Smart and sustainable urban development in Egypt: the case of Nabta Smart Town

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Abstract. Nabta Smart Town (NST), in New Borg el Arab, close to Alexandria, is an ambitious project under planning that includes residential and commercial facilities, in combination with high quality “Educational Magnets” capable of creating a dynamic community and generating all sorts of interesting activities. Therefore, the uniqueness of NST is building a fully integrated and inclusive neighbourhood - Educational Magnet, Residential, Commercial (shopping, leisure and entertainment), with Administrative Offices (including high-end security). The initial conceptualization of NST by the local promoters envisions a culture that protects, maintains and recycles within the community. The collaboration of VTT Technical Research Centre of Finland Ltd. (VTT) was sought to ensure that the Master Plan (MP) and the buildings of the University, as well as the Residential and Commercial facilities of NST comply with the standards of a modern EcoCity adapted to the Egyptian context. The first phase of the work focuses mainly on carrying an EcoCity Energy Efficiency Feasibility Assessment. Specific methodologies and tools developed by VTT have been used to ensure adaptation of the solutions proposed to the local conditions. This paper discusses the results obtained using the methodology developed by VTT, its applicability at different scales, as well as its replicability potential - not only in other locations in Egypt, but also worldwide.

1. Introduction

According to the World Bank, cities have a key role in climate change, accounting for roughly 80 percent of the global greenhouse gas emissions [1]. Rapid urbanization in developing countries is bringing about numerous risks in relation to social instability, poor infrastructure, potential water crises, environmental degradation, etc. Moreover, the recently adopted New Urban Agenda expects the world’s population to double by 2050, which will place even more pressure on cities and exacerbate not only the demand for energy, but also the greenhouse gas emissions [2].

In this critical situation, sustainable urban planning and development can substantially contribute to decreasing the cities’ adverse effects on climate change and to improve the living conditions of millions worldwide. Hence the relevance of Nabta Smart Town (NST) in New Borg El Arab, close to Alexandria, an ambitious project aiming at setting an example of sustainable urban design and construction adapted to the local conditions in Egypt. The pertinence of the positive transformation envisioned by NST project should be understood in the context of the enormous challenges faced by Egyptian cities [3], struggling with high unemployment, lack of decent housing, water scarcity, chaotic traffic, air pollution, noise, etc. Unfortunately, Alexandria and even New Borg El Arab (even though to a much smaller extent), are not an exception.

Known as “The Pearl of the Mediterranean”, Alexandria was the capital of Egypt for almost a thousand years, and currently is the second largest city in the country with a population of 5.3 million
as of January 2019 [4]. Between the Mediterranean Sea to the north and Lake Mariout to the south, its contemporary urban development began in the 19th century with a series of emblematic projects like El Mahmoudia Canal (1819), Egypt’s first railway (1854), or the tramway (1863). Early in the 20th century, an extensive planning scheme was developed for the city (1920), and the Corniche sea boulevard was built (1934). Alexandria still has a number of beautiful buildings from this period designed by Greek and Italian architects. However, since 1952 Egypt has undergone many political, social and economic changes, and its cities, particularly Cairo and Alexandria, have experienced a constant expansion, sadly not following sustainable urban development patterns. As a consequence, Alexandria is nowadays facing numerous challenges like a very high population growth rate, unemployment -particularly among the youth-, proliferation of informal settlements, large number of unsafe buildings, inefficient mobility, or high pollution levels in El Mahmoudia Canal and Lake Mariout [5].

Figure 1. Two views of the Corniche, Alexandria’s waterfront promenade originally designed by architect Pietro Avoscani in 1870, and nowadays a major traffic corridor. It runs for over ten miles from the Citadel of Qaitbay to Al Montaza. (Pictures: Pixabay)

Figure 2. Rapid urbanization in Alexandria (Picture: Pixabay). Cases like that of the so called “Leaning tower”, a symbol of the city’s corruption, are sadly not an exception in a country where 400 residential buildings collapse every year [6].

New Borg El Arab City (NBC), 60 km to the south-west of Alexandria and 7 km away from the Mediterranean coast, is a new city established by presidential decree 506/1079 with a population of 150 000 inhabitants. NBC is expected to reach 570 000 inhabitants by 2022 [7]. At present, the city has around 1270 production factories and most of the workers are commuting daily from Alexandria [8].

A few years ago VTT Technical Research Centre of Finland Ltd. (VTT) and the Egypt-Japan University of Science and Technology (E-JUST) located in NBC, carried out a joint project called “EcoNBC, EcoCity Capacity Building in NBC” (2013-2015) funded by the Institutional Cooperation Instrument (ICI) under the Ministry for Foreign Affairs of Finland. The project’s main objective was to increase the know-how of E-JUST on sustainable urban planning according to VTT’s EcoCity concept.
Raising the awareness of local stakeholders was another important objective. To that end, EcoNBC project developed a number of activities that provided a fairly good understanding not only of the city’s most pressing problems, but also of how to provide solutions that respond to the local conditions.

