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Clean Energy Access Prioritiser - Handbook

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Abstract

The Clean Energy Access Prioritiser (CEAP) is a decision-support tool designed to identify priority areas for clean energy interventions and investments. The CEAP is a web-based multi-criteria tool that integrates various geospatial datasets combining factors such as energy demand, environmental conditions, and social aspects. The tool is valuable for policymakers, international donors, governments, and philanthropic investors in the energy sector. This handbook highlights the benefits and applications of the CEAP, including evidence-based energy planning, spatial suitability analysis, scenario comparison, access to key spatial datasets, gap analyses, and understanding trade-offs between clean energy planning objectives. Furthermore, the handbook provides a step-by-step guide on how to effectively use CEAP and explains the significance of different variables in the tool, categorised into market supply, market demand, environmental and climate factors, and socio-political aspects. Lastly, a use case scenario is presented for Benin, demonstrating the practical application of CEAP in identifying suitable areas for the electrification of educational facilities. The handbook guides users through the variable selection process and the definition of priorities based on specific objectives. Overall, this handbook provides an overview of CEAP's features and benefits, along with guidelines on how to effectively use the tool, and emphasises the tool's ability to promote collaboration and engagement among stakeholders through its online accessibility.

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1 Introduction

The Clean Energy Access Prioritiser (CEAP) is an open-source decision-support tool designed to identify priority areas for clean energy interventions and investments. The spatial planning tool allows users to evaluate clean energy projects with a multi-sectoral approach, including environmental, socio-economic, technical, and political aspects.

This web-based tool allows for multi-criteria selections helping identifying priority areas (hot and cold spots) in real-time based on custom priorities. The automatic geo-processing capabilities encompass more than 30 variables, spanning aspects such as energy demand, environmental and social conditions.

The CEAP can be of interest to both institutional and private stakeholders in the energy sector, i.e. policymakers, international donors, governments, and philanthropic investors.

2 Applications and benefits of the Clean Energy Access Prioritiser

Using a web-based geospatial decision-support tool for prioritising areas for clean energy interventions and investments offers several advantages, which can be seen in the possible applications listed hereafter.

- **Design evidence-based energy planning scenarios:** The tool enables users to tailor their clean energy planning scenarios based on evidence and data-driven analysis. Decision-makers can explore different scenarios by assigning different levels of importance to each factor depending on specific-user priorities. The tool's ability to integrate various geospatial datasets from multiple sources into a single spatial indicator allows users to gain a comprehensive understanding of the particular factors influencing clean energy planning in each area. This helps users in making informed decisions and designing strategies that align with their specific energy planning goals.

- **Perform spatial suitability analysis**: The tool allows users to conduct spatial suitability analysis by considering various factors such as renewable energy potential, environmental constraints, infrastructure availability, and socio-economic conditions. The multi-criteria-weighted analysis generates a composite index (or score) on the fly (Battistella el al. 2023) that compares the suitability of each planning unit for clean energy deployment in relation to the specific needs of the user. In this way, decision-makers can identify the most suitable areas for clean energy technologies, ensuring optimal utilisation of resources and maximising the benefits of clean energy projects.

- **Access to relevant spatial datasets**: The tool provides access to relevant spatial datasets that support clean energy planning and decision-making. These datasets can be explored and combined together and can be downloaded from the original source.

- **Map and compare scenarios across different user priorities:** The CEAP offers interactive and exportable outputs such as maps and charts underpinning the results of the selected planning scenarios. These visual supports help users to identify patterns, trends, and areas of overlap or divergence between several scenarios. In this way, users are guided in the selection and pre-evaluation of the most effective clean energy interventions.

- **Conduct gap analyses:** Decision-makers can use the tool to conduct gap analyses, identifying areas or aspects where there is a shortfall or lack of clean energy interventions. By comparing the existing state with the desired goals or targets, decision-makers can identify gaps in clean energy infrastructure, and potential areas for improvement, and prioritise interventions accordingly.

