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Environmental Policy to Develop a Conceptual Design for the Water–Energy–Food Nexus: A Case Study in Wadi-Dara on the Red Sea Coast, Egypt

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Abstract: In the next twenty years, the scarcity of food shortage and drinking water will appear in Egypt due to the growth of industries and agriculture. This paper develops a conceptual design of the new technologies in the field of water–energy–food in new cities. Border lines are the internal relationship, external influence, and linkage system evaluation for WEF nexus. The major problems of using fossil energy in desalination are emissions and non-renewability, as well as the preference for dispersed freshwater production instead of concentrated output. The design of a desalination system that is integrated with renewable energies is critical these days. This type of system can also reduce the production of environmental pollutants due to reduced energy consumption and transfer of freshwater. GIS data from the United Nations have confirmed the existence of an underground reservoir in Wadi-Dara that can cultivate 1000 acres using smart farming techniques to reach a circular economy for an integrated solution between the water–energy nexus. The possibility of cultivating a hundred acres in Wadi-Dara on the Red Sea coast exists, through which about one million people could be settled. In this comprehensive review, we conducted a deep study in order to establish a sustainable integrated lifestyle in the Dara Valley region in terms of the availability of potable water, clean energy, and agriculture. Sustainable integrated solutions were conducted for seawater desalination using beach sand filtration wells as a pretreatment for seawater using renewable energy, e.g., wind energy (18% wind turbines), and photovoltaic panels (77% PV panels). Strategic food will be cultivated using smart farming that includes an open ponds cultivation system of microalgal cells to synthesis (5.0% of bio-fuel (. Aqua agriculture and aquaponics will cultivate marine culture and integrate mangrove, a shrimp aquaculture. A municipal waste water treatment is conceived for the irrigation of shrubby forests and landscapes. Mixotrophic cultures were explored to achieve a sustained ecological balance. Food, poultry and animal waste management, as well as a cooker factory, were included in the overall design. The environmental impact assessment (EIA) study shows a low risk due to anticipated net zero emissions, a 75% green city, and optimal waste recycling. This research assists in combining research efforts to address the challenging processes in nexus research and build resilient and sustainable water, energy, and food systems.

Keywords: Wadi-Dara valley; sustainability; water–energy nexus

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1. Introduction

Today, the world faces the challenge of survival due to the diminishing of our limited resources and the accelerating effects of climate change in recent times. In total, 2 billion people lack access to safely managed drinking water at home, and 771 million entirely lack access to safe water [1]. According to the latest International Energy Agency (IEA) data, about 775 million people live without electricity, a number which increased by 20 million in 2022 [2]. According to the recent United Nations report, the number of hungry people worldwide rose to 828 million [3]. The increasing rates of water scarcity, poverty, desertification and other effects of climate change require a radical rethink of our limited resources. Developing interconnected channels between our limited resources to reach the maximum sustainable benefits may solve the resource scarcity with climate change mitigation. Numerous international nonprofit organizations (IRENA, UN, FAO), as well as academic researchers, have created "nexus reviews" that provide readers with an overview of the various modeling and management techniques used in nexus studies [4–8]. Food and agriculture nexus tools offer a simple approach for particular evaluation. According to FAO, the applied tools are aimed at communication and building awareness (FAO, 2018) [9]. The Water–Energy–Food (WEF) Nexus Research Community has responded to these issues with proposals for integrating current frameworks and resources [10–14].

Africa is one of the areas most affected by climate change. It has the highest number of hungry people in addition to the lack of access to drinking water and electricity. Egypt plays an essential role in cooperation with Nile basin countries to mitigate poverty and secure water resources. Egypt attaches utmost importance to the water issue in terms of preserving its water resources and good management of these. This has been translated into many comprehensive and specific legal agreements with the Nile basin countries, which mandate that everyone to respect them and not violate them [15,16]. In return, Egypt cooperates with other Nile basin countries and participates in many development projects [17]. Egypt has also contributed to establishing many dams and underground drinking water stations and has prepared the essential investigations for projects to build multi-aim dams to provide drinking water and electricity to the African countries' citizens. Among the major agreements is the agreement of 1959 [18], according to which Egypt obtains 55.5 BM^3 of water annually, Sudan receives 18.5 BM^3, and the total river revenue is 84 BM^3. About 10 BM_3 are lost during the flow from south to north due to leakage and evaporation. In addition, the 2015 principles agreement declaration between Ethiopia, Sudan, and Egypt in Khartoum confirmed cooperation based on understanding, benefits, and gains for all beneficiaries. This agreement is based on international law principles and understanding the water requirements of downstream and upstream countries in various aspects [19]. Egypt's water resources are estimated at 81.39 BM_3 annually, most of which comes from the Nile River water, in addition to minimal amounts of desalination, rainwater, deep groundwater, and treated wastewater.

In contrast, the total water needs in Egypt reach about 114 BM3 annually (as per the Water Resources Ministry report on 28 March 2021) [20]. The surface groundwater reimburses the gap and agricultural wastewater reuse in the valley and Delta, in addition to importing food products from abroad, corresponding to 32.61% of water annually [21]. A lack of water can impede agricultural production. However, achieving a balance between food security and water sustainability is generally difficult [22–24]. Desalination is a process that removes dissolved minerals and salts from seawater, brackish water or treated wastewater. The water of the oceans and seas is salty; thus, it is not directly utilizable. Therefore, we can conclude that some special processes are needed to desalinate this salty water. Better water quality will cut overall costs and improve any desalination plant's operating efficiency. These improvements can range from eliminating scale and preventing erosion in water and steam-carrying equipment, leading to reduced maintenance and retention time for better finished products; therefore, we can say that better water quality = better operation. Most widely applied and commercially proven desalination technologies fall into two main categories: thermal (evaporative) and membrane-based ones. Membrane-based technologies are less energy intensive than thermal techniques. Energy consumption directly affects the cost effectiveness and feasibility of using membrane-based desalination technologies. As shown in Figure 1 [25], many applied techniques can produce desalinated water. The choice of technique mainly depends on the feed water source and the required quality of obtained water.

