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Combined Energy-Water-Food (EWF) Procession: Project-based Approach to the Sustainable Development of North-Sinai Settlements

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Abstract

The tripod of energy, water, and food (EWF) are recognized as the key driver of any socio-economic development worldwide. In Egypt, attention is being increasingly given to the impact of population growth and urban and rural development on the environment. This research-based study is aimed at promoting a combined technique that can probably enforce the agricultural development strategy and issues of food security in terms of water and energy efficiency in new desert settlements in Egypt. It hypothesizes that combined appropriate technologies can pave the way to an enabling setting that secures a more sustainable use of the available natural resources. The goal is to approach an interdisciplinary research system that employs an EWF technique,while better identifying national and cross cutting priorities in the environment and climate change related sectors. To attain this goal, the study is determined to explore the potential of integrating these combined techniques into the settlement context and envision this integration in terms of their technical performance, economic payback and social impact. Methods used include the integration of building attached greenhouses (B-GH), water desalination, sol-water ponds, and solar collectors for attaining greenhouse cooling loads and seawater desalination.

Keywords: *Combined Techniques, Renewable Energy, Water, Food, EWF, Sustainable Settlements, North Sinai.*

1. Introduction

In recent times, global trade has vastly expanded, imposing cities to become less reliant upon their hinterland for sustenance and become increasingly importing not only their consumer goods, but also food, energy, water and building materials from distant sources. In the meantime, the waste produced in urban areas has increasingly been exported to distant regions, the case that often indicates how far the origin of food and energy and the destination of wastes are invisible to urban dwellers. These dependencies, developed over the last decades in the Egyptian urban/rural communities might not be ecologically or geopolitically stable, secure or indeed, sustainable. The problem is that the limits imposed by the expansion of the urban ecological footprint do not become evident until they are translated into local impacts, such as higher food or energy prices, frequent floods or the increment of environment-related diseases such as skin cancer, and thus less quality of life for residents[1].

It is well recognized at the international scale that Energy-Water-Food (EWF) system is a driver of socio-economic development. Key aspects of the system are: a) water management under climate change & hydrology; b) water-energy systems; and c) water quality (drinking & waste water).

Therefore, there is a need for integrated management in order to achieve sustainability. [2]To analyze the current situation, it has been witnessed a strong influences on the EWF resources' systems due to climate change. For example, pollution of water resources through uncontrolled discharge of waste effluents has been highly affecting food production; especially in developing countries are heavily affected in different degrees. Authorities' actions toward these catastrophic issues have been reactive rather than proactive, Fig. 1

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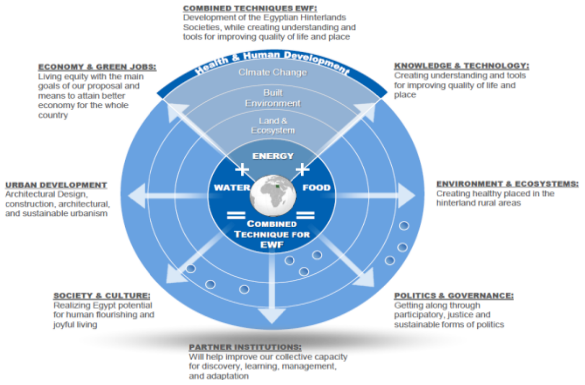

Fig. 1. Motivations for adopting the combined technique for energy, water, and food production

2. Motivation and Key Drivers

According to experts, Egypt could face a severe water shortage if the conflict with the Nile source countries is not resolved. For these reasons, water efficiency and food security, combined with an overall conservation strategies for the three major components of mitigation: (1) energy; (2) water; and (3) food - highly equipped with advanced techniques for water desalination and energy production - are matters of national security and public policy for Egypt in the short, medium, and long terms, Fig. 2 [3].

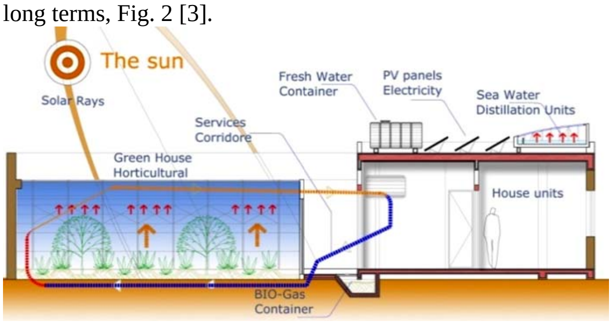

Fig. 2. Motivations for adopting the combined technique for energy, water, and food production, the author

2.1. Research Revolution after January 25th Revolution

As an attempt to sorting out this dilemma, our ESU laboratory has demonstrated an overview of the state of developing long-term practical findings and methodologies to foresight the sustainable future of urban planning and architecture development in the new Egyptian desert and rural communities, mainly in the promising hinterlands. After the Egyptian Revolution of January 25th, our focus as a living lab was immediately placed on addressing the energy-water-food problem in an attempt to provide in-depth answers to very specific questions to the future communities with use of renewable energies. As a developing country with many ambitious urban and rural development plans, Egypt looks at the tripod Energy-Water-Food (EWF) as renewable yet vulnerable resources, essential to sustain life, development and the environment. Egypt is not a rainy country and does not contain many groundwater resources, but still with other means that are necessary for living that are renewable energy sources, Nile River, two long and extended coastal boarders, and untapped human potential.

