Project Title: Multidimensional Study of Wind Energy Potential in Alamein

Short title: WE-Alamein

Keywords: Wind energy, multidimensional study, Al-Alamein, Egypt

Funding and duration:

Total Cost: EGP 497,968 Duration: 12 Months Theme: Energy

Proposal Summary

The Egyptian economic transformation vision foresees the north coast as one of the main pillars for future economy and development. Transformational urban and economic development is being carried out along the 400 km length coastline from New Alamein eco-city to Al-Salloum. The north coast region The World Bank global wind atlas shows that the average energy density in that region is in the range of 0.5 to 1 kW/m^2 and average wind velocity higher than 5 m/s. These estimations show promising potential of wind energy. This project presents the first comprehensive evaluation of wind energy viability and feasibility in Egypt's north coast. The project adopts a multidimensional approach to reproduce the spatiotemporal wind field over the north coast utilizing status quo GIS-BIM-CFD integrated simulation systems. The project's primary goal is to identify the best wind energy systems for power generation in the region and estimate its economic feasibility. Secondary objectives include identification of the main characteristics of atmospheric boundary layer and urban aerodynamics of Alamein city. The outcome of this project will be the first comprehensive evaluation of wind energy potential in Alamein city and region.

ملخص المقترح

تطرح الرؤية المصرية للتحول الاقتصادي الساحل الشمالي كأحد الركائز الأساسية للاقتصاد والتنمية في المستقبل، وعلى ذلك يتم تنفيذ تنمية حضرية واقتصادية شاملة على طول شريط الساحل الشمالي الغربي بطول 400 كم من العلمين إلى السلوم. يوضح أطلس الرياح العالمي أن متوسط كثافة طاقة الرياح في منطقة الساحل الشمالي يتراوح بين 0.5 إلى 1 كيلوواط/متر مربع، ومتوسط سرعة الرياح أعلى من 5 م/ث. تُظهر هذه التقديرات إمكانات واعدة لطاقة الرياح. يقدم هذا المشروع أول تقييم شامل لجدوى طاقة الرياح في الساحل الشمالي لمصر. يتبنى المشروع نهجًا متعدد الأبعاد لإعادة إنتاج مجال الرياح الزماني-المكاني على الساحل الشمالي باستخدام أنظمة المحاكاة المتكاملة للوضع الراهن GIS-BIM-CFD. إن الغرض الرئيسي من هذا المشروع هو تحديد أفضل أنظمة طاقة الرياح لتوليد الطاقة في المنطقة وحساب جدواها الاقتصادية. تشمل الأهداف الثانوية تحديد الخصائص الرئيسية لطبقة الحدود الجوية والديناميكا الهوائية الحضرية لمدينة العلمين. سينتج هذا المشروع أول تقييم شامل لإمكانيات طاقة الرياح في مدينة العلمين وإقليمها.

1. INTRODUCTION

1.1. Renewable energy in Egypt: The 2035 Integrated Sustainable Energy Strategy

Economic growth in Egypt, estimated at 5.6% for 2019, is forecast to strengthen to 6% in 2021, supported by broad-based economic reform programs since 2016[1]. Egypt possesses an abundance of land, sunny weather and high wind speeds, making it a prime location for renewable energy sources. The renewable energy equipment market is potentially worth billions of dollars. The Government of Egypt is cognizant of the need for a sustainable energy mix to both address increasing demand, and to move to a more environmentally sustainable and diverse electricity sector. The 2035 Integrated Sustainable Energy Strategy, which builds on previous strategies, emphasizes the importance of renewable energy. Egypt intends to increase the supply of electricity generated from renewable sources to 20% by 2022 and 42% by 2035, with wind providing 14%, hydro power 2%, and solar 25% by 2035.

The New & Renewable Energy Authority (NREA)[2] plays a strategic role in implementing the government's renewable energy plans. It currently has about 500 MW of wind power plants in operation and 1340 MW under development and implementation and is expected to contribute substantially to the rapid expansion of wind power capacity. There are also three privately owned independent power producers (IPPs) with total generation capacity of about 2.5 GW, which started operations 2002-2003 under 20-year long power purchase agreements with EEHC. The Egyptian government renewable energy plan for 2015-2023 include 3.2 GW of government projects; including 1.25 GW under BOO mechanisms and 920 MW as IPPs[3].

