

HYAFRICA

15 AUGUST 2022 – 14 AUGUST 2025



LEAP-RE

Long-Term Joint EU-AU Research
and Innovation Partnership on Renewable Energy

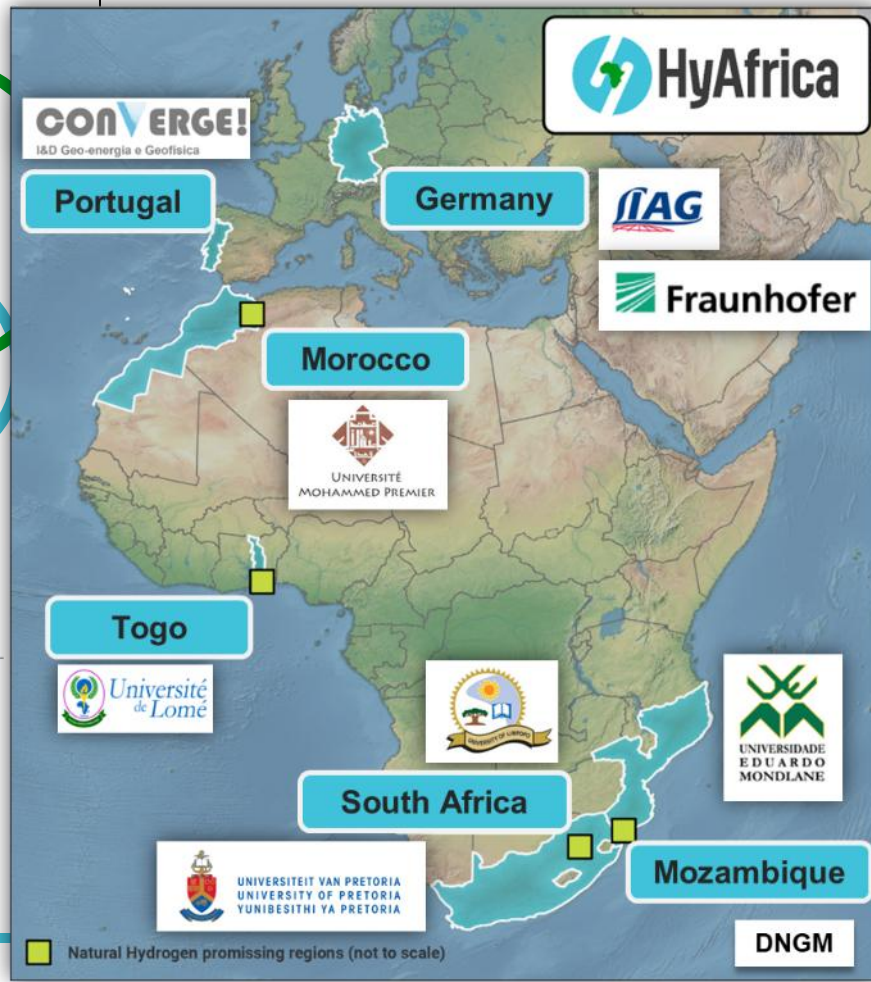
Pillar-1 project



The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.

Consortium

One SME (coordinator), 2 research institutes, 5 universities and 1 governmental regulatory body.



Aim of the project

- Map **natural hydrogen resources** in promising regions of Morocco, Mozambique South Africa, Togo and assess its **potential for being applied in standalone energy systems** for isolated communities.

Relevance vs MAR#3 and MAR#4

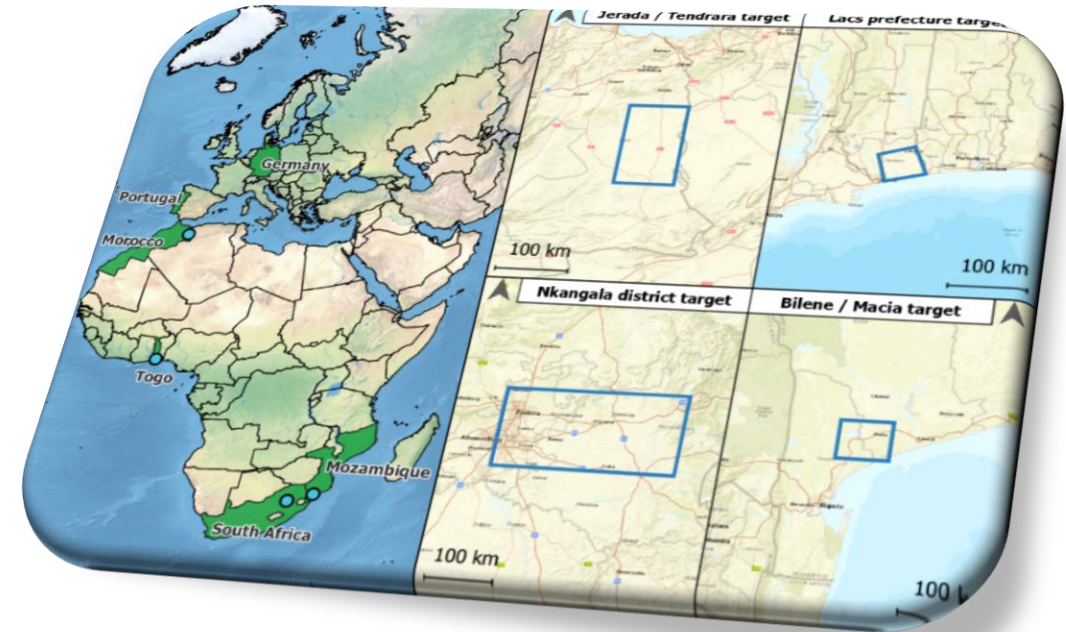
- Local source of energy to isolated communities in stand-alone and off-grid systems
- Natural hydrogen is a constant energy source – reliability of power supply
- Reduces energy costs and develops local economies by creating job opportunities.
- No GHG – water is the only by-product. Unlike green H₂, natural H₂ reduces energy-water competition.

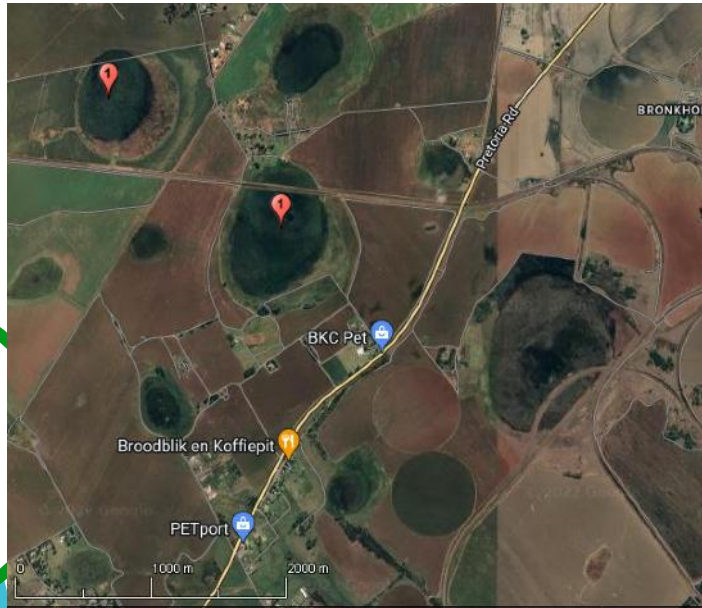
SO1 - identify and map existing resources and increase knowledge about the controlling geological conditions

SO2 - develop roadmaps for natural hydrogen exploration and exploitation in the target countries.

SO3 - assess the socio-economic impact and develop business models for standalone, off-grid and mini-grid systems based on H₂.

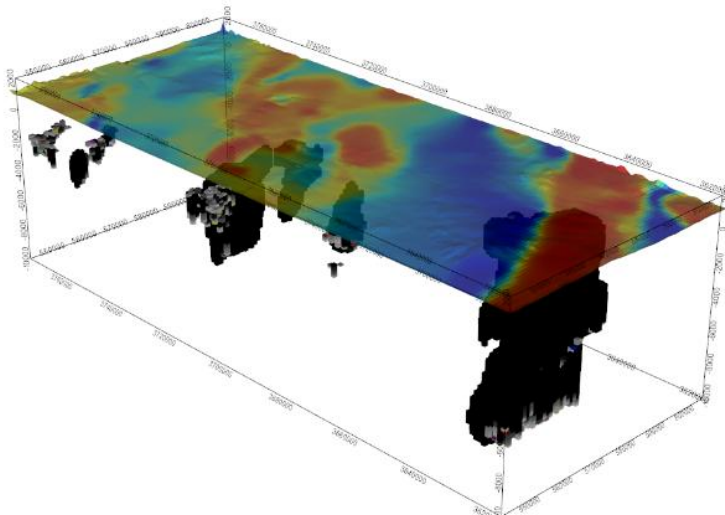
SO4 - build awareness and capacity on natural hydrogen application in standalone and mini-grid systems among the academic community and institutional stakeholders.

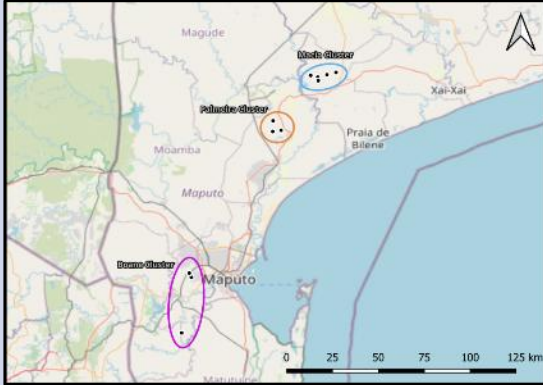

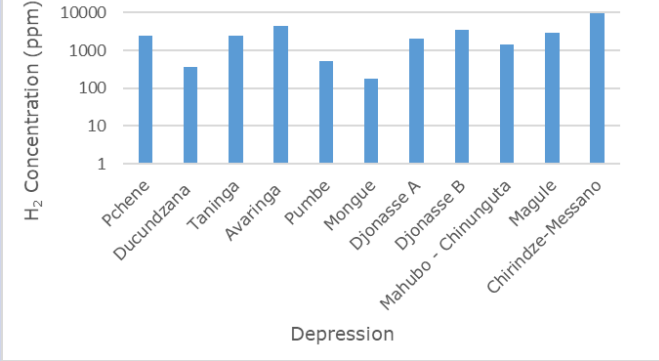
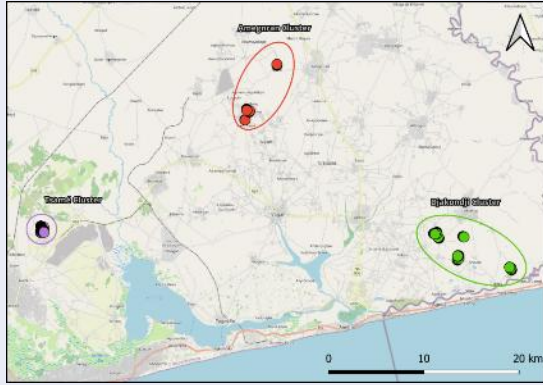

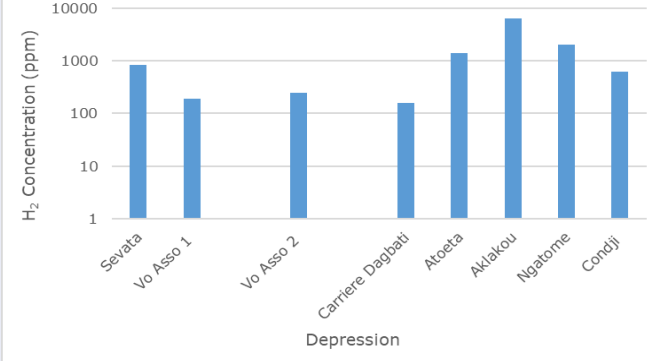
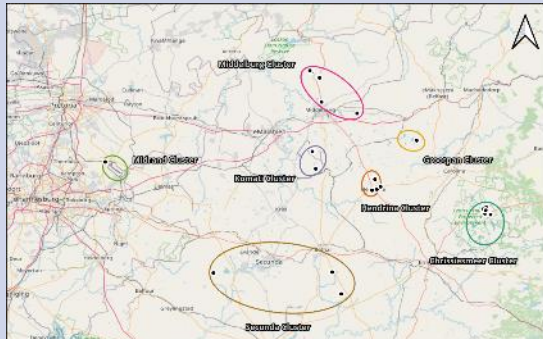