In our proposal we look at the mutual dependence between cities and their hinterland as a delicate one, where its balance is constantly influenced by the urbanization process. In developed countries, on the other hand, urban sprawl which continues to consume vast amounts of rural areas, often poses a threat on the natural eco-systems and watersheds. As rural areas surrounding cities are converted through suburban development, the comparative advantage of food produced in proximity to urban markets has been lost, thus stressing the trend of globalization for food to be shipped and transported from far away locations. This phenomenon, known as food-miles, increases the ecological footprint of cities that is interpreted into more gray energy consumption for food mobility - perhaps much more than the calorific value of the food itself [4].

Our proposal defines the principal elements of natural resources to include agricultural land, water, the promising potential for renewable energy (solar and wind), and their sustainability. Since attention is specially given to the impact of growth and development on Egypt's environment and related sectors, including water, sanitation, health and waste management, our focus has been driven to the enforcement of agricultural development strategy and issues of food security in terms of water and energy efficiency [5]. The importance of introducing environment-friendly practices such as ecotourism is highlighted, with the potential threats of climate change, water scarcity, and energy scarcity, and the need for adaptation within long-term sustainability goals.

There is a number of crosscutting institutional and systemic challenges that are interlinked, allowing for weakness in the environment sector in Egypt. The environment should not be a "standalone" sector responsible for cleaning up the waste generated by other sectors. Our proposal looks at the combined strategy of EWF – by its very nature - as a way that can allow for a better identification of national and cross cutting priorities in the environment and climate change related sectors. These priorities, if tackled properly, will provide an enabling policy setting to secure the sustainable use of the available natural resources. The task is complex but economic and social rates of return will be very high. An earlier example of this combined method by the waste management sector whose processing includes recycling, composting and energy-generating projects.
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2.2. Enhancing Quality of Life by Means of the Combined EWF Strategy

According to the Egypt Human Development Report 2010, the energy sector is the main source of greenhouse gas (GHG) emissions with 92% of Egypt's energy demand met by using fossil fuels. It is worth noting that Egypt's GHG emissions are relatively limited (0.7% of global GHG), where they grew to 193 million tons of CO_2 equivalent in 2000 from 116 million tons of CO_2 equivalent in 1990. However, Egypt is subject to potential impacts of climate change, including sea level rise, inundation of the low lying lands in the Nile Delta that could reach 10-12% of the total area, impacts on water resources and agricultural productivity and associated social and economic effects. Moreover, 57% of the Egyptian population lives in rural areas, considered more vulnerable to climate change, with an expected shortage of basic food items [6], [7], [8].

Here comes the climate change as a closely linked aspect to the health sector, with expected increases in morbidity and deaths due to non-communicable diseases, disasters, and vector-borne diseases. There are some efforts to reduce the impacts of climate change in some sectors, whilst poor effort is paid to cope with the different direct and indirect impacts of climate change on health [9]. The Combined EWF Strategy will enable building institutional capacity to be pursued vigorously in order to deal adequately with the necessary adaptation measures, providing Egypt with both a strategy and a trained capacity to implement the required measures. From this perspective, NGO_s are implementing partners in development cooperation of or project, and their role is likely to grow even further as aid volumes head towards increases over the medium term.

It is hoped that together, the three pillars of the combined EWF strategy and their associated deliverables in our proposal will strengthen the argument for continued national and international engagement. It is also hoped that this endeavor, when completed, will improve coherence amongst national and international development partners and enhance development effectiveness and efficiency in multifaceted directions. It will help both the Government of Egypt (GOE) - both in the transition period and once the new system is in place - to better account for development results in the rural hinterland areas so that residents can more easily see tangible results into better quality of life [10].

2.3. Lessons from Local and Regional Urban and Rural Development

Previous experience of utilizing solar energy systems, water treatment, and food production has been recognized through a number of leading practical rural development projects in different Egyptian areas and along other countries in the MENA region.