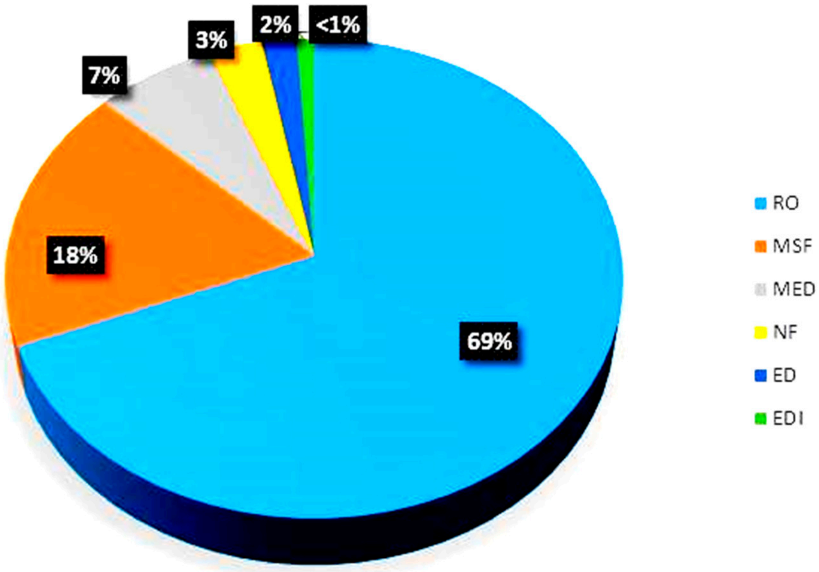

Figure 1. Distribution of water desalination applied techniques for desalinated water production all over the world (RO: reverse osmosis, MSF: multi-stage flash, MED: membrane distillation, NF: nanofiltration, ED: electrodialysis, EDI: electrodeionization).

As shown in Figure 1, there are two main technologies: membrane-based technologies and thermal technologies. Membrane-based technologies represent 77% of the total desalinated water production where RO is the major applied technique, which represents 70% [26]. Thermal technologies (MSF and MED) represent only 33%. The illegal and indiscriminate construction on agricultural lands wasted large areas of agricultural land that represent the main source of our food. This investigation presents the dimensions of the problem and how to benefit from planning for urban expansion outside the governorates. The new cities are subject to a national plan at a high level that meets the needs of each governorate in terms of population and job opportunities. In our current conceptual design, we proposed a new city in the desert and near the Red Sea coast called Wadi-Dara (WD), which is located 47 km south of Ras Ghareb and 113 km north of Hurghada. The village of Wadi-Dara is located on the main paved asphalt road. The most important features for WD are: more than 75% of the land is paved as shown in Figure 2, and the rest of the area is hills and sand blocks; there is no electricity network, no fresh water source and no industry or agriculture. Its winds are strong most of the year because it is a coastal city, though it does not have a port. Regarding the sun irradiation, WD (black circle) has high sun irradiation, reaching 2548 kwh/m^3 per year. The underground water reservoir in Wadi-Dara is estimated by the head of the Regional Center for Space Science and Technology at the United Nations [27] to be sufficient to cultivate 1000 acres using modern technology. Harnessing the WEF nexus tools with the demanded integrated solutions of the Wadi-Dara area will lead to sustainable development with an enhanced circular economy.

Smart farming is being carried out on a massive scale using the Internet of Things (IOT), artificial intelligence (AI), and agricultural data analysis. This is an example of creating interconnected multidisciplinary channels to achieve the maximum benefits, something which is applied in most advanced countries. Agricultural data analytics offers farmers practical and pertinent insight for smart agriculture, leading to increased crop productivity and yield security [28–30]. A very significant amount of remote sensing (RS) data has been made available for agricultural research and other uses as a result of the advancement and evolution of earth observation (EO) technology, notably satellite remote sensing (SRS) [31–33]. Using agricultural data analytics and machine learning (ML), it has been possible to assess the performance of crops in various geographic locations with particular field conditions as well as the economic impact of natural disasters on yield production [34,35]. To forecast how crops will behave in various scenarios under certain field conditions, integrative and multi-scale AI models have been applied [36–41]. Nowadays, mobile technology has spread to even the most remote regions of developed countries. The spread of smart mobile technology into the most rural and isolated regions of developing countries offers an unparalleled opportunity to connect rural producers with urban consumers and connections to foreign investors who can support investment and knowledge transfer [42–44]. With the correct platform, it is possible to build lasting value, increase financial inclusion, enhance food safety, and eventually enable less privileged farmers to utilize the existing agricultural resources to their fullest potential [45]. In addition, Chlorella, Schizochytrium, Arthrospira, Nannochloropsis, Scenedesmus, Euglena and Haematococcus are microalgae genera that can be applied as aquatic and animal feed [46–49]. Considering this application, several research studies have already been performed, aiming to analyze microalgae's effect on animal feed. Microalgae have been studied for partial protein replacement, meat and egg yolk quality improvement, and immune response [50]. The proposed conceptual design of the WEF nexus in this work based on the actual area using the available data of its resources will benefit policymakers, investors, and the local community. We introduced an accurate and affordable solution for the sustainable development of the WD valley.

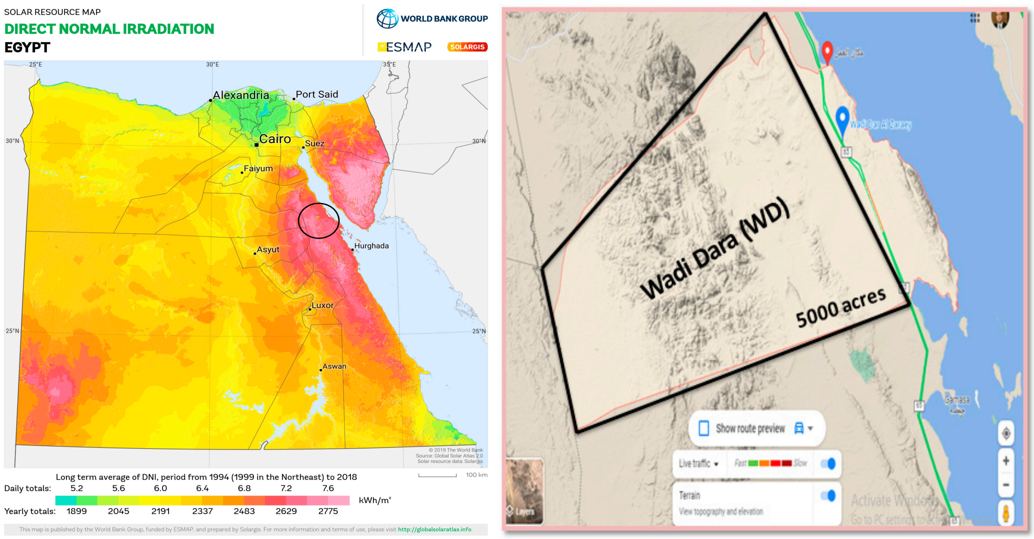

Figure 2. Wadi-Dara (WD) location at Red Sea coast and sun irradiation.

