MANSOURA UNIVERSITY
FACULTY OF LELTRES
–

BENBAN'S SOLAR PV PARK IN ASWAN, EGYPT: A STUDY IN NEW INSTITUTIONAL ECONOMIC GEOGRAPHY

BY

Dr. Gamal Mohamed Attia Mustafa

Assistant Professor of Economic Geography- faculty of postgraduate African studies - Cairo University

Journal of The Faculty of Arts- Mansoura University

71th ISSUE- OUG. 2022

BENBAN'S SOLAR PV PARK IN ASWAN, EGYPT: A STUDY IN NEW INSTITUTIONAL ECONOMIC GEOGRAPHY

Dr. Gamal Mohamed Attia Mustafa

Assistant Professor of Economic Geography- faculty of postgraduate African studies - Cairo University

Abstract

The study aims are analyzing institutional organization , technical, and spatial characteristics of solar park institutions, discussing social and cultural ties and relations between institutions, clarifying the role of institutions in local and regional development, identifying risks face, and Proposing an integrated spatial plan for a benban PV solar park complex(Grand Benban).

Institutional Approach one of the new Approaches in economic geography that focuses on the social framework of economic life and the role of institutions in the formation and synthesis of economic action and the organization of economic relations of the institutional environment between markets, companies, local authorities, and trade unions.

The study of institutional characteristics concluded that there is a strong and tight institutional organization that includes developers, operating and maintenance companies, and sub-contractors for cleaning and security works. A strong and tight institutional organization due to Division of work, maximizing specialization, hierarchy of administrative organization, and participation of companies with global expertise in the field of solar energy such as Norway, Spain, France, Italy, India and China.

The study of institutional thickness concluded that it is weak due to the weakness of the local content of solar panels, inverters, transformers, etc. The social embeddedness of Benban companies is still in the stage of evolution and formation; it may reach the stage of maturity, if the electronic industries and research & development become localized in Egypt.

Key words: solar PV- institutional thickness- social embeddedness- benban- institutional Economic Geography

ملخص البحث:

تهدف الدراسة الي تحليل التنظيم المؤسسي والخصائص المكانية والتقنية والفنية للمؤسسات في مجمع الطاقة الكهروضوئية. مناقشة الروابط الاجتماعية والعلاقات الثقافية بين المؤسسات. توضيح دور المؤسسات في التنمية المحلية الاقليمية في اقليم بنبان والوقوف علي المخاطر التي تواجه المؤسسات، واقتراح خطة شاملة لتنمية اقليم بنبان الكبري.

اعتمدت الدراسة علي المنهج المؤسسي في الجغرافية الاقتصادية وهو احد الاتجاهات الجديدة بها الذي يركز علي الاطار الاجتماعي للحياه الاقتصادية ودور المؤسسات في تكوين وتركيب الانشطة الاقتصادية وتنظيم العلاقات الاقتصادية للبيئة المؤسسية بين الاسواق والشركات والسلطات المحلية والاتحادات التجارية.

انتهت دراسة التنظيم المؤسسي للشركات الي وجود تنظيم مؤسسي قوي يضم المطورين وشركات الصيانة و التشغيل والمقاولين؛ وترجع قوة التنظيم الي تقسيم العمل وتعظيم التخصص وهيراركية التنظيم الاداري ومشاركة مؤسسات ذات خبرات عالمية في مجال الطاقة الكهروضوئية كالشركات النرويجية والاسبانية والفرنسية والايطالية والهندية والصينية.

انتهت دراسة التكامل المؤسسي الي ضعف التكامل المؤسسي بسبب ضعف المحتوي المحلي لتصنيع مكونات انتاج الطاقة الشمسية والتجهيزات الاخري. كما أن التكتل الاجتماعي لشركات ومؤسسات مشروع بنبان لا زالت في طور النشاة والتكوين وقد تصل الي النضج اذا توطنت الصناعات الالكترونية والبحوث والتطوير في مصر.

الكلمات المفتاحية: الطاقة الكهروضوئية- التكامل المؤسسي- التكتل الاجتماعي- بنبان – الجغرافية الاقتصادية المؤسسية.

1. Introduction

In October 2017, the Benban's Solar Park was successfully financed by different lender groups led by development finance institutions and multilateral development banks, including the International Finance Corporation and European Bank for Reconstruction and Development. By mid-2019, when all the plants forming part of the Benban's Solar Park are predicted to be completed, the Benban's Solar Park will have a capacity of 1,650 megawatts of electricity and will be one of the largest solar installations developed anywhere in the world.

The study **aims** are analyzing institutional organization , technical, and spatial characteristics of solar park institutions, discussing social and cultural ties and relations between institutions, clarifying the role of institutions in local and regional development, identifying risks face, and Proposing an integrated spatial plan for a benban's PV solar park complex(Grand Benban).

- **Study notion**

This paper Studies and analysis institutions capacities, institutional thickness and social embeddedness, its role in local and regional development, its risks, and its strategies to reduce risks and increase impacts.

- **Hypotheses**

The strong institutional capabilities, rational strategies and potential of the region reflect the developmental role of solar energy production enterprises in Benban. The institutional integration and the institutional social cohesion of the solar energy institutions in Benban contribute to shaping the geo-economic structure of the region. Solar energy for-profit and non-profit organizations will play a clear role in the local and regional development of Benban.

- **Previous studies**

- Nawaz**,** S. & Mangla, I. 2021.The economic geography of infrastructure in Asia: The role of institutions and regional integration**.** This paper examines the spillover effects of infrastructure on economic growth after controlling institutions and regional integration**.** The analysis confirms the complementarity of infrastructure with institutions and regional integration, which implies that factors act as a stimulus to improve the spillover effects of the infrastructure**.**
- Abdel Mawgoud, Y. and Faraj, M. 2021. Production of electricity from solar energy in Aswan Governorate with application to the Benban station: A study in energy geography using GIS. It deals with the production of electricity from solar energy in Aswan and Benban stations, the future of photovoltaic energy production in the governorate and its problems in Benban.
- Domingues, R. 2015.The institutional perspective in economic geography. This article presents a preliminary study of the institutional approach through the lens of economic geography. In the theoretical framework, the line of thought of Veblen (1965) and Douglass North (1993) on institutional economics is highlighted, recovering concepts such as institutions and organizations.
- Bathelt, H., & Glückler, J. (2014). Institutional change in economic geography. This paper develops a rigorous concept of institutions to investigate the interrelationships between institutional and economic change from the perspective of economic geography. It discusses how economic interaction in space is formed by existing institutions, how this leads to economic decisions and new rounds of action, and how their intended and untended consequences impact or enact new/existing institutions.
- Kušar**,** S**.** (2011). The Institutional Approach in Economic Geography: An Applicative View**.** This study dealt with the institutional approach in economic geography which developed as part of a broader cultural shift in economic geography in the 1990s. It highlights the importance of formal and informal institutions, technology, institutional embeddedness, and historical lock-in for understanding how development occurs in regions**.**
- Cox**,** K**.**2011. Institutional geographies and local economic development: Policies and politics**.** The paper discusses the centrality of the accumulation process**;** localism is a major feature of the literature on institutions and local economic development**,** and the territorial structure of the state**.**

- Amin, A. 2004. An Institutionalist perspective on regional economic development.th study dealt with the economy and economic governance in institutional economics, the institutional turn in regional development studies, and regional policy orientation.
- Martin, R.2003. Institutional Approaches in Economic Geography**.** The study analyses delimiting institutionalist economic geography, conceptual frameworks for institutional economic geography, and institutional thickness and regional development.
- Cumbers, A. Mackinnon, D. & McMaster, R. 2002. 'Institutions, social relations and space: the limits to institutionalism in economic geography. Institutional perspectives have been used to open a 'third way' between the orthodoxies of neo-classical economics and Marxist political economy. The paper purposes to connect institutionalist insights to recent political economy approaches that stress the dynamic and relational nature of space and scale.
- **Methodology**

Institutional Approach one of the new Approaches in economic geography that focuses on the social framework of economic life and the role of institutions in the formation and synthesis of economic action and the organization of economic relations of the institutional environment between markets, companies, local authorities, and trade unions (Mackinnon & Cumbers, 2019, :46-49).

One of the key elements in expansion of economic geography and re-orientation has been what might be called the "institutional turn," the recognition that the form and evolution of the economic landscape cannot be fully understood without giving due attention to the various social institutions on which economic activity depends and through which it is shaped. This perspective has developed as a reaction to the behavioral approaches that became prominent in the 1960s and early 1970s and French regulation theory (Martin, 2003:77-78).

institutional perspectives have been used to open a 'third way' between the orthodoxies of neo-classical economics and Marxist political economy, where the former is assumed that market forces will in the longer term reduce regional inequalities as utility maximizing firms move from high cost to low-cost regions, and the latter 'top down' Keynesian approaches in which state intervention is required to redistribute income and employment between regions. 'embeddedness', 'institutional thickness' and 'path dependency' are focusing attention on the 'horizontal' relations between firms and formal and informal institutions within regions and localities, to the exclusion of the vertical and hierarchical relationships between regional agencies and higher-level state institutions (Cumbers, A. MacKinnon, D., and McMaster,R. 2002,pp.1-13).

Institutional thickness or integrity consists of key four elements. **The first** is a strong institutional presence, in the form of institutional arrangements (firms, local authorities, chambers of commerce and other business association, financial institutions, development agencies, labor unions, research and innovation centers, and various voluntary bodies). **The second** is a high level of interaction amongst these institutions to facilitate mutual and reflexive networking, cooperation, and exchange, thereby producing a significant degree of mutual isomorphism amongst the ensemble of local institutional arrangement. **Thirdly**, institutional thickness depends on there being well -defined structures of domination, coalition-building, and collective representation to minimize sectionalism and inter-institutional conflict. This leads, **fourthly**, to notion of inclusiveness and collective mobilization, that is, the emergence of a common sense of purpose around a widely held agenda, or project, of regional or local socio-economic development. The specific local combinations of these elements define the degree and nature of local institutional thickness. Institutional thickness is prerequisite to regional restructuring and regeneration and particularly as a policy tool for stimulating new regions of high technology and innovation-based economic development (Martin, 2003:87-88).

Social embeddedness

Institutional economic geographers have spatialized the sociological concept of embeddedness emphasizing how particular forms of economic activity are not only grounded in social relations, but also rooted places through the concept of territorial embeddedness (Mackinnon & Cumbers, 2019, p.46). According to Granovetter 1993 a leading exponent of the concept of embeddedness, economic institutions are constructed through the mobilization of resources through social networks and historical development of society, polity, and technology. Institutions are social networks. Economic activity is embedded in these social networks or institutions that it depends on interaction with agents in those networks. Within economic geography, the embeddedness hypothesis argues that trust, reciprocity, cooperation, and convention have a key role to play in successful regional development (Martin, 2003:84).

