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Quantifying the Saved Social Costs of the Solar Energy Projects Funded by the EBRD in Egypt

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ABSTRACT

The world is changing into a village due to the common need to meet the population's energy demands. Scholars link such transformation with energy's relevance in meeting economic and social development and improving human welfare. This paper aims to evaluate the social cost savings of solar energy projects funded by the European Bank for Reconstruction and Development (EBRD) in Egypt. The paper provides an overview of the EBRD's involvement in promoting renewable energy in Egypt and its impact on the country's energy mix. The paper analyzes the three solar energy projects funded by the EBRD and their contribution to reducing carbon emissions and promoting sustainable development. Through calculating the avoided carbon dioxide (CO_2) emissions and the saved social costs of these projects, the study concludes that the contribution of the EBRD is substantial, which highlights the importance of partnering in renewable energy to achieve sustainable development goals and mitigate climate change.

Keywords: Renewable Energy, Egypt, EBRD, Solar Energy, Social Cost, Carbon Dioxide
JEL Classifications: Q42, O13, Q20, Q52

1. INTRODUCTION

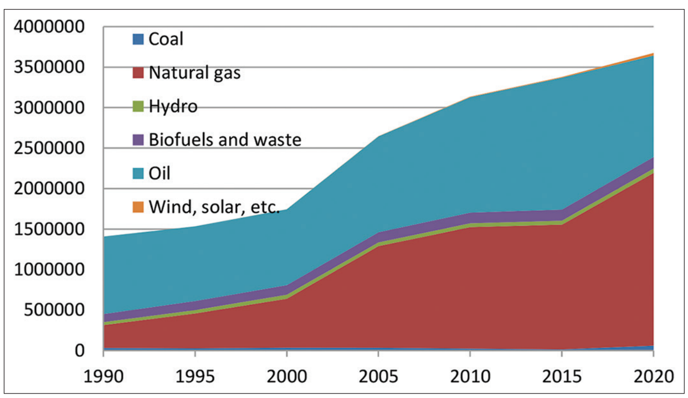
The concept of the world becoming a global village is attributed to the shared necessity of meeting the energy demands of the growing population. Several studies have established a correlation between this transformation and the significance of energy in facilitating economic and social development as well as enhancing human welfare. This implies that the world is becoming more interconnected and interdependent, with energy playing a crucial role in shaping its future. Global warming has posed a major challenge to the world's sustainability, prompting international agencies to develop policies, plans, and strategies to address the problem. A critical approach includes investing in renewable energy sources (RES). RESs refer to energy sources that are generated from natural resources that are replenished over time and do not deplete, such as sunlight, wind, rain, tides, and geothermal heat. Studies on RESs have increased worldwide, with researchers considering RESs critical to addressing global warming and fossil fuel depletion issues. Currently, the world depends mainly on "fossil fuels, nuclear resources, and renewable resources" as "the three main sources of energy" (Qazi et al., 2019). However, scholars admit that fossil fuels are unsustainable due to their negative impacts and depletion levels. They mainly produce harmful gases, including carbon dioxide, nitrogen oxide, and sulfur dioxide, leading to global warming (El Safty and Siha, 2021). As a result, the high temperatures have created global warming, endangering the planet and its living species (Shahzad, 2012). Besides, although nuclear resources provide clean energy, they have negative environmental impacts, leaving renewable energy as a critical source for enhanced sustainability.

According to the International Renewable Energy Agency (IRENA), Egypt has the potential to generate up to 53% of its electricity from renewable sources by 2030. Figure 1 shows the energy supply in Egypt. The graph demonstrates Egypt's reliance on natural gas and oil for energy. This is despite the fact that North

African and Middle Eastern countries have a high potential for solar and wind energy due to their geographical location and climate. One of the main factors that makes Egypt a potential source of renewable energy is its abundant solar resources. The nation receives a lot of solar radiation throughout the year, which makes it a great place to generate solar power. In fact, Egypt has one of the highest solar potentials in the world, with an average of 2000 kWh per square meter per year. According to the US International Trade Administration (ITA), Egypt is classified as a "sun belt" nation by the Solar Atlas of Egypt, receiving direct solar radiation of 2000-3000 kWh/m^2/year. The country experiences 9-11 h of sunshine per day from north to south, with minimal cloudy days (International Trade Orgranization, 2022). Solar-produced electricity is currently priced between 2 and 3 cents per kilowatt-hour (kWh), which is a significant decrease from the previous price of 7-8 cents per kWh. This reduction in price has made solar energy more affordable for consumers. Figure 2 depicts the evolution of Egypt's RE supply over time.