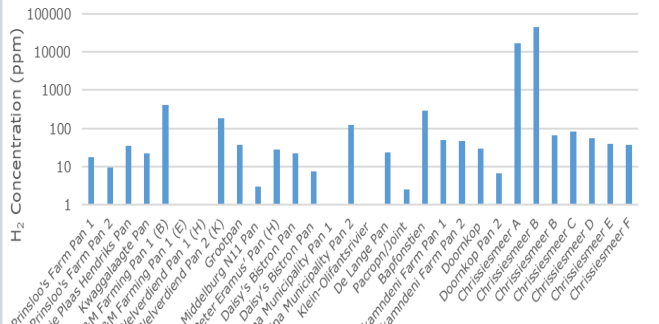




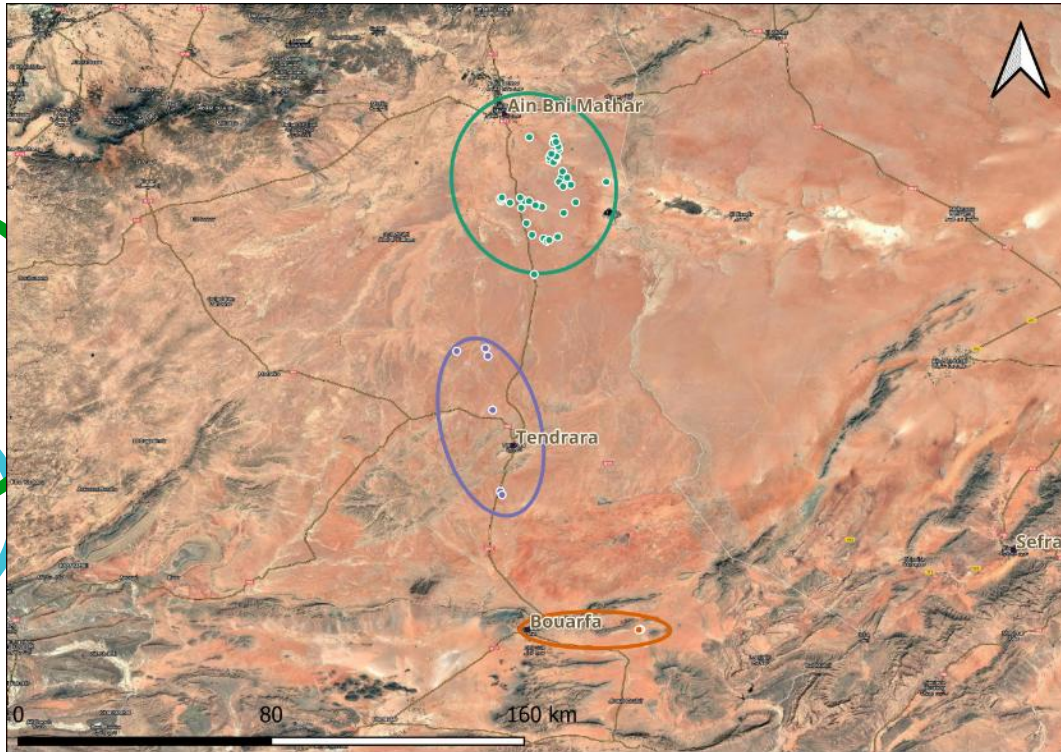
Remote sensing: Depressions as proxies for seeps;
Surface geochemistry: *in situ* H₂ measurements (and radon)
Geophysics: gamma spect. and existing magnetic/ gravimetric / seismic data
Laboratory analysis: soil gas composition
Structural geology: regional discontinuities and deep faults
Magnetic / gravimetric anomalies: 3D modelling and H₂ origin

Definition of hydrogen system



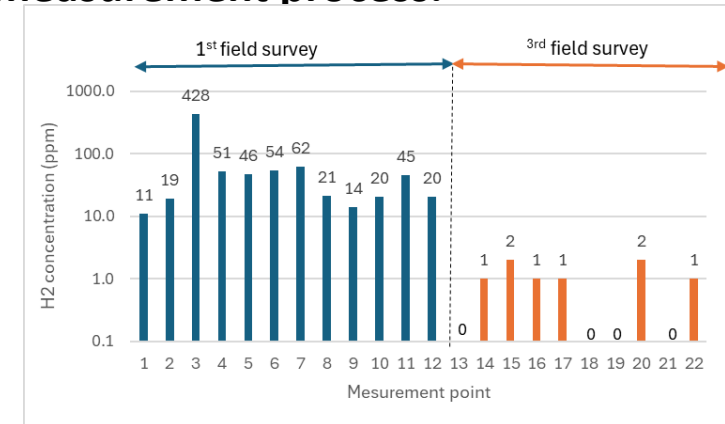
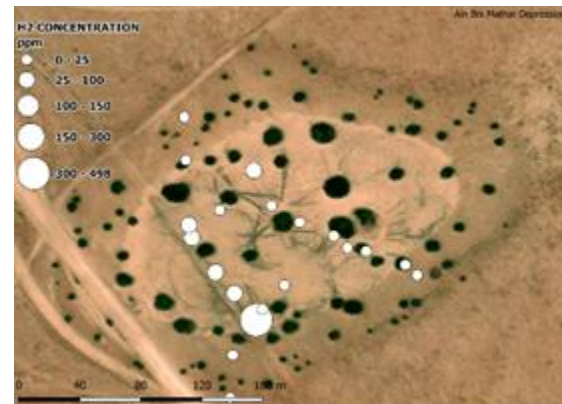
| Country | Clusters | measurements and samples | H2 concentration (ppm) | Max H2 conc. (ppm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|-----------------------|---|---|--|--------------------|------------------------|----------------------|-------|----------------------|------|----------------------|-------|----------------------|-------|----------------------|-------|----------------------|-------|----------------------|-------|----------------------|-------|----------------------|-------|-----------------------|-------|-----------------------|--------|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-----------------------|-----|-------------------|
| Mozambique |  | 511 measurements, 17 samples  |  <table><tr><th>Location</th><th>H2 Concentration (ppm)</th></tr><tr><td>Pchene</td><td>~1500</td></tr><tr><td>Ducundzana</td><td>~400</td></tr><tr><td>Tananga</td><td>~1500</td></tr><tr><td>Avaringa</td><td>~2500</td></tr><tr><td>Pumbe</td><td>~500</td></tr><tr><td>Mongue</td><td>~200</td></tr><tr><td>Djonasse A</td><td>~1500</td></tr><tr><td>Djonasse B</td><td>~2500</td></tr><tr><td>Mahubo - Chinunguta</td><td>~1000</td></tr><tr><td>Magule</td><td>~2500</td></tr><tr><td>Chirindze-Messano</td><td>~10000</td></tr></table> | Location | H2 Concentration (ppm) | Pchene | ~1500 | Ducundzana | ~400 | Tananga | ~1500 | Avaringa | ~2500 | Pumbe | ~500 | Mongue | ~200 | Djonasse A | ~1500 | Djonasse B | ~2500 | Mahubo - Chinunguta | ~1000 | Magule | ~2500 | Chirindze-Messano | ~10000 | 9 500 ppm (0.95%) | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Location | H2 Concentration (ppm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pchene | ~1500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ducundzana | ~400 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Tananga | ~1500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Avaringa | ~2500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pumbe | ~500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mongue | ~200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Djonasse A | ~1500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Djonasse B | ~2500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Mahubo - Chinunguta | ~1000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Magule | ~2500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Chirindze-Messano | ~10000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Togo |  | 168 measurements, 13 samples  |  <table><tr><th>Location</th><th>H2 Concentration (ppm)</th></tr><tr><td>Sevata</td><td>~1000</td></tr><tr><td>Vo Asso 1</td><td>~200</td></tr><tr><td>Vo Asso 2</td><td>~300</td></tr><tr><td>Carrière Dagbati</td><td>~150</td></tr><tr><td>Atoeta</td><td>~1500</td></tr><tr><td>Akikou</td><td>~6000</td></tr><tr><td>Ngatome</td><td>~2000</td></tr><tr><td>Condji</td><td>~600</td></tr></table> | Location | H2 Concentration (ppm) | Sevata | ~1000 | Vo Asso 1 | ~200 | Vo Asso 2 | ~300 | Carrière Dagbati | ~150 | Atoeta | ~1500 | Akikou | ~6000 | Ngatome | ~2000 | Condji | ~600 | 6 500 ppm | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Location | H2 Concentration (ppm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Sevata | ~1000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vo Asso 1 | ~200 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Vo Asso 2 | ~300 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Carrière Dagbati | ~150 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Atoeta | ~1500 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Akikou | ~6000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ngatome | ~2000 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Condji | ~600 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| South Africa |  | 1733 measurements, 25 samples  |  <table><tr><th>Location</th><th>H2 Concentration (ppm)</th></tr><tr><td>Pheliso's Farm Pan 1</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 2</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 3</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 4</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 5</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 6</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 7</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 8</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 9</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 10</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 11</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 12</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 13</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 14</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 15</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 16</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 17</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 18</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 19</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 20</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 21</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 22</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 23</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 24</td><td>~10</td></tr><tr><td>Pheliso's Farm Pan 25</td><td>~10</td></tr></table> | Location | H2 Concentration (ppm) | Pheliso's Farm Pan 1 | ~10 | Pheliso's Farm Pan 2 | ~10 | Pheliso's Farm Pan 3 | ~10 | Pheliso's Farm Pan 4 | ~10 | Pheliso's Farm Pan 5 | ~10 | Pheliso's Farm Pan 6 | ~10 | Pheliso's Farm Pan 7 | ~10 | Pheliso's Farm Pan 8 | ~10 | Pheliso's Farm Pan 9 | ~10 | Pheliso's Farm Pan 10 | ~10 | Pheliso's Farm Pan 11 | ~10 | Pheliso's Farm Pan 12 | ~10 | Pheliso's Farm Pan 13 | ~10 | Pheliso's Farm Pan 14 | ~10 | Pheliso's Farm Pan 15 | ~10 | Pheliso's Farm Pan 16 | ~10 | Pheliso's Farm Pan 17 | ~10 | Pheliso's Farm Pan 18 | ~10 | Pheliso's Farm Pan 19 | ~10 | Pheliso's Farm Pan 20 | ~10 | Pheliso's Farm Pan 21 | ~10 | Pheliso's Farm Pan 22 | ~10 | Pheliso's Farm Pan 23 | ~10 | Pheliso's Farm Pan 24 | ~10 | Pheliso's Farm Pan 25 | ~10 | 44 000 ppm (4.4%) |
| Location | H2 Concentration (ppm) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 1 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 2 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 3 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 4 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 5 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 6 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 7 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 8 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 9 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 10 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 11 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 12 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 13 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 14 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 15 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 16 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 17 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 18 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 19 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 20 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 21 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 22 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 23 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 24 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pheliso's Farm Pan 25 | ~10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

What about Morocco?



683 points measured. Three field surveys
 1st and 2nd field survey- high H₂ concentrations, up to 450 ppm
 3rd field survey – different methodology – H₂ on background values.

Artifacts - H₂ originated by measurement process.