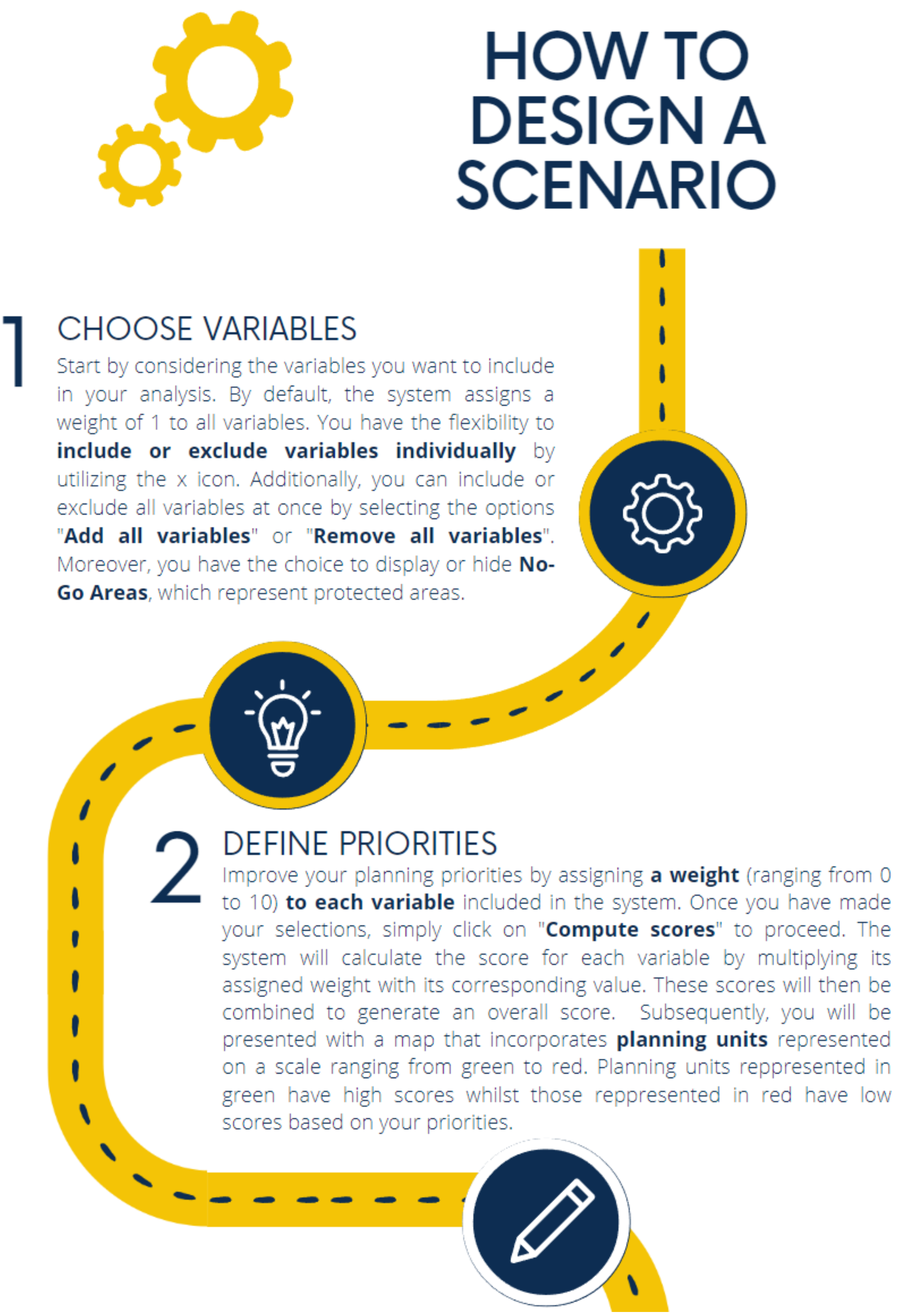
- **Understand trade-offs between objectives:** The tool allows decision-makers to assess and understand the trade-offs between different objectives. For example, they can evaluate the trade-off between maximising clean energy generation and minimising environmental impacts. By considering and visualising these trade-offs, decision-makers can make more balanced and informed decisions, ensuring that the deployment of clean energy technologies aligns with broader sustainability objectives.

- **Promote collaboration and engagement among stakeholders:** The CEAP tool inherently encourages collaboration and engagement among different stakeholders involved in the decision-making processes. By sharing the tool online, decision-makers can gather input from various experts, local communities, and interested parties, fostering transparency and inclusivity.

3 How to use the Clean Energy Access Prioritiser

This section provides four essential steps to effectively utilise the Clean Energy Access Prioritiser tool. Additionally, it provides a detailed understanding of the crucial factors to consider when defining priorities in a user-tailored planning scenario.

Figure 1. Infographic showing the process to define a planning scenario using the CEAP.



3 PERFORM LOCAL ANALYSIS

To further refine your analysis you can use the slider placed on the top-left corner to visualise and select the **top-ranking areas**. Additionally, you can narrow down your analysis to a subset of the planning domain using a regular rectangle or a self-drawn polygon. The **square symbol** allows you to select a square-shaped area, while the **polygon symbol** enables you to manually define a custom area of interest by drawing a polygon on the map.