1.2. New Alamein eco-city: key figures and future plan

One of the 2030 strategic goals is establishing new cities is to better utilize the coastal areas, normally regarded as seasonal destinations. A case in point is the North Coast, one of the country's most popular summer vacation venues, yet one of the most sparsely populated areas due to the lack of social infrastructure such as medical and educational facilities. New Alamein City, in the Marsa Matrouh governorate, looks to change that. Billed as an eco-city, New Alamein is a 50,000 acres city that will be home to 3 to 4 million residents and integrate touristic, residential, agricultural, commercial and industrial activities. Construction on the USD 337 million project started in 2014. The city's first phase is expected to house up to 400,000 residents and include commercial complexes and a yacht harbor[4]. New Alamein City which considered to be fourth generation cities, has perceived as "the diamonds of investments in the region". The developers show efforts to make these developments approachable to both marketable and housing communities, as the newspaper reports[5].

[1] https://www.afdb.org/en/countries/north-africa/egypt/egypt-economic-outlook
[2] http://nrea.gov.eg/
[3] https://www.privacyshield.gov/article?id=Egypt-Renewable-Energy
[4] https://www.amcham.org.eg/publications/industry-insight/issue/12/New-Cities-on-the-Horizon
[5] https://worldarchitecture.org/article-links/egpge/new-alamein-is-branded-as-the-diamond-of-investments-in-egypt.html

1.3. **Wind Energy Potential in North Coast: A review of literature**

Despite the promising wind energy potential in North Coast, as shown in figure 1, very few studies has been conducted to investigate its harvesting mechanisms and possible contribution to the country's strategic vision. A study conducted at the Swedish Royal institute of Technology (Färegård, Miletic, & von Schultz, 2019), utilizing an econometric simulation model, showed that 50% of electric power demand in Alamein could be produced efficiently from renewables by 2040. More than half of such prediction was attributed to wind energy. Such study confirmed earlier works that evaluated the promising wind energy potential along the Egyptian North Coast line. Rated power of up to 620 MWh was found feasible using WS-30 wind turbine technology in Dabaa, 59 km west of Alamein, while other locations such as Sidi Barrani and Marsa Matrouh were found to have potential energy rating of 590~600 MWh as demonstrated by econometric simulations (Abdelhady, Borello, & Santori, 2015).