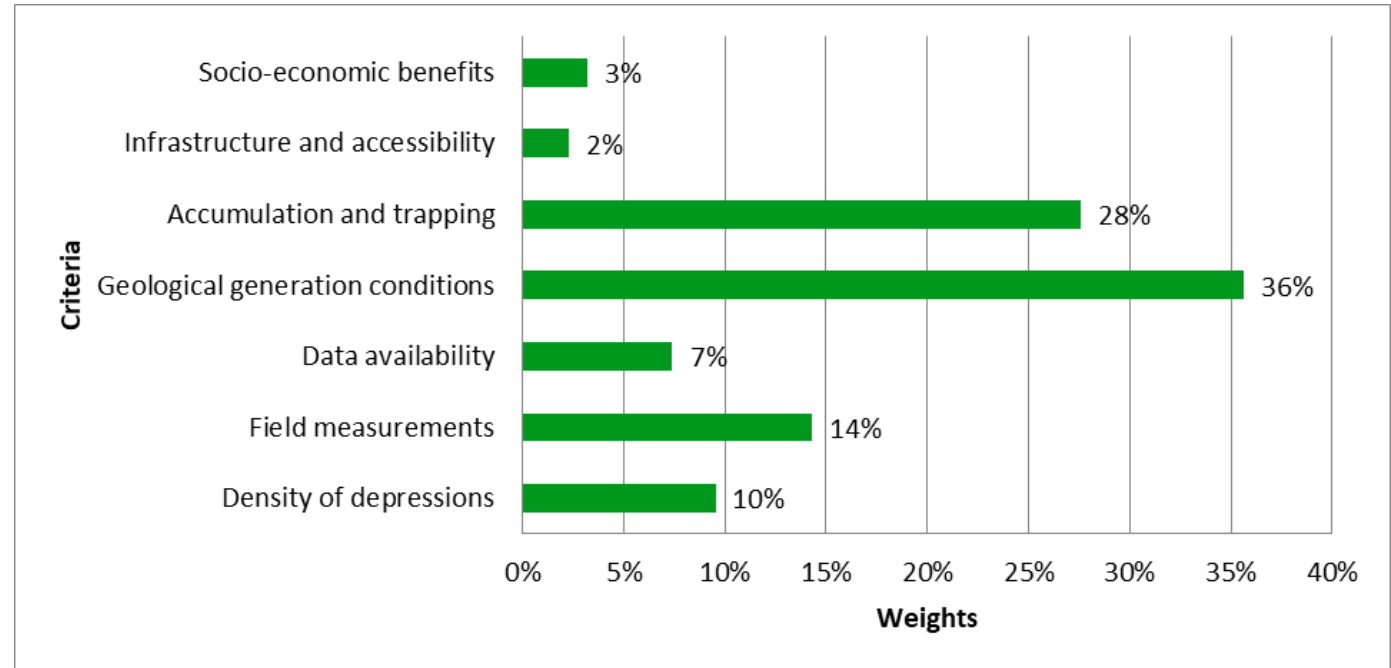
Moroccan team pursuing with measurements in another Area - **Khemisset.**

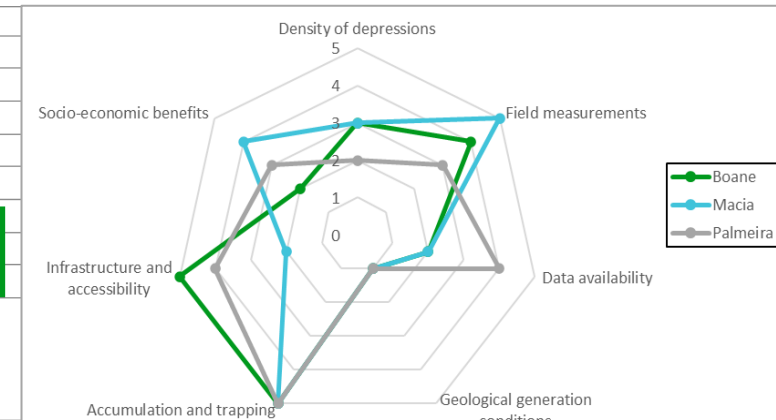
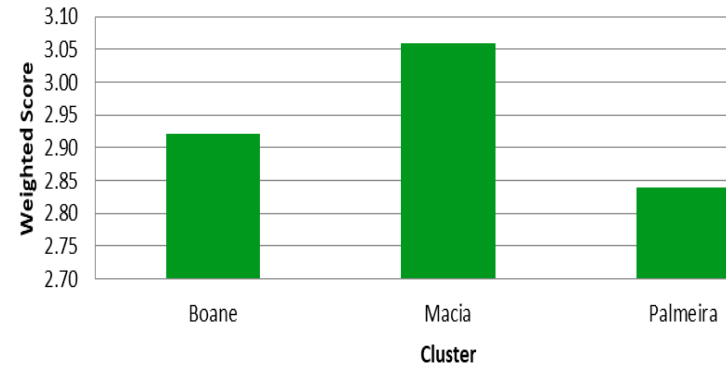
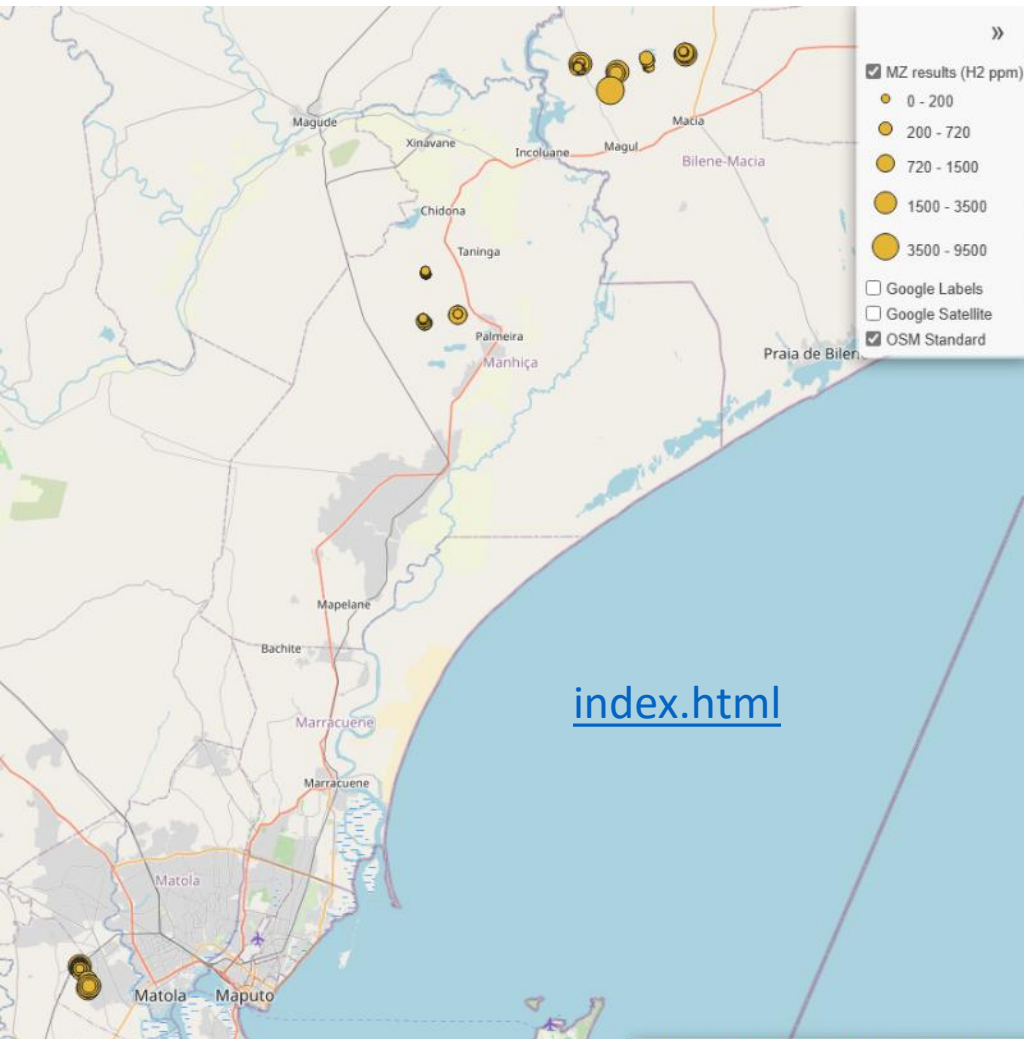
Ranking of target zones

Analytic Hierarchy Proccess (AHP) – implemented with 7 criteria (technical, socio-economic)

Saaty's scale of relative importance (Saaty, 2005)

| SCALE | NUMERICAL RATING | RECIPROCAL |
|---------------------------|------------------|------------|
| Extremely Preferred | 9 | 1/9 |
| Very strong to extremely | 8 | 1/8 |
| Very strongly preferred | 7 | 1/7 |
| Strongly to very strongly | 6 | 1/6 |
| Strongly preferred | 5 | 1/5 |
| Moderately to strongly | 4 | ¼ |
| Moderately preferred | 3 | 1/3 |
| Equally to moderately | 2 | ½ |
| Equally preferred | 1 | 1 |





The Macia and Boane areas stand out, with **several depressions yielding peak field readings above 1000 ppm and up to 9500 ppm.**

Potential generation mechanisms include water-rock reactions in mafic or ultramafic basement lithologies and structural control by graben-bound faults.

Macia and Boane warrant prioritization for follow-up surveys, flux monitoring, and shallow borehole investigations.