One of social dimensions of embeddedness is scale and density of intelligent people and institutions, as reflected in the skill and professional profile of labor market, the volume and quality of training and education across different levels, the depth of linkage between schools, universities, and industries, the quality and diversity of the research, science, and technology base, and the availability of intermediate centers of information and intelligence between economic agents and their wider environment (e.g. commercial media, trade fairs, business services agencies) (Amin,2004:54).

The three pillars of this Approach are: institutions, strategies, regions. Strong institutions drive prudent strategies for the development and prosperity of qualified regions.

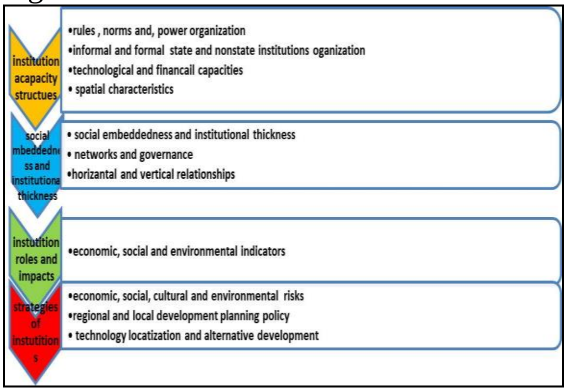

Fig.1. Institutional economic geography approach conceptual framework

Source: Author based on Yeung, 2000, Martin, 2003, Kušar, 2011, Domingues, 2015, Mackinnon & Cumber, 2019.

- **Statistical techniques:**
- Performance ratio (PR) = Yf / Yr
  Where Yf means final PV system yield, Yr means reference yield.
- Capacity utilization factor (CUF) = Actual Energy Output/

Name plate Capacity × Time period (h)

- CO_2 (tCO_2) = EL (MWh) × GEF (tCO_2/MWh)

Where EL is Net daily energy output, GEF is Grid emission factor.

- PV solar labor = installed capacity × standard labor number
- PV solar Breakdown costs = Modules $^{+}$ Inverters^{+} Cabling^{+} Security^{+} Grid^{+} Frames^{+} Project management
- Average benchmark costs of PV solar energy = Land^{+} PV Modules^{+} type of technology^{+} Power conditioning unit/ inverters^{+} Grid connection^{+} Preliminary and operating expenses^{+} Civil and general work^{+} Developer fees. (Pillot et al, 2021:6).
- Electricity yield of a PV system = h*npre*nsys*nrel*Pnom
  h = Peak Sun Hours, npre= Pre-conversion efficiency

nsys = System efficiency, nrel= Relative efficiency, Pnom = Nominal power at STC (IRENA, No date: 30).

,

- **GIS tools**
- Image analysis / processing/ clip image
- Spatial analyst / slope
- Geo processing / Buffer.

Data source:

Statistical source:

- IRENA (2021), Renewable capacity statistics 2021. International Renewable Energy Agency (IRENA), Abu Dhabi.
- IRENA (2021), Renewable Energy Statistics 2021. The International Renewable Energy Agency, Abu Dhabi.
- Ministry of Electricity and Renewable Energy, 2019/2020. Egyptian Electricity Holding Company, Annual Statistical Report, Cairo.
- New & Renewable Energy Authority, 2019, 2020.Annual Report, Cairo.
- New & Renewable Energy Authority, 2018. The Solar Atlas of Egypt, Cairo.
- New & Renewable Energy Authority, NREA Meter, 2020, 2021, various publications, Cairo.
- Aswan Governate, 2021.Annual Statistical Guide, Aswan.
- Sun Rise Company, Unpublished Data, Weather Statistics, BenBan site, 2021.
- Sun Rise Company, Unpublished Data, Energy Statistics, BenBan site, 2021, 2022.

ESIA Reports

- Acwa power, 2020. Environmental and Social Impact Assessment, 200 MW Photovoltaic Power Project Kom Ombo.
- Scatec solar, Environmental and Social Impact Assessment for Red Sea Solar Power 50 MW (AC) in Benban, Aswan, 2017.
- Environmental & Social Impact Assessment for 50 MW PV Power Plant in Benban, Aswan, Egypt, final report, 2016.
- ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016.

- **Legal and Legislative Sources:**
- Feed Tariff Law, No.1947, 2014, Prime Minister's decision, Cairo.
- Renewable energy law No.203/2014, Prime Minister's decision, Cairo.

Table (1) Characteristics of satellite image of study area

Sensor	Pixel size	XY coordinate system	Bands	Date
LANDSAT8	30,30	WGS_1984_UTM_Zone_36N	8	1-11-2019

- **Field study, observations, layout and interviews**
- Field study and observations of BenBan PV solar park, 9 Jan., 2022.
- Eng. Ayman Fayek, Aqwa Power Company, personal interview, December 20, 2021, 26 March, 2022.
- Dr. Hala Ramadan, Director of Studies Department, New and Renewable Energy Development Authority, personal interview, December 20, 2021.
- Eng. Ahmed Bakr, Facilities Management Contractors Company, personal interview, December 23, 2021.
- Aisha Mohamed, social specialist, Hassan Allam Company, personal interview, January 8, 2022.
- Eng. Ahmed Mansour, Production Manager, Sun Rise Company, personal interview, January 9, 2022.
- Eng. Ahamed Ragab, occupational safety officer, Sun Rise Company, personal interview, January 9, 2022.
- Miss. Noha Hazem, Facilities Management Contractors Company, personal interview, January 9, 2022.
- New & Renewable energy Authority, Benban site PV, final layout, 1:1000, Cairo.2015.
- Sun Rise Company, layout of PV Solar plant, Benban site, 2022.

1. Spatial characteristics of benban's solar park institutions : location and localization

1.1. Location of benban

Benban's solar PV Park located in Aswan Governorate, 18km to the west bank of the Nile River and 43km to the north of Aswan, with an approximately 4 km from the paved Western Desert Highway Luxor-Aswan see Fig.2.

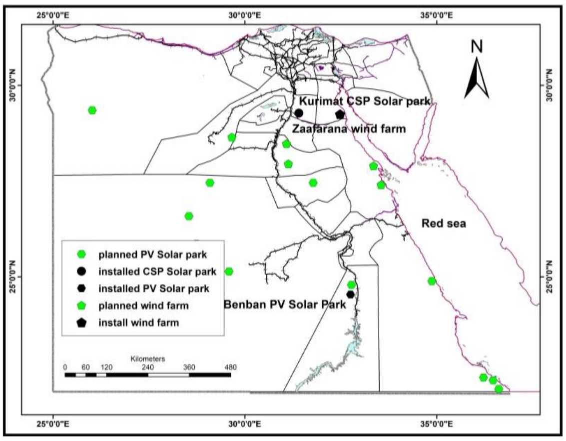

Figure.2. Renewable Energy projects sites in Egypt until, 2035

Source: author based on New & Renewable Energy Authority, 2019, 2020

The project lies approximately on latitudes ˚24 ́26 and ˚24 ́27 north of the equator, ˚32 ́41 and ˚32 ́44 east of the Prime Meridian and is 0 m above Sea Level (environmental impact assessment of benban's PV solar power facility, 2016, p.7). Benban's project occupies 37.2 km, see photo.3.

- **Localization of benban's PV solar park**

The site selection for solar power plants was determined by various Criteria like:

1- The annual total **solar radiation** value of the region, which is planned to establish an electricity generation plant based on solar energy, should be equal to or higher than 1620 KWh / m2 year. The total value of solar radiation ranges between 2472 kWh per m2 in Benban and 2439 kWh per m2 in Fares. see table.3.fig.3.

2- The total annual **sunshine time** is 2738 hours / year, and the daily value is 7.5 hours / day. The hours of sunshine in the Benban region range from 10 in the winter to 13 hours per day in the summer.

3- The increase in **the average temperature** of the region causes a decrease in the efficiency of the photovoltaic systems. In these regions, if the system is desired to be installed, the use of the modules which are suitable for the high temperature value increases the cost. Therefore, suitable temperature ranges between 15–40°C ((Kereush & Perovych, 2017, p.41).Then, Average temperatures in the region range between 14°C in January and 32.7°C in July.table.2.

4- The proximity of the power plant to **other renewable power plants** means that they are connected to the same connection center. In this case, production is allowed up to the open capacity. There is no previous project in the region for renewable energy, but there is a later project for solar energy in KomOmbo (field study, 9 Jan.2022).

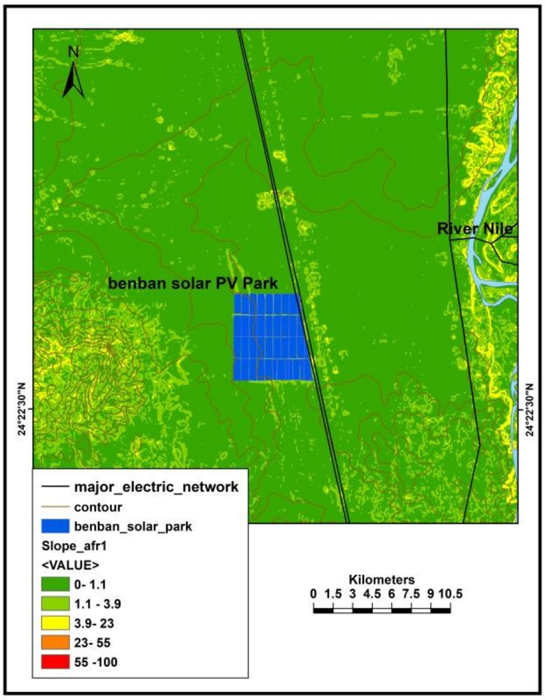

Fig. 3. Surface slope in benban's solar park region, 2019

,

Source: author based on satellite image, Nov.2019.

5- The **slope** rate of 3% causes the cost increase, while 0% slopes cause water accumulation and drainage problems. The optimum slope rages between 5-15º (Kereush & Perovych, 2017, p.41). In benban region, the slope rate ranges between 0 to 1.1% and 1.1 to 3.9% see fig. 3.

6- Solar Energy Park is **land-dense**: benban solar park covers area 37.2 km2. A well-designed PV power plant with a capacity of 1MWp is estimated to require between one and two hectares (10-20 thousand m2 of land) (International Finance Corporation, 2015, p.58). The density of the land in the Benban's solar park ranges between 17800 m2 in Alcazar Company and 20400 m2 per mega in Enerray Company.

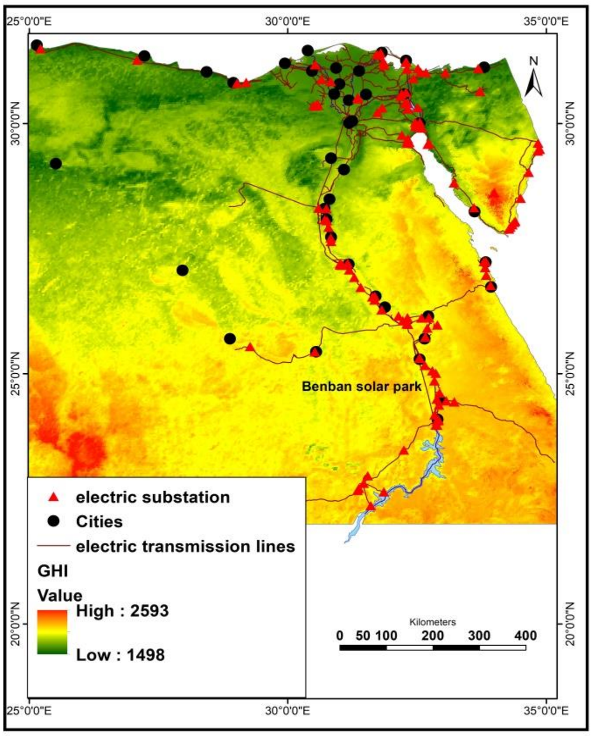

Fig.4. Global horizontal irradiation in Egypt, 2017(kwh/m2)

Source: author based on solar-med-atlas.