2.1.1. Solar Water Heating: Urban & Peri-urban Areas

Three solar-heat water projects funded by the Small Grants Program (SGP) have been implemented in three poor rural villages and well-off communities at Menia Governorate in Upper Egypt [11]. The project helped to reduce the use of agricultural residues, gasoline, and electricity to heat the water for the daily activities of peoples there, as it environmentally contributes the mitigation of smokes and energy consumption to develop and promote the following aspects:

- *Social awareness*; abandonment of traditional methods concerning the pollution and climatic changes,
- *Quality of life*; improving sanitation help, and therefore lead to health benefits for the poor residents,
- *Socio*-economic aspect; generating employment opportunities for youth, and provide educational and training programs,
- *Financial & Political aspects*; attracting the involvement of social organizations, private sector, and encouraging government incentives, legislation and green codes.

2.1.2. Combined Renewable Energy Practice; El Bassaisa CDA

El Bassaisa Community Development Association (CDA): Founded in 1983, El Bassaisa CDA's aim has been to lessen the negative consequences of traditional practices, and the use of non renewable energy sources, and to set up more efficient practices using renewable energy. An additional task has been to raise awareness over the importance of efficient and renewable energy. Biogas and solar heater technology has been introduced to a number of villages in Sharqiya governorate using college graduates trained in the techniques of installing and servicing biogas units, solar heaters and cells [12], [13].

3. Methodology

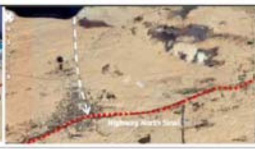
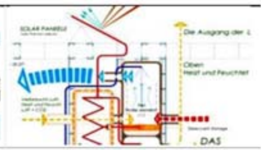
The study is determined at examining the major potentials for integrating renewable energy technologies, using electrical solar energy applications in specific, into the Egyptian built environment in hinterlands, desert areas, Coastal Zone and rural areas and the sequential possibility to use this in water and food procession. As part of our research studies related to examining the feasibility for using VLS-PV project and methodology for developing the Egyptian desert, using sustainable framework, the study stems from former theoretical studies, in Suez Canal region as a case study, and for developing the Egyptian rural and Coastal region, North-Sinai is selected as it has an optimal and suitable infrastructure for the research, and using examining grid-connected PV systems into the urban context [14].

Through the Case studies, different numbers of parameters are considered requested to design and installing of PV systems, using simulation tools for estimating the average performance of PV system in different positions in the built environment. The results have been complied into performance graphs. The introduced graphs in Table 1, and Fig. 3 are mainly focused on:

- The relation of annual energy performance versus PV panel feasible angels and area for different dwelling blocks.
- Energy output of PV systems based on panel's tilt and azimuth angles [15].

Potential partners for the implementation of the project are indicated in Figure 4.

Table 1. Scales of intervention, specifications, and studies required

Scale					
	Urban Planning	Urban Development	Urban Design & landscape	Architectural Design and Construction	Building Technology & Physics
Specifications & studies	- Regional Mobility and transportation. - Natural and Local resources. - Governmental developmental trends and future plans. - Region characteristic and climate. - Land use. - Regional services and centers. - SERVICES – Accessibility for public, private, community - voluntary services. -	- Social and cultural characteristic. - Constructions Materials and resources. - Private and Public transportations. - GOVERNANCE ; Effective and inclusive participation, representation and leadership. - Local governance and network. - Electricity and water network. - Economy –diverse local economy. - Environmental ; life quality, urban design &	- Land use and Urban Design. - Services center. - Accessibility and network design. - Streets network and traffic system. - Pedestrian distances and units accessibility. - Landscape and Green areas. - Sanitary services and network. - Self-sufficient community. - Local Governance, representation and leadership.	- Housing and the built environment – - Construction materials and methods. - Dwellings prototypes and urban design. - Freshwater network and sewage systems. - Building thermal mass and physics. - Environmentally friendly society. - Courtyards ratio and dimensions. - Self-food production.	- A quality built and natural environment. - Heating and cooling loads. - Indoor environmental quality. - Water recycling system. - Water desalination system. - Annual Electricity and energy demand. - Renewable energy supply. - Building and system maintenances. -