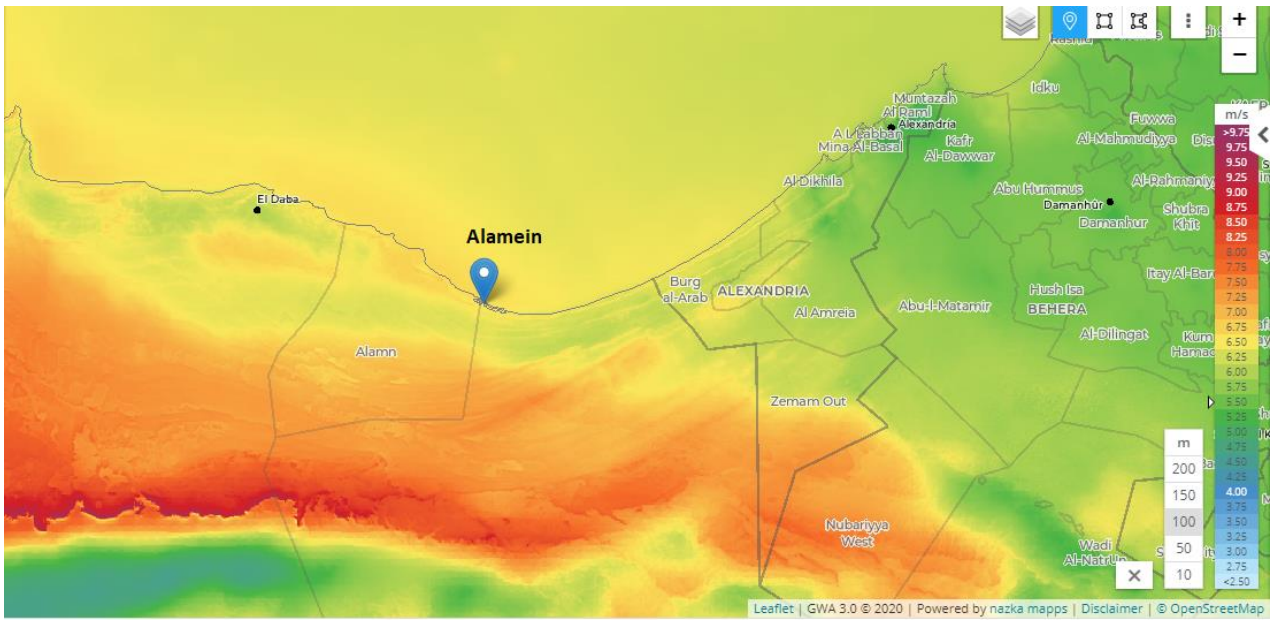

Figure 1. Wind speed map for north coast showing Alamein location. Wind speed exceeds 5 m/s in the coast line and increases up to 9 m/s 40 km to the south of Alamein. Source: Global Wind Atlas https://globalwindatlas.info/

A Wind-quality Analysis Simulation Program (WASP) showed that electricity could be produced from wind energy in three locations namely Marsa Matrouh, Sidi Barrani and Dabaa at as low cost as 2 €cent/kWh (Ahmed Shata & Hanitsch, 2006). An early metrological study estimated the annual energy density in Dabaa and Marsa Matrouh at 211~208 kWh/m^2/year. Along with the wind speed values shown in figure 1, these estimations positions the North Coast region in suitable wind energy resources criteria as identified by the International Renewable Energy Agency (Hermann, Miketa, & Fichaux, 2014). The remaining studies aimed to identify wind energy potential in Egypt neglected the North Coast (Abdelhady, Borello, & Shaban, 2017; Essa & Mubarak, 2006; Lashin & Shata, 2012).

1.4. Problem Statement and Scope of Research

Exiting literature and data show that there is a potential opportunity to generate efficient electricity from wind energy in Alamein city and its surrounding region. However, the optimum technology, location and expected impact on the urbanization and resources are all still unknown. Therefore, the opportunity is yet to be realized on the economic level so any investment opportunities would subsequently be identified. The problem statement can detailed as following:

1.4.1. **The detailed aerodynamic characteristics of ABL in Alamein is unknown.** There have been no studies aimed at reconstructing the aerodynamic field either by simulations or direct measurements. This information is necessary to optimize the technology identification and selection (Porté-Agel, Wu, Lu, & Conzemius, 2011). Also, the evaluation of urban, environmental and sustainability aspects of wind farms require prior knowledge of the aerodynamic characteristics (Baidya Roy, Pacala, & Walko, 2004; Wang, Luo, Wu, & Fan, 2019).

1.4.2. **The optimum technology to generate electricity from wind energy in Alamein is unknown.** This technology could range from residential micro-wind turbines (Akour, Al-Heymari, Ahmed, & Khalil, 2018; Drumheller, Antonio, Chapman, Allison, & Pierrakos, 2015) or dedicated large scale wind farms (Sangpanich, Ault, & Lo, 2009) which both match the wind speed range in Alamein.

1.4.3. **Optimum location, environmental and urban impacts as well as econometric feasibility of wind power stations are unknown.** In order to realize the wind energy potential and prospective investment opportunities, comprehensive case scenarios must be formulated. These scenarios should identify the geographical, environmental, urban and economic requirements to achieve sustainable utilization of wind energy.

The proposed scope of research deems that such required information could be reliably obtained by integrating the available information from GIS with CFD simulations of Atmospheric Boundary Layer (ABL) and apply optimization techniques accounting for econometric, urban and environmental sustainability criteria. This is an *in silico* project limited to computational studies using CFD programs, GIS and satellite imagery, and building information models. The project does not include the undertaking of any field measurements or experiments. Looking at ABL aerodynamics and environment from a coupled GIS-CFD approach has been described to offer detailed and reliable insights in numerous studies (Dhunny, 2017; Jie et al., 2014; Kwon & Kim, 2014; Roelofs, 2011). The impact of different wind energy extraction technologies on the urban outlook of Alamein will be investigated by integrating BIM as optimization tool to achieve sustainability criteria. This scope of optimizing urban planning of wind power stations has been reported in numerous studies (Deng, Cheng, & Anumba, 2016; Wei, Bonenberg, & Zhou, 2019).

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2. PROJECT OBJECTIVES

Based on the existing information concerning wind energy potential in new Alamein city and region, the proposed project aims at:

2.1. Evaluate the potential of wind energy extraction and electricity generation.

2.2. Identify the optimum wind energy technology for application in Alamein.

2.3. Evaluate the sustainability of wind energy farms and their impact on urban landscape and water-earth resources in the region.