7- The wide surfaces of the panels and reflectors used for energy production activities cause damage from the **high-speed winds**. If the wind speed in the region exceeds 25-30 mps, (48- 58 knots) the system may be damaged, so regions with high wind speeds should not be preferred. Therefore, the wind speed in the region ranges between 9.4 knots in March and 8.3 knots in December see table.2.

8- **Distance to Energy Transmission Lines**. Large-scale power plants are not preferred to be within 10 km of the national network. In smaller and medium-sized production facilities, distances between 5 and 10 km to the national network are still not preferred in terms of economic efficiency of the investment. Benban's solar park is 4 km from the Upper Egypt Electricity Transmission Line, the Nag Hammadi High Dam line, with a length of 236 km and a voltage of 500(Egyptian Electricity transmission company,2020).

Table 2.climate characteristics of benban's solar park, 2017-2020

	Average temperature ˚C	Wind speed knots	Average relative humidity %	Rainfall mm	Evaporation Rate (mm/day)
Jan.	**14**	**8.7**	**39**	**0.1**	**5**
Feb.	**16.7**	**9.1**	**30**	**0.1**	**7**
March	**20.7**	**9.4**	**23**	**0.2**	**10**
April	**25.8**	**9.4**	**18**	**0.2**	**13**
May	**29.7**	**9.1**	**16**	**0.4**	**15**
June	**32.2**	**9.1**	**16**	**0**	**16**
July	**32.7**	**8.8**	**18**	**0**	**15**
August	**32.7**	**8.7**	**20**	**0**	**14**
September	**30.1**	**9**	**22**	**0.1**	**13**
Oct.	**26.4**	**8.9**	**26**	**0.3**	**10**
Nov.	**20.1**	**8.4**	**35**	**0.1**	**7**
Dec.	**15.5**	**8.3**	**40**	**0**	**5**
Average	**24.7**	**8.9**	**25.25**	**0.1**	

Source: ESIA for Al Tawakol Photovoltaic Power Plant in Benban, Environics, Aswan, 2016: 27-30, ESIA, Komo ombo, 2020.

9- **Water availability**: The quantity of water required varies according to available cleaning technologies and the local climate, however approximately 1.6 litres per m2 of PV modules may be required (International Finance Corporation, 2015p.63). Three methods have been investigated for module cleaning, namely: Dry cleaning: Wiping modules with dry clothes or high pressurized air. Wet cleaning: Wiping modules with wet cloth. Washing: Washing with high pressure water. The water will be trucked to site when needed. The consumption on site is anticipated to be limited to 10 m3 /month, as the method used for regular cleaning of PV modules will be dry cleaning. Occasional water cleaning (approximate 8 – 10 times a year) will require higher volumes in the range of 800 - 1,000 m^3 per year. There are above-ground tanks to store water that is brought from the new city of Aswan with a capacity of 740 m3 per month(the field study for benban, January 9, 2022).

10- The **use of property** in the area where the power plant will be installed includes public and treasury lands, and it is of great importance to reduce the project cost and implement the project. NREA has allocated 37 km2 for generating electricity from solar power, with a usufruct at a rate of 2% annually (Hala Ramadan, 2022).

11- Choosing a place within or near the area of influence of the **prohibited areas** specified in the Master Plans should be avoided. The project area is desert land and the nearest residential area (Benban village) is about 17 km to the east of the site by the Nile bank.

12- To eliminate or at least minimize this risk, site selection should be made as far as possible to **earthquake fault lines** (Tunc, et al, 2019, p.1356). Egypt is divided into 5 seismic zones, and the project is located within zone 2. The project is complying with Egyptian codes, regulations, particularly the Egyptian building code with respect to type of construction and design requirements (ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016:65).

Table.3. Monthly average of solar energy in KWH/m2 for PV and CSP systems in Aswan solar energy parks

Solar energy system	**Solar energy PV KWH/M2**		**Solar energy CSP KWH/M2**	
Projects	**Beban**	**fares**	**Benban**	**fares**
Jan.	151	148	217	218
Feb.	163	160	206	207
Mar.	220	216	267	266
Apr.	233	230	248	248
May	248	246	248	249
Jun	252	250	265	266
Jul	257	255	271	273
Aug.	243	240	254	255
Sep.	216	213	246	248
Oct.	190	187	230	231
Nov.	156	153	218	218
Dec.	145	142	215	216
Total	2472	2439	2885	2895

Source: New & Renewable Energy Authority, 2018. The Solar Atlas of Egypt: 136-137.

13- In the northern hemisphere, **the orientation** that optimizes the total annual energy yield is true south. (International Finance Corporation, 2015p.69). However, to continuously orient the panels towards the sun, the benban project adopts a single-axis tracking system (Field study, 9 Jan.2022).

1.2. Technical characteristics of Benban's PV solar park institutions :

Generally, Silicon solar cells produce electricity and convert the energy of sunlight photons into electrical energy. The current from these transformations is direct current, such as the current generated by dry batteries, not AC (Alternative Current), such as the current generated by generators in power plants. Direct current is converted into AC using transformers (Ayyash, 1981, p.270) see fig.5.

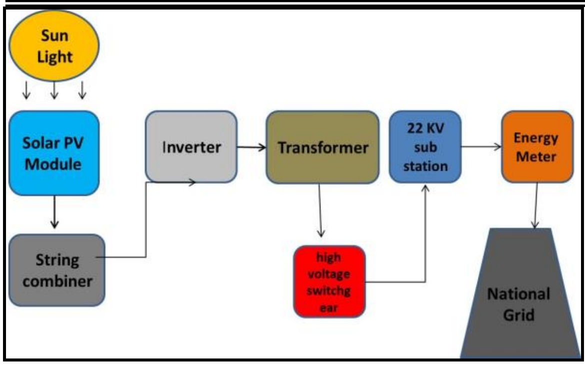

Fig.5. output steps of Solar PV plant in benban
Source: Author based on Sekyere, et al, 2021:5.

The generation process of electrical energy from solar energy is as follows:

1- Radiation falls on solar cells that produce a constant current and constant voltage. The current and voltage generated by the cells are collected through the collecting plates.
2- The collector panels transfer the generated power through cables to the power conversion devices, inverters which convert power from direct current to alternative current see Photo.5.
3- The AC power is transferred to the electrical transformer, which raises the voltage from 530 volts to 22 kV.
4- The ring connection is made through ring main units with feeders of 22 kV, which are responsible for linking with the national electricity transmission network see photo.6.
5- The distribution takes place through electricity distribution stations, where the voltage is reduced to 11 kV to feed residential and industrial areas and so on see fig.5. (Eng. Ahamed Mansour, 9 Jan., 2022).photo.1.

The 50-megawatt-hour solar power plant includes 20 blocks; each block contains 31 modules per string for each string, 310 strings and one inverter. The total number of solar panels is 190,774 panels. The station also contains two meteorological stations to monitor the climatic elements affecting the production of electricity from solar energy see fig. 6. Table 4. Photo.4.

However, to continuously orient the panels towards the sun, the project will adopt a single-axis tracking system. Compared to a fixed mount, a single axis tracker raises annual output by approximately 15% to 25% see Photo.2. It is worth mentioning that adequate spacing will be saved between the PV arrays to limit the impact on shade. This distance takes into account maintenance and operation. (ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016:48). Scatec solar plant is the largest and the first project using bifacial solar modules. The bifacial modules are producing energy from both sides of the solar panel, increasing the total clean energy generation. However, Cells that produce electricity require greater distances between cells of the bifacial modules, produce the same output as other stations, and they are more expensive in terms of price and maintenance (Eng. Ayman Fayek, 2022) see Photo7.

The composition of solar panels depends on the type of panel used. Silicon-based (c-Si) PV technology (including mono-crystalline, poly and multi-crystalline, ribbon and amorphous silicon) currently dominates the market, with a market share of about 92% (IRENA and IEA-PVPS, 2016). However, the materials used for the inverters, mounting structures and cables are often common regardless of the selected panel technology. To manufacture and install 1 megawatt (MW) of silicon-based solar PV plant, Almost 70 tonnes of glass are needed for the PV panels, almost 56 tonnes of steel and 19 tonnes of aluminum go into the mounting structures and panels, and around 47 tonnes of concrete are required for foundations. Other key materials, such as 7 tonnes of silicon, 7 tonnes of copper and 6 tonnes of plastic make up smaller share of total weight of material for a solar PV plant (IRENA, 2017, P.12-13).

most of the companies, in benban, using Poly Crystalline PV panel type, due to its low cost; high efficiency; middle temperature characteristics; good life time;

safe environmental consideration, low effect of shade, and required 4-5 acres Land/per MW (16187 – 20234 m2 /MW).

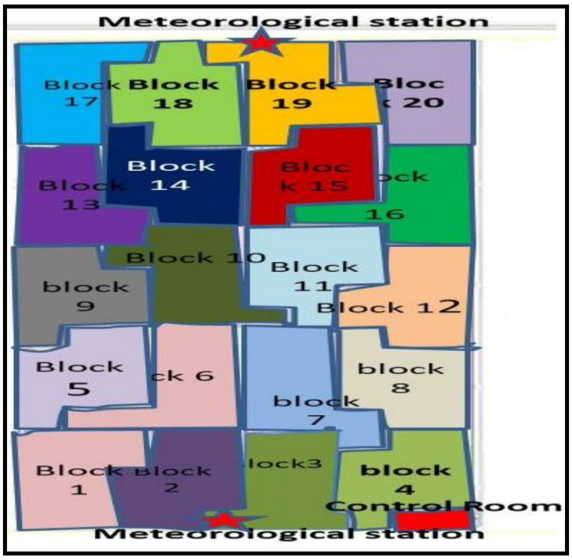

Fig.6. layout of sun rise plant in benban solar park, 2022

Source: author based on field study, 9 Jan., 2022

1.3. Institutional organization characteristics of benban's solar park.

The institutional organization of the Benban Solar Energy Project consists of the New and Renewable Energy Authority, the Benban Investors Association, the International Finance Institutions, the Service Management Company, a group of developers, maintenance and operation companies, and a group of contractors. The institutional organization ends with the Egyptian Electricity Transmission Company.fig.7.