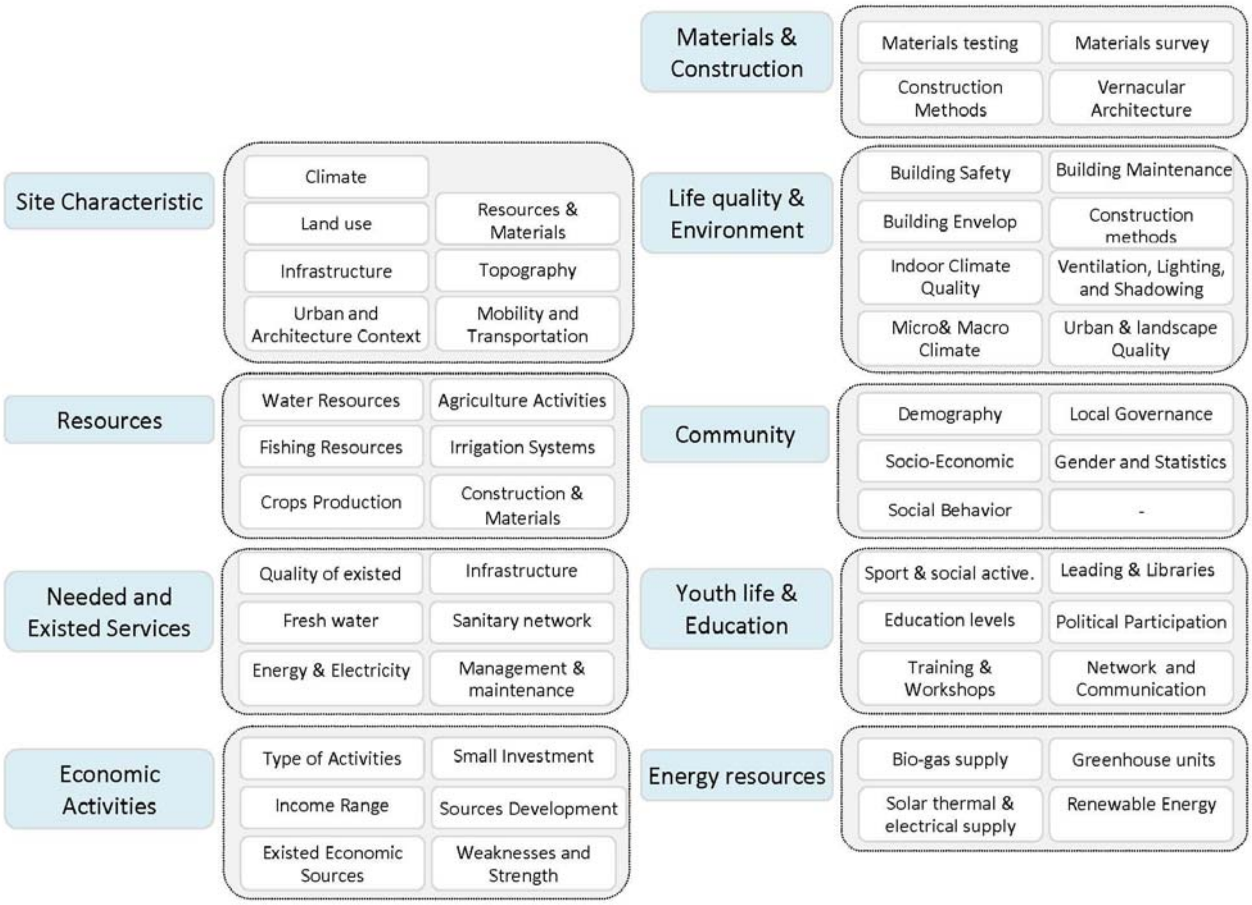


Fig. 3. Main issues required for research and development (R&D) and data modeling and processing