2.4. Map the optimize locations for wind energy farms.

3. PROJECT DESCRIPTION

3.1. Research Framework

The project framework integrates four analytical dimensions to achieve its objectives. These dimensions are:

3.1.1. Complete aerothermodynamic assessment of wind energy potential.

3.1.2. Sustainability evaluation and environmental impact of wind energy.

3.1.3. Urban and architectural impact of wind energy farms on the city and its region.

3.1.4. Econometric analysis of wind energy in Alamein

3.2. Research Methodology

The proposed project methodology encompasses four primary stages to achieve the planned objectives. These stages are:

3.2.1. Stage 1: Simulation of the Atmospheric Boundary Layer (ABL) using computational fluid dynamics (CFD)

3.2.2. Stage 2: Determination of the urban and architectural sustainability criteria of Alamein city and region using BIM

3.2.3. Stage 3: Identification of the impact of wind energy farms on water-earth resources in the region using GIS

3.2.4. Stage 4: Technological, geographical and economical optimization of appropriate wind energy farms technology

3.3. Research Design

3.4.

The four stages identified in (3.2.) are designed to be implemented in a series of investigation procedures, as shown in table 1. The project path, procedure duration and implementation plan are explained later in this proposal.

Table 1. List of investigation procedures explaining the overall research design of the project.

Research Stage	Investigation Procedure
Stage 1	(1) Acquire terrain topology from GIS (2) Acquire landscape plan and build CAD models. (3) Acquire wind speed and air density data from satellite imaging (4) Building a computational domain for the atmospheric boundary layer using Computational Fluid Dynamics (CFD) (5) Apply object functions for location and technology optimization for the atmospheric boundary layer
Stage 2	(6) Define sustainability strategy and criteria for Alamein city and region (7) Translate sustainability criteria to econometric model and formulate a sustainable energy model for the city

	(8) Integrate the object functions from (5) into the CAD representation of the sustainability criteria (9) Apply sustainability optimization object functions for location and technology of wind energy
Stage 3	(10) Define criteria for potential impact of wind turbine farms on earth-land resources in the region (11) Apply the defined criteria on the location and technology of wind energy
Stage 4	(12) Build an optimization program to integrate (5), (9) and (11) in one optimization procedure to evaluate the potential of wind energy in Alamein city and region and define the optimum location(s) and technology that would achieve the defined econometric, sustainability and resources criteria.

3.5. Anticipated Results

The first comprehensive feasibility study about the potential of power generation from wind energy in Alamein city and region.

3.6. Expected Project Outcome

3.6.1. This project can be best described as an investment research project. The expected feasibility study would clearly identify, describe and explain any investment opportunities in the wind energy sector in Alamein.

3.6.2. Two papers in Q1 international journals.

3.7. Project Resources

Resource	Availability	Details
CFD software on HPC	Not available	To be acquired by licensing SimScale™ cloud service
GIS maps and satellite images	Available	To be accessed through collaboration with the department of earth-land resources at city of scientific research.
BIM software on HPC for city-scale modeling and simulation	Not available	To be acquired by licensing ENVI_MET™ software
Office space	Available	AAST Alamein campus

Desktop computers for local data curation and analysis	Not Available	To be acquired

4. TEAM INFORMATION

The project team contain four members in addition to the PI. While the PI's main focus is strategic planning and monitoring/guidance of research progress, other team members will focus on developing the elements of the methodology framework, pursue work packages and achieve objectives. Team information is provided in table 2.

1.4.1. Key Relevant References:

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Table 2. Team members' information, time contribution and subsequent cost

Name of Res. Team Member in English	Name of Res. Team Member in Arabic	University / Institute In English	Position / Title	% of time spent on project	No. of months	Incentive per month (LE)	Number of other projects and their IDs	Total % of time spent on other projects	Contact No
Ahmed Farouk El-Safty	أحمد فاروق الصفتي	AASTMT(PI)	Dean, College of engineering and technology, Alamein Campus	20%	12	1600	NA	NA	01006009749
Khalid M. Saqr	خالد محيي الدين صقر	AASTMT	Assistant Professor	20%	12	1600	NA	NA	01066754147
Iham F. Zidane	أيهم فريد زيدان	AASTMT	Assistant Professor	40%	12	1600	NA	NA	01272324222
Fahd Hemeida	فهد عبد العزيز حميده	AASTMT	Assistant Professor	30%	12	1600	NA	NA	01223605221
Sami Z. Mohamed	سامي زكي محمد	City for Scientific Research (SRTA-City)	Researcher	20%	12	1600	NA	NA	01001516711