4 EXPORT DATA

Once you have completed the aforementioned process, an orange box will appear, providing you with valuable information about the selected area's unique characteristics. You will have the opportunity to explore "**What makes this area special**" in more detail. Additionally, you will be able to **export your scenario** as a map and raw data in CSV format, enabling you to further analyse and utilise the results as needed.

4 Understanding of the CEAP variables

The table below describes and characterises the variables included in the Clean Energy Access Prioritiser (CEAP). As the algorithm underlying the CEAP tool does not admit negative values, we present two variables (i.e. Farthest from the grid and closest to the grid) which indicates positive and negative effects that a factor might have on the prioritisation process (i.e. in this case distance to the grid).

Tables 1-4 intend to eliminate misunderstandings not only about the doubled variables, but also about the meaning of the maximum value (green) and minimum value (red) for each variable.

Additionally, tables 1-4 contain the links to a general description of the meaning of each variable and the technicalities and context behind (Africa Knowledge Platform's Datasets).

The following tables are updated on a regular basis, to access the most updated version please use the following link.

Table 1. Market supply variables: minimum/maximum values and source of information

MARKET SUPPLY	Minimum value (red)	Maximum value (green)	Source
Closest to the grid	Longest distance to electric grid (LV; MV; HV) per planning unit.	Shortest distance to electric grid (LV; MV; HV) per planning unit.	(Kakoulaki & Moner-Girona. 2020) Datasets | Africa Platform (europa.eu)
Farthest from the grid	Shortest distance to electric grid (LV; MV; HV) per planning unit.	Longest distance to electric grid (LV; MV; HV) per planning unit.	(Kakoulaki & Moner-Girona. 2020) Datasets | Africa Platform (europa.eu)
Power plants	Lowest density of power plants per planning unit.	Highest density of power plants per planning unit.	(Sanchez et al. 2020) Datasets | Africa Platform (europa.eu)
Solar potential	Lowest solar potential, measured by a long term yearly average of global horizontal irradiation in the planning unit.	Highest solar potential, measured by a long term yearly average of global horizontal irradiation in the planning unit.	(Huld et al. 2020) Datasets | Africa Platform (europa.eu)
Wind potential	Minimum wind resources measured by mean wind power density in the planning unit.	Maximum wind resources measured by mean wind power density in the planning unit.	(Global Wind Atlas. 2023) Datasets | Africa Platform (europa.eu)
Hydropower potential	Lowest hydropower potential in the planning unit.	Highest hydropower potential in the planning unit.	(Sanchez et al. 2020) Datasets | Africa Platform (europa.eu)
Most accessible areas	Longest accessibility time to travel to the area.	Shortest accessibility time to travel the area.	(Weiss et al. 2015). Datasets | Africa Platform (europa.eu)
Least accessible areas	Shortest accessibility time to travel the area.	Longest accessibility time to travel to the area.	(Weiss et al. 2015).

			Datasets | Africa Platform (europa.eu)
Electricity grid (existing or planned)	Highest density of electric lines per planning unit.	Lowest density of electric lines per planning unit.	(Kakoulaki & Moner-Girona. 2020) Datasets | Africa Platform (europa.eu)

Table 2. Market demand variables: minimum/maximum values and source of information

MARKET DEMAND	Minimum value (red)	Maximum value (green)	Link
Industrial areas	Planning unit is not covered by built-up surface allocated to dominant non-residential (NRES) uses.	Planning unit is fully covered by built-up surface allocated to dominant non-residential (NRES) uses.	(Pesaresi et al. 2020) Global Human Settlement - GHS-BUILT-C_GLOBE_R2023A - European Commission (europa.eu)
Population	Lowest density of residential population per planning unit.	Highest density of residential population per planning unit.	(Schiavina et al. 2023) Datasets | Africa Platform (europa.eu)
Health centers	Lowest density of health facilities per planning unit.	Highest density of health facilities per planning unit.	(Kakoulaki & Moner-Girona. 2021) Joint Research Centre Data Catalogue - Healthcare facilities and electricity access in Af... - European Commission (europa.eu)
Educational facilities **(primary and secondary)**	Lowest density of educational facilities per planning unit.	Highest density of educational facilities per planning unit.	Process of publication (Moner-Girona, et al 2023) Joint Research Centre Data Catalogue - Datasets for a multidimensional analysis connectin... - European Commission (europa.eu)