Table.4 technical specifications of sun rise Company plot 18 in benban's solar park, 2022

Array	DC capacity	No. of Modules per string	No. of strings	module		Inverter number
				Spec.	No.	
1	3.2	31	310	335	9610	1
2	3.2	31	310	335	9610	1
3	3.01	31	290	335	8990	1
4	3.2	31	310	335	9610	1
5	3.12	31	310	325	9610	1
6	3.12	31	310	325	9610	1
7	3.12	31	310	325	9610	1
8	3.15	31	310	325/330	9610	1
9	3.17	31	310	330	9610	1
10	3.17	31	310	330	9610	1
11	3.17	31	310	330	9610	1
12	3.17	31	310	330	9610	1
13	3.17	31	310	330	9610	1
14	3.17	31	310	330	9610	1
15	3.17	31	310	330	9610	1
16	3.17	31	310	330	9610	1
17	2.90	31	284	330	8804	1
18	3.17	31	310	330	9610	1
19	3.17	31	310	330	9610	1
20	3.17	31	310	330	9610	1
total	62.988		6154		190774	20

Source: field study, 9 Jan. 2022, sun rise plant site.

The Organizational tasks of **new and renewable energy authority** are preparing the land for roads, electricity and infrastructure services, and offers the land in return for 2% of the total production annually as rent for the land or usufruct for a period of 25 years in the Benban project, examining the equipment and its efficiency, and preparing studies to choose the most appropriate site for the localization of solar energy plants, Preparing the financing methods, and Responsible for formulating the contract agreements with the qualified contractor. The Prime Minister's decision was issued in 2015 No. 14/15/4/37 to allocate the land for renewable energy projects through usufruct rights. Therefore, the government allocated 7,600 km 2 in the Gulf of Suez, in the east and west of the Nile, Benban and Kom Ombo, of which 5,700 km 2 were for wind energy projects at 75% and 1,900 km 2 for projects 25% solar energy. Transmission and distribution facilities are obligated to give priority to the delivery of electricity generated from renewable sources (IRENA, 2018:38-39) (Hala Ramadan, 2022).

The project controls include the financial aspects, provided that the financing of solar energy projects is 70% from foreign sources and 30% from local sources, Contracts stipulate that the local content be 20-25%, increased to 65%. In 2017, the price of establishing a megawatt was million pounds, which fell in 2020 to 350 thousand pounds due to the increase in supply of solar cells in globally (Dr. Hala Ramadan, personal interview, December 20, 2021).

Benban's Solar Investors Association includes 7 members elected to represent the investors and companies of the Benban's Solar Project to communicate with all government bodies, its decisions are mandatory for all companies. It appoints a general coordinator for services, Facility Management Contractors, FMC. The banks financing the project oblige the companies to implement social responsibility projects and allocate part of their profits to these projects (Engineer Ayman Fayek, Aqua Power Company, personal interview, December 20, 2021).

Facility management contractors

The Facilities Management Contractors Corporation organizes external visits, whether governmental, private or international, to project companies. It manages facilities and infrastructure such as water and sanitation through the management of water and sanitation in the new city of Aswan, electricity, road maintenance, traffic regulation, security, health services, firefighting, and management of solid, organic and hazardous waste, Oil, gas and medical waste.

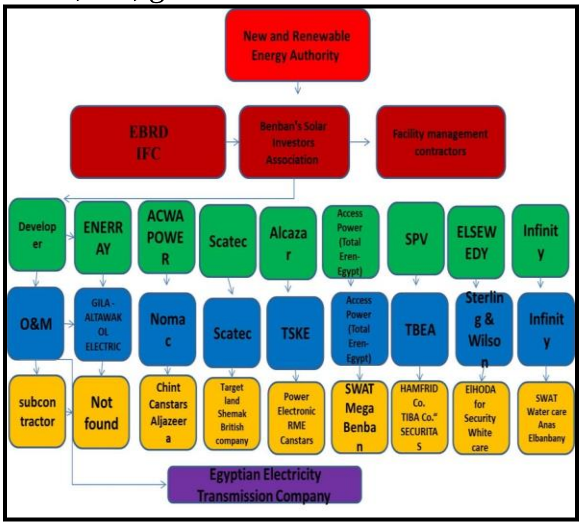

Fig.7. institutional organization of benban's solar park, 2022

Source: author based on facility management contractors, 2022.

Table.5. Selected Phase Two Solar Projects at Benban, Aswan financed by EBRD

developer	Capacity size	Funder:
TBEA Enara (38% Acciona Energia, 38% Enara Bahrain, 24% TBEA Xinjiang SunOasis	**1 x 50 MW**	**AIIB: USD 17.5-19 million IFC: USD 15-20 million**
Al Subh Solar Power (50% Acciona Energia, 50% Enara Bahrain	**each**	
Enara SunEdison (38% Acciona Energia, 38% Enara Bahrain, 24% TBEA Xinjiang SunOasis)		
Arc for Renewable Energy (50% Desert Technologies, 25% SECI Energia, 25% Enerray)		
TAQA Arabia for Solar Energy		
Phoenix Power (51% Phoenix Power Venture, 23.8% Infinity Solar, 23.8% ib vogt GmbH, 1.4% Cedrus Enterprise Holding)		
Alcazar Energy		
Delta for Renewable Energy (75% Alcazar Energy, 25% Nile Capital Holding)	**1 x 50 MW each**	**AIIB: USD 17.5-19 million IFC: USD 15-20 million AfDB: USD 18-19 million**
SP Energy, owned by Shapoorji Pallonji		
Arinna Solar Power (52% Albilal Group, 25% Enerray, 15% Desert Technologies, 7% Tech Project Development Group)	**1 x 20 MW each**	**AIIB: USD 12-14 million IFC: USD 12 million**
Winnergy for Renewable Energy (51% Al Tawakol Electrical, 25% Enerray, 15% Desert Technologies, 8% Spectrum International)		

Source: American chamber of commerce in Egypt, 2017, p.26.

In addition to the management of infrastructure and facilities, this institution manages the management of social responsibility projects and social services in the villages surrounding the solar energy project. There is also a section for managing workers' complaints in the project, and that institution plays a prominent role in coordinating between companies within the project, governmental and private organizations and civil society organizations (Eng. Ahmed Bakr, Facilities Management Contractors Company 22 December, 2021).

International and Financial institutions

The European Bank for Reconstruction and Development (EBRD) is one of the biggest financiers for several project consortia. The Bank is currently in the process of lending to **16** Benban PV projects worth around € 456 million, representing an implementation of 750 MWp of projects. As part of the World Bank Group, **the International Finance Corporation (IFC)** approved a $ 660 million financing package in late July 2017 for the construction of 500 MW of solar parks in the 1.8 GW solar complexes in Benban. According to the Egyptian government, **13** solar plants will be realized in Benban. The total cost is more than $ 730 million.

The IFC is leading a consortium of nine international banks that includes the African Development Bank (AfDB), the Asian Infrastructure Investment Bank (AIIB), the Arab Bank Bahrain, the UK's development finance institution CDC, the Europe Arab Bank, the Industrial and Commercial Bank of China, the Development Bank of Austria, the Global Environment Fund and the French Development Agency (American chamber of commerce in Egypt, 2017, p.25) see Tables 5&6.

In Benban, the construction of the first project under the first feed-in tariff regulation period was finally approved in March 2017.The project for the **Infinity** 50 solar park with a capacity of 64.1 MWp, financed by **the Bavarian State Bank and the Arab African International Bank** with $126 million, is already construction. Project partners are Infinity Solar, Solizer and the German company ibvogt GmbH. One-axis tracker systems with a newly developed technology are used by the German company Mounting Systems GmbH and thus allow a 25% higher energy yield (Deutsch - Arabische Industrie - und Handelskammer, 2017, p.61). One solar plant financed by proparco,and one solar plant was financed by self-equity (Shaker,2019:33).

Table.6. Selected Phase Two Solar Projects at Benban, Aswan IFC Consortium funding
Source: American chamber of commerce in Egypt, 2017, p.26.

	Funder: EBRD	
Developers	**Size**	**Funding**
ACWA Power, working with Hassan Allam Holding and Al Tawakol Electrical	**2 x 50 MW 1 x 20 MW**	**EBRD investing USD 70.9 million for the three plants; total investment of USD 190 million**
Infinity Solar, ib vogt GmbH and BPE Partners	**2 x 50 MW 1 x 30 MW**	**EBRD investing at least USD 43.4 million; total investment of USD 190 million**
Alfanar Company	**1 x 50 MW**	**EBRD investing USD 29 million; Islamic Corporation for the Development of the Private Sector investing USD 28.5 million**
Elsewedy Electric and EDF Energies Nouvelles	**2 x 50 MW**	**EBRD investing USD 54 million for the two plants; Proparco will also help finance the plant**
Access Power and EREN Renewable Energy	**2 x 50 MW**	**EBRD investing USD 58 million; Proparco investing USD 53.6 million**
Scatec Solar and Norfund	**6 plants totaling 400 MW**	**EBRD investing USD 243 million; Green Climate Fund investing USD 48 million; total investment of USD 450 million**

Developer is owner of PV solar plant, design policies and evolution of performance rate. Key management activities that carried by developer or a contractor includes interface management, project planning and task sequencing, management of quality, management of environmental aspects, and health and safety (IFC, 2015; 112).

Operation and maintenance (O&M) is essential to maximize both energy Yield and plant's use full life. It is responsible for all aspects of O&M including works performed by sub-contractors such as inverter servicing, ground keeping, module cleaning, checking module connection integrity, monitoring of PV system, and security (IFC, 2015: 125).

Egyptian Electricity Transmission Company (EETC) is responsible for signing the power purchase agreement (PPA) and loan agreement as a provisional guarantee, Priority dispatch of renewables, preparing the necessary connection for the projects, and paying energy cost to producers. The Electricity Utility and Consumer Protection Regulatory Agency Issues the licenses and revise the proposed project tariff and Sets the transmission fees (IRNEA, 2018:38).

The strength of the institutional organization in the Benban project is due to two main factors: see fig.8 the division of labor and the maximization of specialization and its hierarchy between developer companies such as scatec, maintenance and operation companies such as Sterling Company, and contractors who carry out security and cleaning works, most of which are companies from the villages of Benban Bahri, Qibli, Raqqa, Faris, Mansourieh, and the Services and Coordination Corporations in Aswan. The second factor is benefiting from the leading international expertise and experiences in the field of solar energy from foreign countries such as India, China, Norway, Spain and others.

Institutional thickness or integrity

Most of the international financial institutions, which are the main financiers of large-scale renewable energy projects, are reluctant to accept the local content requirement for reasons of competition and import. Most of the solar panels import only a few from the Benha Factory for Electronic Industries, which is affiliated with military production, and the Arab Renewable Energy Company, ERICO, which is affiliated with the Arab Authority for Industrialization. Although the new investment law of 2017 stipulates that a 30% discount from the investment costs of investment projects in the field of new and renewable energy and the exemption of machinery, equipment and supplies in the manufacture of new and renewable energy from customs duties. Thus, in order for there to be integration and interconnections between local institutions and institutions producing electrical energy from solar panels, it is necessary to localize the industries of panels and solar energy cells.