5. PROJECT MONITORING

Activity Name	M 1	M 2	M 3	M 4	M 5	M 6	M 7	M 8	M 9	M1 0	M1 1	M1 2
Work Package (A): Build *in silico* model of ABL in Alamein												
(A.1) Obtain and process topology and average marine wind speed, direction and air density data from GIS												
(A.2) Obtain urban landscape and plan of Alamein from CAD												
(A.3) Integrate GIS and CAD data to generate *in silico* model of ABL												
Work Package (B): CFD Simulation of Alamein's ABL aerodynamics												
(B.1) CFD model verification and validation												
(B.2) Two dimensional parametric studies												
(B.3) Three dimensional parametric studies												
(B.4) Integration with BIM and econometric evaluation calculations												
Work Package (C): Wind energy technology selection												
(C.1) Selection of wind energy technology based on optimum location(s) and unit energy cost												
(C.2) Integration of wind energy technology information (location and cost) with GIS-BIM framework												
Work Package (D): Urban and environmental optimization of wind power stations in Alamein												
(D.1) Identify object functions to optimize urban and environmental sustainability of wind power stations												
(D.2) Multidimensional optimization and analysis												
Work Package (E): Project documentation, paper and report writing												

6. PROJECT COST

Eligible costs	Break downs		AASTMT support (L.E.)
(A) Staff Cost	PI		19200
	Four team members		76800
	Consultation fees		30000
	Total Staff Cost		126000
(B) Equipment	One computer and office printer (for in-house data curation and analysis)		15000
	Total Equipment		15000
(C) Expendable Supplies & Materials	Stationary		3000
	Total expendable Supplies & Materials		3000
(D) Travel	Internal Transportation (for team members to and fro Alamein)		12000
	Total travel		12000
(E) Other Direct Costs	Services	• SimScale cloud-CFD license • ENVI_MET software license	246000
		Computer services (OS, database and computer security software)	4000
	Publications & patent Costs		20000
	Workshops organization or Training		60000
	Project Management software (ASANA license for 5 researchers for one year)		11968
	Total other direct costs		341968
(G) Total Costs			**EGP 497,968.00**

7. DISSEMINATION PLAN

7.1. **Project launch press conference:** A press conference would be held at AAST Alamein campus to announce the launch of the project to attract and engage potential partners from the industry.

7.2. **Quarterly press release:** To report the project progress and increase awareness of the wind energy potential in Alamein.

7.3. **Pre-final national exposure and outreach:** Before the project concludes its final findings, a series of activities such as seminars and workshops should be organized with partners from

the industry to translate the project momentum towards economic and investment potentials.

7.4. **Project ending press conference:** A final press conference would be held at AAST Alamein campus to announce the main findings of the project.

Acknowledgment Form

By signing below, I acknowledge that I have read, understand and accept to comply with all the terms of the foregoing application, mentioned in AASTMT general conditions and guidelines for submitting a research proposal, including, but not limited to:

- The total number of the application pages should not exceed **30 pages** excluding a cover page, as well as all sections of the proposal (as mentioned in AASTMT General Conditions and Guidelines for Submitting Research Proposal).
- At any time, a contracted AASTMT project team member should only be participating in a maximum of one project.
- Allowable budget maximum limit should be strictly adhered to in the project proposal. In all cases, requested budget has to be justified in detail.
- AASTMT guidelines, IPR rules, code of ethics, etc. (www.aast.edu), should be read carefully and adhered to. These are integral parts of the contract.
- All proposals – in addition to PI and other data - must be uploaded to the AASTMT website by the designated deadline. Uploaded PI data should conform to the corresponding data in the application form.

Applications will not be considered eligible and will be discarded in the following cases:

- Proposals submitted by e-mail or sent as hard copies or uploaded to the AASTMT website after the deadline.
- Proposals not conforming to the designated format.
- Proposals whose uploaded PI data does not conform to PI data in the proposal file.
- Proposals in which the allowable budget maximum limit has been exceeded.
- Proposals in which maximum allowable contracted AASTMT project participation limit has been exceeded.
- Proposal letter does not include a scanned copy of the signed and stamped PI institution endorsement letter in case of team member work outside AASTMT.
- Proposal does not include a scanned copy of the signed acknowledgment form.

Date & Signature: _____