UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

GEIPP
GLOBAL ECO-INDUSTRIAL PARKS PROGRAMME

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Applications of Green Hydrogen in Eco-Industrial Parks

Best Practice Series

GEIPP

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UNIDO

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Introduction and State of Play

Industrial energy consumption accounts for more than one-third of global energy usage (UNIDO 2023) and is projected to grow substantially in the coming years. Fossil fuels continue to hold a significant position as the primary energy source for industrial activities, accounting for 68% of energy consumption in 2021.

In contemporary energy transitions and industrial paradigms, green hydrogen has emerged as a prominent alternative within the spectrum of renewable energy options.

Currently, hydrogen finds applications in refining, ammonia, and methanol production. In the future, it has the potential to be employed in various industrial processes, including steel production (for direct reduced iron), transportation, and heat generation (UNIDO 2023). Ongoing research explores the use of hydrogen as a substitute for natural gas in activities such as glass manufacturing, brick production, and building materials like cement. Studies carried out by IRENA (2022) suggest that the primary use of hydrogen can be in industrial production, given that certain processes cannot be directly electrified using existing production methods.

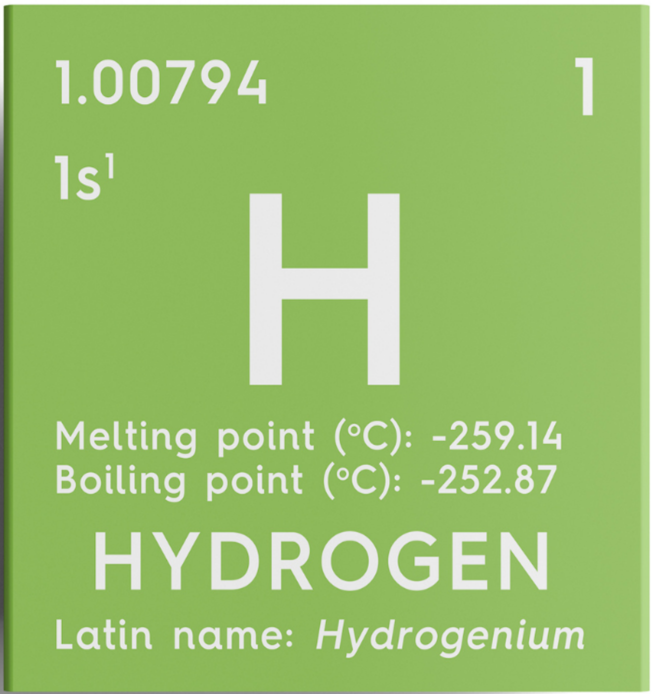
Green hydrogen is generated through the process of water electrolysis utilizing renewable electricity. Fossil fuels contribute to approximately 99% of global hydrogen production, with 6% derived from natural gas and 2% from coal. In 2018, the International Energy Agency (IEA) reported a global hydrogen production of 75 million tonnes (Mt), while electrolysis-based production in 2022 represented only 0.035 Mt of the total global output. As a result, fossil fuels currently dominate the production landscape, collectively contributing to around 830 MtCO2 emissions per year. To expedite the shift towards clean energy and reduce reliance on fossil fuels, it is crucial to encourage the expansion of green hydrogen production.

Table 1. *Types of hydrogen and current production*

Term used	Description	Current production
Grey hydrogen	Grey hydrogen is produced from fossil fuels (natural gas or oil) through steam reforming and causes process-related CO_2 emissions.	74 Mt (2018)
Blue hydrogen	Blue hydrogen is based on the same processes as grey hydrogen, but additional carbon capture and storage technologies are applied to permanently store the process emissions underground (carbon sequestration) or bind it in a solid product (e.g. bricks).	0.75 Mt
Green hydrogen	Green hydrogen is produced via water electrolysis using non-emitting (renewable) electricity.	0.035 Mt

The industrial sector is currently facing growing pressure to swiftly embrace renewable energy sources and technologies to work towards a carbon-neutral future. Hence, Governments, industries, and various stakeholders are adjusting their approaches to industrial development in response to evolving framework conditions, incorporating green hydrogen into their strategies.

Currently, numerous countries have either established or are in the process of developing roadmaps and strategies centered around green hydrogen. There is anticipation for a swift growth of green hydrogen, projecting its coverage to reach up to 14% of the global final energy consumption by 2050 (UNIDO, 2023).