Educational facilities without electricity (primary and secondary)	Lowest density of educational facilities lacking access to electricity per planning unit.	Highest density educational facilities lacking access to electricity per planning unit.	Process of publication (Moner-Girona, et al 2023) Joint Research Centre Data Catalogue - Datasets for a multidimensional analysis connectin... - European Commission (europa.eu)
Area equipped for irrigation	Planning unit is not covered by irrigated areas.	Planning unit is fully covered by irrigated areas.	(Siebert et al. 2013) AQUASTAT - FAO's Global Information System on Water and Agriculture
Groundwater irrigation	Planning unit is not covered by irrigated area supplied by groundwater.	Planning unit is fully covered by irrigated area supplied by groundwater.	(Siebert et al. 2013) AQUASTAT - FAO's Global Information System on Water and Agriculture
Livestock	Lowest density of livestock per planning unit.	Highest density of livestock per planning unit.	(Timothy et al. 2014) Datasets | Africa Platform (europa.eu)

Table 3. Environmental and climate variables: minimum/maximum values and source of information

ENVIRONMENTAL AND CLIMATE	Minimum value (red)	Maximum value (green)	Link
Elevation	Lowest elevation per planning unit.	Highest elevation per planning unit.	(Rosen et al. 2007) Datasets | Africa Platform (europa.eu)
Slope	Lowest slope per planning unit.	Highest slope per planning unit.	(Rosen et al. 2007) Datasets | Africa Platform (europa.eu)

Natural areas	Planning unit is not covered by natural areas.	Planning unit is entirely covered by natural areas.	(Buchhorn, 2022) Datasets | Africa Platform (europa.eu)
Intact forest	Planning unit is not covered by Intact Forest.	Planning unit is entirely covered by Intact Forest.	(Potapov et al. 2017) Datasets | Africa Platform (europa.eu)
Protected and Conserved Areas	Planning unit is not covered by Protected and Conserved Areas	Planning unit is entirely covered by Protected and Conserved Areas	(UNEP-WCMC and IUCN, 2023) Datasets | Africa Platform (europa.eu)
Temperature anomalies	Lowest variation of average global temperatures compared to a reference value in the planning unit.	Highest variation of average global temperatures compared to a reference value in the planning unit.	(Vose et al. 2021) Temperature Anomaly: Yearly (NOAA) - 1880 - Present - Science On a Sphere
Drought risk	Planning units less likely to be affected by droughts.	Planning units most likely to be affected by droughts.	(Carrão et al. 2016) Datasets | Africa Platform (europa.eu)

Table 4. Socio-political variables: minimum/maximum values and source of information

SOCIO-POLITICAL	Minimum value (red)	Maximum value (green)	Link
Food security	Lowest vulnerability to hunger, highest food quality in the planning unit.	Highest vulnerability to hunger, lowest food quality in the planning unit.	(INFORM. 2023) Datasets | Africa Platform (europa.eu)
Armed conflict	Lowest number of political violence and protest events in the planning unit.	Highest number of political violence and protest events in the planning unit.	(ACLED. 2022) Datasets | Africa Platform (europa.eu)

Refugee camps	Lowest amount of refugee settlements in the planning unit.	Highest amount of refugee settlements in the planning unit.	(Baldi et al. 2021) Joint Research Centre Data Catalogue - Refugee Settlements Electricity Access (RSEA) - European Commission (europa.eu)
Connectivity	Lowest mobile network performance.	Highest mobile network performance.	(Ookla. 2022) Datasets | Africa Platform (europa.eu)

5 Use case: Educational facilities without access to electricity

This section illustrates a use case to facilitate the understanding of the tool's full potential. It considers a practical scenario where the user aims to identify suitable areas for the electrification of educational facilities based on the criteria of a specific programme. By following this use case, the user will gain practical insights into leveraging the tool effectively.