![Figure 3. Two views of New Borg El Arab. (Pictures: Pekka Huovila)](image)

2. Nabta Smart Town in NBC

Nabta Smart Town (NST), located in NBC, is an ambitious project under planning that includes residential and commercial facilities, in combination with high quality “Educational Magnets” capable of creating a dynamic community and generating all sorts of interesting activities. Therefore, the uniqueness of NST is building a fully integrated and inclusive neighborhood - Educational Magnet, Residential, Commercial (shopping, leisure and entertainment), with Administrative Offices (including high-end security). Nabta’s mission could be summarized as follows:

- To contribute to the improvement of human conditions in the region.
- To use science, technology and culture to achieve the goals of solving society’s problems through sustainable improvements of human resources in the region by providing superior education to its students, and to offer pragmatic and innovative solutions to address human needs through outstanding products and services.
- To promote and support the establishment of strong businesses, as well as technical and commercial ties between international industries and organizations and their counterparts in countries and regions covered by Nabta University.
- To capitalize on “Science & Technology Diplomacy” to promote understanding between the nations.

The initial conceptualization of NST by the local promoters of the project envisions a culture that protects, maintains and recycles within the community. Everything from regenerative urban agriculture, edible landscaping, and energy-producing building designs, will be considered when designing and creating a sustainable living ecosystem, for this generation and generations to come. Nothing goes to waste, renewable energy sources will be deployed as much as possible, other natural resources and living features will be used, reused, and regenerated efficiently and effectively. Sustainable lifestyles will be promoted among the local community, and participation encouraged.

2.1. Collaboration with VTT

In this context, the collaboration of VTT was sought to ensure that the Master Plan and the buildings of Nabta University, as well as the Residential and Commercial facilities of NST comply with the standards of a modern smart EcoCity adapted to the local conditions of Egypt. Additionally, this work should capitalize on the recommendations and findings of “EcoNBC Feasibility Study. Transforming New Borg El Arab into an EcoCity” [9], one of the main outcomes of the abovementioned EcoNBC project, and thus become the first development pilot project that makes direct use of those.
Therefore, together with the local partner, the Khairy Foundation for Human and Social Development (KFHSD), VTT prepared a project proposal under the name of “Sustainability Assessment of Nabta Smart Town (NST) and Actions for Improvement: an Overview” that got funded by the 10YFP Trust Fund (One Planet Network SBC Programme). From its inception, the project tried to establish direct links with the UN Climate Change Conference, 21COP held in Paris in 2015, and the international campaign to decrease CO2 emissions and increase the use of renewable energy. Also linked to the 2030 Agenda for Sustainable Development, the project will significantly contribute to the following Sustainable Development Goals (SDGs) [10]:

![Figure 5. SDGs directly related to the main objectives of NST Project.](image)

The first phase of the work focused mainly on carrying an EcoCity Energy Efficiency Feasibility Assessment. Therefore, special attention was paid to energy and resource efficiency when assessing the MP (including passive features, use of indigenous vegetation and local materials, comprehensive sustainable mobility, user behaviour and participation, etc.). Specific methodologies and tools developed by VTT have been used, and even improved, to ensure adaptation to the local conditions in Egypt of the solutions proposed [11].

![Figure 4. Concept Master Plan of Nabta Smart Town commissioned by the local promoters and developed by Atkins, a well-known global design, engineering and project management consultancy. (Image: UpScale Development Llc and Atkins)](image)
3. Energy Assessment of NST Master Plan. Main findings

3.1. Approach and assessed cases
As mentioned above, the methodology developed by some of the authors has been used for carrying out the energy assessment of NST Master Plan. Several meetings with relevant stakeholders have been held in order to collect relevant information about the buildings to be assessed. Preliminary buildings information:
1. Shape and pre-architectural design of buildings according to the main zones in the Master Plan;
2. Construction techniques (wall, roof and floor stratigraphy) and relevant building envelope solutions;
3. Construction materials, including local materials such as white stone;
4. Occupancy patterns & Opening hours (in case of non-residential buildings).

![Figure 6. Example of residential building floor layout.](image)

Building models have been generated using Transient System Simulation Tool (TRNSYS) software [12] for estimating the energy demand of the town. In particular, three different building models have been created to emulate educational, office and residential buildings. Each of these building models has been associated to a building typology present in the Master Plan. Table 1 shows the total area of the different building typologies, in accordance with the Master Plan, and the building model paired to the building typology and used to emulate the energy behaviors. Table 2 shows the thermal properties of the construction materials that have been considered in the building models.

| Master Plan | Total area (m²) | Building typology | Paired building model |
|-------------|----------------|-------------------|----------------------|
|             | 101465         | University Neighbourhood | Educational |
|             | 51970          | Business           | Office               |
|             | 46565          | Cultural           | Educational          |
|             | 180471         | Family             | Residential          |
|             | 23490          | Hotel              | Residential          |
|             | 20223          | Commercial         | Office               |
|             | 16240          | Schools            | Educational          |
Table 2. Thermal properties of the construction materials used in the model.