Nevertheless, significant uncertainties are linked to its widespread deployment. Responding to this development, UNIDO explores various pathways through its technical assistance to companies, employing resource-efficient and cleaner production assessments.

As part of the shift to renewable energy sources and balancing energy consumption, eco-industrial parks are also encouraged to increase the adoption of green hydrogen generation and use. As eco-industrial parks are designed to optimize resource utilization and minimize negative environmental impact, they show significant compatibility with green hydrogen development.

Shifting from theory to practice, the GEIPP Best Practice series aims to explore the feasibility of green hydrogen development within Industrial Parks. Each case study outlined in this publication examines the identification, planning, and execution of green hydrogen opportunities in IPs

These case studies aim not only to emphasize the theoretical alignment of green hydrogen with EIPs but also to delve into the practical applicability of this relationship. These real-world instances exemplify the viability of integrating green hydrogen production into industrial ecosystems, marking progress toward a more sustainable and efficient industrial landscape.

CASE STUDY 1: UNIDO'S GREEN HYDROGEN INDUSTRIAL CLUSTER

The United Nations Industrial Development Organization (UNIDO) has launched the Global Programme for Hydrogen in Industry (GPHI). This initiative aims to support developing countries in overcoming challenges, ensuring an equitable hydrogen transition, and prioritizing social and environmental considerations.

The development of green hydrogen facilities necessitates a careful consideration of technical feasibility and substantial investments. Therefore, it is vital to identify key industrial sectors where the production of green hydrogen can yield tangible benefits.

Despite the promising opportunities, the transportation of green hydrogen remains challenging. While it can be transported through pipelines, the associated costs remain significant. It can also lead to 70% of the energy lost during the process.

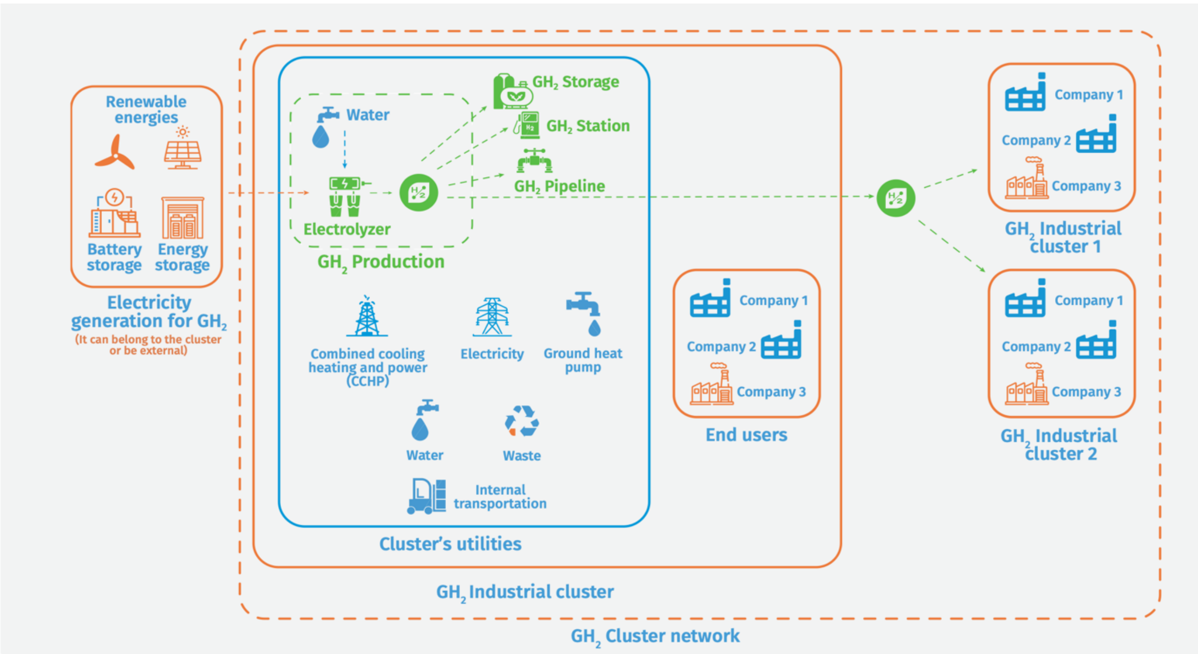
Addressing this challenge, UNIDO has introduced a green hydrogen industrial cluster model, facilitating the local utilization of the produced H2. This model aims to enhance the viability of green hydrogen applications and contribute to the overall success of the GPHI.