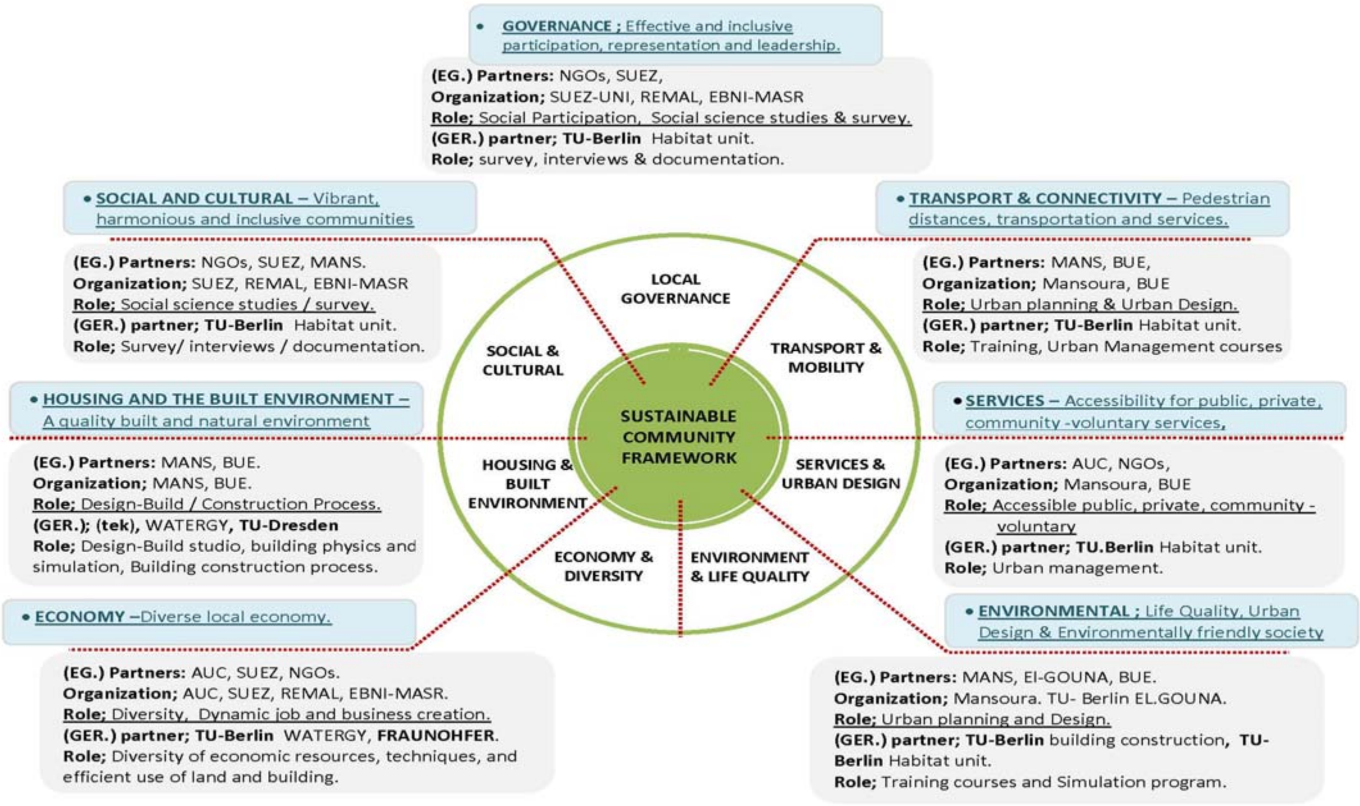


Fig. 4. Potential partners for the implementation of the project given within the sustainable community framework

4. Questions of Feasibility to Approach an Action Plan

For the feasibility of the tackled approach, a few questions may arise:

1- How can buildings connected to greenhouse units contribute some considerable enhancement and sustainability of water resources?
2- How can buildings, landscape and greenhouses provide sustainable provision of water recycling and supply?
3- How can greenhouse units be an affordable thermal solution for optimizing the built Environment?
4- Why are Coastal regions more suitable for the interconnected greenhouse units?
5- Can a combined solution that implies seawater, passive solar energy, solar collectors, sol-water ponds, and greenhouses provide autarky of water resources, food, and energy in North African regions?
6- How successful would greenhouse and urban context integrate into the concentrated solar power plants (CSP) and the specified topics of the technical project, e.g., Trans-Mediterranean Renewable Energy Cooperation (TREC)?

To answer the above questions, the prototype building is envisioned, within its proposed urban context, followed with an analysis of the technical and socioeconomic issues inherited.

4.1. Building Prototype in the Urban Context

For the urban context, suggested private houses will be arranged in a way that ensures better land investment while meeting the needs of the landlord, while governmental prototypes are arranged with reference to the national policy, site aspects, owners' ages and onsite socioeconomic activities, Fig. 5.

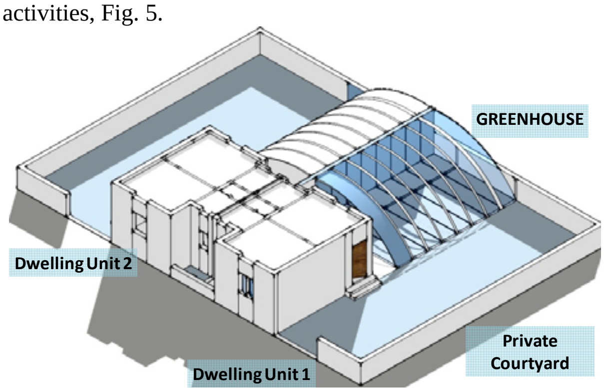
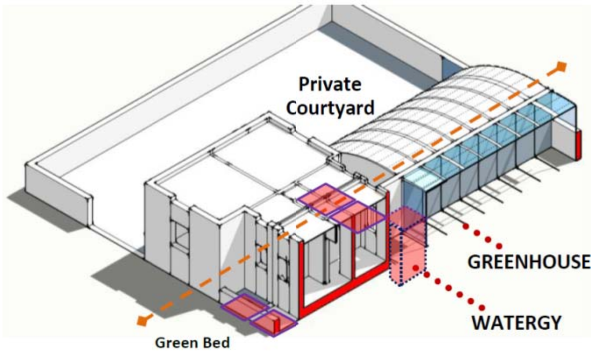