Significant efforts have been undertaken to explore the WEF nexus from various aspects, including calculation of resource flows and their dependencies, assessment of technology and policy applications. In addition, several studies have been published that illustrate the concepts of WEF nexus and nexus governance or implementation. This helped improve people's perceptions about the WEF nexus. However, none of the reviews provides a critical analysis of nexus concepts, research questions, and their implications on the selection of modelling approaches. Hence, in this paper, we provide a critical review on the water–energy–food nexus from three aspects, including the nexus concepts, research questions and methodologies, and identify the directions and challenges for future research. This will help bring research efforts together to address the challenging questions in the nexus and develop the consensus on building sustainable and resilient water, energy and food systems. By selecting policies and management structures that maximize WEF relations, including water–energy (water for energy and energy for water) and water–food (water for food) interconnections, the project aims to maximize human-environmental security in the Wadi-Dara on the Red Sea Coast. Our strategy is based on the concept that through strengthening the connections across WEF clusters, transformative, sustainable solutions may increase human-environmental security and reduce vulnerability. There are compromises and conflicts between the several material users in this case as well as among the WEF resources.

2. Conceptual Design

Design

Wadi-Dara on the Red Sea coast, Egypt, is the future city conceived here. We assume a minimum capacity of the WD city to be around 1000 citizens. Rough calculations and a pilot model have been designed for energy consumption, water consumption, and housing needs per capita on both scales; lower capacity (1 K citizen) up to higher capacity (1000 K citizen) as clearly shown in Figure 3. According to the background paper for the state of food security and nutrition in the World 2020 FAO [51,52], we design a pilot model depending on FAO official reports. Water–energy–food nexus is a closed syndrome in which the factors depend on each other; we cannot secure food without securing water or energy and vice versa. The growth rate of population at which the range expands and the invasion speed is the basic descriptive statistic for invasion dynamics is calculated according to Equation (1) [53]. The λ is determined by the environment and by the life cycle of the population.

$$\frac{\partial n}{\partial t} = f(n)n + D\frac{\partial^2 n}{\partial x^2} \quad (1)$$

where n (x, t) is population density at location x and time t. These models neglect demographic structure, attempting to capture population dynamics in the density-dependent per capita growth rate $f(n)$. They also neglect possible complexities in the dispersal process that are incompatible with the diffusion formulation.

Figure 3. Conceptual design for Wadi-Dara valley per capita.

3. Results and Discussion

3.1. Beach Sand Filtration Well and Seawater Desalination

According to the conceptual design of this work, the water demand is mainly for domestic use, cultivation and other activities. The only available water source in the area is Red Sea water with total dissolved salts (TDS) values of 42,000 mg/L. Desalination of seawater is considered one of the most intensive energy consumption operations in water treatment technologies due to the high pressure applied to overcome the high salinity of feed seawater, which is accompanied by significant environmental impact as well. Therefore, we proposed to use an integrated system between the vertical sand well filtration and the desalination plant to generate the freshwater demand for domestic use while simultaneously generating other agricultural water demand. It will be covered by the treatment of domestic wastewater and utilizing brine water for other activities, which can produce food and small businesses, as shown in Figure 4.

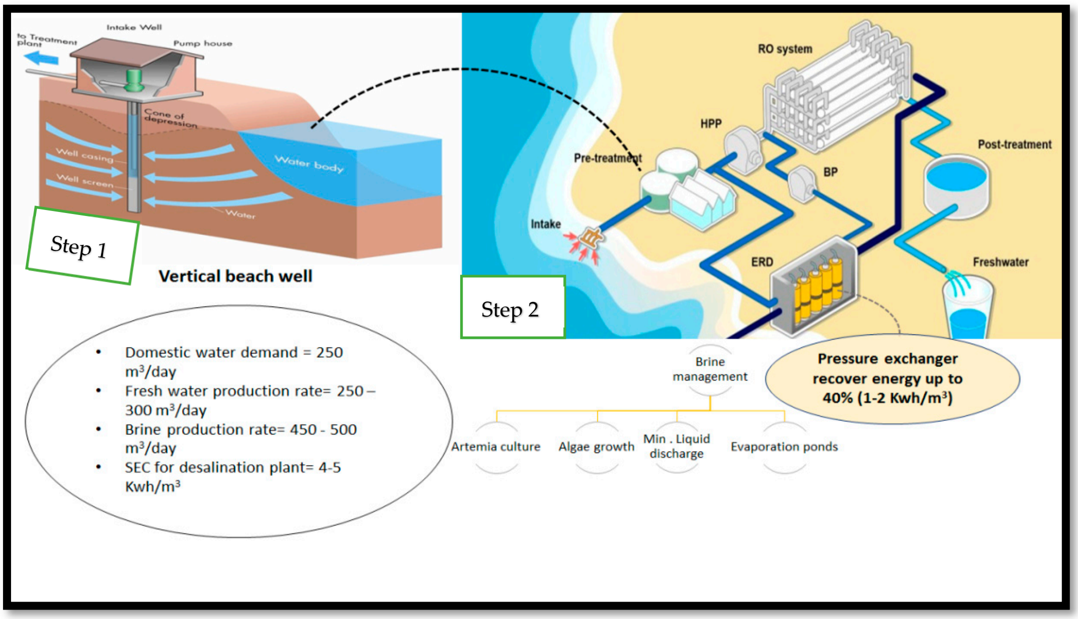

Figure 4. Integration system between vertical sand well filtration and desalination plant.

Through natural filtration, the beach well sand filtration can reduce the spell out of BDOC. Beach wells provide water with less turbidity, constant water temperature, lower dissolved organic content and higher dynamic stability [54,55]. Bartak et al. [56] collected and assessed operational results from the existing beach sand filtration sites of the Dahab beach well desalination plant, Egypt. The results showed a notable reduction in the targeted parameters, particles, colloids, biodegradable fractions of TOC, dissolved organic contents, and higher biostability. It was demonstrated that beach sand filtration would be a valuable pre-filtration step in RO-based drinking water production systems. These beach wells improve water quality by removing particles and organic matter. Comparing to seawater SDI values, 2.6 to 2.7, taken from the nearby Sharm El-Sheik old harbor plant, Dahab beach wells delivered good quality feedwater with an SDI value of 0.27 to 0.82 with no need for further pretreatment. Furthermore, the chemical consumption rate per month used for pre-and post-treatment is about 30% to 50% lower than that at the Sharm El-Sheik old harbor plant.

The applied reverse osmosis desalination process is integrated with eco-friendly beach filtration as a pretreatment technique. The well beach sand filtration technique is environmentally friendly and has low maintenance and operating costs; moreover, it does not require chemical additives or other consumables. Since there is no supplied electric source, we propose to integrate the desalination plant with a photovoltaic (PV) solar system to develop a PV-RO integrated desalination plant [57–61]. In addition, the generated brine could be used to recover consumed energy by using a pressure exchanger with energy recovery of up to 40%. The desalination plant's production capacity is based on the aforementioned area's capita where the water demand is 1000 m^3/person/year. The generated brine wastewater from the desalination plant will be used to grow Artemia, a good feed protein for shrimp. In addition, brine could be used in Nannochloropsisto to cultivate blue tuna mariculture. The integrated forward osmosis membrane bioreactor and fertilized drawn forward osmosis (FDFO) could be used for municipal wastewater [62]. The produced water can be used in agriculture and other food production activities.