In order to encourage and stimulate new and renewable energy projects, the Ministry of Electricity and Renewable Energy issued mechanisms and policies, including the mechanism of competitive auctions and bids. The Egyptian Electricity Transmission Company issued a tender for a photovoltaic capacity of 600 megawatts in West Nile in December 2017.(Rashad, et al, 2021:35).

The Electricity Utility and Consumer Protection Regulatory Agency issued relevant regulations and contracts to supply. A long-term power purchase agreement is signed; Agreement with the offer that provides the lowest price per unit of energy produced (kilowatt-hours) and the electricity produced is sold either to end-users or to distribution facilities depending on the numbers of consumers.

Government's investment mechanisms in solar energy

Egypt allows for four types of investment models. **The first**: companies are awarded engineering, procurement, and construction (EPC) contracts for projects that are then turned to over to be owned and operated by government. **The second**: allow independent power producers (IPPs) to build, own, and operate (BOO) plant for 20-25 years and sell the electricity to the EETC. **The third type**: allow small scale IPPs to build plants on government allocated land and sell their electricity to private and industrial end users. **The fourth investment model** is the FiT program ;(feed in tariff) the government signs a power purchase agreement (PPA) to buy wind and solar energy at fixed or specified prices. Established under law no. 203, the FiT program is intended to attract small scale renewable energy investors (American chamber of commerce in Egypt, 2017, p.30) see table.7.

Established by Renewable Energy Law 203 of 2014, the FiT was hailed as a way for the government to achieve its ambitious energy goals: generating 20% of the country's electricity from renewable sources by 2022. Although the first phase of the program fell well short of the high expectations, phase two has attracted significant interest from both foreign and domestic developers as well as from international financing institutions. The phase one started in Jan. 2015, while the phase two initiated in Sept. 2016.With FiT investors reaching financial close at the end of October and the linking of several non-FiT agreements, renewable energy projects are moving ever closer to feeding the national grid. The third phase of feed in tariff program was not implemented due to the depreciation of the Egyptian pound after the liberalization of the exchange rate in November 2016, which made borrowing in dollars more dangerous for investors (Rashad et al., 2021, 20).

Moreover, the customs tariff applied to imports of project components and spare parts was reduced to 2% instead of 5%, and the value-added tax applied to imports was reduced 5% instead of 14%, Requirement to obtain a letter from the Renewable Energy Authority to obtain this customs reduction.

Social Embeddedness

Benha Company for Electronic Industries, affiliated to the Ministry of Military Production, concluded a cooperation protocol with the Chinese company GCL to manufacture solar cells locally by making use of the white sand silica available in Egypt in large quantities. Egypt's obtaining licenses from international institutions such as the Chinese company avoids the high costs of research and development required for such capital-intensive industries.

The solar concentrator station was established at the National Center for New Energy Research of the Academy of Scientific Research, which aims to implement joint projects in the field of research, development and experimental production in the field of new energy, including the manufacture of solar cells (Rashad et al., 2021, 25).

To support the social relations between the Benban project and the region in which it was founded, a solar energy department was established at the Benban Technical Secondary School to graduate workers for maintenance and solar panels cleaning. The engineers and technicians are also graduates of engineering faculties at Aswan University, South Valley universities, and technical institutes in southern Upper Egypt (field study, 9 Jan.2022).

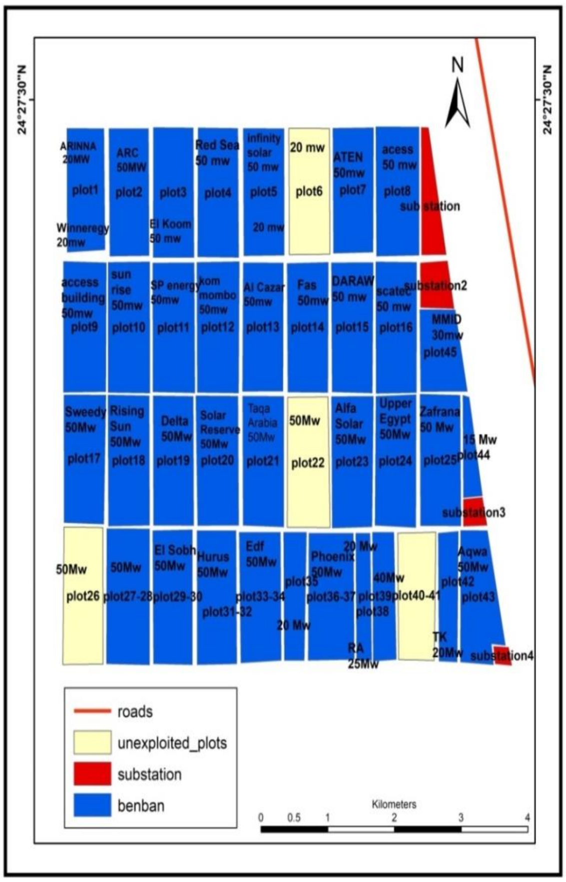

Fig.8. layout of benban's PV solar park by developer and capacity, 2022

Source: author based on field study, 9 Jan.2022.satellite image, Nov., 2019, Mohamed Shaker, American chamber of commerce Egypt, 2019, p.32.

Therefore, the New and Renewable Energy Strategy 2035 must be linked to the manufacture of solar cells and panels, similar to the Malaysian experience and the National Strategy for Science, Technology and Innovation 2030. The Egypt Manufacturing Electronics initiative faces the same challenges as the National Science, Technology and Innovation Strategy.

Table.7. Purchase prices of electric energy produced from solar power plants-Feed in Tariffs program

Capacity small scale	**Phase one piasters/kwh**	**Phase two Piasters/kwh**
Residential <10kw	84.4	108.5
<200kw	90.1	
200KW-<500KW	97.3	
>500 KW rooftop	N/A	102.0
Capacity Medium and Large scale	Phase one U.S. Cents/kwh	Phase two U.S. cents/kwh
500kw-< 20 Mw	13.6	7.8
20Mw-50 Mw	14.3	8.4

Source: American chamber of commerce in Egypt, 2016, p.34. Prime Minister's Decree No. 1947 of 2014 regarding the purchase prices of electric power produced from non-renewable sources. Prime Minister's Decree No2532 of 2016, the purchase prices of electric power produced from renewable sources.

2. **<u>benban's Solar Park institutions as spatial dynamic for local development</u>**

- **Economic impact of benban's PVsolar park institutions**

It is noted from Figure (9) that hydropower is the dominant energy of renewable energy production in Egypt during the period 2011-2020 , while PV solar energy is in a clear growth, as it doubled from 25 gigawatts in 2011 , reached 4,500 giga watts in 2020 i.e. production doubled 180 times.

The volume of production in the Benban project was about 4 TWh in 2022; it varies from one company to another within the complex. The largest of these companies in terms of production are scatec, El Sewedy, Alcazar and Infinity see tables.8. & 9. The production decreases in the months of January, February, September, October, November and December, and increases in the rest of the months from March to August, due to the variation in the levels of solar radiation during the months and the positive relationship between output and solar radiation see fig.10.

Table.8. productive characteristics of benban's solar park, 2022

Developer,O &M	Nationalit	Size km2	Number o employee	Number of plots	Total capacity Mw
Csail Alcazar)(	Chinese Pakistani	3.56	143	7,13,19,29	200
ACWA POWER NOMac	Saudi Arabia	2.64	60	3, 42,43	120
Scatec	Norway	6.12	43	4,12,15,16,2 25	300
)Total Eren-Egypt(	France	2.04	50	8,9	100
SPV Tebia	Spain	2.55	156	10,18,28	150
Sterling & Wilson, elsweedy	India	4.58	90	11,14,17,21,3 0	250
Infinity	Egypt	3.44	68	5,20,32,45	180
Voltalia	France	0.50	9	39	25
Alfa Solar Al fanar	Saudi Arabia	1.02	12	23	50
ENERRAY Gila	Italia	2.04	24	1,2,46	90
Health &safety services	Egypt	2.95	223	-	-
Total	-	31.44	878	32	1465
Unexploited plots	-	5.56	-	8	260

Source: author based on facility management contractors, 2022. Deutsch Arabische Industrie - und Handelskammer, 2017:60.

Fig.9. production of renewable energy in Egypt 2011-2020(Gwh)

Source: Author based on The International Renewable Energy Agency (IRENA) (2021), Renewable Energy Statistics 2021, Abu Dhabi. Different pages

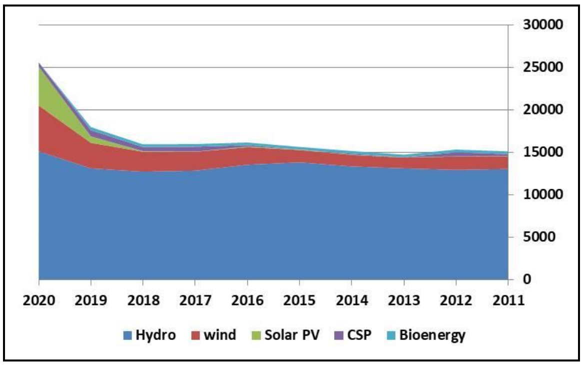

Fig.9. output of renewable energy in Egypt 2011-2020 Gwh

Source: Author based on NREA,2020

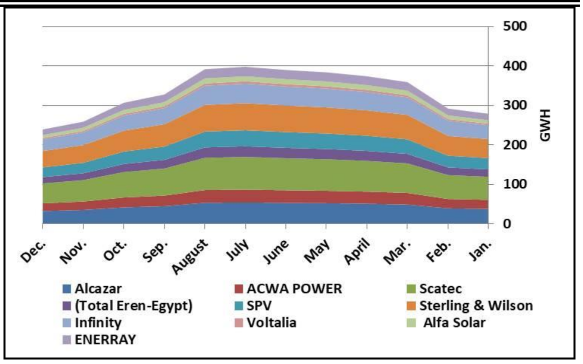

Fig.10. Monthly estimation of output of solar energy in benban PV solar park in 2020/2021 by developer

Source: author based on NREA Meter, 2020, 2021, various publications

Electricity yield of a PV system = h*npre*nsys*nrel*Pnom

h = Peak Sun Hours, npre= Pre-conversion efficiency

nsys = System efficiency, nrel= Relative efficiency, Pnom = Nominal power at STC (IRENA, No date: 30).

