Locational potential of offshore wind renewable energy in South Africa's coastal Special Economic Zones (SEZs)

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Introduction

- **Energy security**, **energy equity** and **environmental sustainability** are central to the UN's 17 Sustainable Development Goals (SDGs), outlined in the **2030 Agenda**.
- SDG 7 specifically focuses on ensuring affordable, reliable, sustainable, and modern **energy for all.**
- **Sustainability** within the SDGs includes socially equitable, environmentally prudent, and economically viable outcomes.
- Energy insecurity affects Africa disproportionately, with 80% **(600 million people)** of the global total of 760 million people **without electricity** being in sub-Saharan Africa
- In **South Africa**, energy access and the just energy transition, highlight the stark reality of **balancing** energy security and sustainable development.

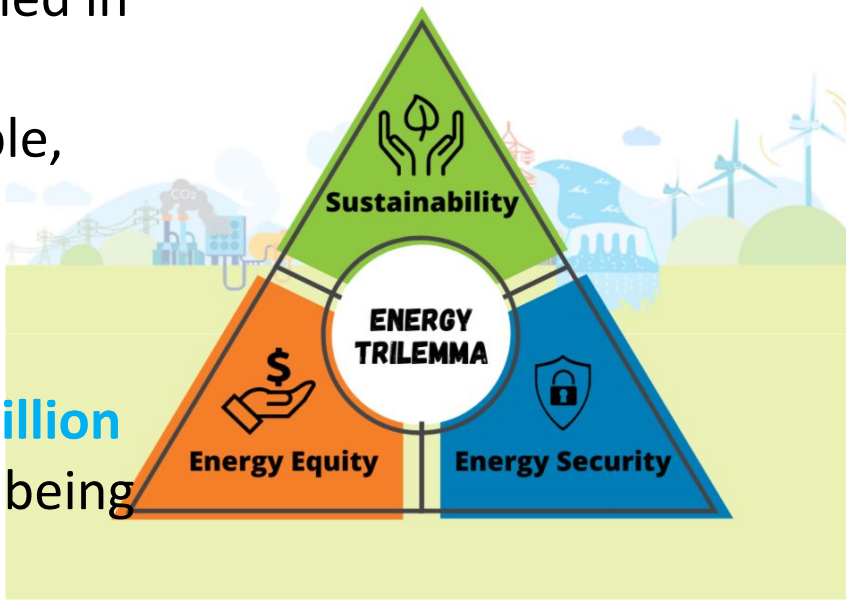
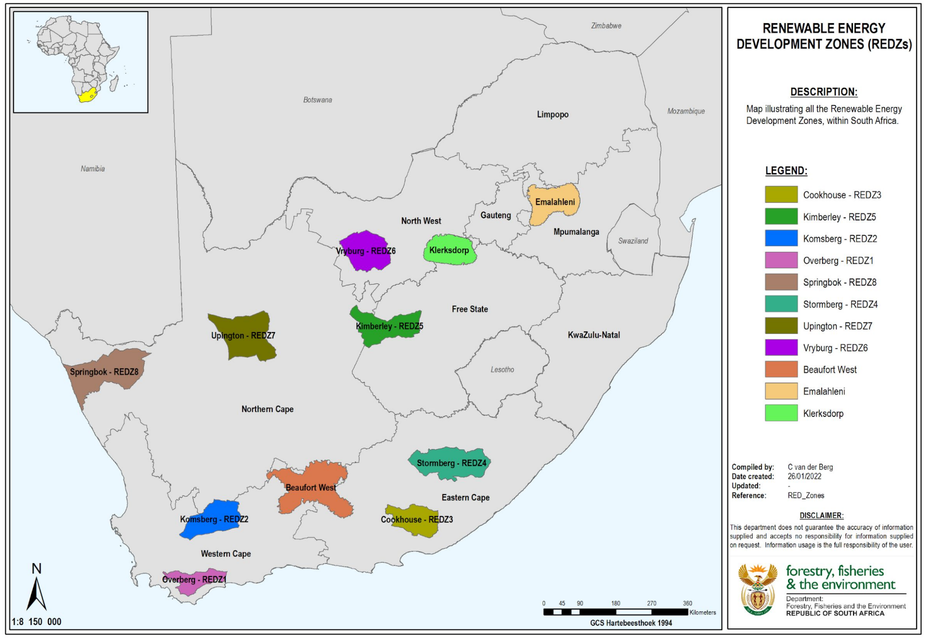