Green Hydrogen Industrial Clusters (GHIC)

GHIC refers to industrial areas or groupings where there is a collective utilization of green hydrogen (including its production, transportation, and application) and renewable energy electricity. These regions also utilize various resources to serve diverse purposes, such as material manufacturing, heating and cooling, local transportation, and industrial feedstock.

This concept could work well with the industrial park where businesses are located in the common property.

Figure 1. *Schematic overview of a green industrial cluster*



Based on an exhaustive analysis of 20 different hydrogen and renewable energy clusters and valleys, UNIDO developed a model that provides guidance for governments and industries in the preparation, implementation, and upscaling of green hydrogen industrial clusters[1].

Table 2. *Phases of the development of green hydrogen industrial clusters*

Phase	Activities in the phases
Phase 1: Preparation of green hydrogen clusters	• Awareness-raising • Stakeholder engagement • Preparation of the objective, strategy and work plan of a green hydrogen cluster • Feasibility studies • Financial mobilization
Phase 2: Deployment of technologies for green hydrogen	• Commissioning of pilot projects • Production, process adaptation and use of green hydrogen in industrial processes • Testing of pilot projects • Commercial operation
Phase 3: Upscaling the use of green hydrogen in industry	• Programmes for uptake and challenges • Development of green hydrogen networks

Three phases are outlined in this model–awareness and capacity building, pilot projects, and full-scale uptake. In Phase 1, efforts will be directed towards preparing industrial clusters to a state where pilot projects for green hydrogen can be initiated in Phase 2. During this phase, initial pilot initiatives will receive support, and the cluster will undergo adjustments to facilitate sector integration and future expansion.

Phase 3 aims to implement green hydrogen strategies effectively, ensuring a 100% supply of green hydrogen to meet the production cluster's hydrogen demand. This will generate success stories and exemplary practices for potential replication. Continuous monitoring and evaluation exercises will be conducted across all phases to monitor progress and update the model in response to technological, cost, and environmental advancements.

UNIDO is gearing up for the pilot phase of this model, scheduled for 2024, and will be assessing its applicability in industrial parks. Like the industrial park concept, GHIC encourages collaboration and synergies among industries within a shared geographic area. The GHIC can benefit from the eco-industrial park's collaborative environment by leveraging synergies with other industries, sharing infrastructure, and creating a more integrated and sustainable industrial ecosystem.

[1] UNIDO (2023), Green Hydrogen Industrial Cluster Guidelines, https://www.unido.org/sites/default/files/files/2023-08/GH2_ClusterGuidelines.pdf?_token=1613503223

CASE STUDY 2: GREEN HYDROGEN PROJECT IN THE ELIDZ, SOUTH AFRICA

The pre-feasibility study in June 2023 charts an extensive roadmap for developing a green hydrogen project in one of GEIPP's priority parks in South Africa, the East London Industrial Development Zone (ELIDZ). Green Hydrogen Solutions (GHS) spearheaded this study for its specialized arm, GHS Green Hydrogen Eastern Cape (GHSEC).

This initiative is prompted by heightened demands from key tenants at ELIDZ, including industry giants like Mercedes Benz South Africa (MBSA), who are mandating a shift to carbon neutrality in its industrial facilities and value chains.

Outlined in the study were two project phases envisioned by GHS:

- Phase 1: Replace non-critical liquefied petroleum gas (LPG) and potential fossil fuels in a pilot project for industrial heat, incorporating hydrogen as a fuel for logistics in vehicles with fuel cells or internal combustion engines running on hydrogen.
- Phase 2: Utilize hydrogen to produce electricity through a fuel cell (power to power) to the grid and convert hydrogen to ammonia for exports.

Proposed Green Hydrogen Development

The image illustrates the East London Industrial Development Zone (ELIDZ) map, with the proposed hydrogen site positioned in the top right corner, approximately 1.2 kilometers from a proposed desalination plant.

The primary water source for the envisaged green hydrogen production facility is anticipated to be the proposed desalination plant within the East London IDZ. There are potential smaller-scale desalinated water investments in the IDZ (not depicted on the map). Alternative water sources include a potential wastewater reclamation plant with a sewage line parallel to the industrial zone and a reservoir supplying potable water, serving as a backup water source.

