities' locations (Suez closer to Cairo, Port Said closer to the Mediterranean Sea), their economies (trade, tourism, etc.) or maybe their inhabitants' experiences play a role. Future studies are needed to investigate this issue in order to understand which other factors are better able to explain attitudes towards green hydrogen production and export among people living in Suez.

Further aspects merit discussion, once we contrast our findings to those of other authors: Our study complements many aspects mentioned by UNIDO [53] and shows the differences in acceptance between the inhabitants of Port Said and Suez seem limited. As Emodi et al. [10] suggest, a detailed analysis relating to factors such as prior knowledge, environmental knowledge and personal and distributional benefits might have displayed a more nuanced picture. Likewise, Scovell [29] demonstrates that psychological factors also play in important role regarding acceptance. Nevertheless, our findings align with findings from Gordon et al. [11] underscoring the necessity to create local benefits. While our study does not display acceptance problems, this seems to be especially important relating to exports that were less favorably viewed than domestic use. Regarding our overall positive attitude results, findings from Schönauer and Glanz [29] suggest that it is advisable to interpret these with great caution. In a qualitative study with a

German sample, they demonstrate that acceptance of green transformation projects diminishes once construction starts and the (short-term) negative effects clearly display. Furthermore, it should be kept in mind that green hydrogen production is not synonymous with sustainable hydrogen production. Further social and economic aspects must be considered if hydrogen production was to be not only green but sustainable as a whole [9].

5.2. Limitations of the analysis

Limitations of the survey especially address our limited ability to explain the differences between Suez and Port Said respondents regarding the regression models, particularly against the background of comparable results between the two locations in the other analyses. As stated above, more research is needed to focus on this topic. Moreover, in the decision question between export and domestic use of green hydrogen from SCZONE, a fairly large number of respondents chose not to answer. We do not know whether this means that people found both options equally attractive, whether they were lacking knowledge on the topic, or whether they had other reasons to refuse to answer. In future studies, we are going to improve questions like this by giving more differentiated response options.

Further limitations address more general points of the survey. We have conducted the survey in the same year as the 2023 Egyptian presidential elections, hence we cannot rule out any kind of politically desired response behaviour. On the other hand, the elections were held in December 2023 and our survey was conducted in February and March 2023, which reduces the risk of interference. Another limitation addresses the absence of questions regarding attitudes towards potential trade partners (i.e., European countries) in general or the measurement of the issues relating to alternative trade partners (e.g., China) to be able to determine a potential bias against Europe among the respondents. Nevertheless, we did not find any statistically significant difference in the appreciation of exporting green hydrogen to Europe and using it domestically.

6. Conclusion

This study aimed at closing the gap on local acceptance of green hydrogen production in Egypt's Suez Canal Economic Zone (SCZONE), which stands out as major supplier for green hydrogen exports to third countries. By surveying locals in Suez and Port Said, two potentially strategically important locations for green hydrogen production and trade, we aimed at gaining insights into local perceptions and factors facilitating local support for these projects.

Overall, the survey indicates high potential for societal support regarding green hydrogen generation in SCZONE. This support is largely unconditional of the option to deploy hydrogen nationally or use it for export. These findings hold true both from the perspectives of people living in Suez and Port Said, underlining the small differences of perceptions in both production sites.

Factors influencing support slightly differed between the locations: While Suez respondents' belief in improved political relationships proved a strong motivator, the arguments of further investments and improved energy access were more predominant in Port Said. In both sites, the belief of raised income due to exporting hydrogen strongly contributed to a positive attitude of respondents. From a policy perspective, the government is well advised to secure local support for green hydrogen projects. Our analysis shows that this support can be ensured by strongly emphasizing the perspective of economic and social development. Engaging in local cooperation should be seen as a key component is this respect. Local engagement of the workforce will be especially crucial as it allows locals to benefit from green hydrogen production. Future studies are advised to broaden their scope by addressing trade relationships with various regions (e.g., Europe and China) in comparison to provide a more complete picture of the public opinion. Also, an expansion of surveys onto other countries in the Middle East/North Africa region could provide promising insights. Despite the scope, the methodology could also be broadened in future studies, i.e., augmented by qualitative components such as focus groups in order to avoid distorting responses to difficult questions. Overall, our study provides first important results on public opinions regarding hydrogen trade partnerships with other countries.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Marc Ringel: Writing – review & editing, Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Gerrit Stöckigt:** Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Conceptualization. **Hawal Shamon:** Writing – review & editing, Writing – original draft, Validation, Methodology, Investigation, Formal analysis, Conceptualization. **Stefan Vögele:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Conceptualization.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijhydene.2024.06.239.

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