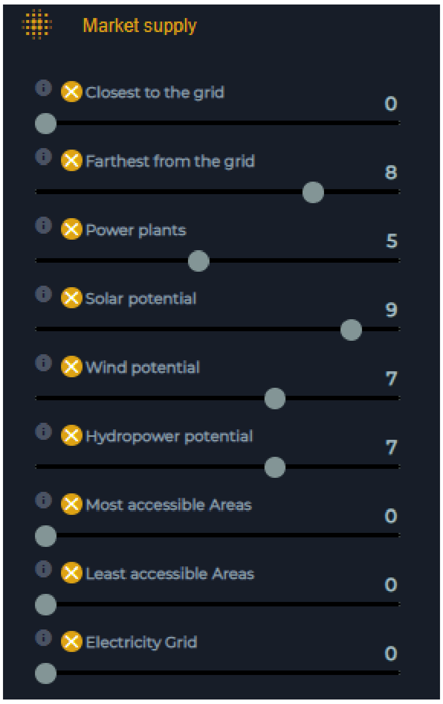
5.1 Select variables

To streamline decision-making process, users have the option to exclude those variables that are not relevant. Variables can be excluded in two ways: either all at once or individually. To remove all variables in one go, users can simply click on the "Remove all variables" button. Alternatively, a more selective approach is also available and allows to exclude variables one by one. Next to each variable, an "x" icon is available. Clicking on this icon the system will remove the respective variable from consideration. By utilising these exclusion options, users can customise their analysis to focus on the most relevant variables for their decision-making process.

The following scenario focusses on areas where electricity access to schools is currently not guaranteed. Here is how users can approach the variable selection and weighting process based on four pillars:

5.1.2 Market supply

Figure 2. Screenshot of the market supply pillar.



The goal is to provide electricity where currently there is no access, variables relevant to this objective such as existing energy infrastructure and energy potentials need therefore to be selected. In this case, it is important to select areas that are not closed to the existing electric grid (i.e. following the national criteria of 5 km away from grid) and then exclude the variable representing the presence of electric grid which measures the density of lines in each selected area. On top of this, data that indicate the presence of power plants might be of interest. Furthermore, users might consider the areas with higher potential of energy sources such as solar, wind and hydropower, as they enable clean energy supply. Finally, since focusing on hard-to-reach places would be extremely demanding, users may want to know what the level of accessibility of each planning unit is.

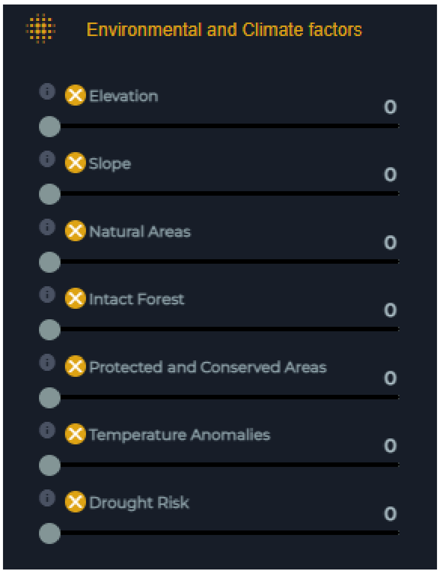
5.1.3 Market demand

Figure 3. Screenshot of the market demand pillar.

From the energy demand perspective, the priority is to identify areas with a high prevalence of educational facilities lacking electricity, therefore variables that do not directly relate to this objective need to be removed.

5.1.4 Environmental and climate factors

Figure 4. Screenshot of the environmental and climate pillar.



Users may consider including environmental factors that relate to the preservation of ecosystems and biodiversity in the analysis. These factors - such as Protected and Conserved Areas - are essential to be taken into account when planning clean energy areas to avoid the implementation of large energy infrastructures in environmentally sensitive territories for large infrastructures and promote decentralised energies when there are energy needs inside the protected areas. By considering these factors the disruption of habitats can be minimised, and the ecological balance can be improved. Furthermore, this pillar helps assess the resilience and adaptability of clean energy systems. By considering climate-related factors such as drought risks users can select areas that are less vulnerable to environmental hazards. Prioritising resilient clean energy areas enhances the longevity and reliability of energy infrastructure, reducing the potential for disruptions in educational facilities.

5.1.5 Socio-political aspects

Figure 5. Screenshot of the socio-political pillar.

Socio-political aspects play a crucial role and help ensure the equitable distribution of clean energy access. Users may want to consider how planning units score as regards food security and connectivity, i.e. internet accessibility and network performance. Additionally, it may be relevant to address whether educational facilities are exposed to political violence and protest events.

Important to note is that the variables availability can be further expanded based on specific user requirements. The list of information gathered and processed to assess the performance and usability of the tool is a preliminary one and can be enhanced.

5.2 Define priorities

Once variables that are relevant to analysis are identified, users can assign a specific weight to each of them based on their importance influencing the final result.

To assign weights, the following example can be considered:

1. Energy Potential (High Weight: from 7 to 9):

   As these factors are highly important for the scope of this analysis, a high weight to variables related to energy resource potential needs to be assigned. Since solar energy has high potential in the studied country and is a very modular technology appropriate for small electricity consumptions its weight is selected at (9) and the weight of wind and hydropower potential at (7).