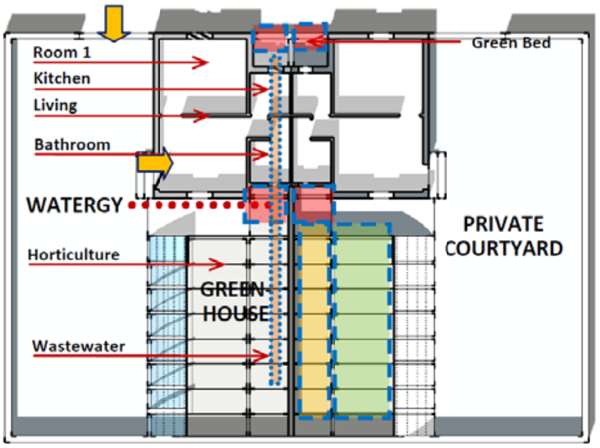
Fig. 5. Suggested private houses within the existing urban context

It is of high important to recognize building prototype form, design, and plans that are related to site properties for the case study model, while considering the future extension and development of the urban context.

It is also important for construction material to consider building materials and their physical characteristics. It is rather important to recognize the behavior of occupants, the affect on the combined water/energy systems and climate control inside the building and the greenhouse unit, Fig. 6 (a and b).



a)



b)

Fig. 6. Integrating the combined water/energy units into the house unit: a) perspective, b) plan

At this point, it should be stressed that details of the above model should correspond with the governmental national projects and prototypes. It should be a prototype model that is capable of copying and adapting with each region properties, while differences can be recognized and adapted at the socioeconomically level. The research could work in advance with the investment and NGOs projects types as it usually provide maintenance and controlled projects.

4.2. Mitigating the Technical Details

4.2.1. Overheating Problems, Mainly in Summer

The problem in adapting greenhouses with North African climate occurs when the heating temperature inside the greenhouse becomes higher than the critical degree for the grown plants inside.

4.2.2. Excessive Cooling Loads, Mainly in Winter (Watergy Prototype)

Due to global warming and environmental degradation, the temperature and climate conditions in most of the Egyptian regions are above their normal readings recorded in 2000 – a similar case was mitigated by the concept of Watergy where more cooling loads than heating loads are needed on most times of year for climatic optimization of the settlement [16]. Watergy is a cooperative EU research project combining two different prototype applications that ultimately aims at the habitation development of remote areas like the desert, coastal and Polar Regions, as follows:

- *Application for Greenhouse Horticulture:* This prototype uses closed greenhouse concept to preserve the water demand, plant protection, accumulation of CO_2 aeration losses in hot and arid regions, and requires irrigation and horticulture activities [17].
- *Building Technology Application:* A prototype that has been constructed in Berlin to function as a mixed use development for residence and offices with integrated greenhouse façade. It employs solar collectors and performs an advanced water treatment mechanism, with passive insulation techniques for buildings [18].

This Watergy project has been designed for the EU climate conditions. Mitigating the technical problems of the project will basically depend on the results of feasibility study on the prototype design models, local materials used for building and greenhouse construction, careful analysis of sewage water system and/or water sorting, all with reference to the community behavior, cost benefit analysis and the existing condition of the urban/rural network.

4.2.3. Life-cycle Cost

Based on the relatively high cost of the system's technical elements at unit I & II, mainly for specific devices; i.e. fans and pumps; tubs, desiccant materials… the initial cost of the building and greenhouse unit will still be high. Hence, the form should call for more adaptive modifications to social stance, in terms of culture, materials, building techniques, all with respect to the financing source for the projects.

4.2. Mitigating the Socio-economic Issues

Cost-benefit analysis for the project helps estimate how much sustainable the project applications will perform. For production-based economy and business, the return on the investment (ROI) for the building-greenhouse (B-GH) prototype discussed above could increase by providing a cohesive relation between each individual dwelling system and capital production. Mitigating this issue, thus, will be attained by easier integration of the B-GH prototypes into the existing environment and the vast socio-economic framework at the peri-urban scale, Fig. 7.

Fig. 7. Recommended socioeconomic-oriented B-GH design

Waste to energy (W2E) through biogas is to be used for cooking. This has to be recognized in the dwellings design to attain energy independence and prove more sustainability. As for the social context within the site, the peri-urban areas are fulfilled with different social behavior, economic activities and climate conditions, most of which are based on the location itself. In this regard, developing the proposed B-GH type for every specific location at the NA region with careful analysis and study of its socio-economic condition will ensure a more successful adaptation into the existing social environment, and thus should provide practical solutions for such problems.

5. Case Study: Application at the Coastal Region Connected to Rural Areas at Northern Sinai

The selected area is located at North Sinai: a rural community at Bir Qatia with some existing greenhouse units, Fig. 8, Fig. 9, and Fig 10.