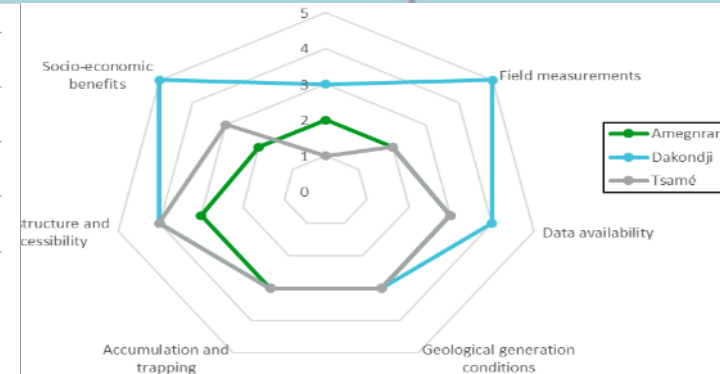
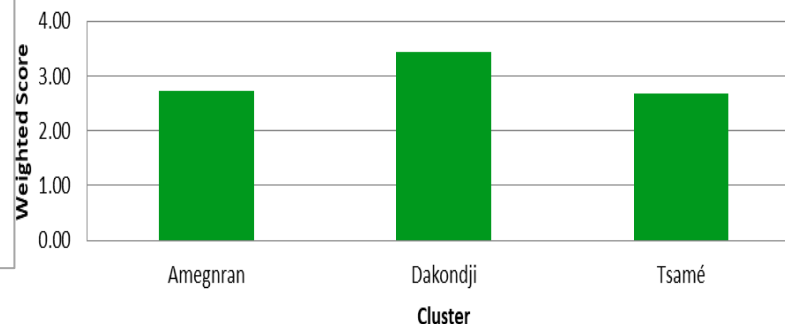
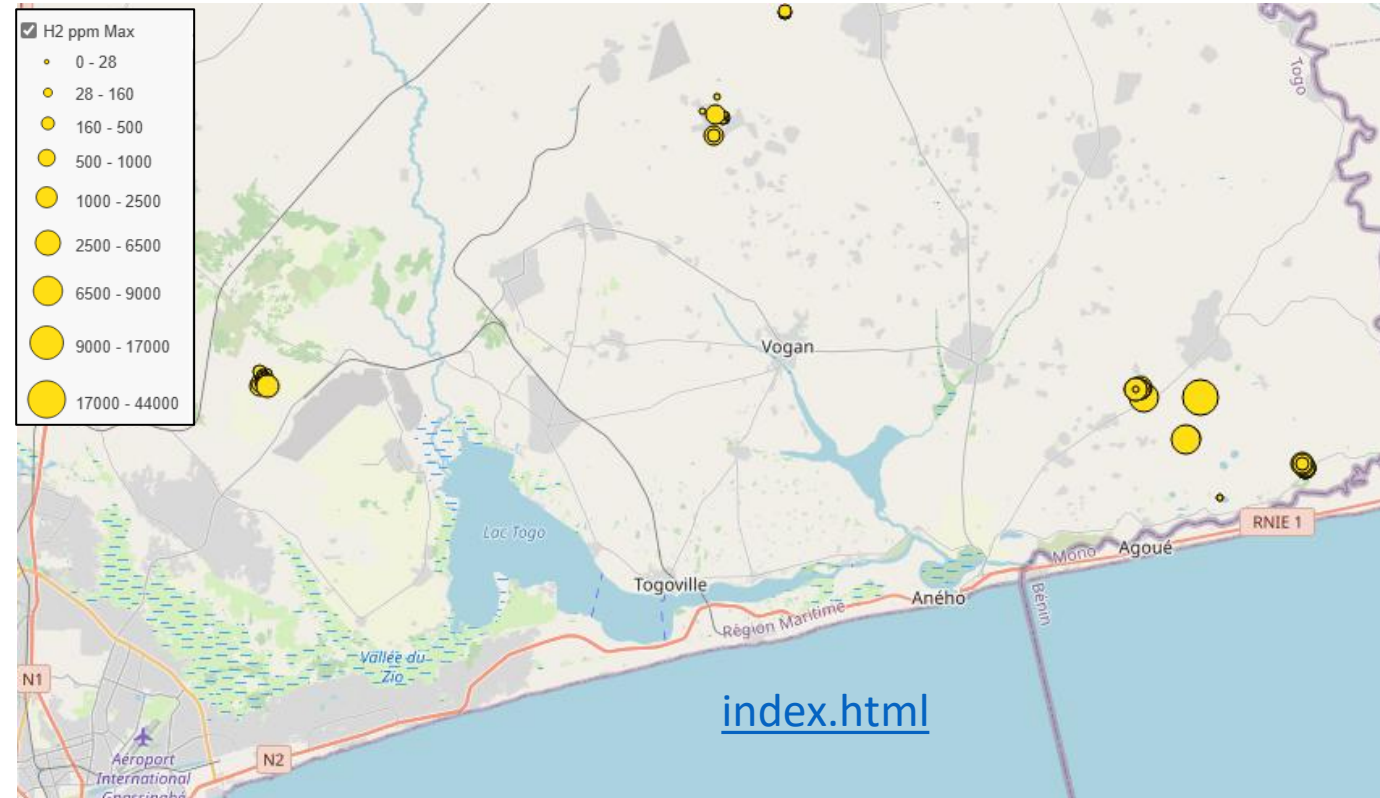
Ranking of target zones

Togo priority areas

Dakondji cluster revealed stronger anomalies, with field peaks reaching 6500 ppm and multiple laboratory-confirmed values above 200 ppm.

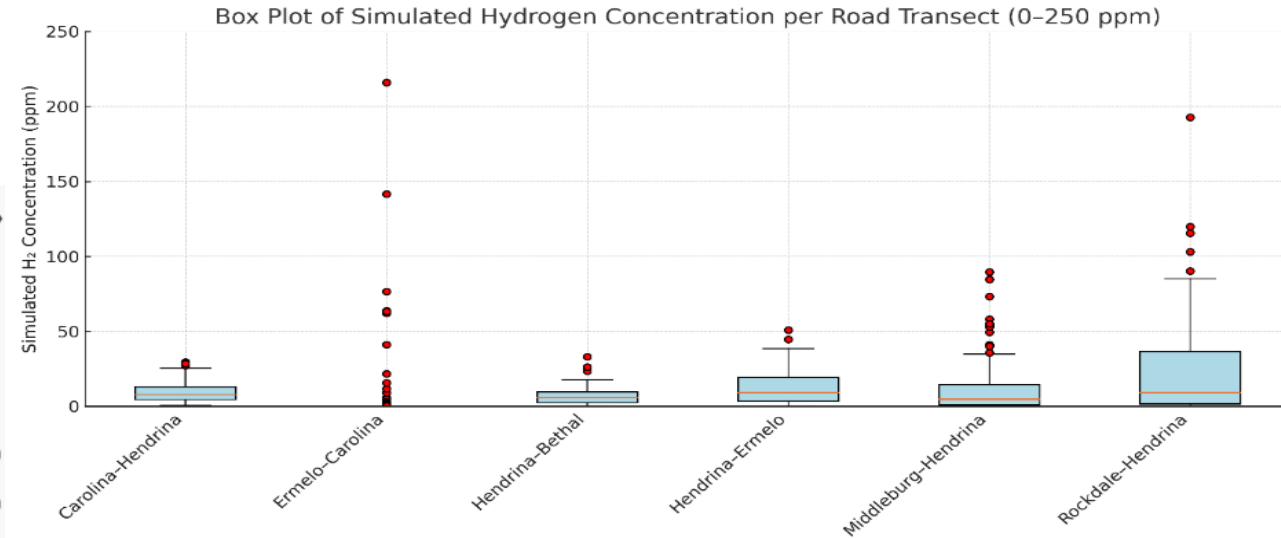
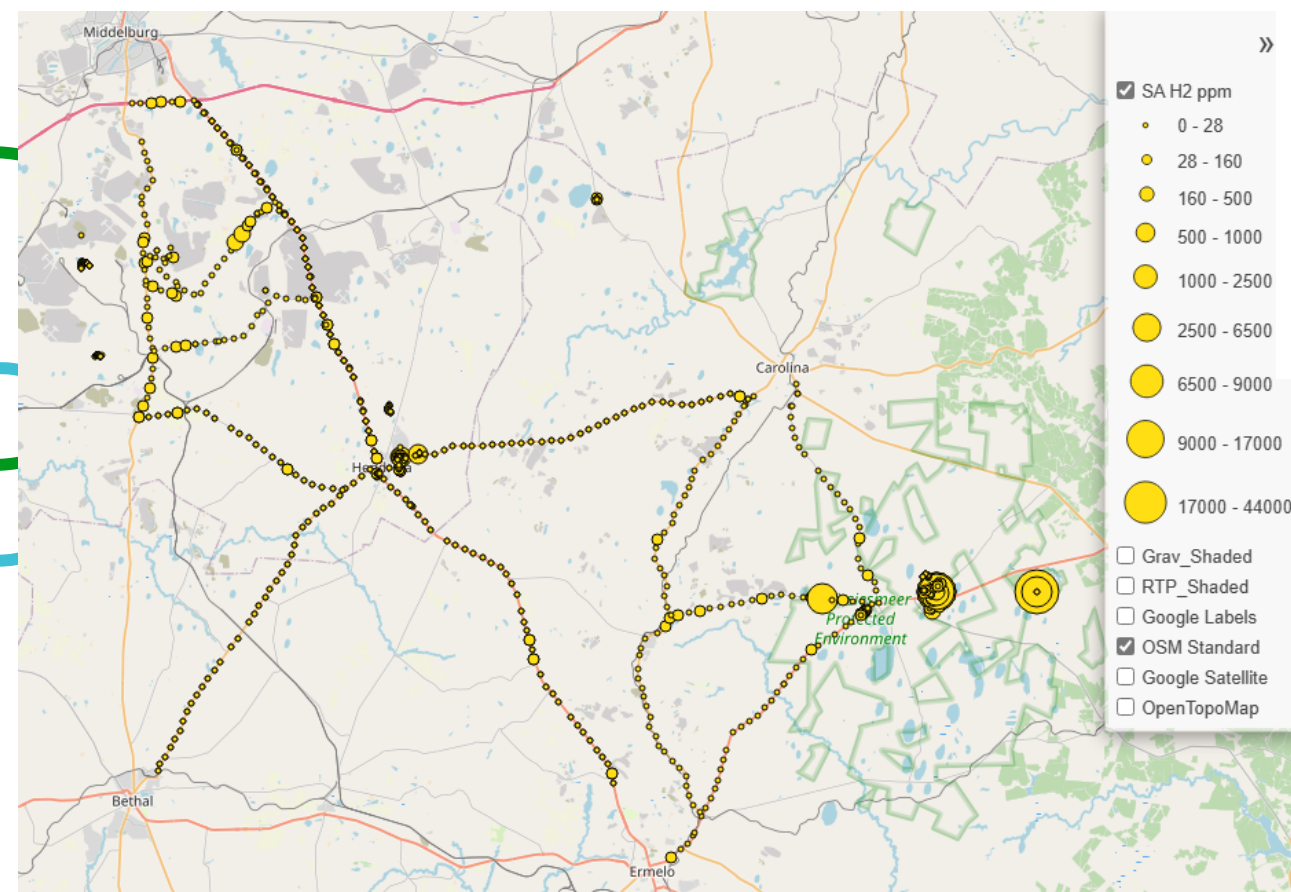
Complex faulting, Pan-African basement reactivation, and sedimentary cover—may facilitate hydrogen migration. Possibility of radiolytic origin.

Dakondji emerges as a promising candidate for continued exploration- integration of fault mapping, shallow coring, and long-duration gas monitoring could be essential for evaluating its potential.



Ranking of target zones

South Africa priority areas



Komati and Hendrina clusters - multiple field peaks of 1,000–2,500 ppm, and the Chrissiesmeer cluster delivered **exceptional values—up to 44,000 ppm (4.4%)** in the field and **16,700 ppm** in the laboratory.

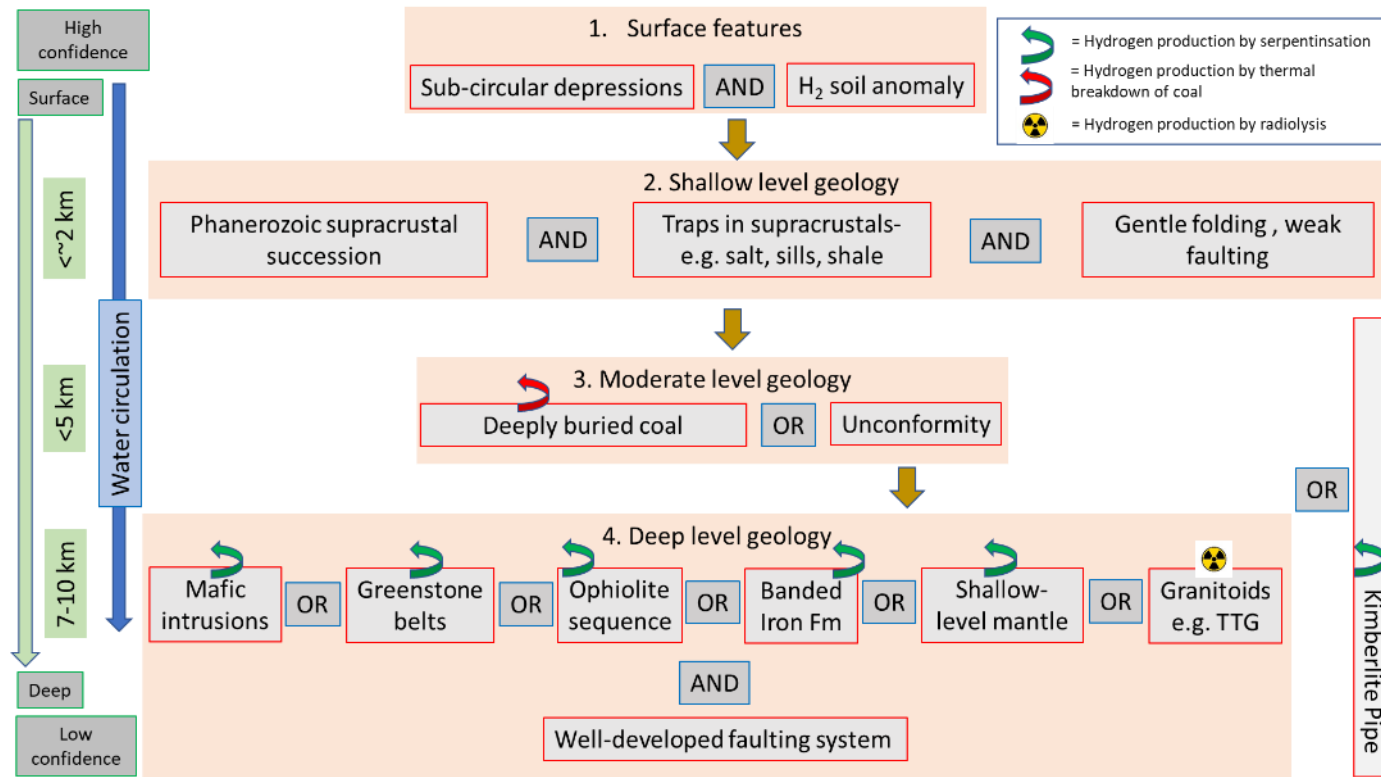
Complex Precambrian cratonic crust overlain by Paleozoic strata