2. Presence of Power Plants (Medium Weight: 5):

   We suggest to assign a weight of 5 to variables related to the presence of power plants. This indicates that this variable is moderately important for this objective.

3. Farthest from the Electricity Grid (High Weight: 8):

   We suggest to assign a weight of 8 to the variable representing the distance from the existing grid (furthest to the grid) following the national criteria for the country that is to prioritise the grid connection to areas closer than 5km to the existing grid.

4. Least/most accessible areas (Exclude variables: 0):

   We suggest to exclude variables representing the accessibility of the territory (least/most accessible Areas), as the scope is to prioritise interventions regardless of the distance of schools from roads and transport networks.

5. Presence of Non-Electrified Schools (Highest Weight: 10):

   We suggest to assign a weight of 10 to the variable representing the presence of schools without access to electricity. This indicates that this factor carries the most significant weight in this analysis.

6. Socio-Political Aspects (Low Weight: 2):

   We suggest to assign a weight of 2 to socio-political aspects. This implies that these factors are considered as secondary elements for the scope of this analysis.

In this use case we do not suggest to exclude “No-Go Areas” in the analysis. This is done by simply not ticking the “No-Go Areas” box. “No-Go Areas” encompass strict nature reserves, wilderness areas, national parks and monuments, species management areas, protected landscapes, and areas for sustainable use of natural resources. By including No-Go Areas, we take into account energy needs (as decentralised energy options) also inside protected areas.

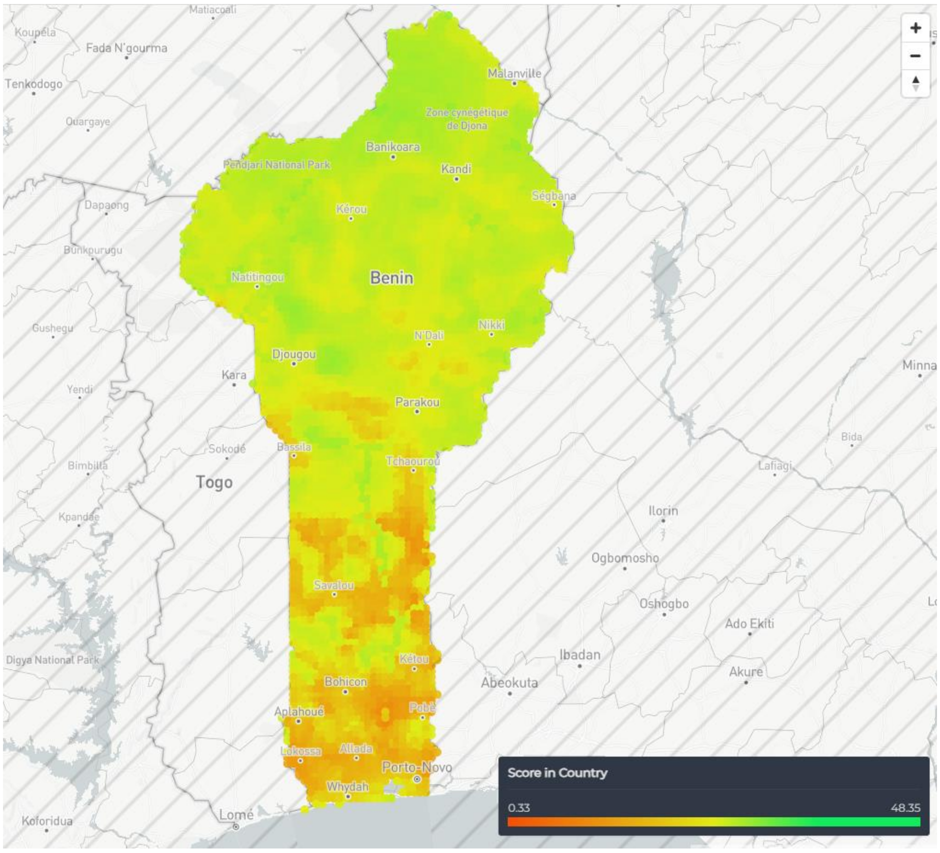
The next step will be to click on “Compute scores”. The resulting map will display the planning units according to a colour scheme spanning from red to green, which represent the lowest and highest priority areas, respectively. Therefore, the algorithms make it possible to identify areas most in need of intervention for the specific planning scenario.

Please explore the tool using this link (browsers such as chrome are preferred) to run the CEAP with the pre-sets that have just been presented.