Fig. 8. Coastal regions connected to rural areas

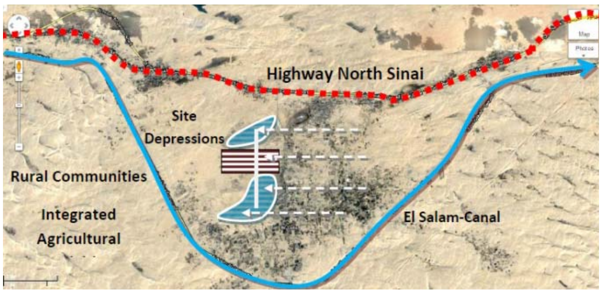


Fig. 9. The rural community at Bir Qatia

Fig. 10. Taking advantage of some existing Green house units

The project will employ the existing small greenhouses in the rural community to support its socioeconomic aspect by using them as infrastructure of the prospective development. People will likely get the message of the project and become involved if their culture and economic base are sustained. The EWF system will integrate into the urban context as illustrated in Table 2.

The integration of the Watergy mechanism is illustrated in Figure 11. The seawater is pumped into the pretreatment plant and processed sequentially until it is desalinated and then pumped back into the residential units at the local settlement units. Sludge residue and grey water are taken offsite and treated at food crop/water collecting unit and plant gravel /non-crop unit respectively. Black water is treated at the same non-crop plant as with sludge residues. New agriculture areas can be added with new source of agriculture water made available.

Table 2. Applying the EWF approach on the case study

Energy	Water	Food	Urban Context
Electricity: stand alone and grid connected	*Source*: off grid, underground grid connected	Activities: agriculture and fishing	Rural areas
Gas: no available infrastructure	*Quality*: moderate	*Soil condition*: fertile	*Building Prototype*: one-story building
Climate: desert/arid zone	*Sewage*: off grid and grid connected	Fishing farms	

This sequence should put into consideration the site layout for both the process flow and future expansion.

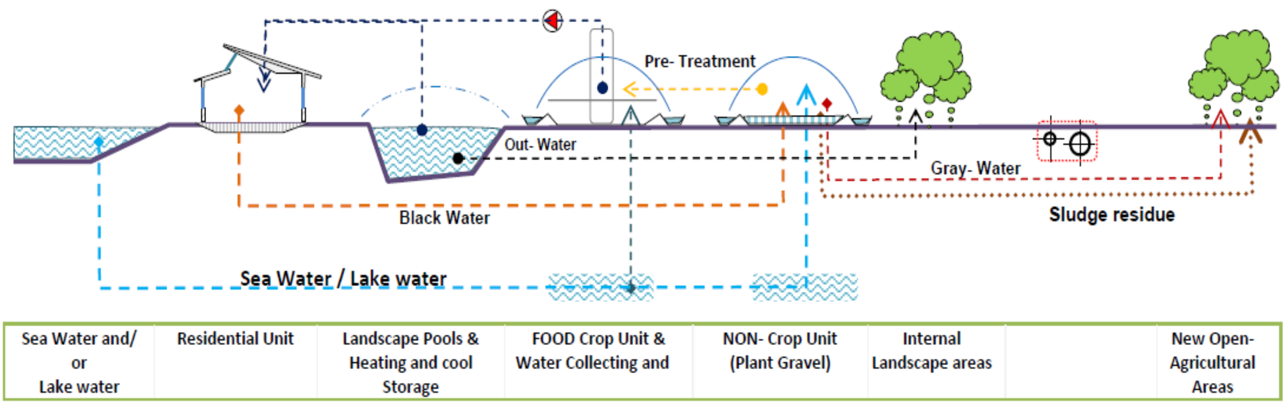


Fig. 11. Integrating the Watergy approach into the case study area

Then a simply designed water distillation system can be attached to every unit in the settlement and distributed over the vast landscape wherever appropriate, Fig. 12. This sol-water approach is a combined technique for using both natural resources to produce stand alone distilled water system for each dwelling.

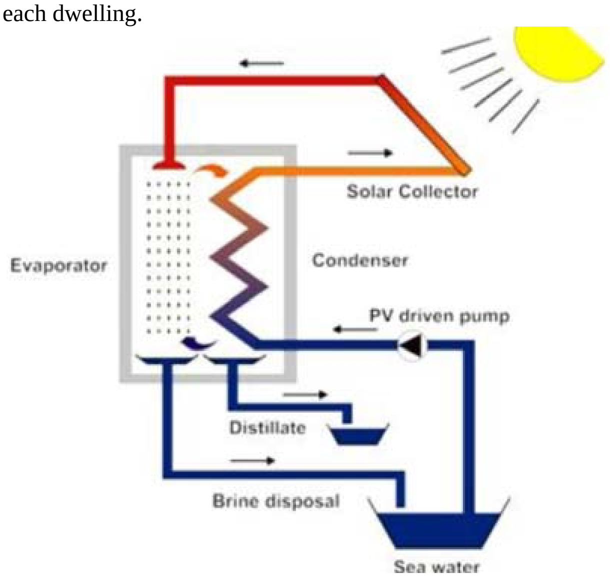


Fig. 12. Employed sol-water techniques to produce distilled water [19]

Domestic scale sol-water pond as illustrated below will additionally help in attempting heating and cooling with other combined passive techniques of sol-water, Fig. 13.