3.2. Energy Optimization

Energy optimization means not using conventional energy sources in the built environment to maximize benefits for the climate and people based on efficiency, thereby achieving enhanced energy savings. Sunlight, wind, and biofuels are all sources of energy in WD. Zero fossil fuel and net zero CO_2 emissions are the energy goals set out to achieve sustainability and a long half-life time for the raw materials resources in WD city, as shown in the breakdown chart in Figure 5.

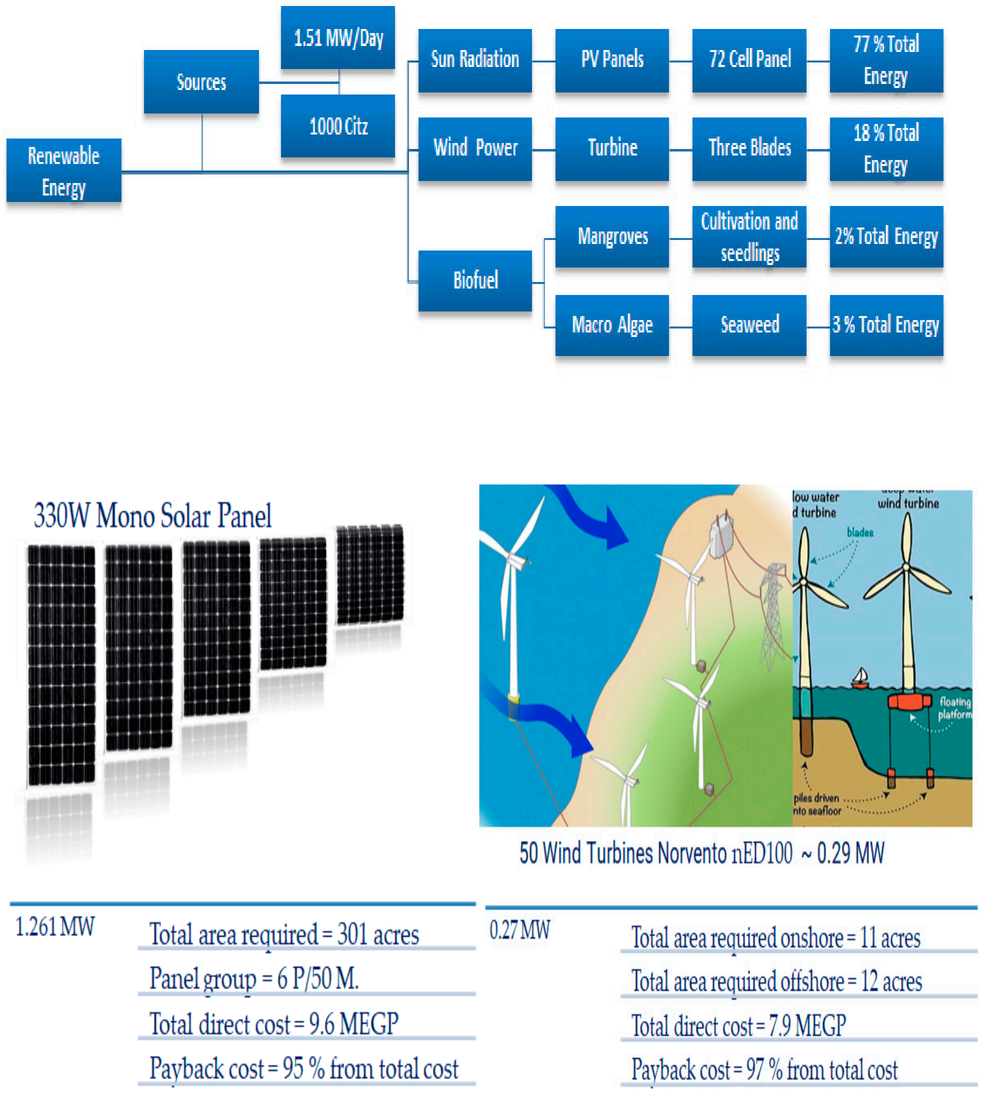

Figure 5. Energy harvesting from PV, wind in WD valley.

Energy harvesting from PV, wind in WD valley as, sunlight radiation is the major energy source, supplying around 77% of the total energy needed using photovoltaic panels (72-cell panels); calculations are estimated as elsewhere [63,64]. Secondly, wind energy is a vital energy source as WD is a coastal city, and the wind velocity is around 10.5 m/s throughout the year. Wind turbine can supply around 18% of the total energy needed yearly. Finally, the minor energy sources are biofuel, such as mangrove and macroalgae, which could supply approximately 5% of the required energy estimated elsewhere [65,66]. When the PV module is selected, the number of modules (unit) is given by Equation (2):

$$\text{N. of modules (unit)} = \text{Solar PV system power (KW)} \times 1000/\text{PV module power (W)} \quad (2)$$

Number of modules per string depends on modules and inverter specifications: V_{mpp} of PV module and M_{PPT} voltage range of inverter. In addition, V_{oc} of PV module and maximum input voltage of inverter, plus Tc (temperature coefficient of V_{oc}) of PV module, according to Equations (3)–(5).

$$V_{mpp.min} = V_{mpp} + [(T_{cell.max} - 25) \times T.C. \times V_{oc}] \quad \text{When T.C. (\%/°C)} \tag{3}$$

$$V_{mpp.max} = V_{mpp} + [(T_{cell.min} - 25) \times T.C. \times V_{oc}] \quad \text{When T.C. (\%/°C)} \tag{4}$$

$$V_{oc.max} = V_{oc} + [(T_{cell.min} - 25) \times T.C. \times V_{oc}] \quad \text{When T.C. (\%/°C)} \tag{5}$$

Number of modules/string (unit) < inverter V_{max}/PV module $V_{oc.max}$. Calculate PV module short circuit current to get $I_{sc.max}$, according to Equation (6).

$$I_{sc.max} = I_{sc} + [(Tcell_{max} - 25) \times T.C. \times I_{sc}] \quad \text{When T.C. (\%/°C)} \tag{6}$$

Number of modules/string (unit) < inverter I_{max}/PV module $I_{oc.max.}$ The angle is approximately 0.9° times of the location latitude. Minimum tilt angle is preferred in the range of 10–15° to allow water and dust evacuation, where minimum ground clearance of 0.5 m is recommended, as shown in Figure 6.