| Material       | Specific Heat [J/kg, °C] | Density [kg/m³] | Conductivity [W/m, °C] | Width [mm] |
|----------------|--------------------------|-----------------|--------------------------|------------|
| Cement plaster | 1000                     | 2000            | 1.4                      | 25         |
| Red bricks     | 1000                     | 1200            | 0.5                      | 125        |
| Insulation     | 900                      | 80              | 0.04                     | 50         |
| Red bricks     | 1000                     | 1200            | 0.5                      | 125        |
| Cement plaster | 1000                     | 2000            | 1.4                      | 25         |

Low-e windows (Tinted double glazed 4/12/4 mm Glass/air/Glass, U=1.69 W/m²°C) have been assumed as provided by the local partner. 20° and 26°C have been set as heating and cooling indoor temperature set points. Use of energy efficient practices, such as natural ventilation (free cooling) and external shading devices, have been also considered. Different internal gains and energy consumption of electrical appliances have been estimated according to the provided occupancy patterns for each of the abovementioned building models. To assess different configuration of RES for supplying the energy to the town, a system model has also been created. A district heat pump has been assumed to be in use.

Regarding renewable energy generation, both PV and wind have been considered. Authors have estimated different RES configurations, considering PV integrated on building roofs and decentralized wind turbines. Particularly, the distribution of PV in different buildings has been optimized to minimize the energy export and, therefore, maximizing the self-consumption. Five scenarios have been considered for the total RES capacity installed in the district:
1. 25% of the district power peak (2.40 MW)
2. 50% of the district power peak (4.81 MW)
3. 75% of the district power peak (7.21 MW)
4. 100% of the district power peak (9.61 MW)
5. Enough RES capacity to achieve Net Zero Energy District (NZED) - a district that produces the same energy that it consumes

3.2. Main results

Figure 7 shows the main results of the energy Assessment of NST Master Plan, depicting imported and exported energy from and to the grid; the on-site energy consumption from PV (energy produced and consumed in the same building); the building to building energy transaction (District,B2B voice in the chart; renewable PV energy produced in a building and consumed in another); the consumed wind energy (District,Wind); the total wind and PV capacity; and the total renewable energy system capacity (sum of wind and PV capacity).

The results show that using only PV generates more energy export than using a combination of PV and wind RES. On the other hand, using the right combination of PV and wind generates less export, almost keeping the import from the grid at the same level. This can be noted comparing the cases with and without asterisk. High energy export may lead to excessive stress on the electricity grid outside the town. In order to avoid this situation, as anticipated before, PV capacity integrated in building roofs has been optimized. The results also show that the building to building energy transaction component is considerably less than the on-site consumption. It can also be seen that this is possible to achieve with conventional RES NZED. To obtain a NZED with low energy export 6.7 MW of PV and 3.6 MW of wind should be adopted. The PV distributions on building roofs associated is 25% of residential...
buildings, 34% of office buildings and 58% of educational buildings. Interesting to notice is that the roof of the buildings should not be fully covered by PV.

![Figure 7. Main results of Nabta Town energy assessment.](image)

**4. Discussion**

The main conclusions drawn from the results of the energy assessment presented above can be summarized as follows:

- Before acting on the system, buildings energy demand has to be reduced
- Different energy savings measures should be adopted for different building types
- Optimizing on-site consumption is necessary for reducing the cost on the energy infra
- NZED or Positive Energy District is possible to achieve with conventional RES

Since it has become clear that creating an adequate baseline using the most accurate possible local data and the correct assumptions is of crucial importance, to complete the study it would be necessary to cover also other aspects apart from energy like water, waste, material resources, etc., taking the same approach. Similarly, this energy study should be completed by an in-depth cost analysis.

There is also potential for scalability, and for increasing the efficiency and decreasing CO2 emissions when moving from building scale to district scale while considering the impact of features like vegetation to reduce the heat island effect, or street shading, etc.

Going beyond energy, sustainable building technologies reduce water consumption, which is becoming increasingly scarce in Egypt. Therefore, a follow-up study should include the sustainability assessment of the water system planned for NST covering the following aspects:

- Potable water management and possibility of desalinating underground water for drinking
- Recycling grey and black water for irrigation
- Use of modern irrigation systems
- Potential and economics of using underground water for irrigation
Optimum selection of water system parameters

Smart solutions for water management

Consider the possibility of aquaponics systems

Similarly, the sustainability of NST solid waste management plan should be assessed as solid waste represents one of Egypt’s most urgent problems, both in cities and the countryside. An array of solutions from waste separation at the source, considering transport and logistics, recycling, all the way to waste-to-energy or production of organic fertilizers should be considered for implementation in NST.

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Acknowledgments
The authors wish to acknowledge: the Khairy Foundation for Human and Social Development, the Egyptian partner in NST Project, for their support and assistance during the development of the work; Mr. Pekka Huovila, Coordinator of the One Planet Network SBC Programme for his supervision; and the One Planet Network Secretariat for their guidance during the project.