These sites merit:

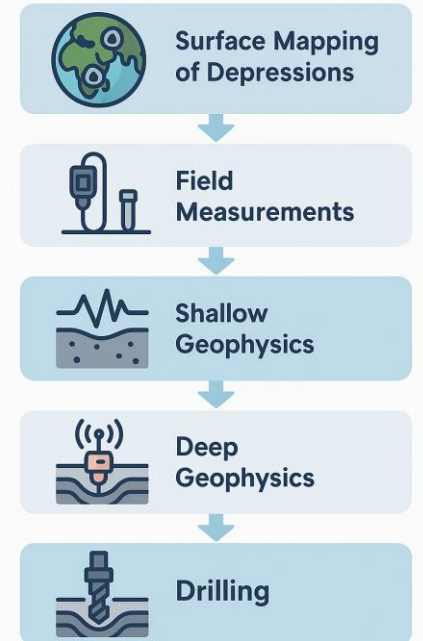
- Continuous gas monitoring
- Shallow borehole drilling for vertical gas profiling
- Integration of field data, remote sensing and geophysical
- Assessment of temporal variability and recharge dynamics

Providing authorities with systematic workflows for exploration 1/3

Stage 1 - Geology, structural geology and the origin of hydrogen

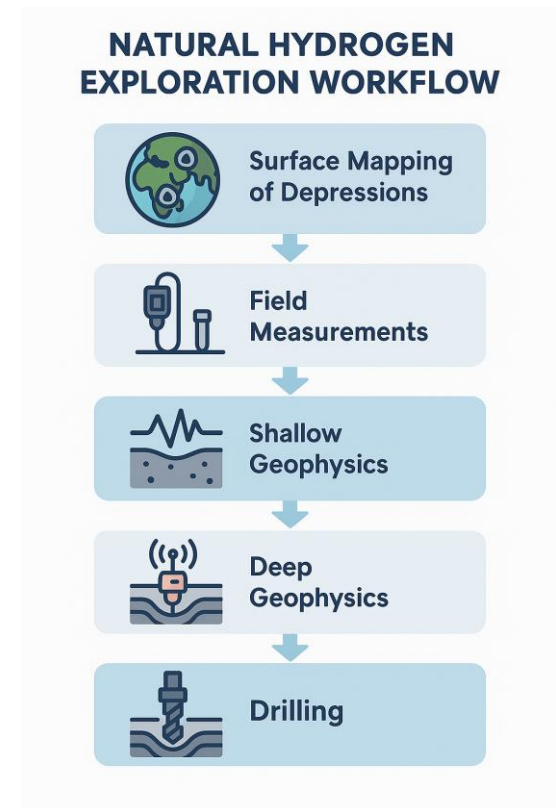
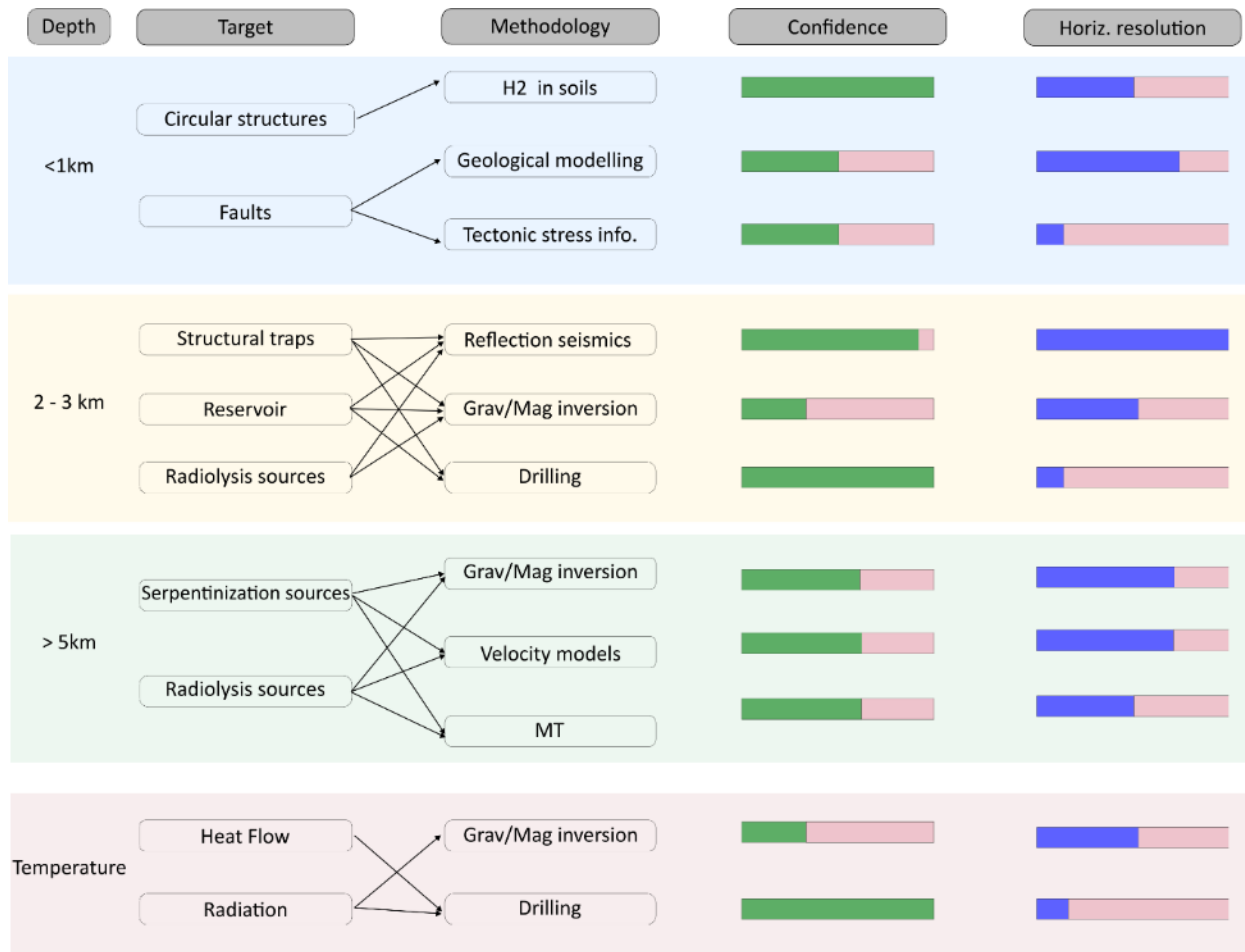


NATURAL HYDROGEN EXPLORATION WORKFLOW



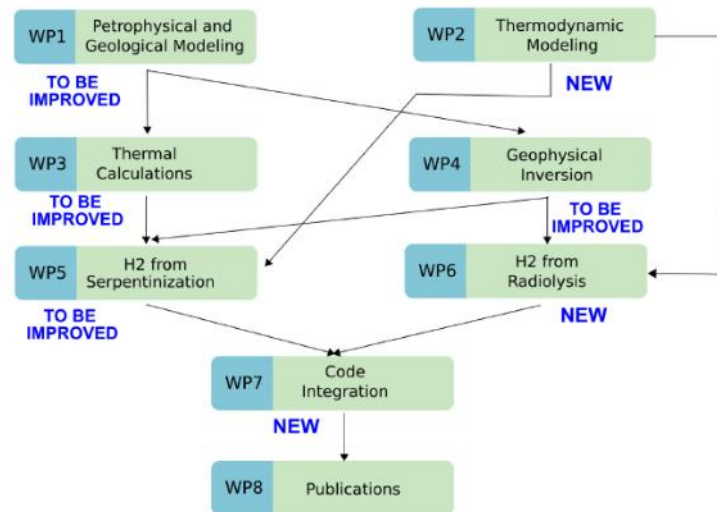
Providing authorities with systematic workflows for exploration 2/3

Stage 2 - Deep geological conditions – geophysics and drilling



Providing authorities with systematic workflows for exploration 3/3

Stage 3 - Tools to quantify the hydrogen generation and consumption rates



Present: H₂ generation from serpentinization

Future: H₂ from radiolysis

PoNHu: "Potential for Natural Hydrogen"

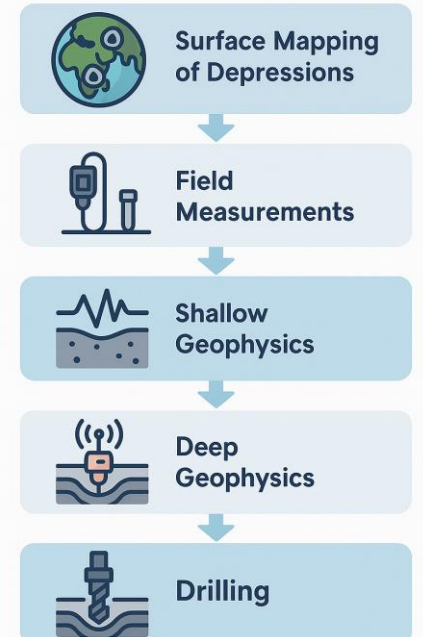
```

1 import os
2 import sys
3 import numpy as np
4 import matplotlib.pyplot as plt
5 import discretize
6 from discretize.utils import active_from_xyz
7 import time
8 import seaborn as sns
9 from scipy.interpolate import griddata
10 import pandas as pd
11 import warnings
12 from scipy.stats import gaussian_kde
13 from datetime import datetime
14 import xarray as xr
15 from matplotlib.lines import Line2D
16 from tqdm import tqdm
17
18 warnings.filterwarnings('ignore')
19
20 # Begin of time
21 start_time = time.time()
22 current_time = datetime.now().strftime("%Y%m%d_%H%M%S")
23
24 dir_path = r"/home/christiansen/Python/HyAfrica" + os.path.sep
25
26 # Define the folder name with date and time
27 folder_name = f"Results_{current_time}"
28 results_path = os.path.join(dir_path, folder_name)
29
30 # Create the folder if it doesn't exist
31 if not os.path.exists(results_path):
32     os.makedirs(results_path)
33     print(f"Results will be saved in folder: {results_path}\n")
34
35 # Define the CustomPrint class for redirecting stdout
36 class CustomPrint:
37     def __init__(self, file_path):
  