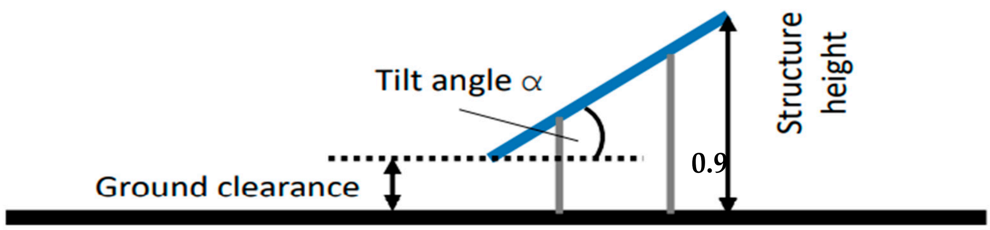

Figure 6. Tilt angle dimensions.

Calculations of minimum values are shown in Equation (7); the minimum sun altitude angle β is on 21 December, which is when the worst shading occurs, β = 90°, Earth's axis tilt angle ≈ 66.56° latitude. Figure 7 shows the minimum raw spacing dimensions.

$$D = W \times (\cos\alpha + ((\sin\alpha/\tan\beta)) \tag{7}$$

where:

$d = D - (W * \cos\alpha)$
$d \approx 1.5 * H$

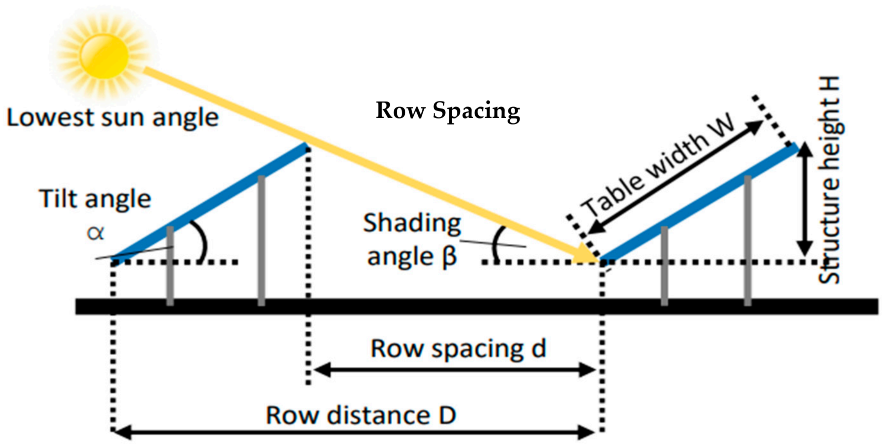

Figure 7. Minimum row spacing dimensions.

As a low-cost method for harvesting microalgae for bulk biomass production, biological flocculation using fungi or bacteria holds many potentials when microalgae production is combined with wastewater treatment because wastewater can provide the necessary carbon source for the flocculating microorganisms [67]. One kg of algae could transform 20% of its biomass into biodiesel according to its content from fatty acids. The other contents from harvested algae-like components: proteins and carbohydrates, which are used in the production of biogas. Figure 8 shows that the energy production from algal biomass is about 5% biofuel of the total production in WD valley.

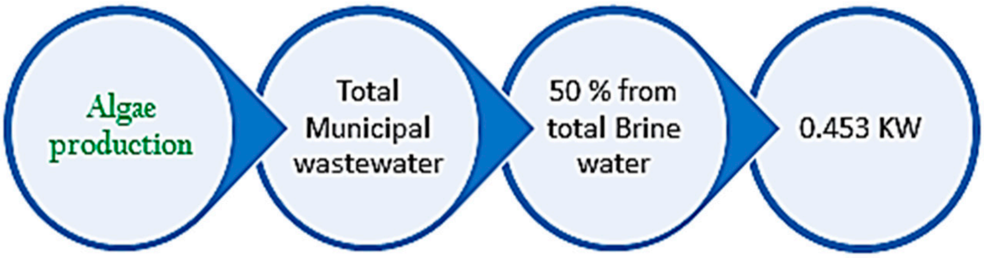

Figure 8. Algae production and total energy recovery in WD valley.

3.3. Cultivation

3.3.1. Crop Virtual Water Content

The virtual water content is the amount of water that could be needed to produce a unit mass of the commodity at the place of consumption. The definition of "virtuality water" can be divided into two categories: production-based method and consumption-based approach [68]. The latter quantifies virtual water in terms of the actual water used to produce a unit mass of the commodity at the place of production. VWC is, therefore, the actual water needed to grow crops, which is converted to vitality after being exported or imported to the place of production or consumption. In this conceptual study, the 99 acres included need 250.186 M^3 water/year. A city's capacity to provide food for in-city use is known as food self-sufficiency (SS). The ratio of grain output to consumption is known as the SS of grain. A city's grain (SS) is greater than 1, suggesting that it produces adequate food for local use and export. Egypt is one of the largest importers of wheat and a nation whose people consume almost one third of their calories from wheat products (FAOSTAT) [47,69]. Therefore, in the conceptual WD city, grains suggested to cultivate are wheat, maize and fava bean. Table 1 summarizes the annual production of different crops in Egypt. In addition, Figure 9 shows the crops' annual cultivation and water consumption per capita for WD valley in order to achieve SS. Moreover, hydroponics will cultivate more than 150 and up to 200 paper crops in one square meter at the WD valley.

Table 1. Annual production of different crops in Egypt [69].

Cultivation of Plants	Production/Kilo. Tones (KT)
Cultivation of plants	6400 KT
Maize production	108 KT
Barley production	4,893,507 KT
Rice, paddy production	16,135 KT
Vegetables primary production	4452 KT

3.3.2. Smart Farming

In order to make the best use of and protect the existing resources in the protected agricultural system, new techniques such as big data, IOT and AI may be used to accomplish sustainable crop production in accordance with the physical, social, and economic situation of a region. We must manage an intelligent agricultural system capable of attaining sustainable production because of the extensive and exhaustive use of natural resources [70].

The primary issue now is the climate, which is continually changing because of the intensive use of natural resources. In this study, we thoroughly examined a variety of technologies, approaches, and models for various applications, including yield estimation, crop sowing dates, cropland monitoring, land surface temperature, irrigation forecast using satellite images, and prediction of water dynamics in the soil. These techniques are useful for reporting environmental conditions such as soil moisture, weather, and prevailing climatic conditions, saving time, manpower, and fresh water. It is suggested that the data be stored continuously for a maximum of 15 days to update the farmer with any changes in the growing conditions [71,72].