5.3 Perform local analysis

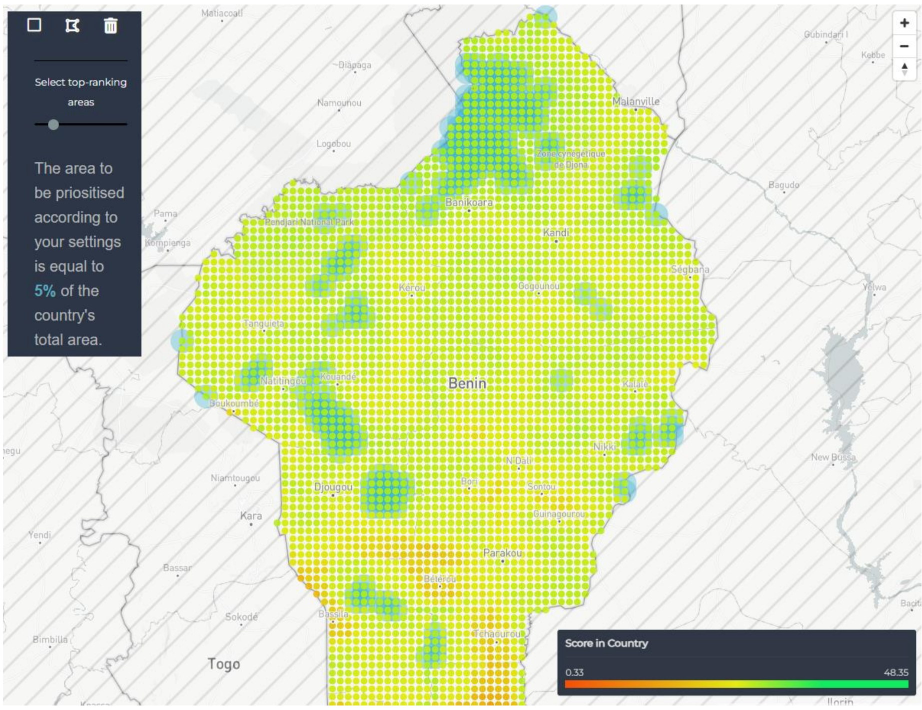
Once the scores are computed, the CEAP tool allows to analyse results by several maps/diagrams. Fig. 6 shows the result of the parameters selected above, the Northern part of Benin has the highest scores, and specific hotspots (greenest) with high scores can be found in the North and in the North-West side of the Country.

Figure 6. Screenshot of map displaying the planning units according to a colour scheme spanning from red to green.



To further select top-ranking areas, a slider is available in the top-left corner. This will allow to highlight a specific percentage of the highest-scoring planning units. Fig. 7. Shows a selection of the 5% top-ranking areas.

Figure 7. Screenshot of map highlighting in blue the 5% top-ranking planning units.



Users can also isolate the portion of lands to be further analysed by using the square or polygon symbols: these tools allow to draw a polygon on the map and select the planning units of interest. (Fig. 8).

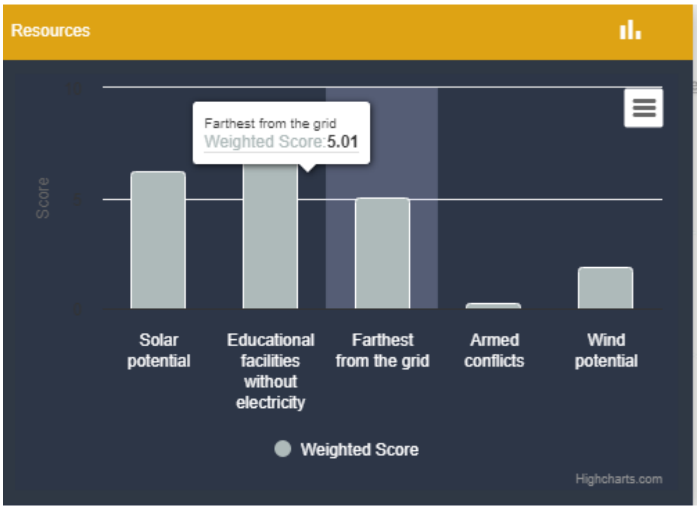
Figure 8. Screenshot of map displaying a custom square-shaped selection of underlying planning units.

5.4 Explore and export analysis

After selecting the polygon, an orange box will appear in the top right-hand corner. Here, users can access to a number of information including:

- The size of the selected area (in square km);
- A column chart (Fig.9) with the scores obtained by the selected variables weighted according to the assigned priority. The columns represent the average value of the scores assigned to each planning unit included in the selected area;

Figure 9. Screenshot of the column chart displaying the scores obtained by the selected variables and their assigned weight.