Image from asiacleanenergyforum

Real World Problem

South Africa's Energy Landscape

- **Energy crisis** since 2008
- Energy generation mostly from coal, which accounts for ~80.1% making South Africa the **14th highest carbon emitter globally**
- South Africa has significant renewable energy potential: solar, wind, hydropower and biomass
- **Renewables** presently contribute **13.7% to the electricity mix**
- Land Use: 1,22 million km2 of land in SA 340km^2 used for electricity generation
- 36%% of land suitable for solar; 57% suitable for wind development
- **Renewable Energy Sprawl**
- **Offshore Wind Energy** ☺️



South Africa's renewable energy development zones as of 2022

Aims & Objectives

Aim

To **investigate** the physical resource, technical, and market potential of **offshore wind energy adoption** in **South Africa**

Objectives

1. **Evaluate offshore wind energy potential** in South Africa's coastal SEZs using geospatial analysis and various **GIS-based decision-making techniques**, considering factors such as **wind resources**, **environmental impact**, and **infrastructure**.
2. **Estimate** the **power output generation of wind turbines (bottom fixed and floating offshore wind turbines**) and integrate deployment potential with existing or planned industries **within SEZs** to promote economic growth
3. **Examine** current **policies and regulations** affecting offshore wind energy in SEZs, and provide recommendations for policy reform to enhance renewable energy adoption and integration.

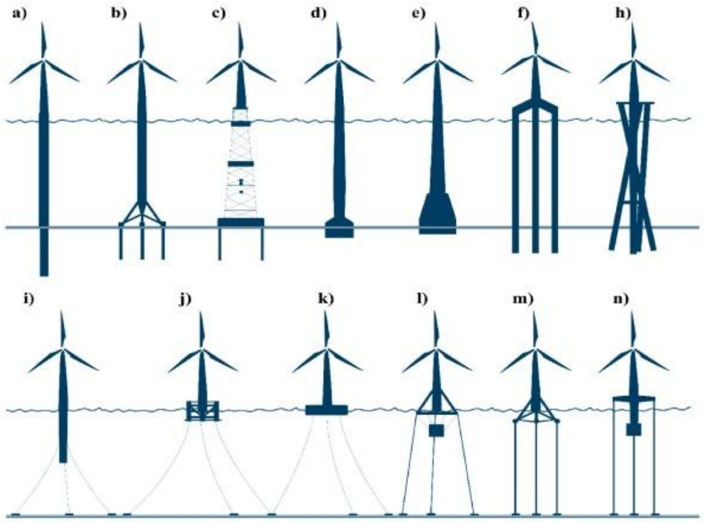
Wind Energy in South Africa

- South Africa's **wind energy resources** are mainly found in the Northern, Western, and Eastern Cape provinces, with limited potential in KwaZulu Natal
- Wind energy has a **better Levelized Cost of Electricity (LCOE)** compared to other renewable sources, making it a favorable option for energy diversification
- **34** onshore wind farms, primarily in the **Northern Cape**, but offshore wind energy (OWE) has not yet taken off in the country or continent
- OWE technology offers advantages over onshore, such as **reduced turbine fatigue, lower turbulence intensity, and fewer land use constraints**
- Global wind power capacity: **837 GW in 2021**, only 7% from offshore systems, by 19 countries