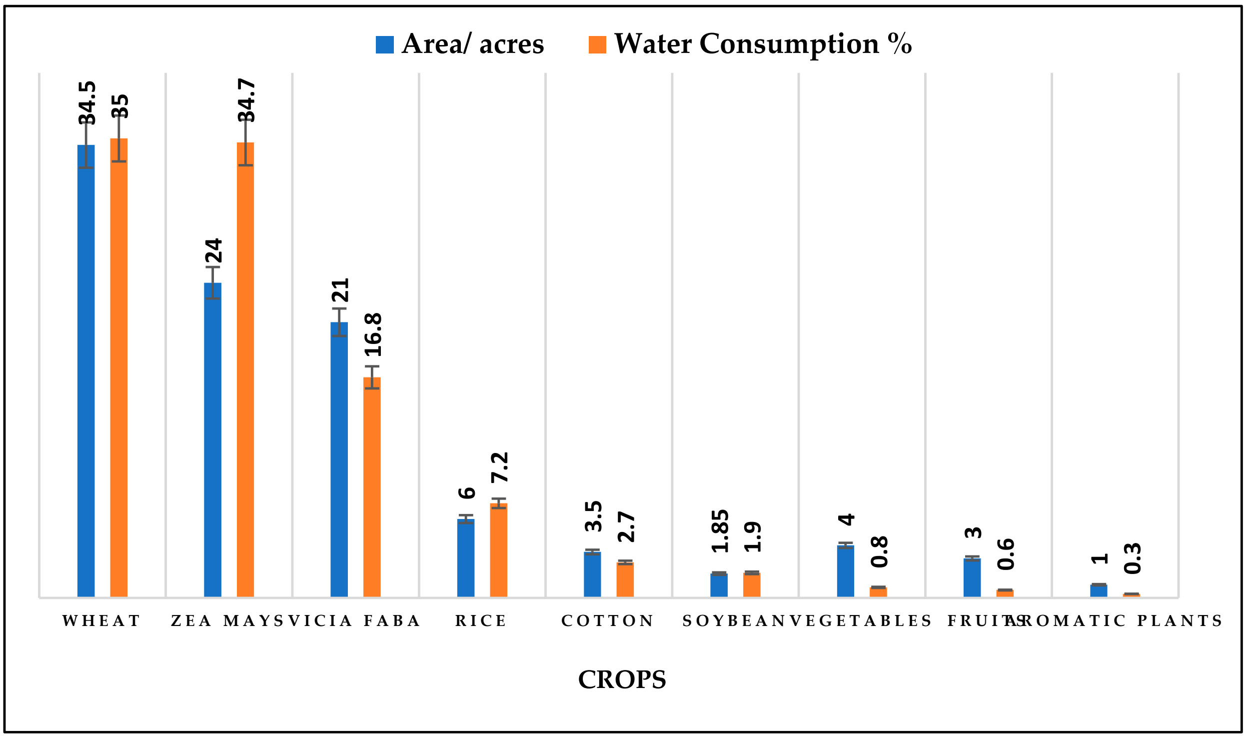

Figure 9. Annual cultivation of plants and its water consumption per capita for WD valley.

3.4. Algae Biomass Cultivation

An open ponds cultivation system of microalgal cells (raceway pond) will be used for algae reproduction to obtain its biomass, as shown in Figure 10. In addition, low-cost photobioreactors produced between hundreds and thousands of tons of microalgae, as reported in Table 2, and it is aimed mainly at high-value products such as nutritional supplements, natural pigments, or aquaculture feed. Figure 8 shows energy production from algal biomass is about 5.0% biofuel of the total output in WD valley. Commercial production of microalgae takes place in special photosynthesis-enhancing reactors, such as closed photobioreactors or open raceway ponds. The biomass concentrations in microalgal cultures are typically modest, ranging from 0.5 g/l in open pond reactors to roughly 5.0 g/l in photobioreactors. Although the microalgae industry has recently created numerous relatively inexpensive designs, the biggest drawback of photobioreactors is their cost [73].

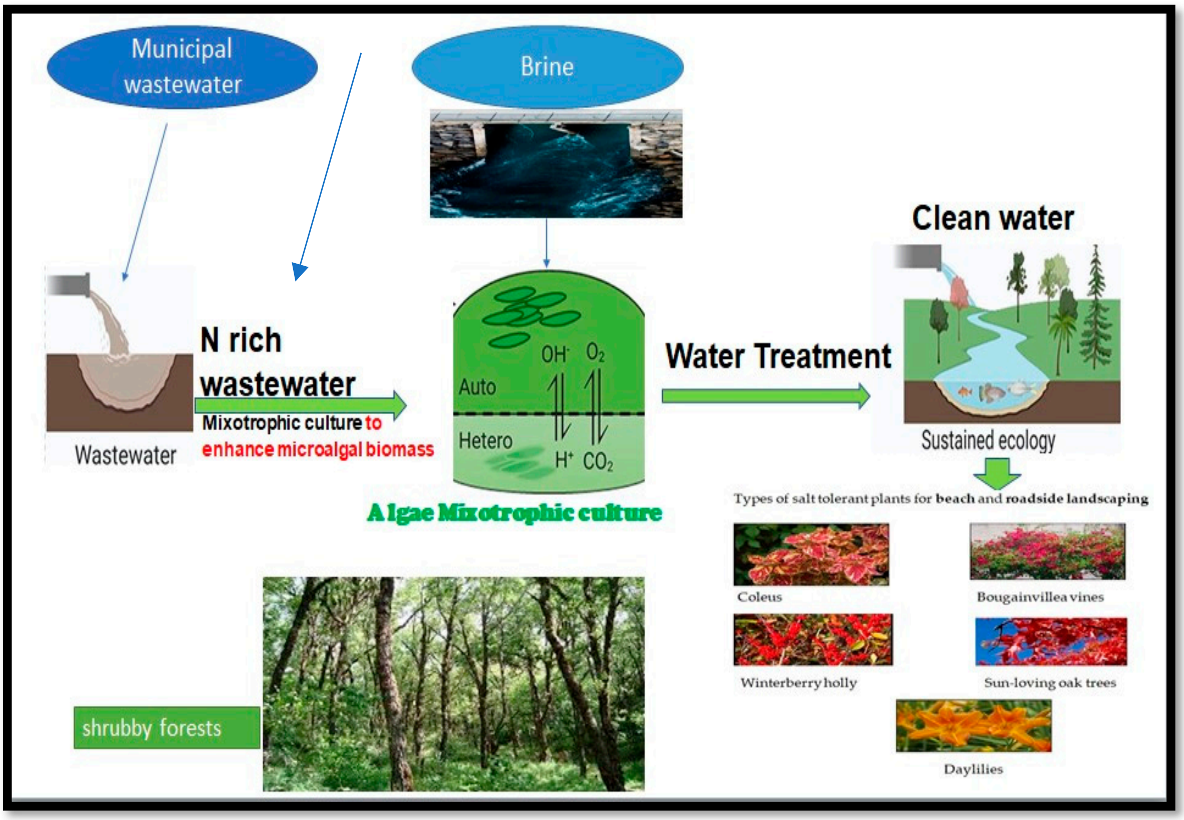

Figure 10. Algae biomass cultivation and its utilization for shrubbery forests and landscaping in WD valley.