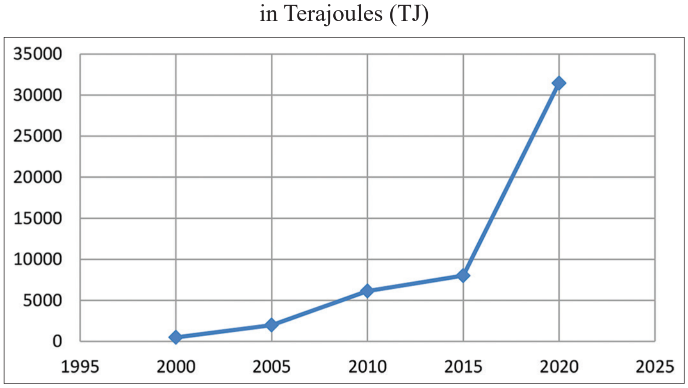
In the area of solar energy, the EU and Egypt have a long history of collaboration. The EU has a strong track record in developing and deploying renewable energy technologies, while Egypt has abundant solar resources. Furthermore, both sides are interested in lowering their dependency on fossil fuels and enhancing energy security. One arm of the EU's support for Egypt is the EBRD. The EBRD is a global organization that supports entrepreneurship and the growth of the private sector across 38 economies on three continents. The European Union, the European Investment Bank, and 69 countries all own shares in the Bank. EBRD investments are aimed at making its investee economies competitive, inclusive, well-governed, green, resilient, and integrated. Since 2014, the EBRD has been actively promoting the growth of renewable energy in Egypt by financing projects and offering technical support to help the country's renewable energy regulations. The bank contributes to solar energy in Egypt through its financing of a large-scale solar project, the Benban Solar Park, a medium-sized project, the Kom Ombo project, and a smaller-scale solar project for commercial and industrial customers, the Dina Farms project.

Figure 1: Total energy supply by source in Egypt between 1990 and 2020 in Terajoules (TJ)



Source: International Energy Agency (2022)

Figure 2: Renewable energy supply in Egypt between 2000 and 2020 in Terajoules (TJ)



Source: International Energy Agency (2022).

The Benban PV project is a large-scale solar power plant complex that extends over 37 km^2 and is located in the Aswan governorate of Egypt. The Benban PV project was initiated by the Egyptian government in 2012. A group of international financial organizations, including the World Bank, the African Development Bank, and the EBRD, are providing funding for the project. The project consists of 32 individual power plants, each with a capacity ranging from 20 MW to 200 MW. Construction of the Benban PV solar plant was completed in 2019, and it is now fully operational. The EBRD also provided technical assistance to help ensure that the project met international environmental and social standards. Since 2012, the EBRD has been involved in the development of the Benban solar park. The EBRD has invested over US$1.1 billion in 16 photovoltaic solar plants, which have a combined capacity of 750 MW. This represents more than half of the park's contracted capacity (Zgheib, 2022). Egypt's Benban solar park has made a substantial contribution to the nation's capability for renewable energy. As of 2017, the park has added 2.65% of the total installed capacity, which is a 165% increase in renewable capacity. All of the solar plants in the park are connected to the national electricity grid, providing clean and reliable energy for North Africa's largest economy. The project has a capacity of 1.8 GW, which is enough to power over one million homes with renewable energy (Aristeidou, 2021).

In 2021, a group of international financial institutions, including the EBRD, the OPEC Fund, the AfDB, the GCF, and the Arab Bank, signed a financing package with ACWA Power to construct the largest private solar plant in Egypt, Kom Ombo. The 1.8 GW Benban complex, Africa's largest solar park, is <20 km from the new plant. 130,000 households are intended to be served by the facility. The construction of the Kom Ombo solar plant is intended to increase Egypt's energy capacity by 200 MW, boosting the proportion of renewable energy and encouraging private sector involvement in the country's power sector. The project will have roughly 650,000 solar panels and be constructed on a 670-acre plot (Zgheib, 2021).

The EBRD also offers money for minor initiatives in addition to larger ones. A 6 MW solar photovoltaic (PV) power plant at Dina Farms in the Beheira governorate, which is 80 km from Cairo, was built and is currently in service thanks to funding from the EBRD. The largest dairy farm in Africa, Dina Farms, will be able to use sustainable energy to meet some of its energy needs thanks to this power plant. This project, which is the first EBRD-funded private-to-private renewable energy effort in Egypt, entails a corporate private-private partnership for the direct electricity supply from a privately owned generator to a private off taker (Zgheib, 2020).