```

Type
 open source

Owner
 IAG

NATURAL HYDROGEN EXPLORATION WORKFLOW



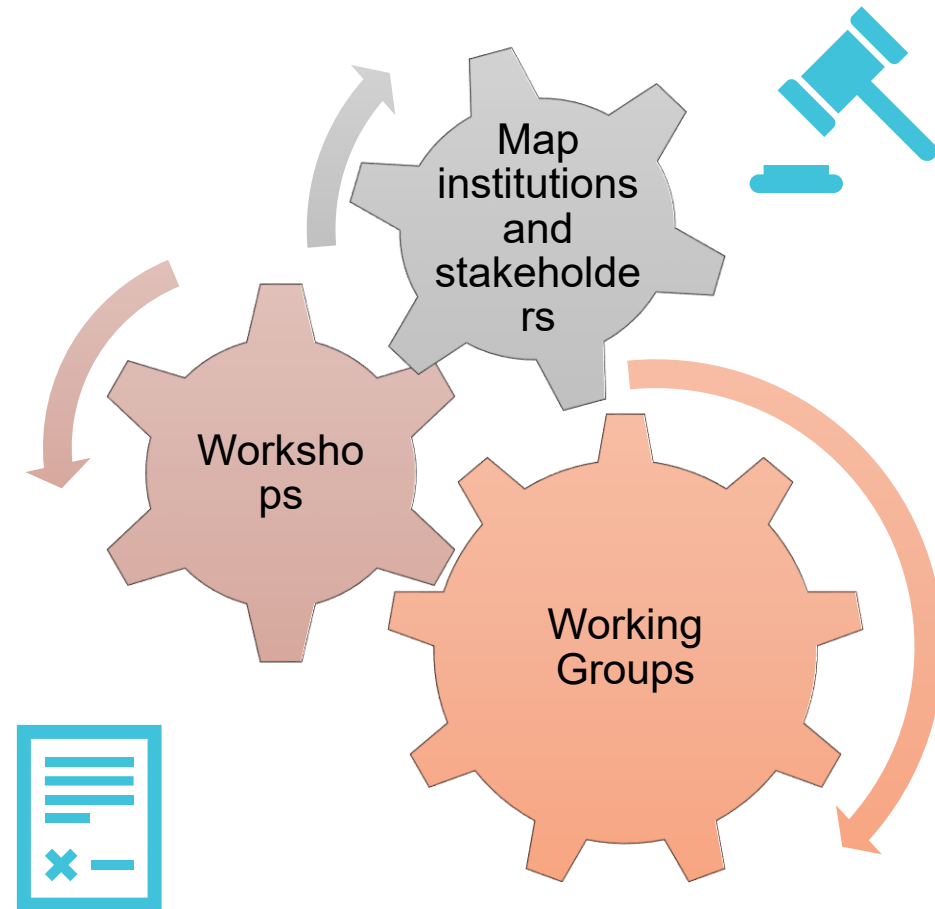
Providing authorities with a regulatory framework 1/2

Assess **legislation and regulatory gaps** in target countries

Engage with local policy makers

Develop mechanisms to **include natural H₂ in the Energy or Mining Laws** of target countries

Develop roadmaps in target countries for for **natural H₂ strategies**





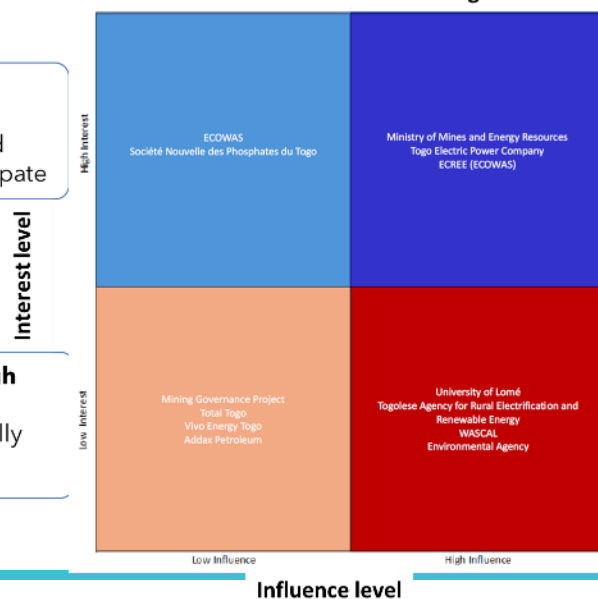
Providing authorities with a regulatory framework 2/2



Natural Hydrogen in National Energy Laws

| Country | Current legal status | Suggested approach |
|--------------|---|--|
| South Africa | No dedicated law; natural H ₂ implicitly treated as petroleum; licences via PASA. | Treat under petroleum law; issue guidelines; align with green H ₂ roadmap. |
| Morocco | No specific legislation; mining & hydrocarbons laws provide entry points; ONHYM exploring. | Integrate into mining law; choose regulator (METSD/ONHYM); dual-institutional model. |
| Mozambique | No H ₂ law; Mining & Petroleum laws exist; MIREME/INP & ARENE oversee energy sector. | Incorporate into Mining or Petroleum laws; develop renewable energy strategy. |
| Togo | Mining & hydrocarbons codes exclude H ₂ ; definitions need revision. | Amend mining or hydrocarbon code to include H ₂ ; clarify licensing and regulation. |

Interest and Influence matrix with organizations



High Interest & Influence
Keep in the loop and encourage to participate

Interest level

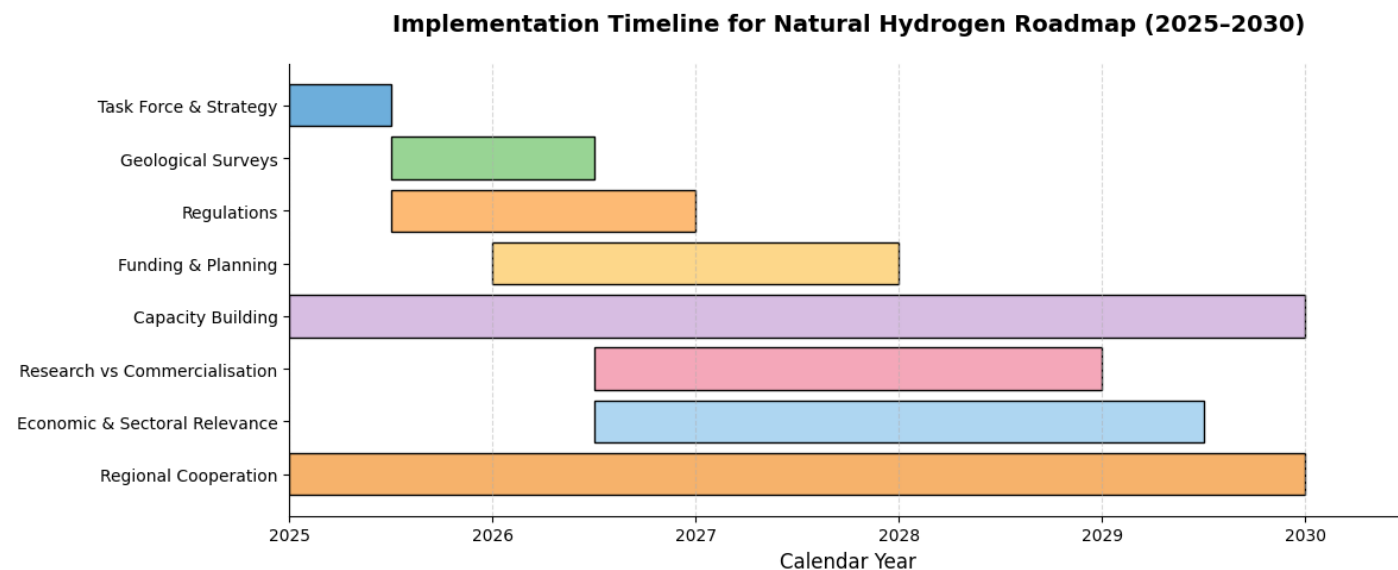
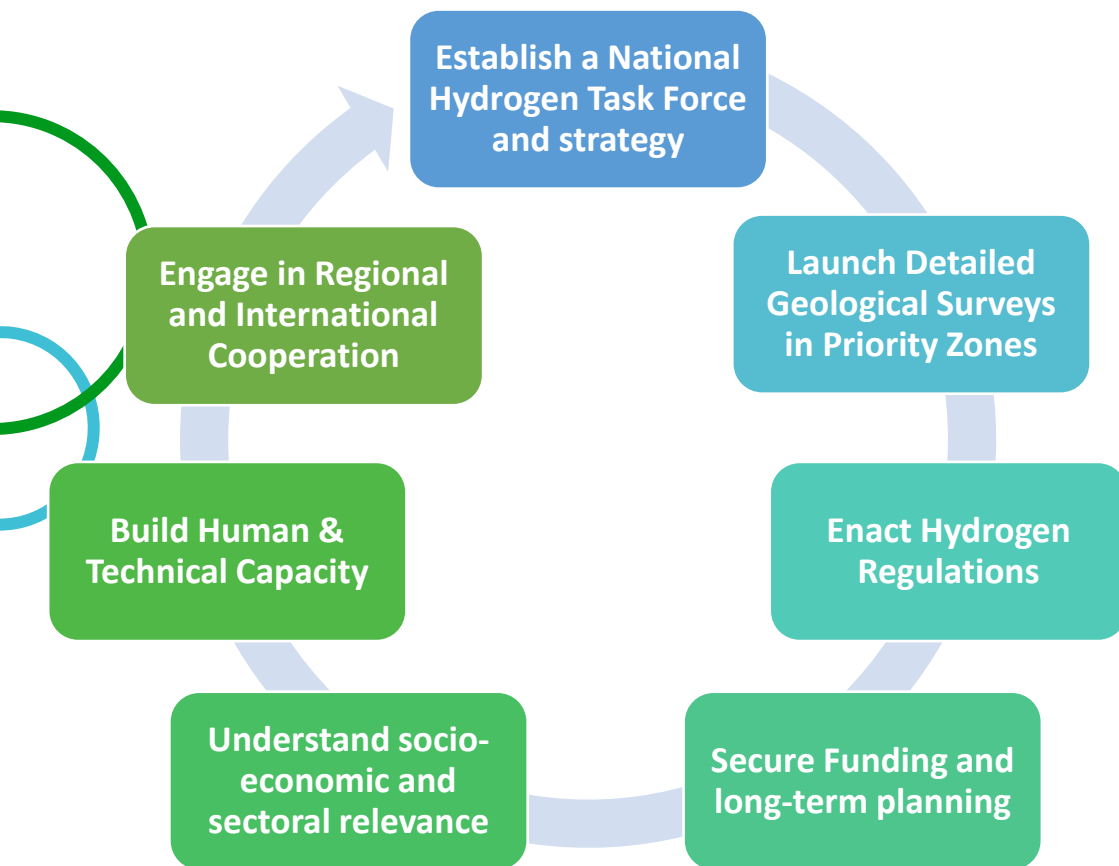
Low Interest & High influence
Check in occasionally and provide key information

High interest & Low influence
Contact regularly and educate thoroughly

Low Interest & Low influence
Monitor closely and give access to information

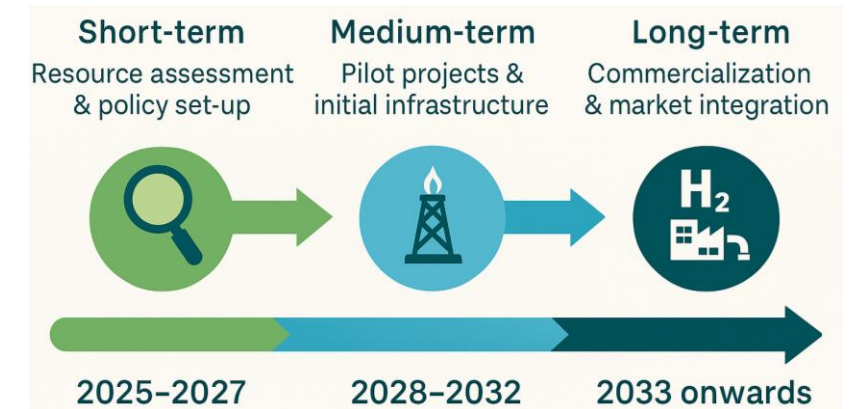
Influence level

Providing authorities with a roadmap and action plan 1/2



Providing authorities with a roadmap and action plan 2/2

Country-Specific Recommendations



Morocco

Integrate H₂ into Mining Code; empower ONHYM
Prioritise Tadrara & other basins; pilot ammonia with OCP
Maintain international partnerships; apply 'farm-in' model