In terms of energy supply, the ELIDZ is currently engaged in the implementation of 15 MW solar PV rooftop installations, predominantly intended for the existing tenant. Therefore, an additional energy supply is deemed necessary. A plan outlines the installation of 8 MW of electricity from solar PV adjacent to the desalination plant. Further potential sources of green electricity include two solar projects and a 1.8 MW wind project under development approximately 50 kilometers away from the industrial zone.

Investment and Funding

The case study focused on the development of Phase 1. In this phase, potential off-takers were categorized into Tier 1 and Tier 2 based on anticipated demand and assessed through interviews with potential users of green hydrogen in and around ELIDZ. These potential users include MBSA, Summerpride, First National Battery, Isringhausen, and Sundale Dairy, logistics companies in the ELIDZ (DSV, MSC, VDS, Bigfoot, and Milltrans), and truck suppliers to the logistics companies, i.e., Volvo, Isuzu, Daimler Trucks, Toyota, and Scania.

Based on the assessment, Tier 1 alone could support a pilot-scale plant producing 195,842 kilograms of green hydrogen annually. If off-take arrangements are secured from all the potential off-takers, larger volumes (Tier 1 + 2) of 1,925,786 kg per year could be considered.

The financial aspects, including capital expenditure (CAPEX), operational expenditure (OPEX), and simple payback periods, were detailed for both Tier 1 and Tier 1 + 2. The capital expenditure (CAPEX), operational expenditure (OPEX), and simple payback periods for Tier 1 and Tier 1 + 2 are as follows:

- Tier 1: R84.8 million CAPEX, R12.8 million OPEX per year, eight years simple payback period.
- Tier 1 + 2: R755.1 million CAPEX, R121.9 million OPEX per year, 9-year simple payback period.

The study anticipates that actual project capital expenditure might be lower post-contracting, enhancing project returns. Predictions indicate that, with decreasing production costs and rising carbon taxes, green hydrogen could achieve price parity by 2030 with conventional solutions. Financing is expected from private investment, with the UNIDO EIP Access-to-Finance Tool providing additional options.

To ensure the project's viability, GHSEC needs to establish power purchase agreements (PPAs) for renewable energy from diverse sources from the national grid company Eskom or Buffalo City Metropolitan Municipality (BCMM). The power demand for Tier 1 is 2 megawatts (MW), while Tier 1 + 2 will require 20 MW.

GHSEC must establish a contractual agreement with the identified water supplier/s for water provision. The water supply may originate from one of three potential desalinated water investors in the ELIDZ or potentially through water reclamation from wastewater. The water needs for Tier 1 amount to 2,400 cubic meters (m3) or kilolitres per year, and for Tier 1 + 2, it increases to 23,000 m3 per year.

Hydrogen sales and purchase agreements will be crucial for cost recovery, and success factors include sustainable and cost-effective renewable electricity, water availability, and competitive pricing.

Potential Risks and Mitigation Strategies

The project carries the promise of substantial reductions in emissions and the creation of job opportunities. Nevertheless, it confronts political uncertainties marked by instability and economic hurdles, notably constrained domestic markets.

Additional political risks encompass potential delays in environmental authorization processes and a perceived lack of commitment from the South African Government towards the broader energy transition within the country.

Economic challenges include a constrained local market within and near the ELIDZ, coupled with difficulties in securing private investment funds. This can be alleviated by directing efforts towards establishing an industry that harnesses South Africa's natural resources, fostering the growth of a large-scale sector capable of facilitating cost-effective hydrogen production for both domestic and export markets. Encouraging private sector investment and community engagement are also key to addressing the challenges.

CASE STUDY III: GREEN HYDROGEN DEVELOPMENT IN THE SCZONE, EGYPT

The Suez Canal Economic Zone (SCZone) is the primary regulatory authority for all industrial zones located within the Suez Canal zone. It also cooperates with GEIPP Egypt to implement an EIP project in one of its industrial parks (Orascom Industrial Park) in Sokhna.

The SCZone, is an economic zone situated along the globally significant Suez Canal Maritime route. Comprising four industrial parks, the SC Zone accommodates over 400 operational establishments, including 14 developers engaged in fostering investment and economic growth.