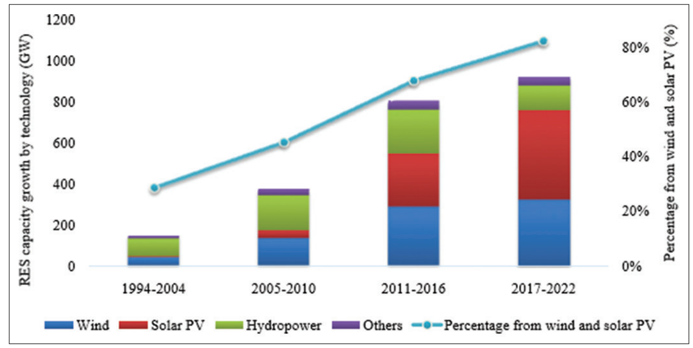
In order to evaluate the benefits of RE projects, scholars calculate saved social costs and avoided CO_2 emissions. The saved social cost is a valuable tool for policymakers who are considering investing in renewable energy. By estimating the social cost saved, policymakers can see the economic benefits of reducing greenhouse gas emissions. This paper aims at evaluating the contribution of the EBRD in financing solar energy projects by estimating the avoided emissions and the saved social costs of these projects. The next section is a literature review, followed by a methodology section, a results section, and a final section for conclusions.

2. LITERATURE REVIEW

RE entails energy derived from limitless sources. Its collection occurs primarily from naturally replenished resources on a human timescale. RESs "rely mainly on flows of energy carried in physical rather than chemical form" (Jackson, 2000). Research shows that the RE's growth remains policy-driven, with the proponents aiming at "improving energy security, protecting the climate, and encouraging economic development" (Benedek et al., 2018). Despite the growing debate on energy resources' utilization, RE's supporters maintain the need to choose an energy source that incorporates factors such as "cleanliness, cost, stability, efficiency, and environmental effects" (El Araby et al., 2019; Shahzad, 2012). Since RE meets such requirements, studies depict its importance under plentiful supply due to its infinity. Besides, RESs are hygienic and have fewer environmental impacts than conventional fossil energy (Shahzad, 2012; Ibrahiem, 2015). In 2008, roughly 19% of the world's total energy consumption was from renewable sources (Singh et al., 2011). However, only 1% of all RE investments made worldwide were made in Africa and the Middle East (Schäfer, 2016). Research shows Africa as the lowest total energy consumer worldwide (Wamukonya, 2001). Therefore, international agencies and governments have insisted on promoting RE projects, citing their ability to tackle sustainability and climate change concerns (Daly, 2014). As a result, they have invested in "low-carbon energy, electricity networks, and energy efficiency," which increased from 39% in 2014 to 45% in 2015 of the total energy investment worldwide (Dranka et al., 2020). Although specific challenges have erupted, global organizations have escalated RE capacity, focusing primarily on solar and wind PV systems. With these advantages, scientists and economists urge individuals to adopt RE to reduce their energy costs and enhance sustainability.

There are numerous sources for RE. Figure 3 displays the increase in RE worldwide. A notable one involves solar energy. Its generation occurs through "direct" solar energy, a RES drawn from the sun (Owusu and Asumadu-Sarkodie, 2016). Solar energy is currently the most available RES globally, leading to its consideration as the "most suitable substitute for fossil fuels" (Qazi et al., 2019). According to a report released in 2000, solar radiation's absorption on earth was at "an average rate of 120,000 TW (Terawatt), around four orders of magnitude (10,000 times)

Figure 3: Global renewable electricity growth



Source: (Dranka et al., 2020, p. 340)

higher than the current global energy demand" (Jackson, 2000). Its harvest occurs through solar panels, which generate PV power and produce electricity (Seifeddine and Abdeldjalil, 2017). Solar energy's utilization is also in solar lights, water heaters, and calculators, with researchers considering it effective in energy storage from the sun during the daytime and later used at night (Shahzad, 2012). The World Energy Council (WEC) provides that "the total energy from solar radiation falling on the earth was more than 7,500 times the world's total annual primary energy consumption of 450 EJ" (Owusu and Asumadu-Sarkodie, 2016). Therefore, despite its limited embrace, solar energy is crucial for meeting RE needs.

Several governmental strategies and plans are currently focused on sustainable development (SD). It functions in three dimensions, including "economic, social, and environmental" (Güney, 2019). Since the world grapples with climate change, researchers are proposing the need to explore the relationship between RE use and SD to facilitate "energy access, promote a healthier environment, and achieve energy access equality among people" (Aboul-Atta and Rashed, 2021). The UN developed the SDGs as critical blueprints to guide societies to overcome challenging issues. Scholars encourage the SDGs' adoption to help solve the current energy crisis through RES and technologies (Dincer, 2000). The UN defines the SDGs as "a universal call to action to end poverty, protect the planet, and ensure that all people enjoy peace and prosperity" (Aboul-Atta and Rashed, 2021). Despite having seventeen goals and 169 targets, the SDGs' focus on renewable energy is the seventh one, including "affordable and clean energy" (Aboul-Atta and Rashed, 2021). Researchers cite the need to attain "net-zero carbon emissions by 2050 through technically feasible, cost-effective, and socially acceptable interventions" (Brent, 2021). The goal has pushed governments, individuals, and intergovernmental agencies to realize a sustainable future, mainly due to the SDGs' unique opportunities to replace existing petroleum-derived materials with RES. According to the available research, the UN, through its SDGs, aims to combat climate change's impacts in the twenty-first century, creating a sustainable future for the coming generations (Owusu and Asumadu-Sarkodie, 2016). With this approach, the SDGs would establish a shift from fossil fuels to RES. Green economic growth that relies on RE ensures not only environmental but also economic sustainability (Wei et al., 2023). However, the COVID-19 pandemic had a multifaceted impact on energy transition, including changes in global supply chains, energy poverty, government support, RE production capacity, and divestment from fossil fuels (Tian, 2022).