Mozambique

Decide classification (petroleum vs mining); coordinate Ministry/INP/Geological Institute; Focus Bilene–Macia area; plan local power blending & community benefits; Seek co-financing (AfDB, EU); replicate farm-in; share revenues

South Africa

Amend MPRDA to include H₂; designate PASA/DMRE/DSI roles; Prioritise Chrissiesmeer; explore ultramafic complexes & boreholes; Co-fund pilot with mining/energy firms; engage private investors

Togo

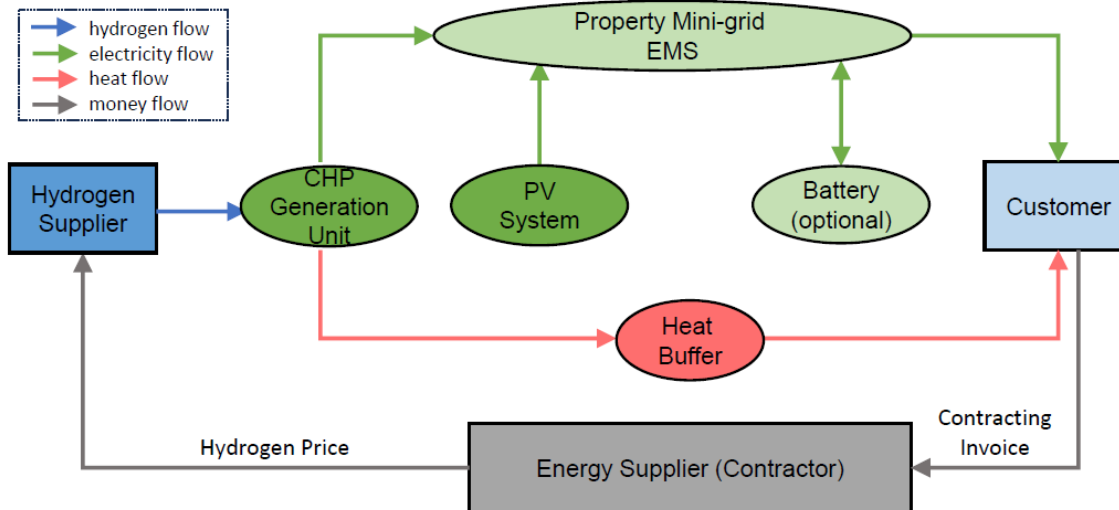
Issue decree/amend Mining Code; build regulatory capacity; Focus on Dakondji area; drill test well; pilot community/fertiliser; Partner internationally; leverage ECOWAS/AU; secure donor support

Business use cases studied

South Africa

Morocco

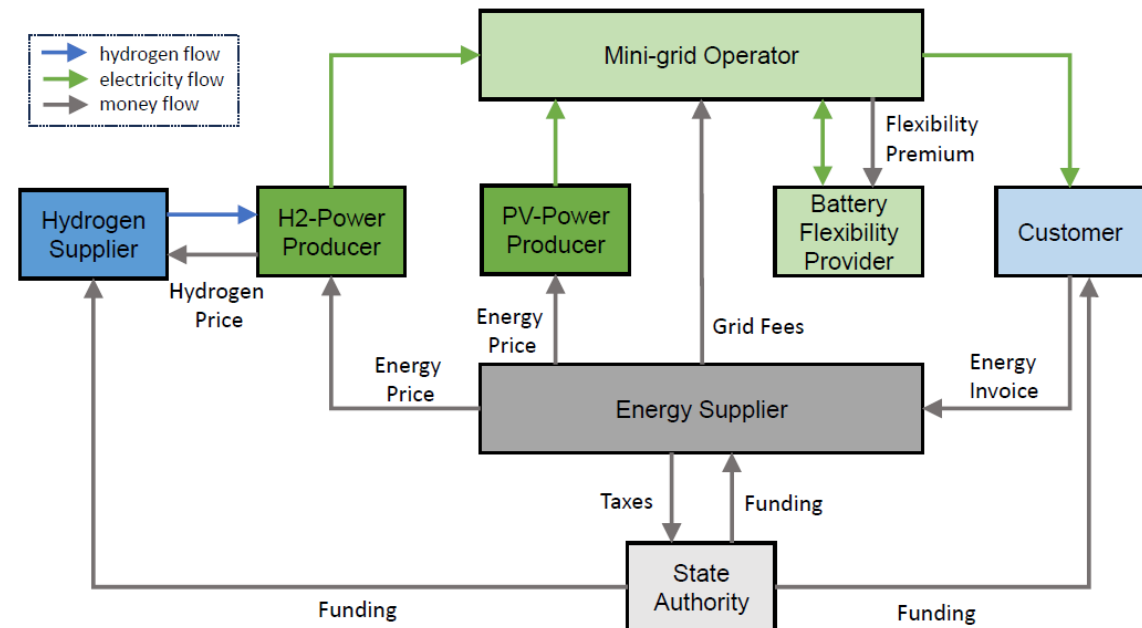
BUC - Improvement of security of supply



Mozambique

Togo

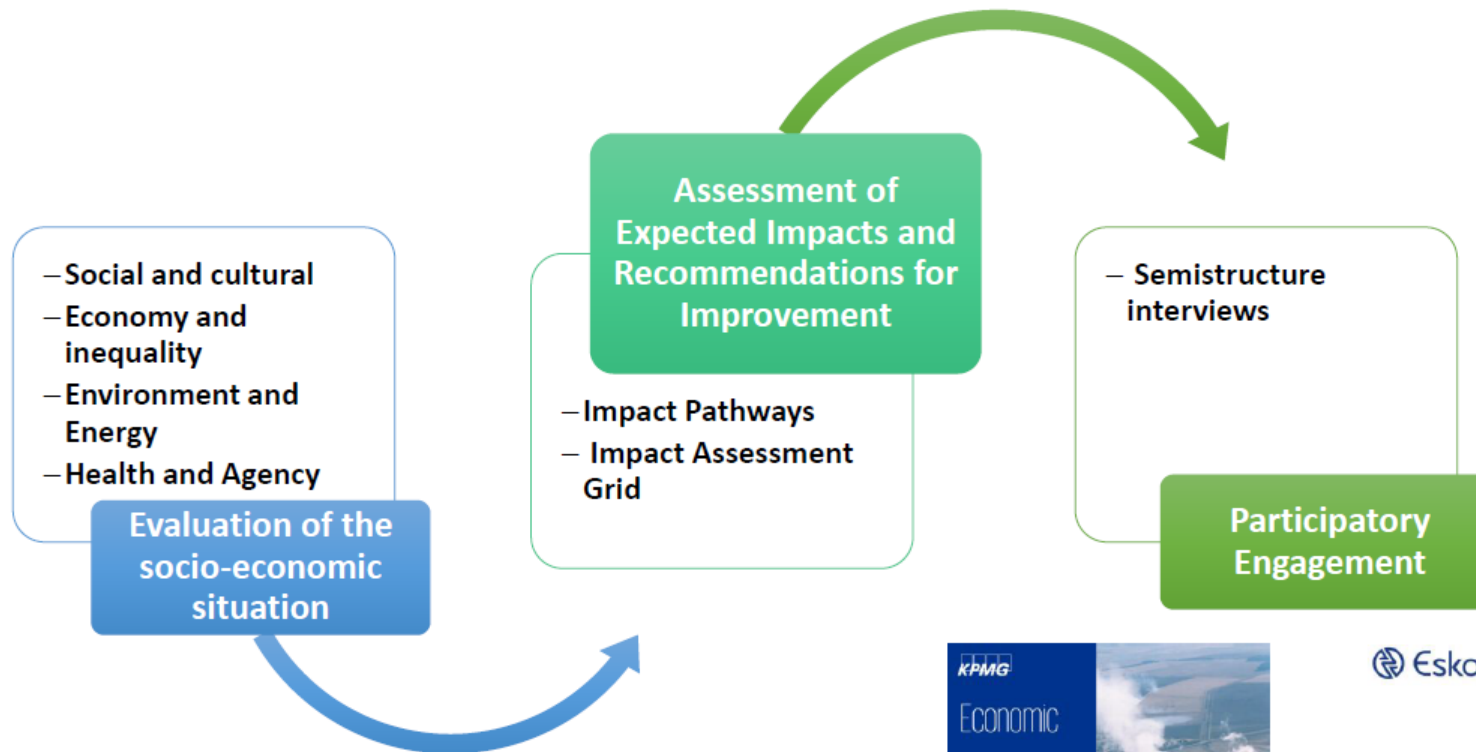
BUC - Electrification of rural areas



Business use cases studied

- Compared to an electricity price of 0.13 €/kWh in Hendrina the price for white hydrogen should be not more than **1 €/kg** to be competitive with electricity generation run with a gas turbine
- An LCOH of **0.5 \$/kg** for natural hydrogen is possible (source: Mathur) – it is not unrealistic
- As result from the sensitivity analysis H₂ price is more important than the full load hours for a gas turbine to produce profitable electricity
- The LCOE of mini-grids is very high (**0.38 €/kWh** for the analyzed example in Benzane - MZ) and customers of low-income communities can not pay much more than **0.09 €/kWh** . So, funding is needed regardless of the used fuel (diesel or hydrogen)
- Hydrogen storage units are very expensive and store only small amounts of hydrogen. A hydrogen bundle of cylinders (200 –300 bar) stores 9 –13 kg (these are only 300 –435 kWh or 30 –44 lt diesel); costs are **8 –12 k€**).

Socio economic Impact – Methodology



Based on:



SOCIO-ECONOMIC IMPACT STUDY
FOR THE SHUTDOWN AND
REPURPOSING OF
KOMATI POWER STATION



Socio economic Impact – Mini-grid Operator (BM1)

- Context – Benzane is a remote rural village (~900–1 200 people) in Mozambique's Zinave district. There is no grid connection; only small isolated systems serve health care, water and telecom. The province's electrification rate is about 27.7%.
- Social & Cultural – Households of 5–8 members with strong kinship networks. Christian and traditional beliefs coexist; communal rituals and respect for elders foster cohesion.
- Economic & Environmental – Subsistence farming, livestock and beekeeping dominate; infrastructure is limited (school, health post, wells). Unsafe water and wood smoke pose health risks; governance is male-dominated.
- **Anticipated Impact** – A mini-grid can supply reliable, decentralised electricity, enabling businesses, improving services and creating jobs. **Success hinges on inclusive governance, gender equity and complementary interventions in water, health and nutrition.**



Socio economic Impact – Fuel Switch Contractor (BM2)

- Coal Decline – Hendrina’s economy has been shaped by coal. Declining mining and decommissioning of power stations have led to poverty, unemployment and social distress; supply chains and public services have deteriorated.
- Diversification & Transition – Opportunities include agriculture, renewable energy and light manufacturing. Provincial and national plans (MGEDP, JET) aim to build an inclusive green economy, but governance gaps, investment shortfalls and skill mismatches remain obstacles.
- **Mission of BM2** – Retrofit existing generation units to operate on natural hydrogen, combined with PV and storage. This supports Hendrina’s transition by offsetting job losses and catalysing complementary industries; success requires coordinated policies and financing.