Table.9. Estimation of monthly production of solar energy developers in Benban Park, 2022

Developer	Jan.	Feb.	Mar	April	May	June	July	August	Sep.	Oct.	Nov.	Dec.	total
Alcazar	38.4	39.8	49.3	51.3	52.7	53.5	54.6	53.8	45.1	42.2	35.7	33	549.4
ACWA POWER	22.7	23.6	29.3	30.6	31.4	31.9	32.5	32.1	26.8	25	21.1	19.5	326.5
Scatec	58.4	60.5	74.8	77.9	79.9	81.2	82.8	81.6	68.5	64.2	54.3	50.2	834.3
)Total Eren-Egypt(	18.7	19.4	24.1	25.2	25.8	26.2	26.8	26.4	22	20.6	17.3	16	268.5
SPV	28.6	29.6	36.7	38.3	39.3	39.9	40.7	40.1	33.6	31.4	26.5	24.5	409.2
Sterling & Wilson	48.3	50	61.9	64.4	66.1	67.2	68.5	67.5	56.6	53	44.9	41.5	689.9
Infinity	34.7	38.7	44.5	46.3	47.6	48.3	49.4	48.5	40.7	38.1	32.2	29.7	498.7
Voltalia	3.9	4.1	5.3	5.5	5.7	5.8	5.9	5.8	4.7	4.4	3.6	3.2	57.9
Alfa Solar	8.8	9.2	11.6	12.1	12.4	12.6	12.9	12.7	10.5	9.8	8.2	7.5	128.3
ENERRAY	16.7	17.3	21.6	22.5	23.1	23.4	23.9	23.5	19.5	18.3	15.2	14.3	239.3
total	280	290	360	375	385	391	399	393	329	308	260	240	4022

Source: authors calculation based on Electricity yield of a PV system = h*npre*nsys*nrel*Pnom

h = Peak Sun Hours, npre= Pre-conversion efficiency

nsys = System efficiency, nrel= Relative efficiency, Pnom = Nominal power at STC (IRENA, No date: 30).

Fig.11. relationship between total radiation and solar output in sun rise, 31 dec.2021 by Hour

Source: author based on sun rise statistics of energy and weather, 31Dec.2021

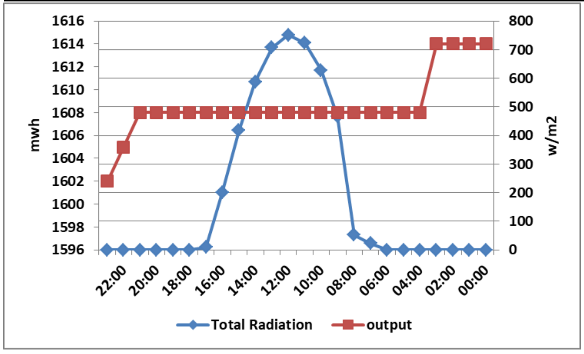

Fig.12. relationship between total radiation and solar output in sun rise, 2 march.2022 by hour

Source: author based on sun rise statistics of energy and weather,2 march.2022

It is noted from 8.9. Figures that the production increases with the increase in solar radiation during the period of sunshine hours during the day, but the production increases in March to reach 1612 megabytes, while production does not exceed 1,122 mega/hour in December due to the difference in the levels of solar radiation. Output increases during the night due to the reverse sense of the inverters which generate active power, reactive power and a number of batteries that not produce electricity, but the voltage goes out to maintain the connection with the network.

- **Social impact of benban's PV solar park institutions**

The size of the population in the villages surrounding the Benban's project is about 60,000 people, distributed over five villages, the largest of which are the villages of Al-Mansouriya and Benban Bahri see table 10.

Table.10. population characteristics and services in benban solar park, 2021

Village	population	employers	employees	Education Illiterate	Potable water (m3 /hr)
Benban Bahary	13137	21	3,682	2143	200
Benban Qebly	8870		2,848	1584	300
El Raqaba	10213	11	3682	1876	100
Fares	11307	-	-	-	-
Mansouria	14615	-	-	-	-
Total	58142				1100

Source; Aswan statistical guide.2021; 37- 44

In term of sustainable development, the project has allowed the value chain of the solar PV industry to flourish in Egypt. Each Mw installed creates 13 sustainable jobs in the industry, Most of it from local labor (more than 70% local integration).

With a total at 229,055 person-days needed to develop a solar PV plant of 50-megawatt MW), labor requirements vary across the value chain. People working on O&M are needed throughout the project lifetime, and therefore represent the bulk of the labor requirements (56 percent of the total) , Equipment manufacturing (22 percent) , installation and grid connection (17 percent) also require significant labor inputs.

The project provided nearly 20,000 job opportunities over two years, the construction period of the project from January 2018 to November 2019, varying between workers, technicians, engineers and other administrative jobs. The number of workers in the project reached about 12 thousand in the peak period from November 2018 to February 2019, while the number of workers in the project during the operating period reached 1,000 workers, with an average of 15 workers per site, including engineers, workers, technicians and administrators see tables 8, 11.

The project included Egyptian and foreign workers, engineers and technicians, the target of international banks was 20 percent of the Aswan governorate as a local worker, the percentage ranges between 50 percent, -70 percent. The wages differed between companies according to the law of supply, demand and efficiency, but the basis was submission According to the laws of the state in the minimum wage, where the wage of unskilled workers reached 150 pounds per day, which is the lowest category in salaries, and the company provides them with safety tasks and transportation, as well as a daily meal (IRENA, 2017, P.12-13.).

The laws of international development banks, which were represented in a set of plans (14 plans) approved by all the owners and contractors, which covered all aspects of the project, including the Code of Conduct, which clarifies the nature of the relationship with employment and regulates the method of labor transfer and its rules and the covenants between companies and contractors (Aisha, social specialist, personal interview, January 9, 2022).

Benban's Solar Investors Association collects annual financial shares from these companies about one million pounds for the 50 mega project. The companies spend on social projects in Benban Bahri, Qibli, Rakabah, Mansourieh, Faris in health and education, the Nile Ferry between East and West Nile, the tomato project and mango farms drying (Eng. Ayman Fayek, Aqua Power Company, personal interview, December 20, 2021).

Moreover, ACWA power projects -for example- save around 156000 tons of Co2 every year. The project delivers 320 GWh/y of solar energy to the Egyptian grid (Clean Energy Business Council, 2021:33).

- **Environmental impact of benban's PV solar park institutions**

Generation of one unit (kWh) electrical energy from thermal power plants produces 980 g of carbon dioxide, 1.24 g of sulphur dioxide, 2.59 g of nitrogen oxide, and 68 g of ash (Boddapati, et al, 2021).While the majority of estimates for units of PV are between 30 and 80 grams of carbon dioxide equivalent/kilo Watt hour. The levels of electricity from concentrated solar energy are considered to be between 14 and 32 grams of Emissions are lower by volume than those from factories that it works with natural gas.

The mean GHG emissions of manufacturing silicon modules (Lifecycle GHG emissions) is about 85 tCO2e/GWh compared to 888, 499, 733 tCO2e/GW for coal, natural gas and diesel oil respectively. In Egypt, the total average CO2 emission from all thermal power plants is about 540tCO2e/GWh, while total saving of Co2 emission 1435 ton/hour from benban's PV solar park see table.11. Moreover, the expected annual production of the Al Tawakol plant is 58.42 GWh, approximately 31,547 tCO2e is abated annually. (ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016:54).

Table.11. Economic, Social and Environmental characteristics of benban's solar park institutions, 2022

developer	Capacity Mw	Costs million dollar	Output value $Million	Number of labor	Savings of Co2 emissions ton /hour
Csail Alcazar)(	200	340	46.1	2600	196
ACWA POWER	120	204	27.4	1560	117.6
Scatec	300	510	70.1	3900	294
)Total Eren- Egypt(	100	170	22.5	1300	98
SPV	150	255	34.3	1950	147
Sterling & Wilson	250	425	57.9	3250	245
Infinity	180	306	41.9	2340	176.4
Voltalia	25	42.5	4.8	325	24.5
Alfa Solar	50	85	10.7	650	49
ENERRAY	90	153	20.1	1170	88.2
total	1465	2490	335.8	19045	1435.7

Source: author's calculation based on facility management contractors Data, 2022 and standard estiamation.

- **Future of benban's PV solar park**
- **risks of benban's solar park**

Solar PV power generation projects are sensitive to physical and nonphysical factors as follows:

- **Losses**

PV system losses mostly emerge from high array temperatures, insufficient use of the irradiation, inadequate system sizing and inefficiency or failure of system components. There are two losses associated with PV systems, namely; system losses and array capture (also known as collection) losses. System losses arise during the transformation of D. C electricity to A.C electricity. The harnessing of solar irradiance into direct current electricity by the solar cells tends to cause array capture losses.

The various losses of the available energy output are Global corrected for incidence (IAM losses) 2.8%, PV loss due to irradiance level 0.39%, PV loss due to temperature 11.69%, Module quality loss 3%, Mismatch loss 1.10%, Ohmic wiring loss 1.15%, Inverter loss during operation

1.15%, Inverter loss due to power threshold 0.01% and Night consumption 0.01% (Boddapati, et al ,2021:22).

Losses can be decreased to appreciable levels by checking module cleanliness; checking for discoloration of the cells, glass breakage or corrosion of the connections between cells; the tightness of the junction boxes; cleaning the solar panels frequently; upgrading fixing and fastening cables; properly tightening all connections at the ends of cables; checking the connections of all cables by continuity tests; checking the condition of the cables (no rodent injuries); and checking the operation of all protective devices(Sekyere, et al ,2021: 6,8) .

Due to the low efficiency of inverters and their technical problems that reduce the production of electricity from solar power plants, the inverters were completely changed in 3 plants out of a total of 32 plants in Benban in 2021(Eng. Ayman Fayek,March,2022).

- **High Wind speeds**

One of the impacts of strong wind is sand and dust deposition. The study area experiences sand storms during spring and autumn. Higher wind speeds potentially increases the performance losses due to abrasion and/or deposition of dust on PV cells. However, the design of the PV module has taken into consideration selection of coating material that will minimize the abrasive effect of dust. In addition, periodic module cleaning and maintenance will minimize the impact of deposited dust (ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016:65) see table.12. The wind speed decreases during the day and increases during the night and early morning, while the peak production is during the day, so the wind speed does not affect the production see Fig.13.

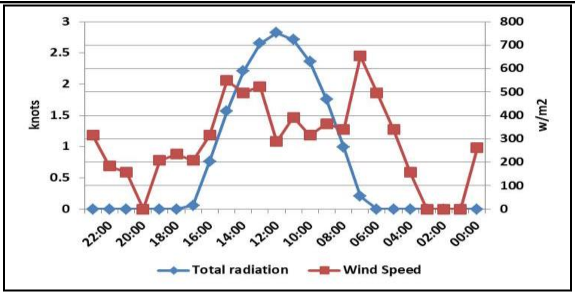

Fig.13. hourly total radiation and wind speed for sun rise company in benban solar park, 31 Dec.2021

Source: author based on sun rise statistics of energy and weather, 31Dec.2021

- **increasing temperature**

The characteristics of a PV module are determined at standard temperature conditions of 25˚C. For every degree rise in Celsius temperature above this standard, crystalline silicon modules reduce in efficiency, generally by around 0.5 percent. In high ambient temperatures under strong irradiance, module temperatures can rise appreciably. Wind can provide some cooling effect, which can also be modeled (IFC, 2015:53). It is noted that the solar radiation increases with the rising in temperature, especially during the day from 12 p.m. until 5 p.m. see fig.14.