Researchers also insist that RESs have multiple opportunities, including energy security and access and the urge to realize social and economic development. The United Nations' (UN) sustainable development goals (SDG) have depicted positive strides towards renewable energy (RE) realization. However, the COVID-19 pandemic's eruption has pushed the European Union (EU) to revamp its European Green Deal (EGD), arguing that it would address emissions-intensive areas through the emission trading scheme (ETS) (Zhongming et al., 2021). Besides, the involved stakeholders cite the growing need to achieve Vision 2030's goals of net-zero emissions, maintaining that RE would be essential in achieving sustainable development (SD) through clean energy utilization (Sathaye et al., 2011; Verde and Rossetto, 2020). A notable nation currently embracing RE involves Egypt, with research showing its perfect location and RES abundance, making it effective for clean energy projects. It has also established appropriate mechanisms to advance its policies to accommodate external partners in clean energy production (El-Refai, 2015). Currently, Egypt has partnered with the EU, with the latter considering the move essential towards attaining its RE target at the lowest cost (Pototschnig and Conti, 2021).

Egypt is a lower-middle-income nation, with its economic activities concentrated in the agricultural, industrial, and service sectors. The country has enjoyed an abundance of RES "with high deployment potential," including "hydro, wind, solar, and biomass" (IRENA, 2018). Studies show that the Egyptian government initiated RE applications and technological systems programs in the late 1970s and associated them with other states and international entities. They included "France, Germany, Italy, Spain, Denmark, Japan, the EU, and the United States (US)" (IRENA, 2018). The cooperation helped Egypt install solar water heaters (SWHs) in its new cities. "It also incorporated SIPHSs, wind farms, and PV applications in water pumping, cold stores, desalination plants, and biogas digesters in rural areas" (IRENA, 2018). Such processes paved the way for the Egyptian government's focus on RE.

A notable improvement occurred in 1986 following the New and Renewable Energy Authority in Egypt (NREA)'s establishment to develop RES in Egypt. The NREA has mainly focused on solar and wind technologies, with research showing its recent expansion to include biomass (IRENA, 2018). Despite such improvements, the country has recorded low per capita carbon dioxide emissions (Kumetat, 2012). Other vital national institutions, such as the Ministry of Energy (MOE) and Egyptian Electricity Holding Company (EEHC), have devoted their efforts to enhancing biomass development. RE resources contributed to 4% of Egypt's primary energy production, with hydro at 3% and wind at 1% in the 2009/10 financial year (IRENA, 2018). The Egyptian government adopted the ESDS Vision 2030, with the core objective of attaining "a competitive, balanced, and diversified economy by 2030 to secure sustainable development and protect the environment" (Salman and Hosny, 2021). Since then, the government has increasingly taken bold steps to diversify its energy sector, focusing on RE development and energy efficiency implementation.

Egypt still operates under the ESDS Vision 2030, which the government intends to depend on to expand its RE contributions. The Egyptian government posits that by relying on Vision 2030's provisions, the country's effective use of RE and energy will positively impact economic growth through augmented businesses (Salman and Hosny, 2021). It also considers its market appropriate for RE, mainly due to the state's qualifications for wind and solar projects (Bälz, 2015). Initially, Egypt was projected to realize 8% and 14% of its total energy production from RE resources by 2021/22 and before 2034/35, respectively. In addition, it anticipated that by "2021/22 and 2034/35, respectively," RE would account for 20 and 42% of its electricity generation (IRENA, 2018). Although it has not attained its initial projection, Egypt has adopted an ISES, an energy diversification approach, to increase RE development and facilitate efficient energy utilization by 2035 (Salman and Hosny, 2021). Studies also depict the country's government through the MOERE and the MOIIC's move to modify its long-term energy strategies. They seek to apply the approach to increase RE input to the total capacity mix by 42% in 2035 (IRENA, 2018). The government hopes to transform its RE sector and achieve energy efficiency with these mechanisms.