Table 2. Types, importance, and effect of microalgae used as aquatic and animal feed [74].

No.	Name of Microalgae	Importance and Effect
1	Chlorella vulgaris	Enhanced meat qualities in Pekin ducks
2	Nannochloropsis sp.	Feed conversion, and fish survival in Nile tilapia
3	Nannochloropsis gaditana	Alternative to current sources for the production of docosahexaenoic acid (DHA)-enriched eggs in hens
4	Schizochytrium sp.	Food for Tilapia
5	Chloroidium	Thermotolerant—and production of palm oil

As a low-cost method for harvesting microalgae for bulk biomass production, biological flocculation using fungi or bacteria holds many potentials when microalgae production is combined with wastewater treatment because wastewater can provide the necessary carbon source for the flocculating microorganisms. One kg of algae could transform 20% of its biomass into biodiesel according to its content from fatty acids. The other contents from harvested algae-like components: proteins and carbohydrates, which are used in the production of biogas. There is a need for environmentally sustainable and energy-efficient methods for the manufacturing of nanoparticles as nanotechnology is used in an increasing number of economic sectors. Algae have been found to be capable of reducing metal ions, which has led to their use in the production of nanoparticles. Numerous studies have been published in recent years due to the ecofriendly, affordable, high-yielding, quick, and energy-efficient nature of algae-mediated biosynthesis of nanoparticles [75].

3.5. Water Management/Municipal Wastewater Treatment for Irrigation

The reuse of wastewater has economic value through the provision of the preservation of freshwater resources. It also reduces the need for synthetic chemicals (fertilizers and pesticides) and provides irrigation with vital nutrients in the water [76–78]. Figure 11 shows a municipal wastewater treatment using a fertilizer solution. This includes a mixotrophic culture to enhance microalgal biomass and lipid production via a consortium of indigenous microalgae and bacteria present in raw municipal wastewater. Types of salt-tolerant plants for beach and roadside landscaping (Coleus, Bougainvillea vines, Winterberry, Sun-loving and Daylilies) and shrubby forests will be irrigated from treated wastewater at WD valley.

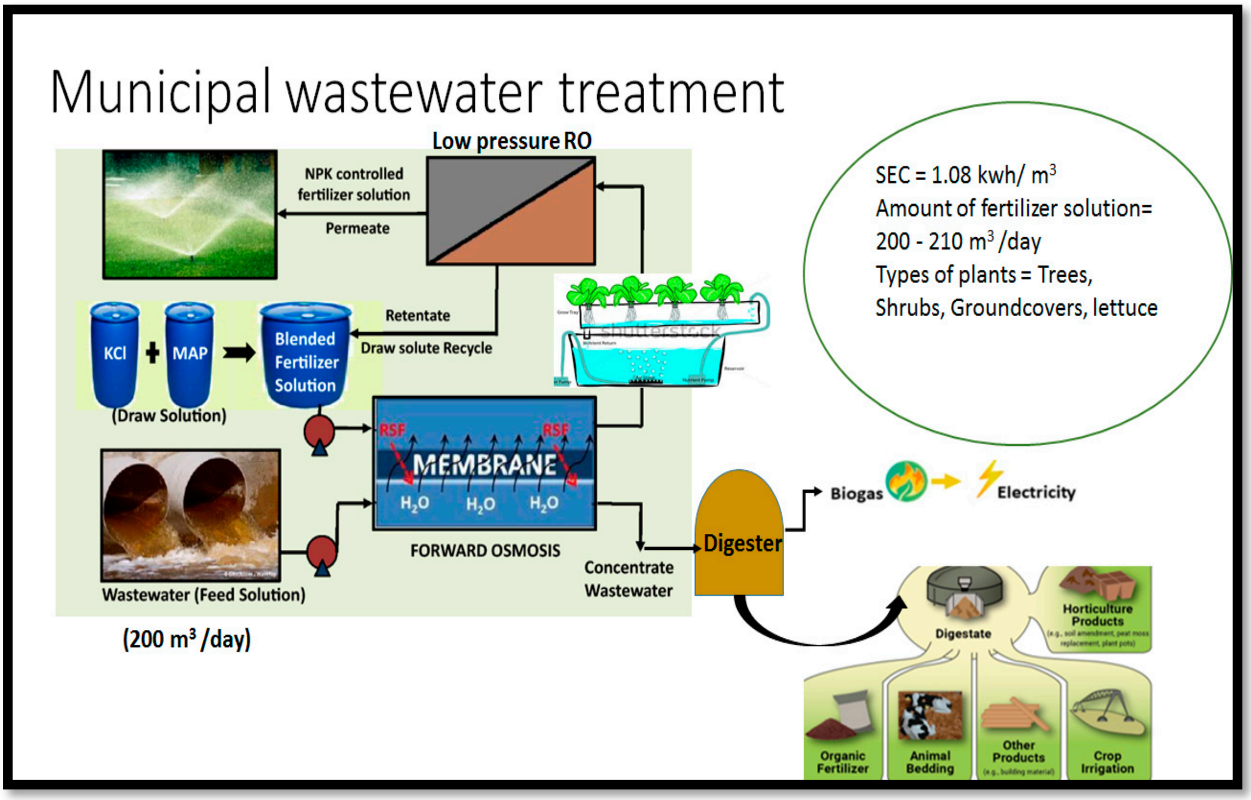

Figure 11. Municipal wastewater treatment fertilizer solution at WD valley.

4. Environmental Impact Assessment (EIA)

A prospective EIA study is an essential tool for indicating the ecological status of a city or any industrial process. The conceptual design for the water–energy–food nexus for Wadi-Dara on the Red Sea coast depends on green energy, zero fossil fuel, wind energy, and mangrove in all city processes, such as seawater desalination, wastewater treatment, and lighting. An EIA study using screening, alternatives, scoping and mitigation shows that WD has a low-risk assessment, registered at level (2), as shown in Figure 12. The recorded EIA level (2) is due to net zero CO_2 emission, 75% green city, waste management and optimal waste recycling.

With regard to Sustainable Development Goal #11 (Sustainable Cities and Communities), encouraging farmers to cultivate the desert and move from a narrow valley to a vast desert to increase the developed areas and build new urban cities far from the Delta and the Nile is important. WD is a suitable example of achieving SDGs goals and sustainability.