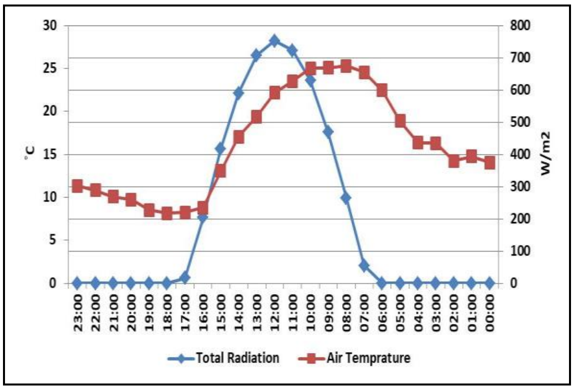

Fig.14. hourly relationship between total radiation and air temperature for sun rise company in benban solar park, 31 Dec.2021

Source: author based on sun rise statistics of energy and weather, 31Dec.2021

During 2021, 6 fires occurred between May(39 ˚C) and August (40 ˚C) in benban's solar PV Park, due to high temperatures, for example, at Total Eren Egypt, Nomac plants and Power Station No. 1 that were extinguished by Health & Safety services (field study, 9 Jan.2022) see table.12. photo.8.

- **Visual Impact Shadow**

Visual effects arise from changes in the composition and character of views available to receptors affected by the proposed development (e.g. residents, recreational users, tourists etc). Visual impact assessment considers the response of the receptors that experience these effects, and it considers the overall consequence of these effects on the visual amenity of the view. There are no receptors near the project area, and these are limited to the transient drivers along the Luxor-Aswan Road (ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016:67).

Table. 12. Climate Hazards of Benban PV solar park, 2016-2020

	Temperature (°C) Mean Maximum	Temperature (°C) Mean Minimum	Dust or Sandstorm days	Clear sky days	Duration of Bright Sunshine (%)
Jan.	**23.7**	**7**	**0.23**	**22**	**70**
Feb.	**25.8**	**7.9**	**0.4**	**23**	**75**
March	**30.1**	**11.4**	**0.9**	**22**	**70**
April	**35**	**15.7**	**1.1**	**24**	**72**
May	**39**	**19.7**	**0.9**	**26**	**79**
June	**40.8**	**22.1**	**0.03**	**30**	**80**
July	**40.5**	**22.5**	**0.07**	**28**	**81**
August	**40.4**	**22.4**	**0.27**	**29**	**82**
September	**38.4**	**20.3**	**0**	**27**	**80**
Oct.	**36**	**17.8**	**0.13**	**26**	**80**
Nov.	**29.4**	**13.2**	**0.1**	**25**	**80**
Dec.	**24.7**	**8.7**	**0.03**	**22**	**67**
average	**33.6**	**15.7**			

Source: Acwa power, 2016; 62-70, Kom omobo, 2020.

In order not to cause dust resulting from car traffic inside Benban Park, the speed of cars must not exceed 35 km per hour on the roads between plants, and that the speed internal the solar power plant plots does not exceed 20 km per hour. Moreover, IFC is prohibited to cultivate trees to avoid shadow (field study, 9 Jan.2022).

- **Glare**

Solar panels are designed to absorb, not reflect, irradiation. However, glint and glare should be a consideration in the environmental assessment process to account for potential impacts on landscape/visual and aviation aspects (International Finance Corporation, 2015p.99). Al Tawakol's site - for example- is located roughly more than 5 km from the Luxor-Aswan road and thus potential glare is not significant.

It is noted that the less the relative humidity during the day, the greater the solar radiation, while the greater the relative humidity during the night, the less solar radiation fig15. Therefore, Glare appears during the night only and increases in the winter months, especially the months of December and January see table.12.

,

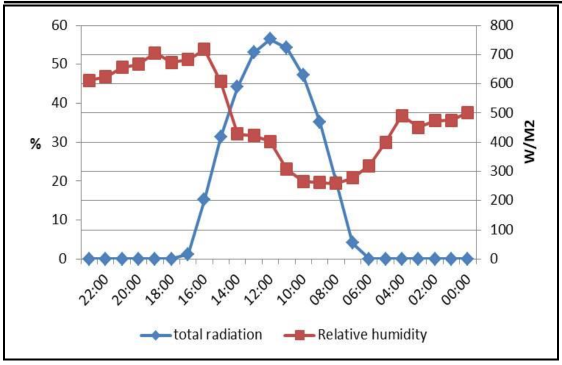

Fig.15. hourly relationship between total radiation and relative humidity for sun rise company in benban solar park, 31 Dec.2021

Source: author based on sun rise statistics of energy and weather, 31Dec.2021

- **PV solar downtime costs**

A PV solar Breakdown cost includes Modules 42%, Inverters 13%, Cabling 4%, Security 1%, Grid 15%, Frames 17%, and Project management 6% (IFC, 2015: 175). Heavy and torrential rains that occurred in Aswan in November 2021 caused the stations to be temporarily out of service at the time of the floods so as not to damage transformers, inverters and cables.

If the production exceeds the design capacity of the station, which is 50 megabytes per hour and reaches 60 megabytes, the Electricity Regulatory Agency will be charged for the designed capacity according to the contract concluded, and therefore companies are obligated to produce the contracted power without exceeding it (Eng. Ayman fayek, 26 March, 2022).

- **<u>Future of Grand benban's PV solar park complex master plan</u>: <u>Optimum land use</u>**

The strategy of renewable energy aims to reach 20% of the total energy produced in 2022. As follows 2% solar energy, 12% wind energy, 6% hydro power. In October 2016, the Supreme Council of Energy adopted the Egyptian Energy Strategy until 2035, and selected the Scenario (4-B) ,economically efficient, to be the reference for energy planning in Egypt during the coming period, which aims to reach the percentage of renewable energy contribution to 42% in 2035, as follows: 4% CSP concentrated solar power, 22% PV Solar, 14% wind energy, 2% hydro power (new & renewable energy authorities, 2020:8). The production of solar energy in 2010 was zero, it was started in 2019 at 3 giga watts, and it is expected to reach 31 giga watt-hours in 2035. Solar energy comes in fourth place after the production of electricity from natural gas, then coal and wind fig.16.

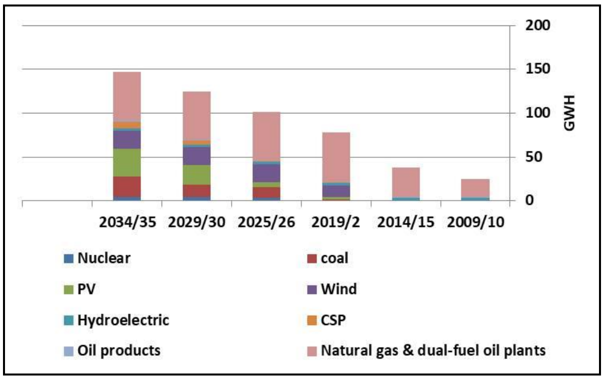

Fig.16. Egypt's Total installed power-generation capacity 2009/10-2034/2035(Gwh)

Source: author, based on International Renewable Energy Agency, 2018:34

Table.13. Evaluation of PV solar Park in benban

month	PR	developer	CUF
Jan.	0.092	**Csail Alcazar)(**	0.313
Feb.	0.109	**ACWA POWER**	0.310
March	0.094	**Scatec**	0.317
April	0.110	**)Total Eren-Egypt(**	0.306
May	0.119	**SPV**	0.389
June	0.127	**Sterling & Wilson**	0.315
July	0.127	**Infinity**	0.316
August	0.137	**Voltalia**	0.264
September	0.139	**Alfa Solar**	0.292
Oct.	0.138	**ENERRAY**	0.303
Nov.	0.128		
Dec.	0.106		
average	0.119		

Source: authors calculation based on performance rate equal temperature/

irradiation, Capacity utilization factor (CUF) = Actual Energy Output/Name plate Capacity × Time period (h)

Capacity utilization factor ranges between 0.18, 0.24 in Germany and Spain respectively (IFC, 2015:55), while CUF ranges between 0.26 in voltalia company and 0.38 in SPV company in Benban's solar PV.

The performance rates in Benban vary according to the temperature and solar radiation. The performance rates are lower in January and March, and the peak is in August, September and October. Table.13.

- Zoning of Grand benban's solar PV complex

The land use around the solar park can be divided according to the levels of conservation into the following zones:

Zone A: buffer zone is Zero land use **(5km).**

Zone B: services zone(5km).

This zone includes benban's solar park development authority, benban's solar research institute, smart services, and benban's development fund.

Zone C (10km): Economic zone contains electronics industries and protected cultivation. The region of Benban is suitable for the protected cultivation of hot tropical crops such as coffee, tea, cocoa, pineapple, oil palms, date palms, dom, acacia, bitter melon, arak, henna, fodder, and hibiscus (Al-Mahdi, 1964, 142). Benban region is also suitable to Jojoba and Jatropha trees for biofuel extraction.

Zone D (10km): Eco- zone includes Eco-Heritage Tourism Resorts **and** Green Industries Park, Eco – City. Moreover**,** Solar Park expansion and Fares PV solar park capacity 276 mg, area 13 km2 and cost are 221 million dollars **see** fig.17**.**

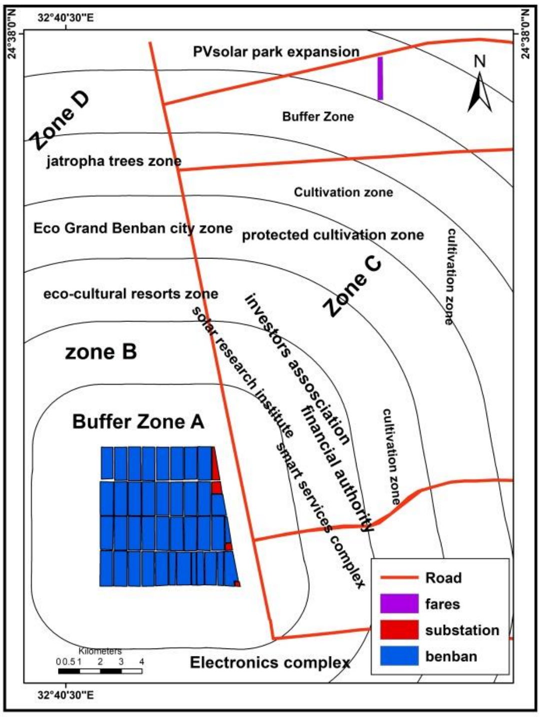

Fig.17. Grand Benban's sustainable development Master Plan, 2030

Conclusion and recommendation

- The study concluded that the theoretical framework of institutional economic geography includes the study of structure, institutional organization, social embeddedness, institutional thickness, the positive impacts of institutions, the risks and their future strategies.
- The study of the spatial characteristics of Benban concluded that it is one of the most suitable sites for the establishment of a solar energy complex in Egypt, according to the standards of the international literature.
- The study of the technical characteristics concluded that most of the companies using Poly Crystalline PV panel type, due to its low cost; high efficiency; middle temperature characteristics; good life time; safe environmental consideration, low effect of shade, and required 4-5 acres Land/per MW (16187 – 20234 m2 /MW).
- The study of institutional characteristics concluded that there is a strong and tight institutional organization that includes developers, operating and maintenance companies, and sub-contractors for

cleaning and security works. A strong and tight institutional organization due to Division of work, maximizing specialization, hierarchy of administrative organization, and participation of companies with global expertise in the field of solar energy such as Norway, Spain, France, Italy, India and China.