The Egyptian government is also investing in RE, a critical strategy towards its 2035 Integrated Sustainable Energy Strategy (ISES) attainment. A notable RE entails hydroelectric energy, with the River Nile currently the primary hydroelectric reserve in the state, generating roughly 13545 GWh yearly. Despite its previous 50% representation of the nation's total electricity in the 1960s and 1970s, hydroelectricity's contribution has decreased to roughly 7.2% (IRENA, 2018). Therefore, the government has started projects to increase hydroelectric stations' power generation. The country also focuses on wind energy. The country is nevertheless "endowed with vast wind energy potential, notably in the Gulf of Suez area," according to Egypt's Wind Atlas (IRENA, 2018). For instance, its distinguished wind system has enabled Egypt to host "large-scale wind projects, especially in the Suez Gulf region where the wind speed reaches 10 m/s" (Taman, 2015). Following the discovery of other new regions to the west and east of the Nile River, the Egyptian government maintains its need to save conventional fuel by utilizing wind energy for significant electricity generation. Since wind-generated electricity has evolved in Egypt, the current call to raise its production highlights the government's commitment to RE.

Other RESs that the Egyptian government encourages include solar and biomass energy. "Egypt enjoys favorable solar radiation intensity," with its solar atlas revealing that the nation receives "between 2900 and 3200 h of sunshine annually" (IRENA, 2018). The Global Atlas platform has reiterated a similar trend, placing Egypt as one of the leading regions for solar energy's exploitation for thermal heating applications and electricity generation. Studies reveal that "Egypt lies in the Sun Belt area," which has allowed it to enjoy "direct normal solar irradiation from 2000 to 3200 kwh/m^2 per year" (Taman, 2015). As a result, Egyptian authorities are currently adopting solar energy in PV applications, including street lighting and rooftop systems (IRENA, 2018). The process has attracted other key achievements, such as developing centralized grid-connected and distributed solar PV, concentrated solar power, and solar water heating (African Energy Reports, 2020).

Egypt's low energy levels have exposed it to the transition from exporting energy to importing it to meet domestic demand. Research shows that the country only has a 23% energy surplus and continues to experience budgetary deficiencies, limiting its successful RE realization (Taman, 2015). Significant challenges relate to the economy, primarily from the lack of convenient mechanisms to fund existing and new RE projects. The nation's private sector's participation in the RE market also remains limited due to high costs and taxes. For instance, "commercial interest rates on loans given to the SMEs are almost 18%," which discourages them from "investing in the RE sector" (Salman and Hosny, 2021). Although Egypt has relied on the Facility for Euro-Mediterranean Investment and Partnership (FEMIP) through the European Investment Bank, its small and medium enterprises RE deployment support has not succeeded. Researchers link the problem with stiff loan requirements, which have subjected the private sector to limited acquisition opportunities (Tagliapietra, 2015). The problem has forced Egypt to import energy to sustain its operations.

Another challenge includes technical constraints that hinder the RE sector's development. Usually, RE requires highly skilled and trained individuals who can maintain and achieve the desired quality (Eliett, 2021). Unfortunately, Egypt struggles with inadequate training centers, exposing its population to limited skills needed to work in the RE field (Taman, 2015). Researchers also link the problem to a lack of appropriate infrastructure. Since the RE sector requires advanced infrastructure, a lack of it "causes a delay in the expansion of rooftop PV installations" (Salman and Hosny, 2021). This obstacle exposes Egypt to postponing its rapid RE application expansion. Despite the nation's government's push to promote regional electricity transmission, insufficient infrastructure has distorted the approach, lowering RE development (Tagliapietra, 2015). Accompanied by the few European countries involved in helping Egypt expand its RE sector, it has become challenging to realize success.

Social challenges also impede the RE sector's growth in Egypt. The problem mainly occurs due to limited public awareness (Taman, 2015). Studies highlight that the energy sector has contributed immensely to Egypt's development, employing roughly 300,000 individuals by 2017 and generating approximately 20% of the nation's GDP by 2017 (Salman and Hosny, 2021). Despite increasing awareness, many Egyptians still lack adequate information about it, with some viewing it as a non-contributor to the country's growth. Others are also unwilling to learn about the RE sector's relevance in todays and future economies (Bernal-Trujillo, 2021). Besides, Egyptians have primarily depended on traditional energy, which has prompted them to oppose the new form of RE (Taman, 2015). With these obstacles, pushing for RE expansion and implementation has proved an uphill task.

Egypt faces legal and environmental obstacles. While it has RE policies, they do not attract people to adopt another alternative energy source. The problem's culmination is inadequate laws, which lower individuals' obligations to use RE (Taman, 2015). Research shows Egyptians' freedom to utilize their preferred form of energy, with very few willing to embrace RE. While the New and Renewable Energy Development and Usage Authority (NREDUA) has mandated RE development, the citizens have not welcomed the move yet, creating a vacuum in its implementation. Usually, RE has impacts on environmental and social fields. Unfortunately, Egypt has not encouraged researchers to study such effects, lowering its citizens' understanding of the issue. Scholars argue that RE's prerequisite involves stopping pollution caused by other energy sources, including coal. However, due to limited studies, Egypt does not have proper mechanisms on how RE would help improve its "energy supply reliability and organic fuel economy" (Salman and Hosny, 2021). Therefore, these challenges depict Egypt as a struggling nation to incorporate RE to align with its 2030 vision.