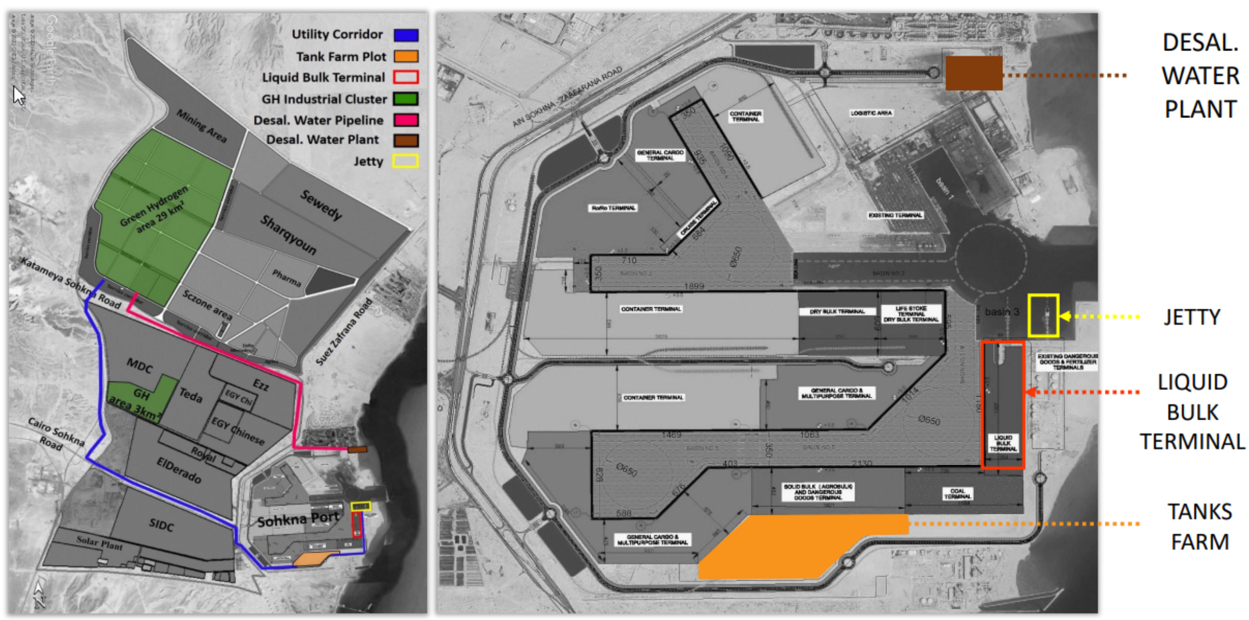
The Suez Canal Economic Zone (SCZone) plays a crucial role in promoting green hydrogen and ammonia projects in Egypt, leveraging its advantageous proximity to the Suez Canal and access to renewable energy resources. Recognizing the potential of green hydrogen as well as ammonia for shipping fuels, SCZone strategically established two clusters located at Sokhna and East Port Said.

Green Fuel Industrial Clusters at SCZone

Egypt presently foresees an influx of investments totaling $85 billion from global developers for a series of projects centered around green hydrogen and green ammonia. The envisaged production yield for the green hydrogen initiative is estimated at 15 million tons per annum. The SCZone has embarked on green hydrogen initiatives, capitalizing on its strategic location and renewable energy potential. The operational model involves integrating renewable energy generation into Egypt's national grid.

Developers build solar and wind capacities outside the SCZone, connecting to the National Grid, which is then tapped into within the SCZone through a power substation. The zone allocated significant land, approximately 30 square kilometers, for these clusters. These areas serve as central points for green hydrogen and ammonia projects, facilitating integration with the Suez Canal and neighboring ports.

SOKHNA Green H_2 Cluster



The SCZone authority invests in various facilities to support the growing green hydrogen sector. Initiatives include desalination plants to meet industrial water requirements, power substations for effective energy distribution, and pipelines connecting industrial facilities to storage units at the port.