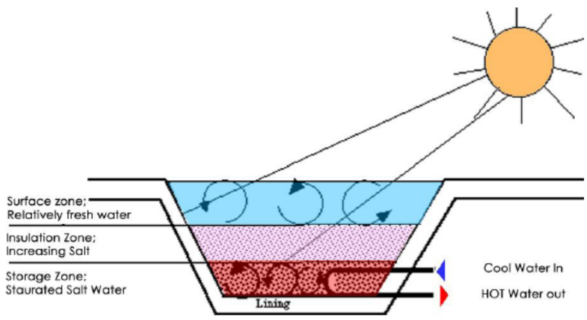


Fig. 13. Employing the water body in attempting passive heating (and cooling) [20]

Over the vast area of Northern Sinai, this connection of seawater- gray water- greenhouse can be experienced, Fig. 14 [21].

Thus, the prospective outcome of these combined techniques will include but not limited to:

- the use of building spaces layout and controlled air movement for cooling greenhouses,
- exploiting the seawater and gray water resources for agriculture,
- attaining evaporative cooling from seawater,
- cooling the CSP solar concentrators, and
- use of the landscape elements (sweet water lakes and salt pools) for water and thermal storage.

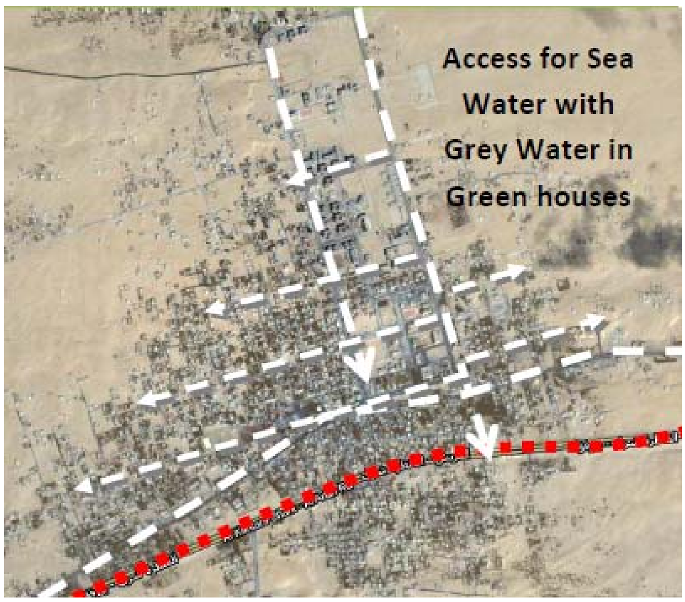


Fig. 14. Employed solar-water-green technique for the case study

6. Conclusion and Recommendations

Implementation of this project based approach is expected to have an impact on the research, education, community, RE Industry, and the Egyptian government as the following:

- *Research*: to focus directly on technology and methodologies of the implementation phases and provision of the tools needed.
- *Education*: to provide real-life cases in a way that allows the practitioner to practice what he/she is learning at the architectural and planning studios into real-time projects.
- *Community*: directly touched at its specific characteristics and opportunities with a great socio-economic potential impact.
- *Government*, where the impact will mainly be done over the management capacity and its realization at decision making stages, housing option and infrastructure management.
- *REindustry* realized on the market: Should be in a way that proposes a new approach of the industry management, to drive entrepreneurs into the desert development field.

In addition to the above envisioned processions, such combined development will put forward the collaboration between governmental and private universities on one side, and corresponding international networks on the other, for further interdisciplinary research cooperation. This will help establish cohesive cooperation, research, and academic network on different scales, where students' participation in prototype implementation process, and academic research integration, especially with the universities of North-Delta, e.g. Mansoura University, Suez Canal University, and Sinai University, and extend an international network with the German universities, world academics, and students from corresponding and complementary disciplines.

At the socio-cultural and economic levels; case studies at these areas where communities seek more investments and appreciation from the government will return some add value both on the qualitative and quantitative levels done through the appropriate techniques discussed above. Social science and human development will be able to take advantage of the new and clear understanding of the database made available and all relevant issues that connects with governance and human behavior at a socio-economic framework.
It would be appropriate to mention the enhanced life standards and sustainability that can be provided to the existing settlements that have lived for a long period of time with a lot of unemployed and undervalued resources.

To ensure an active engagement of the sustainable public/private industrial sector, the role the industrial sector plays to contribute the social participation and sustainability of the targeted settlements in selected region, throughout the advanced materials and new techniques to be examined at the prototype scale.

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