The EU has maintained the need to lower total energy consumption and augment RE. Initially, the union planned to reduce its total energy consumption by 20% by 2020 and increase its share of renewable energy by the same amount. Other primary motives entail realizing environmental protection, competition improvement, and increased security of RE supply (De Alegra et al., 2009; Pacesila et al., 2016). The approach entailed reducing greenhouse gases and air pollutants' emissions through augmented energy efficiency, RE adoption, national climate strategies, saving the used energy, and promoting RES utilization. Studies depict energy cooperation as an essential pillar in "Egyptian-European relations" due to "Egypt's longstanding position as an exporter of energy in the region and Europe's high import dependency on others for securing its energy needs" (Yousef, 2016). Besides, the EU has predicted developing nations will be dominant energy consumers by 2030, prompting the need for total energy production escalation and collaboration (Bozhilova, 2009; CAN et al., 2017). Despite the geopolitical dangers to Europe's energy supplies, the two regions have maintained their relations. Egypt depends on its European counterparts for funds and technical assistance to harness its energy. The European member states also view it as their new supply route for RE (Ozturk, 2013). According to scholars, enhancing development cooperation in RETs would play a fundamental role in enabling SD "in low and lower-middle-income countries" (Kruckenberg, 2015). Besides, although EU-North Africa energy relations have focused heavily on renewables, researchers decry insufficient attention paid to the inconsistencies of policy-making processes (Kilpeläinen, 2013; Lindt, 2021). Therefore, new concerns have revolved around climate change and sustainability, with the EU pushing its member states "to revise their energy policies to create "greener" solutions" (Czeberkus, 2013). It also insists that the member states make quantified contributions and benchmark to plan and review the specified targets (Meyer-Ohlendorf, 2015).

Two of the main benefits of RE are reducing CO_2 emissions and saving on social costs. One study done by Russell (2019) provides a framework for estimating and reporting avoided emissions and provides guidance on how to estimate avoided emissions. Shenot (2014) noted how difficult it is to calculate the saved emissions, especially considering that doing so necessitates a complete comprehension of the cumulative impacts of all emissions from all sources that can have an impact on ambient air quality over any given time period. The author discussed how, with time, evaluations, potential studies, and such calculations should become standard practice. However, it is still not an exact science. Adrian et al. (2022) found that the world can realize a net gain of 77.89 trillion USD by weighing the present value of the benefits from avoided emissions against the present value of the costs of terminating coal and the costs of replacing it with renewable energy.

This paper fills a critical gap in the literature by highlighting the significance of solar projects supported by the EBRD in collaboration with Egypt, and quantifying the reduction in emissions and social costs saved as a result of these projects.

3. METHODOLOGY

The study follows defined steps to calculate the saved social costs of the selected EU-funded RE projects in Egypt. These steps are as follows:

1- Determining the amount of the avoided emissions. According to the U.S. Department of Energy, every kilowatt-hour (kWh) of electricity produced from solar power saves 0.846 pounds of carbon dioxide.

$$AAE=PE*SP \quad (1)$$

Where AAE is the amount of avoided emissions, PE is the produced electricity in kWh per year, and SP is the saved pounds of carbon per kWh.

2- Convert avoided emissions into tons. This is the cost of carbon emissions that the solar energy project avoids, given that 1 lb of carbon equals 0.0005 tons. Thus, the tons of avoided emissions are calculated with the following formula:

$$TAE=AAE*0.0005 \quad (2)$$

Where TAE is the tons of the avoided emission, and AAE is the amount of the avoided emission in lbs.

3- Calculate the saved social costs. The saved social costs are equal to the cost of avoided emissions multiplied by the social cost of carbon which can be calculated as the following:

$$SSC=TAE*SCC \quad (3)$$

Where SSC is the saved social costs, TAE is the tons of avoided emissions, and SCC is the social cost of carbon in US dollars. The social cost of carbon is a measure of the economic damage caused by greenhouse gas emissions. It is typically calculated as the present value of future damages caused by climate change. This study assumes the social cost of a ton of carbon as defined by the Environmental Defense Fund (EDF), which is $50.

There are basically two limitations to this study. Firstly, the social cost of carbon is a controversial topic, and there is no single agreed-upon value. Secondly, the methodology does not account for all of the benefits of renewable energy, such as job creation and improved air quality.

The methodology for calculating the saved social costs of carbon is still evolving. However, the methodology described above provides a general framework for conducting this type of analysis. A similar approach was adopted by Hu et al. (2018) in their social welfare calculations.