Noupoort wind farm in Northern Cape has 35 wind turbines
https://www.mainstreamrp.com/news/6400-2/

Offshore Wind Turbines

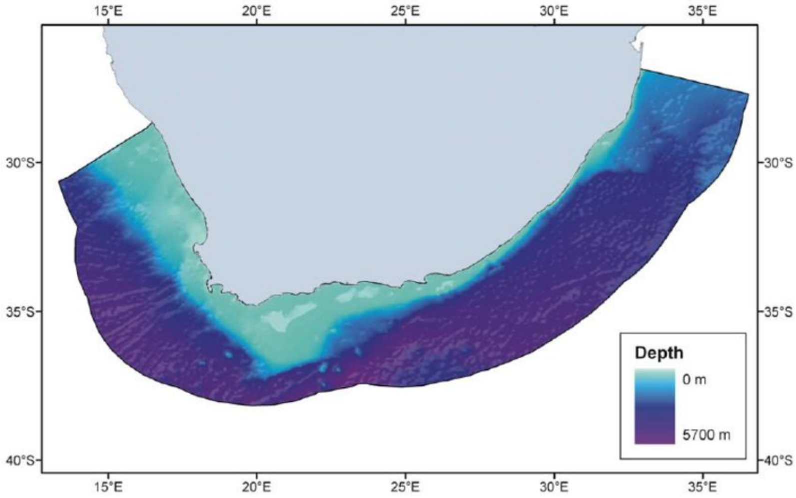
- **Offshore wind energy (OWE) technologies** capture kinetic energy from the wind and transmit it back to shore
- South Africa's offshore environment benefits OWE due to deeper waters further from the coast and strong, consistent wind speeds from the **Agulhas and Benguela currents**, allowing for larger turbine installations
- Various foundation types are used for offshore wind turbines, including **gravity foundations** for shallow depths and more complex structures like **monopiles and jackets** for deeper waters
- OWE development faces challenges related to technical, economic, and regulatory factors
- **Offers higher power density and efficiency**



A schematic of different types of OWTs. Fixed-bottom offshore wind turbines including: (a) Monopile (b) Tripod (c) Jacket (d) Suction caisson (e) Gravity base (f) Tripile (h) Twisted jacket. Floating offshore wind turbines including; (i) Spar buoy (j) Semisubmersible (k) Barge (l) Pendulum floater (m) Tension leg platform (n)Advanced spar.

South Africa's Exclusive Economic Zone

- South Africa's **maritime zones** include **territorial waters** (up to 12 nautical miles), **contiguous zones** (up to 24 nm), Exclusive Economic Zones (**EEZ, up to 200 nm**), and the **continental shelf**
- The country has a **coastline** of approximately **3,650 km** and an EEZ covering over 1 million km^2
- The EEZ extends to **a depth of 5,700** m, with **65% of its area being deeper than 2,000 m**, making it suitable for offshore wind energy development
- **Challenges** in developing offshore wind energy in South Africa include **high costs, lack of investment, technical skill deficits, and regulatory uncertainties**, which Special Economic Zones (SEZs) could help address



Map showing seafloor depths and the boundaries of South Africa's continental Exclusive Economic Zone (EEZ).