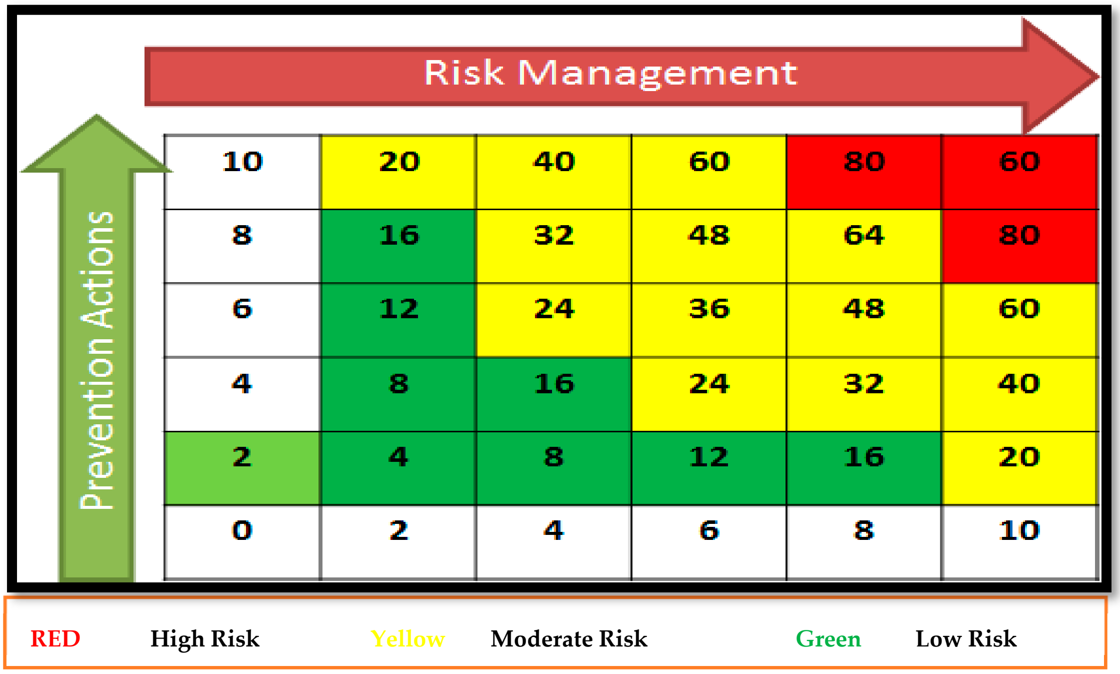

Figure 12. Environmental assessment process stages.

5. Recommendations

Currently, there are two definitions of nexus in the literature; however, they can be combined under integrated system research. The first defines nexus as the relationship between multiple resources, whereas the second views nexus as a novel method for analyzing nexus systems with varied interpretations in varying circumstances. The two definitions can be unified through integrated nexus management to reduce un-foreseen impacts and sectoral trade-offs and to enhance the sustainability and resilience of the entire nexus system. Internal relationship analysis, external effect analysis, and coupled system evaluation are three subcategories of the current study.

Seawater desalination using PV-RO, wastewater treatment, green energy, cultivation using smart farming and waste management are the leading key success indicators for WEF nexus to start new life in Wadi-Dara on the Red Sea coast, Egypt, as shown in Figure 13 below. We summarize the key recommendations in Figure 13. One should take into consideration that the government should bear the cost of the city roads and transportation network to encourage the citizens to build their new life in a dependable and trustable city. The main goal of this work is to introduce a clear solution with a conceptual design for a real case study to help the policymakers, investors, and local community to take action toward sustainable development and building sustainable communities based on our limited available resources. Furthermore, by dividing internal and external components, we are able to conduct a more focused study, highlight site-specific nexus problems, and offer insightful information for prioritizing remedies. The teamwork of this study could be used for any action plans used to implement the entirety or part of this project. Needless to say, this case study's updated data must be taken into account due to accelerated climate changes or other circumstances.

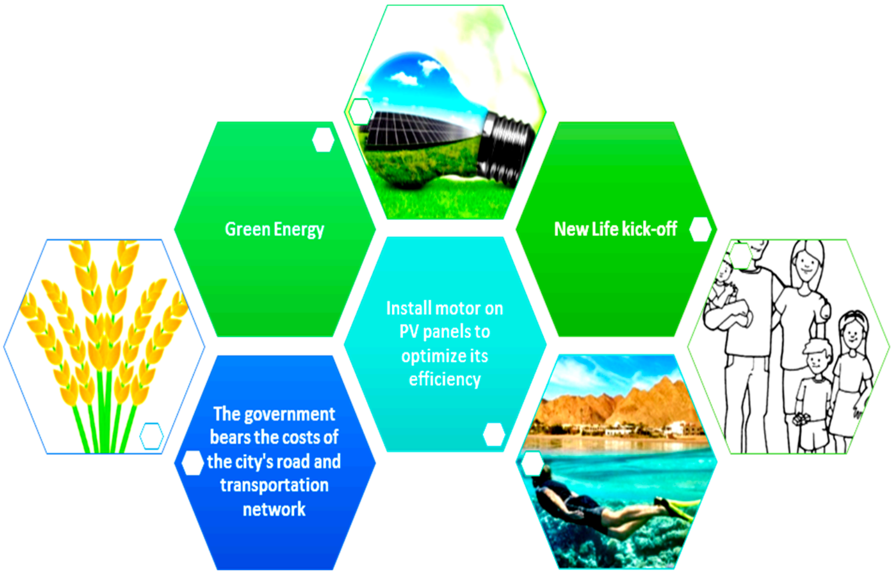

Figure 13. Key success indicators in Wadi-Dara on the Red Sea coast, Egypt.

6. Conclusions

We have highlighted the necessity for a base of knowledge of WEF nexus methodologies in this paper in order to handle the inherent complexity of interactions between water–energy–food resource systems' optimization. Developing a list of concepts with common meanings at the initial stage of label design would be most valuable to re-searchers and practitioners in order to associate these with each term of WEF. Modern technologies can be adapted to the majority of the desert communities close to the Red Sea coast using the Wadi-Dara valley as an idea. The conceptual design is useful to most desert cities near the Red Sea coast using modern technologies in desalinating seawater and wastewater treatment based on renewable energy sources such as sunlight, wind and mangroves. Cultivation of strategic crops, the establishment of aquaculture systems and hydroponics, in addition to drip irrigation using intelligent farming techniques, could be beneficial. The possibility of a new life and job opportunities at WD will reflect positive reactions in all Egyptians, who may choose to move from the Delta to the desert and encourage new generations towards sustainability, seeing this as the main goal to improve living standards. More work is needed in regulating accessible linkages and in ensuring that tools are accessible to stakeholders in decision-making sectors. This can be achieved by integrating collaborative and participatory approaches to linkage tools. Challenges also exist in the evaluation of system performance, where nexus-specific assessment metrics and quantitative approaches need to be developed. Therefore, further 1work is needed to advance comprehensive analyses of the water–energy–food nexus. The WEF program's significance for the nexus at the WD valley, according to current controversies, may be helpful for delineating system boundaries, while enhanced data accessibility attributable to trying to cut technologies holds the potential to address issues related to data and methodologies. This can be achieved by integrating collaborative and participatory approaches to linkage tools.

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