4. RESULTS

The results of the calculation of the annual savings in social costs are presented in Table 1. The table shows the steps of these calculations. The first column from the left provides the name of the projects in which they are ordered by their capacity, and the second column shows calculations of the electricity expected per project in kWh. For the first project, the amount of electricity produced has already been officially announced by the authorities to be 2.8 terawatt-h (TWh) per year.

To calculate the amount of electricity, a conversion from terawatt-hours (TWh) per year to kWh per year requires a multiplication by one million. For the second and third projects, megawatts (MW) are converted to kWh by multiplying the value by 1000. In both projects, 8 h of operations per day and 365 days per year were assumed. Thus, multiplying the number of hours per day by the

Table 1: Calculations of the saved social costs of the solar energy projects funded by the European Bank for Reconstruction and Development (EBRD) in Egypt

Project		(1) Produced electricity in kWh per year	(2) Avoided emissions per year in pounds of carbon	(3) Avoided emissions per year in tons of carbon	(4) Saved social costs per year in US dollars
(1)	1.8 GW Photovoltaic Project of Benban Solar Park	2.8 TWh/year=2.8 TWh/year *1,000,000,000 kWh/year=2,800,000,000 kWh/year[1]	2,800,000,000 kWh*0.846 lbs CO_2/kWh=2,369,280,000 lbs CO_2/year	2,369,280,000 lbs CO_2/year* 0.0005=1,184,640 tons CO_2/year	1,184,640 tons CO_2*$50/ton=$59,232,000
(2)	200 MW Photovoltaic Project of Kom Ombo	200 MW* 1000=200,000 kWh*8 h/day*365 days/year =584,000,000 kWh[2]	584,000,000 kWh* 0.846 lbs CO_2/kWh=494,064,000 lbs CO_2/year	494,064,000 lbs CO_2/year *.0005=223,942 tons CO_2/year	223,942 tons CO_2*$50/ton=$11,197,100
(3)	6 MW Photovoltaic Project of Dina Farms	6 MW*1000=6,000 kWh*8 h/day×365 days/year=17,520,000 kWh/year[3]	7,520,000 kWh/year×0.846 lbs CO_2/kWh=14,818,320 lbs CO_2/year	14,818,320 pounds CO_2/year *0.0005=7,409.16 tons CO_2/year	7,409.16 tons CO_2/year* $50/ton=$370,458

[1]The amount produced per year is the official amount of electricity announced by the Egyptian Ministry of Electricity and Renewable Energy. [2]8 h of operating per day is assumed. [3]8 h of operating per day is assumed

number of days per year by the value of electricity per year in kWh gives the value of electricity per year.

The second column shows the avoided emissions per year in pounds of carbon. Following the U.S. Department of Energy's defined value of 0.846 metric tons of carbon saved per kWh of electricity produced from solar power, the amount was calculated by multiplying the value from column 2 by this value. To convert the amount of carbon in pounds to tons, in column 3, the value from column 2 is multiplied by 0.0005.

The amount converted is multiplied in Column 4 by $50, assuming that the social cost of a ton of carbon, as defined by the Environmental Defense Fund (EDF), is $50.

Results show that project 1 saves around 1,184,640 tons of CO_2/year, project 2 saves around 223,942 tons of CO_2/year, and project 3 saves around 7409 tons of CO_2/year. The three projects funded by the EBRD save around 1,415,991 tons of carbon per year in Egypt. The saved social costs are about $59,232,000, $11,197,100, and $370,458 from projects 1, 2, and 3, respectively. The results suggest that, only through solar energy projects, the EBRD helps Egypt save a combined value of about $70,799,558 per year, which promotes sustainable development in the country. Figures 4 and 5 provide visual representations of the results.