- A radar plot (Fig.10). displaying which variables are the most prominent in the area selected. The custom-weighted scores within the selected area are represented in orange, while the equally weighted scores are displayed in blue. This visualisation allows for detecting synergies and trade-offs as well as interlinkages between the variables that cover the area selected.

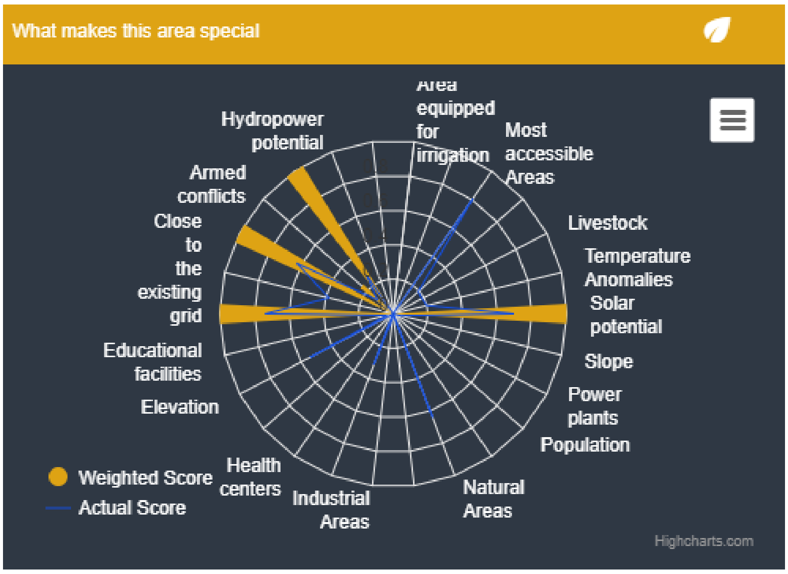


Figure 10. Screenshot of the column chart displaying all scores obtained by the selected variables and their assigned weight.

- To have ready-to-use visuals and data about the envisaged scenario, users can export the charts in various formats including png and pdf, map in png format and data underpinning the analysis in CSV format (Fig.11).

Figure 11. Screenshot of the download section of the CEAP.

6 Conclusions

Geospatial data and analysis play a critical role in informing sustainable energy decisions and overcoming barriers to clean energy deployment across various sectors. The Clean Energy Access Prioritiser (CEAP) serves as a versatile decision-support tool, integrating multiple geospatial factors to enable comprehensive spatial planning for clean energy projects. Its architecture and features provide end-users with an integrated online application that eliminates the need for computational power to run spatial analyses, offering more than what individual indicators or datasets can provide on their own.

Our case study in Benin demonstrated the versatility of CEAP and provided insights into how to better utilise the tool. It emphasized that CEAP is not designed to generate a single spatial prioritization representing a "perfect plan". Instead, prioritisations can vary considerably based on the relative weights assigned to input factors. The CEAP offers decision-makers a range of prioritisation options, allowing them to consider different factors and their varying importance when making renewable energy decisions.

It is important to acknowledge the limitations of the CEAP tool, particularly concerning data availability and accuracy. The effectiveness of the tool relies heavily on the quality and completeness of the raw data used for analysis. Inaccurate or incomplete data can potentially impact the reliability of the results and influence the overall decision-making process.

However, despite these limitations, CEAP provides valuable insights and guidance for clean energy planning processes. By leveraging existing global datasets and enabling real-time analysis, CEAP empowers users to make informed decisions within the constraints of available data. Furthermore, the tool's strength lies in facilitating scenario development and trade-off evaluations. Even in data-poor contexts, CEAP allows decision-makers to identify priority areas and evaluate land-use planning options, serving as a stepping stone towards more comprehensive and data-rich systematic planning.

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List of abbreviations and definitions

CEAP Clean Energy Access Prioritiser

TAF Technical Assistance Facility

RSEA Refugee Settlements Electricity Access

INFORM Inter-Agency Standing Committee Reference Group on Risk, Early Warning and Preparedness

PV Photovoltaic

GHS-BUILT-C: Global Human Settlements - Built-up Areas

GHS-POP Global Human Settlements - Population

AGU American Geophysical Union

UNEP-WCMC United Nations Environment Programme - World Conservation Monitoring Centre

JRC Joint Research Centre

IUCN International Union for Conservation of Nature

NOAA National Oceanic and Atmospheric Administration

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