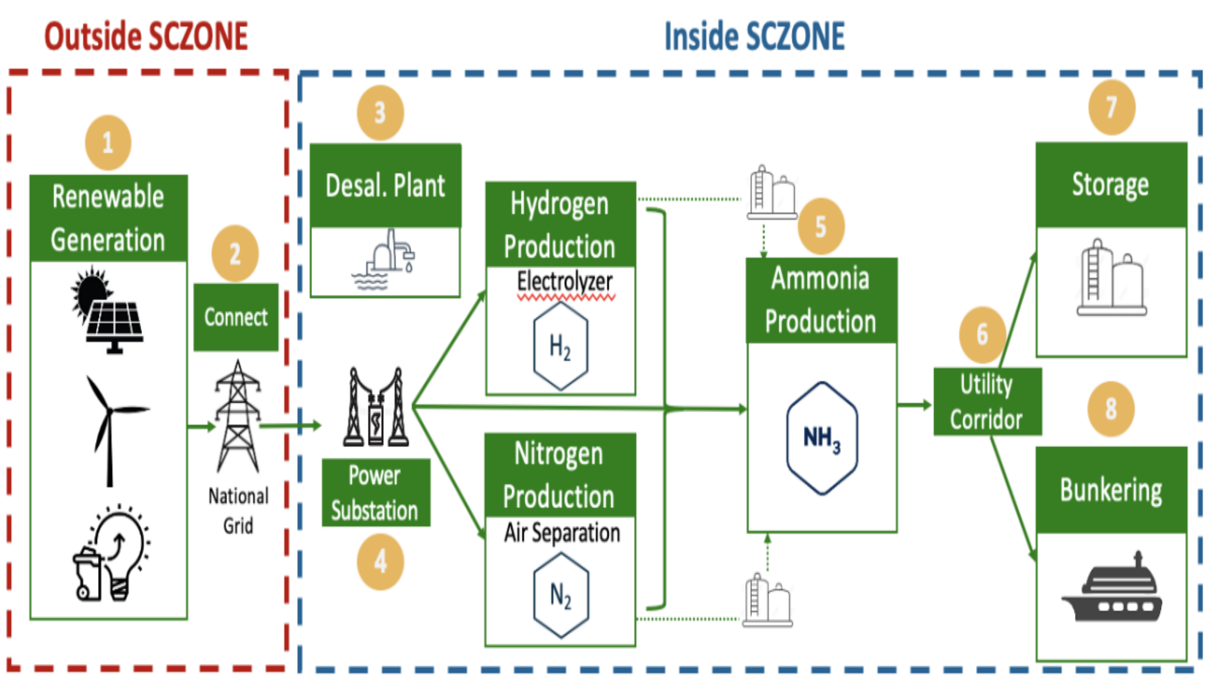
The zone has adopted a shared facilities approach to enhance efficiency and reduce costs. Centralized facilities, such as a water desalination plant, power substations, and storage tanks, are tendered to investors. This collaborative model ensures a more streamlined and cost-effective infrastructure, benefiting both large and small-scale developers.

Currently, it has signed 21 active Memoranda of Understanding (MOUs) with global companies marking substantial interest in green hydrogen and green ammonia projects. Nine of these 21 MOUs have been converted into a legally binding framework agreement.

Responding to the SCZone's interest, GEIPP Egypt assists with developing a roadmap for green hydrogen (GH2) production in Sokhna. This roadmap will outline the steps needed to create a GH2 ecosystem that complies with EIP principles and criteria.

Through this project, GEIPP Egypt supports stakeholders in identifying EIP opportunities and aiding enterprises in achieving economic, environmental, and social benefits through comprehensive analysis. This involves strengthening the capacities of Industrial Parks (IP), supporting park management, and assisting tenant companies in implementing EIP and meeting national requirements.

Figure 3. *Operational Model of Green Fuel Project in SCZone*



Recommendations for the Development of the GH2 Ecosystem based on EIP principles

The overarching objectives of GEIPP's involvement in this project include promoting policies and regulations that actualize Eco-Industrial Parks (EIPs). This involves evaluating the current capacities of park management entities and institutions while concurrently reinforcing national institutions relevant to developing and implementing EIP policies.

Within the realm of EIP, GEIPP Egypt conducts training sessions for stakeholders, facilitating the transfer of knowledge regarding international experiences and best practices in Green Hydrogen (GH2) park development. UNIDO also provides insights into the present and future hydrogen market.

GEIPP offers a set of recommendations to support the Suez Canal Economic Zone (SCZone) in mitigating potential adverse environmental and social impacts that may arise during the construction and operation of the GH2 ecosystem. These recommendations include:

- An outline for assessing the performance of the GH2, incorporating a list of Key Performance Indicators (KPIs) as outlined in the EIP framework. Further, conducting comprehensive environmental impact assessments
- Implementing sustainable land-use practices,
- Engaging with local communities, managing risks, prioritizing waste reduction, establishing eco-industrial park infrastructure,
- Integrating industrial, environmental, social, and digital infrastructure, considering industrial symbiosis, adapting recommendations, and
- Ensuring regular monitoring and evaluation to address emerging challenges.