Figure 4: Avoided emissions of EBRD solar projects in Egypt in tons of CO_2

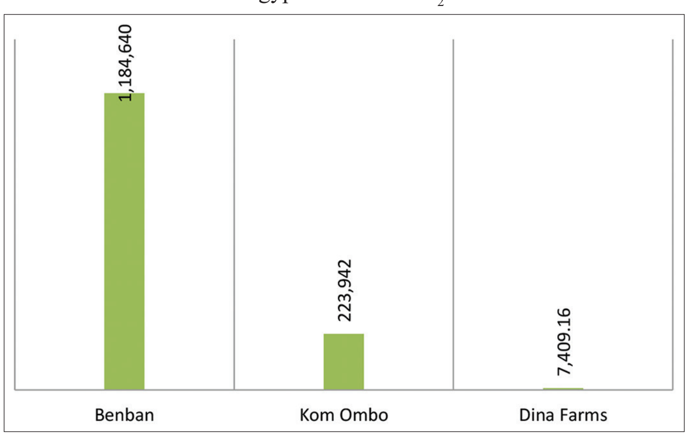
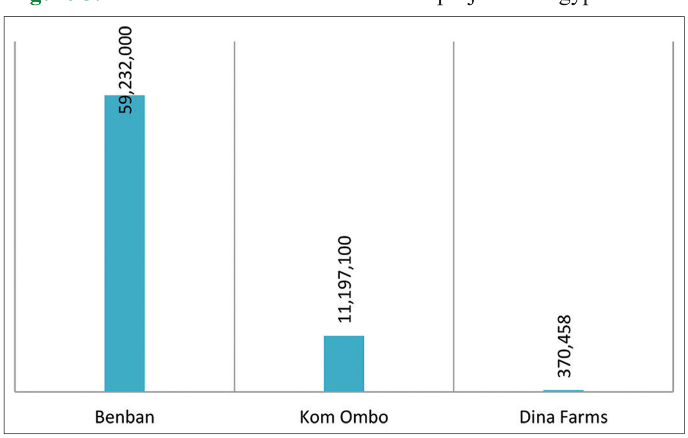


Figure 5: Saved social costs of EBRD solar projects in Egypt in USD



5. CONCLUSION

Egypt boasts a fast-growing renewable energy industry. And, with significant potential to develop the sector even more, the country can add even more value to its economy and accelerate its green transition. The EBRD has played a crucial role in Egypt's development journey, serving as one of its primary partners. The organization has invested in groundbreaking projects and has been instrumental in driving policy reform, particularly in the creation of a regulatory environment that fosters growth and innovation. Moving forward, the EBRD will continue to support Egypt's progress through its various initiatives and programs. This study found that, through financing, the EBRD had helped Egypt save more than $70,799,558 per year by avoiding 1,415,991 tons of carbon. The results show the EBRD's support for Egypt's solar energy sector has been instrumental in helping the country diversify its energy mix and reduce its dependence on fossil fuels. Through its continued engagement with Egypt's government and private sector, the EBRD is helping to build a sustainable and resilient energy system that will benefit both the country and the wider region. Economic, environmental, and social implications of this successful relationship can be summed up as follows:

- Energy Security: The funding of solar power plants in Egypt by the EBRD can enhance the country's energy security by diversifying its energy sources. Solar power is a renewable energy source that can reduce Egypt's dependence on fossil fuels, which are subject to price volatility and geopolitical risks.
- Job Creation: The establishment of solar power plants requires a significant workforce, ranging from construction to operation and maintenance. The funding provided by the EBRD can contribute to job creation in Egypt, particularly in the renewable energy sector. This can help alleviate unemployment rates and stimulate economic growth.
- Foreign Direct Investment: The financial support provided by the EBRD towards the establishment of solar power plants in Egypt has the potential to draw foreign direct investment (FDI) into the RE industry. This investment can bring in new technologies, expertise, and capital, which can further boost economic development in the country.
- Climate Change Mitigation: Solar power is an environmentally friendly and sustainable form of energy that generates very low levels of greenhouse gas emissions when compared to traditional fossil fuels. By funding solar power plants in Egypt, the EBRD can support the country's efforts to mitigate climate change and reduce its carbon footprint.
- Air Quality Improvement: Solar power plants do not release harmful substances like sulfur dioxide, nitrogen oxides, or particulate matter into the atmosphere while generating electricity. By promoting solar energy through funding, the EBRD can contribute to improving air quality in Egypt, reducing respiratory diseases and other health issues associated with air pollution.
- Natural Resource Conservation: Solar power does not require the extraction of finite resources like coal or natural gas. By investing in solar power plants, the EBRD can help conserve Egypt's natural resources and reduce the environmental impact associated with resource extraction.

- Access to Electricity: The funding of solar power plants in Egypt can improve access to electricity, particularly in rural and remote areas where grid connectivity is limited. Solar power has the potential to offer a consistent and environmentally friendly means of generating electricity, thereby improving the standard of living for communities that currently do not have access to electricity.
- Energy Affordability: Solar power has the potential to reduce electricity costs in the long run, as it relies on an abundant and free source of energy (sunlight). By supporting the development of solar power plants, the EBRD can contribute to making energy more affordable for households and businesses in Egypt.
- -Technology Transfer: The funding provided by the EBRD can facilitate technology transfer and knowledge sharing between international investors and local stakeholders. This can help build local capacity in renewable energy technologies, fostering innovation and creating opportunities for Egyptian companies to participate in the global renewable energy market.

However, there is still significant potential for further investment in the country's solar energy sector. Allocating more resources to the country or partnering with other financial institutions to co-finance solar energy projects are recommended steps to finance more solar energy in Egypt. It is advised that future studies adopt a similar methodology, include more RE projects in their calculations, and broaden their field of study to take into account all EU investments in RE in Egypt.

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