Special Economic Zones

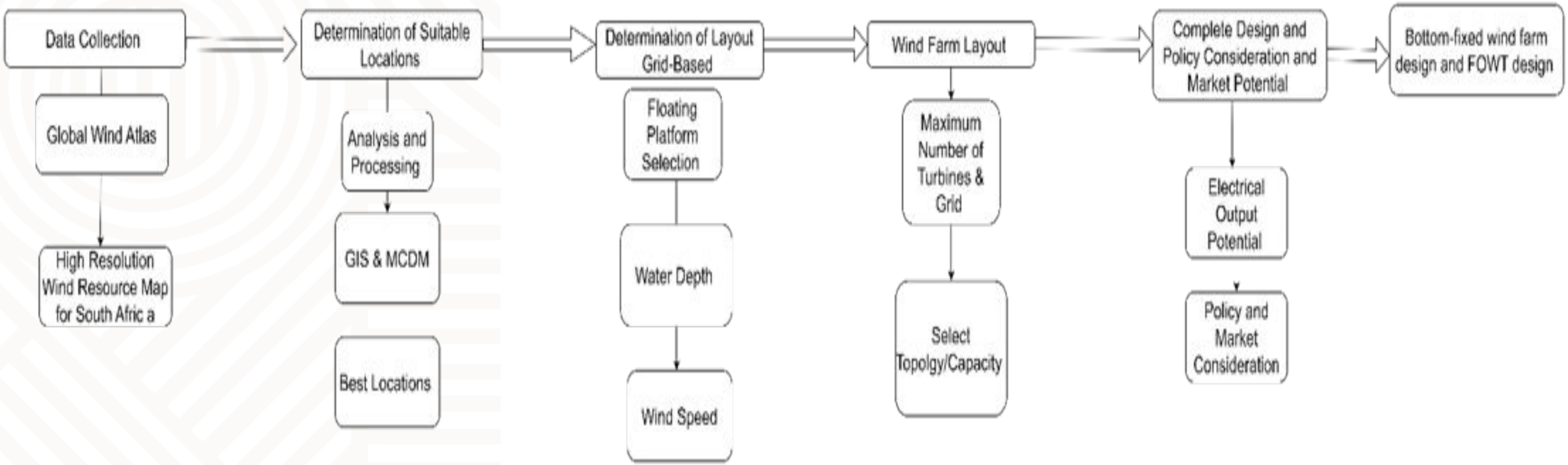
- South Africa has **11 active Special Economic Zones (SEZs)**, established under the SEZ Act No. 16 of 2014, aimed at **targeted economic activities for industrialization, regional development, and job creation**
- SEZs are categorized as Industrial Development Zones, Free Ports, Free Trade Zones, and Sector Development Zones, each designed to facilitate specific economic activities
- **Six** of these SEZs are **located on the coast, enhancing their potential to contribute to renewable energy transitions** through proximity to ports
- The growth of the global OWE sector presents an **opportunity** for South Africa's SEZs to pilot regulatory feasibility studies and streamline the planning process necessary for adopting OWE technology

South African Special Economic Zones

Locational Potential of Offshore Wind Energy in South Africa

- **GIS tools,** including Multi-Criteria Decision Making (MCDM), Analytic Hierarchy Process (AHP), and Multiple Attribute Decision Analysis (MADA), are used to determine optimal sites for offshore wind energy (OWE) development
- These methodologies incorporate various datasets such as **wind speed, ocean depth (bathymetry), and the location of marine protected areas,** which are crucial for OWE site selection
- Key factors for offshore wind feasibility in South Africa include wind speeds above 7 m/s and bathymetric limits of 800–1000 meters for turbine foundations
- Advanced spatial models are utilized to **predict energy production potential** by integrating data on wind patterns and marine constraints within geographic information systems
- The **application of these technologies and methodologies** supports the advancement of OWE, particularly through floating turbine innovations, to effectively harness South Africa's coastal wind resources

Work Flow Design



Significance & Rationale

- The study seeks to **address key challenges in energy security, sustainable development, and economic growth in South Africa**, promoting offshore wind energy (OWE) as a renewable alternative amid an energy transition away from fossil fuels
- Harnessing OWE within Special Economic Zones (SEZs) is **intended to drive industrialization, job creation, and regional economic growth,** directly contributing to the achievement of Sustainable Development Goal 7, which focuses on energy access
- **Research will optimize offshore wind farm deployment by identifying suitable locations based on wind resources**,
- **Analyze existing policies and regulations affecting renewable energy development**, pinpointing barriers and recommending streamlined processes to support offshore wind investments
- **Enhance knowledge in renewable energy technology**