Particular emphasis is placed on KPIs that address the significant Environmental and Social Impact Assessment (ESIA) vis-à-vis benefits at the ecosystem level.

Conclusion:

Eco-industrial parks (EIPs) have emerged as a promising model for promoting sustainable industrial practices, fostering resource efficiency, and reducing environmental impact. Green hydrogen, a clean and versatile energy carrier produced through water electrolysis using renewable electricity, holds immense potential to accelerate the mainstreaming of EIPs, enabling a transition towards a low-carbon and resource-efficient industrial landscape.

Industrial parks offer close proximity to several off-takers of the hydrogen they produce, which is already used to cooperate in the context of the industrial park. The park management entity can facilitate such developments and take part in the investments as part of the value-added services provided to the tenant companies. Green hydrogen development will contribute to achieving carbon neutrality, making it a competitive advantage in attracting progressive and export-oriented tenant companies.

Green hydrogen's carbon-free nature aligns perfectly with the environmental goals of EIPs, enabling the decarbonization of industrial processes and reducing reliance on fossil fuels. Its energy density and versatility make it a suitable substitute for various industrial applications.

The integration of green hydrogen into EIPs can unlock several benefits, including:

1. Renewable Energy and Resource Efficiency

   Green hydrogen can directly replace or complement fossil fuels in industrial applications or be utilized in combined heat and power (CHP) systems, providing both heat and electricity for industrial operations. This can reduce overall energy consumption, eliminate waste heat, and lead to significant energy savings. Excess green hydrogen can be used for process heat or converted into valuable chemicals, further enhancing resource efficiency.

2. Local Economic Development

   The production and utilization of green hydrogen within EIPs can stimulate local economic development by creating jobs in hydrogen production, infrastructure development, and related industries. This can enhance economic resilience and attract new investments to EIPs.

3. Demonstration and Innovation

   IPs can serve as testbeds for green hydrogen technologies, fostering innovation and collaboration among industry players, research institutions, and policymakers. This can accelerate the development and deployment of green hydrogen solutions, driving down costs and increasing its competitiveness.

To effectively leverage green hydrogen for mainstreaming EIPs, several strategies can be employed:

1. Policy Support and Incentives

   Governments can provide financial incentives, tax breaks, and regulatory frameworks to support the development and deployment of green hydrogen projects within EIPs. This can reduce financial barriers and encourage industry adoption.

2. Infrastructure Development

   Investments in hydrogen production facilities, transportation networks, and storage infrastructure are crucial to facilitate the widespread adoption of green hydrogen in EIPs.

3. Knowledge Sharing and Capacity Building

   EIPs can establish knowledge-sharing platforms and training programs to educate industry stakeholders about green hydrogen technologies, applications, and safety protocols. This can enhance their understanding and promote the adoption of these technologies.

4. International Collaboration

   EIPs can collaborate with other EIPs and research institutions worldwide to exchange knowledge, benchmark best practices, and accelerate the development of green hydrogen solutions for the industrial sector.

5. Demonstration Projects and Pilot Programs

   EIPs can initiate pilot projects and demonstration programs to showcase the feasibility and benefits of green hydrogen technologies in industrial applications. This can attract investments and build confidence among industry players.

The integration of green hydrogen into EIPs can be a transformative step towards achieving sustainable, low-carbon industrial practices. With the right strategies and collaborative efforts, EIPs can play a central role in demonstrating, adopting, and advancing green hydrogen technologies, contributing to a more resilient and environmentally conscious industrial future.

Reference:

UNIDO (2023), Safeguarding Environment, https://www.unido.org/our-focus/safeguarding-environment/clean-energy-access-productive-use/industrial-energy-efficiency-and-climate-change#:~:text=Industry%20is%20responsible%20for%20more,over%20the%20next%2025%20years.

IEA (2022), Industry, IEA, Paris, https://www.iea.org/reports/industry

IRENA (2022), Green Hydrogen for Industry, https://www.irena.org/publications/2022/Mar/Green-Hydrogen-for-Industry

UNIDO (2023), Green Hydrogen Industrial Cluster Guidelines, https://www.unido.org/sites/default/files/files/202308/GH2_ClusterGuidelines.pdf?_token=1180120735

Vienna International Centre
Wagramerstr. 5, P.O. Box 300,
A-1400 Vienna, Austria

+43 1 26026-0

www.unido.org

unido@unido.org

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