- The study of institutional thickness concluded that it is weak due to the weakness of the local content of solar panels, inverters, transformers, etc. The social embeddedness of Benban companies is still in the stage of evolution and formation; it may reach the stage of maturity, if the electronic industries and research & development become localized in Egypt.
- The study ended with monitoring the positive effects of the Benban project, which is mainly represented in providing the national electricity network with about 4 TWh, employing about 20,000 workers in the various plants works, saving about 1,435 tons of carbon dioxide emissions and benefiting from social responsibility projects at the rate of one million pounds annual for each company in the villages of Banban Bahri, Qibli, Fares and Mansouriya.
- The study concluded that the most serious risks facing the project are the extreme high temperatures in the summer, which cause fires and damage equipment and cables, and rainfall in winter that stopped the plants.
- The study presented a proposal for the establishment of the Grand Benban Solar Energy Complex to remedy the weaknesses that appeared through the study of the institutional economic geography of the project.

- **Recommendation**

- Localizing the industries of components and parts for solar energy plants, such as solar panels, inverters, transformers and cables in Egypt. There are about sixteen sites of white silica sand in Egypt; the most important locations are Wadi Qena , Wadi El- Dakhl) and El- Maadi,. There are two main locations in Egypt having high quality of silica sands, the first location lies at Zaafrana area (Wadi Dakhl) and the second one locates at north and south Sinai. White silica sands contain most of the Wadi Qena Formation and are exposed in an area of approximately 450 km2 at the western margin of the northern part of Wadi Qena. In addition to east Idfu and El Wadi El Geded sites. The probable reserves were estimated to be about one billion metric tons (Ismaiel, Askalany,and Ali,2017:1713).
- Localization of the solar power plant industry to strengthen social embeddedness and institutional thickness.
- Early monitoring of the weather and preparing a plan to quickly deal with climatic hazards such as torrential rains, high temperatures and dust storms.
- Reducing the price gap between the prices of energy purchased from solar energy companies 8.4 cents equals 146 piasters and the price of energy sold to citizens 0.032 dollar equals 58 piasters through a third and fourth stage to reduce the price of energy purchased from companies.
- Preparing a plan to benefit from solar power plants after the end of the contract period of 25 years through the renewal of the contract for a similar period, Or will the project with its equipment be transferred to the state, or will the land be retrieved free of any equipment?
- Applying the strength of institutional organization and its hierarchy for the solar energy project in Benban to the new solar and wind energy projects, which is mainly represented in the division of labor and maximizing specialization and benefiting from the pioneering experiences and expertise from foreign companies such as China, India, Spain and Norway.

- Soil stabilization around the Benban project to mitigate sandstorms in this dry area by using colloidal emulsions that increase soil resistance to erosion.
- Preparing flood drains and overflows in the event of dangerous floods, especially the area is located at the bottom of a mountain.
- Establishing technical schools specialized in solar energy to prepare and train technicians and solar energy research institutes to graduate engineers and developers.
-
- Applied co- location of wind and solar energy technologies that enable operators to sweat extract the most efficiency from grid connection assets, due to high wind speed and solar irradiation occur at the same time. As it was in Ireland.
- A solar PV system components are up to 90% of the material may be recycled. If a development utilized solar cell containing hazardous material i.e cadmium telluride, reference should be made to the manner in which these material will be disposed.

Photo1.. Benban's sub station

Photo.2. With Eng. Ahamed Mansour production manager of sun rise company beside modules

Photo.3. Benban's PV solar park

Photo.4. meteological station

Photo. 8. Storage room of extinguisher

Photo.5. Inverters and transformer

Photo. 6. Control room of sun Rise Company

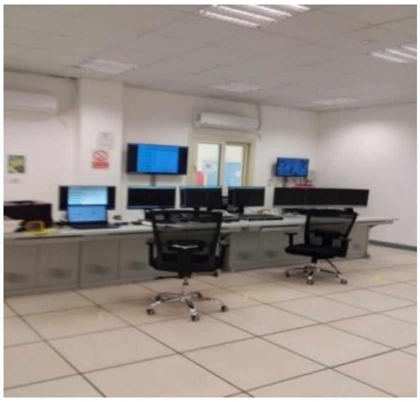

Photo.7. Scatec PV solar plant

References:

1- Acwa power, 2020. Environmental and Social Impact Assessment, 200 MW Photovoltaic Power Project Kom Ombo – Aswan, 5 Capitals Environmental and Management Consulting, Dubai.

2- American chamber of commerce in Egypt, (2017), Industry insight, energy involves, Cairo.

3- American chamber of commerce in Egypt, (2016), Industry insight, energy outlook, Cairo.

4- Al-Mahdi, A, (1964) Hot yields on the shores of Lake Nasser, Egyptian Geographical Society, public lectures, cultural season.

5- Amin, A. 2004.An Institutionalist perspective on regional economic development.in reading economic geography, Ed. Barnes, T., peck, J., Sheppard, and Tickell, A .Blackwell, oxford.

6- Ayyash, Saud Yusuf, 1981 Alternative Energy Technology, the World of Knowledge, No. 38 February. (In Arabic).

7- Bathelt, H., & Glückler, J. (2014). Institutional change in economic geography. Progress in Human Geography, 38(3): 340-363.

8- Boddapati,v., Nandikatti, A.and Daniel,S., (2021) Techno-economic performance assessment and the effect of power evacuation curtailment of a 50 MWp grid-interactive solar power park, Energy for Sustainable Development, 62 :16–28.

9- Clean Energy Business Council, 2021.Accelerating private finance for Arab renewable energy transition, white paper, Abu Dhabi.

10- Cox, K.2011. Institutional geographies and local economic development: Policies and politics. Edited by Andy Pike, Andrés Rodríguez-Pose and John Tomaney, Handbook of Local and Regional Development, Routledge, London: 272-282.

11- Cumbers, A. MacKinnon, D. and McMaster, R. 2002.Institutions, social relations and space: the limits to institutionalism in economic geography, (draft) published by the Department of Geography & Topographic Science, University of Glasgow.

12- Decree of the President of the Arab Republic of Egypt, Law No. 203 of 2014 on stimulating the production of electricity from renewable sources.

13- Domingues,R. 2015.The Institutional Perspective in Economic Geography, Universidade Federal do Ceará. Mercator, Fortaleza, v. 14, n. 2, p.7-19

14- EcoConServ Environmental Solution,2016, Environmental & Social Impact Assessment for 50 MW PV Power Plant [Plot SBN 23-3] in Benban, Aswan, Egypt, final report.

15- ESIA for Al Tawakol Photovoltaic Power Plant in Benban, 2016. Environics, Aswan.

16- International Finance Corporation, (2015), Utility-Scale Solar Photovoltaic Power Plants, A project developer's guide, Washington, D.C.

17- International Renewable Energy Agency, 2018. Renewable Energy Outlook EGYPT, Abu Dhabi.

18- IFC, (2019), scaling infrastructure, Nubian suns, Egypt: scale at speed, Cairo.

19- IFC, 2015. Utility-Scale Solar Photovoltaic Power Plants, A Project Developer's Guide, Washington.

20- IPCC, 2011. Special Report on Renewable Energy and mitigating the effects of climate change,Potsdam.

21- Ismaiel, A. Askalany, M. and Ali, I. May-2017. Evaluation of White Silica Sands North Eastern Desert, in Egypt, International Journal of Scientific & Engineering Research, Volume 8, Issue 5.

22- Kamal, F. & Sundaram, A. (2019) Do institutions determine economic Geography? Evidence from the concentration of foreign suppliers, Journal of Urban Economics, 110:89–101.

23- Kereush, D. & Perovych, I., (2017). Determining criteria for optimal site selection for solar power plants, Geomatics, Land management and Landscape No. 4:39–54.

24- Kušar, S., (2011), The Institutional Approach in Economic Geography: An Applicative View, Hrvatski geografski glasnik 73(1), :39–49.

25- Gašparovi´c, I, Gašparovi´c, M., (2019). Determining Optimal Solar Power Plant Locations Based on Remote Sensing and GIS Methods: A

,

Case Study from Croatia, Remote Sens., 11, 1481:1-18.

26- Martin, R.2003. Institutional Approaches in Economic Geography, in A Companion to Economic Geography, Editor(s): Eric Sheppard,Trevor J. Barnes,John & wiley sons, London**.**

27- Mackinnon, D. &Cumbers, A (2019), an introduction to economic geography, Routledge, London.

28- Nawaz, S.& Mangla, I. 2021.The economic geography of infrastructure in Asia: The role of institutions and regional integration, Research in Transportation Economics, xxx (xxxx) xxx.

29- New & Renewable Energy Authority, 2019, 2020.Annual Report, Cairo.

30- New & Renewable Energy Authority, 2018. The Solar Atlas of Egypt, Cairo.

31- Prime Minister's Decree No2532 of 2016, the purchase prices of electric power produced from renewable sources.

32- Pillot, B., Al-Kurdi, N., Gervet,G., and Linguet,L. (2021). Optimizing operational costs and PV production at utility scale: An optical fiber network analogy for solar park clustering, Applied Energy 298, 1-12.

33- Prime Minister's Decree No. 1947 of 2014, the purchase prices of electric power produced from renewable sources.

34- Rashad, Ahmed, Meligi, A. and Ibrahim, A, July (2021). Policies and Mechanisms of Deepening the Electronic Industries in Egypt in the Light of International Experiences and Evaluation of Local Practices by Application to the Solar Panel Industry, Series of Papers of the Project to Deepen Domestic Manufacturing in Egypt No. 6 National Planning Institute .

35- Scatec solar, 2017. Environmental and Social Impact Assessment for Red Sea Solar Power 50 MW (AC) in Benban, Aswan, Environics.

36- Sekyere, C. Davis, F. Opoku, R. Otoo, E, and Takyi, G.2021.Performance evaluation of a 20 MW grid-coupled solar park located in the southern oceanic environment of Ghana, Cleaner Engineering and Technology 5:1-12.

37- Tunc, A., et al, (2019), GIS based solar power plants site selection using analytic hierarchy process (AHP) in Istanbul, turkey, The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume XLII-2/W13, ISPRS Geospatial Week, 10–14 June 2019, Enschede, The Netherlands.

38- Yeung,H. (2000). Organizing ‘the firm’ in industrial geography I: networks, institutions and regional development, Progress in Human Geography 24,2 pp. 301–315

39- http://www.solar-med-atlas.org/solarmed-atlas/map.htm#c=36.315124,4.218749&p=24.647016,31.640624&t=ghi