- ❖ Building capacity workshop for African partners (September 2022), Casablanca. Specialists in Natural H₂ from Air Liquide, USGS, Université Grenoble Alpes, the European Federation of Geologists and NH2E (SME).
- ❖ Technical building capacity workshops on field exploration (geochemical) for natural H₂ seeps - Morocco (Feb. 2023) and South Africa (June 2023).
- ❖ Workshop “Raising Awareness About Natural Hydrogen” for South African stakeholders , 14 of September 2023, Pretoria, South Africa. Attendees from public and private institutions and sectors including academia, research, mining and energy.
 - ❖ Current state of the art in natural hydrogen research,
 - ❖ the HyAfrica project,
 - ❖ the results of the first HyAfrica field campaign of natural hydrogen exploration in South Africa.
 - ❖ discussion regarding national policy requirements and regulatory issues was also held.



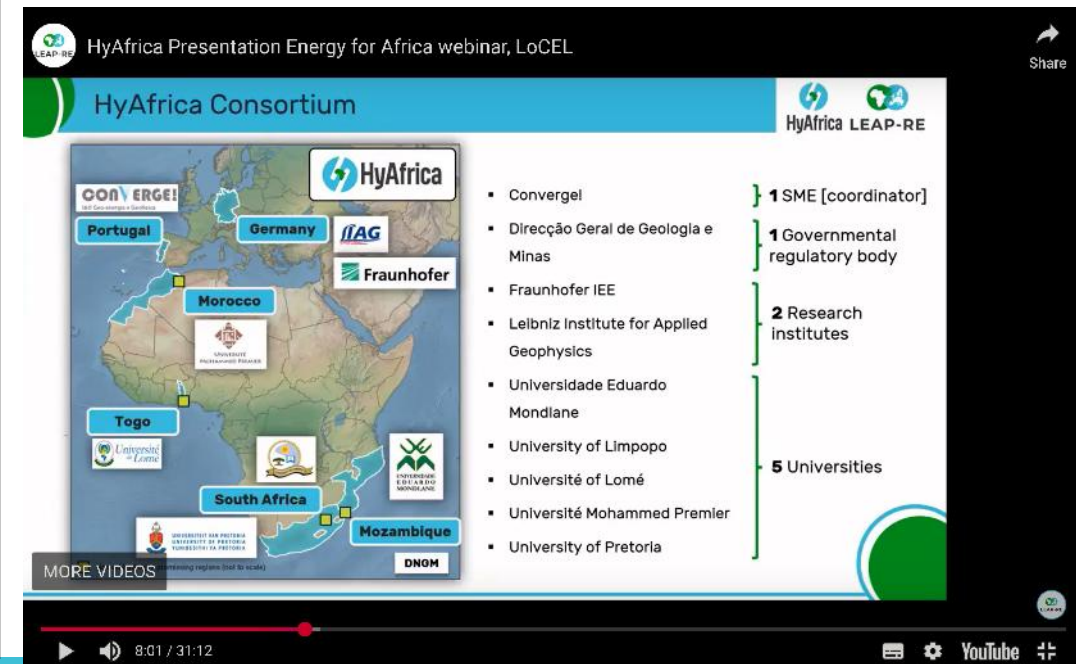
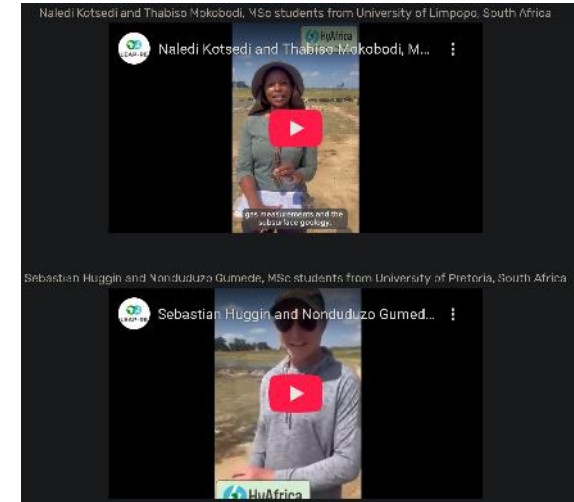
➤ **Online training courses**

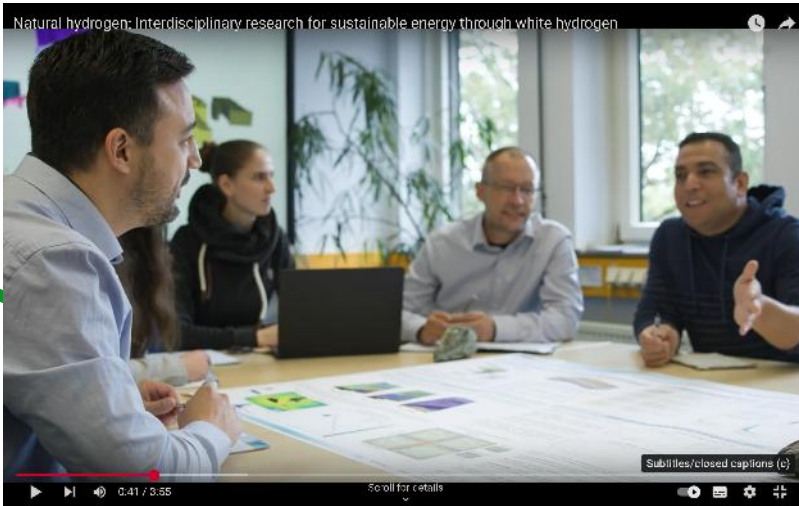
- ❖ Utilisation of remotes sensing and GIS for natural hydrogen exploration. Introduction to QGIS. January 2024
- ❖ Geophysical tools in natural hydrogen exploration. April 2025

➤ **Students engaged in research work:**

- ❖ PhD students : 1 Mozambique, 1 Morocco
- ❖ MSc Students: 2 Mozambique, 4 South Africa
- ❖ BSc students: 4 South Africa

➤ **Production of educational videos about natural H_2**





Leaflets



Detecting Natural Hydrogen at the Surface: Remote Sensing of Sub-Circular Depressions (SCDs)

What are Circular or Sub-Circular Depressions (SCDs)?

Across Africa and other parts of the world, researchers have discovered a link between natural hydrogen escaping from underground and the formation of shallow, round-shaped depressions at the Earth's surface (see Figure 1). These features, often lacking vegetation, are sometimes called "fairy circles" or "cairns", and they can serve as visual clues for finding underground hydrogen sources.

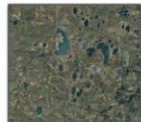


Figure 2 Satellite image of sub-circular depression

What Makes These Depressions Special?

While other natural processes like sinkholes or glacial activity can also form depressions, hydrogen-related SCDs usually show a clear reduction in vegetation. This unique fingerprint helps scientists tell them apart.

How Can We Detect Them?

Using satellite and aerial imagery, the SCDs can be mapped remotely, from a computer, before field visits are conducted. This makes hydrogen exploration faster, safer, and more efficient.

Main Remote Sensing Tools Used in HyAfrica:

Satellite Images: Platforms like Landsat 7/8/9 and Sentinel-2 provide free, high-resolution images covering large areas. Google Earth: Offers easy-to-use images



Figure 3 Google Earth image of SCDs in the terrain for visual identification, often in very high spatial resolution, though it lacks detailed spectral data ready for use (see Figure 2).

Digital Elevation Models (DEM): These help map subtle terrain variations that reveal depressions.

Spectral Indices: The Normalized Difference Vegetation Index (NDVI) highlights vegetation health. Since SCDs often have less or no vegetation, NDVI helps locate them by detecting "bare" spots (see Figure 3).

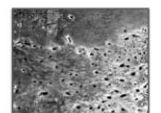


Figure 2 NDVI image



Best-practice workflow to indicate appropriate structural geological conditions to assist future exploration campaigns

The HyAfrica project aims to investigate the potential of naturally occurring hydrogen (H₂) found in specific geological settings across Africa. The study outlines the geological and structural conditions most commonly associated with hydrogen occurrences observed at the Earth's surface. It highlights key indicators of potential natural hydrogen, beginning with surface-level signs of hydrogen flow, followed by geological features such as reservoirs and traps. Finally, it explores possible hydrogen sources located deeper within the crust and mantle.

Workflow

This best-practice workflow (Figure 1) considers key geomorphological, geochemical, and geological features from the surface downward. Although this order contrasts with the typical migration path of hydrogen, which moves from deep sources upward to the surface, confidence in identifying significant factors generally decreases with depth. As a result, the workflow follows a pattern from high to low confidence, aligning with the clear topology followed in exploring potential natural hydrogen resources. The workflow is illustrated in Fig. 1 and covers four key steps: 1) Near-surface factors, 2) Shallow-level factors, 3) Moderate-level factors, and 4) Deep-level factors.

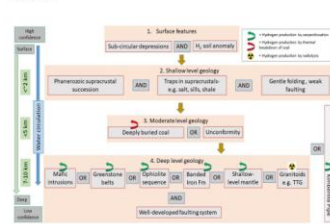
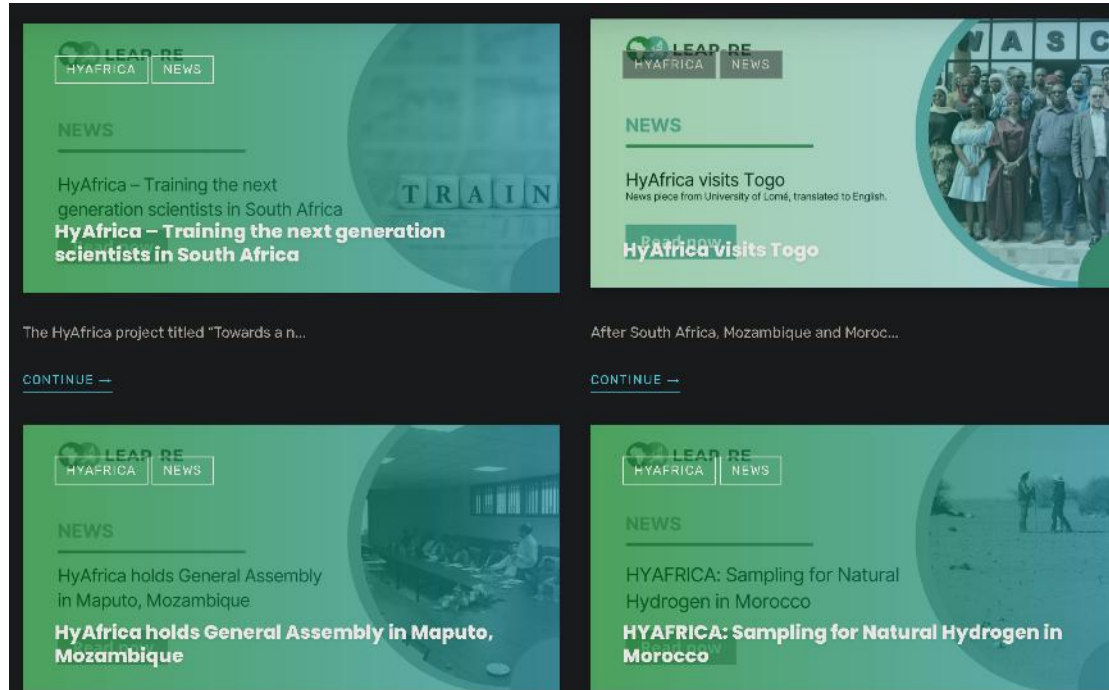


Figure 1 Best-practice workflow to indicate appropriate structural geological conditions to assist future exploration campaigns



Updated website with embedded videos and images

Flyers

Infographics and Posters

EAGE 2024 poster

HyAfrica Project Flyer

Our videos

News from HyAfrica

THANK YOU

CONTACT US FOR MORE INFORMATION



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The LEAP-RE project has received funding from the European Union's Horizon 2020 Research and Innovation Program under Grant Agreement 963530.