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Design Analyses of Sustainable Solar Skyscraper in Cold & Dry Climate of Urmia City, Iran

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A B S T R A C T

Contemporary building sector in Iran is responsible for approximately 40% of ever-increasing energy consumption. Considering the principles of Iranian architecture in terms of adaptability with the climate as well as its habitat, a sustainable solar skyscraper as 60-storey residential complex with an approximate area of one acre which covers more than 150 hundred families from various social classes in Urmia City is well-known as the city garden- designed.
The sustainable vertical construction mentioned above would be designed by taking into account the biological facilities in four separate sections. Therefore, sustainable strategies including the collection of water and recycling it designed with the purpose of energy efficiency, garbage recycling, active and inactive solar architecture and other principles concerning human's sustainable architecture would be taken into account. Sustainable solar architecture approaching energy efficient architecture and environmentally friendly concepts in harmony with local architecture patterns of this region considered for sustainable solar skyscraper in this region which present at least 35% electricity energy demand of the building.

1. Introduction

In the contemporary world, population increasing seeks living spaces for today's generation [1]. But, due to lack of suitable lands for building construction and green spaces in the urban context especially in the mega-polis cities, there is an essential need to consider designing sustainable skyscrapers [2,3]. These types of high height structures are like vertical cities including needed items for users [4,5].

Since Urmia City which is located in the north-west of Iran, possess significant amount of greenbelt space per capita both inside and surrounding the city is well-known as the city garden which in turn has caused a kind of public acculturation and this greenery has been existed in house yard [4]. However, the idea of the construction models in forms of one or two-story big convenient houses with a central yard that used to exist in past cannot be achieved because the urban spaces suiting such matter are either limited [5], cause the tremendous damage to nature, or preparation for such cases requires spending great amount of money and time [6].

Sustainable solar skyscraper as an 60-storey residential complex in Urmia City with an approximate area of one acre is based on Iranian architecture and utilization of Chahar-Bagh (Four-Gardens) and Hasht-Behesht (Eight-Paradises) ideas as well as getting benefited from modern technologies concerning the environment that necessitates hanging gardens on each floor makes it possible to permanently accommodate more than 150 hundred families from various social classes and even other people who are interested in peaceful cohabitation with nature, all of which are designed through functional, architectural, ecological and sustainable strategies, so that besides the enhanced life style quality of the residents, it would have the least negative effect on its surrounding environment [7].

2. Materials and Methods

Conducting a comprehensive and functional research on theoretical and operational basis of solar architecture and as a result combining it with residential spaces, the structural and solar details of the architectural plan are studied, and the results achieved would manifest considering the climatic conditions, site and other restrictions and necessities in the form of designing a sustainable solar skyscraper.

2.1. Site Location

The selected site located in cold and dry climate of Urmia in West-Azarbaijan Province (in the North-west part of Iran) with Latitude of 37.4° East and Longitude of 45.1° North.

Figure 1: Site location in Iran and Urmia

2.2. Climatic Analyses

Urmia, as the capital of West Azarbaijan Province and one of the historical cities located in the north-west of Iran. The climate of complex site is cold-dry with very cold in winter and moderate in summer. Cold and dry climate, west-east winds, using sunlight, angle of sunshine and more profiting form it made the building to be built pacing Kiblah or geographical south. Most of the buildings are south facing where the effects of solar radiation in warming the buildings and melting snow are much tangible. Summer breezes, have a cool effect on the fine of weather and acts as a cooler and natural air conditioner in the buildings. The value of temperature in day heat is higher than that of day coldness. Therefore, insulation and passive heating is of great importance in winter. Urmia climate is cold-dry therefore, insulation and passive heating is of great importance in winter. The highest solar altitude in winter noon is 28º where 77º in summer. Also, utilization of passive solar strategies is the key factor here for optimum heating in winter and effective cooling in summer. Then, glazed surfaces in south facades of buildings must be increased as much as possible [8].

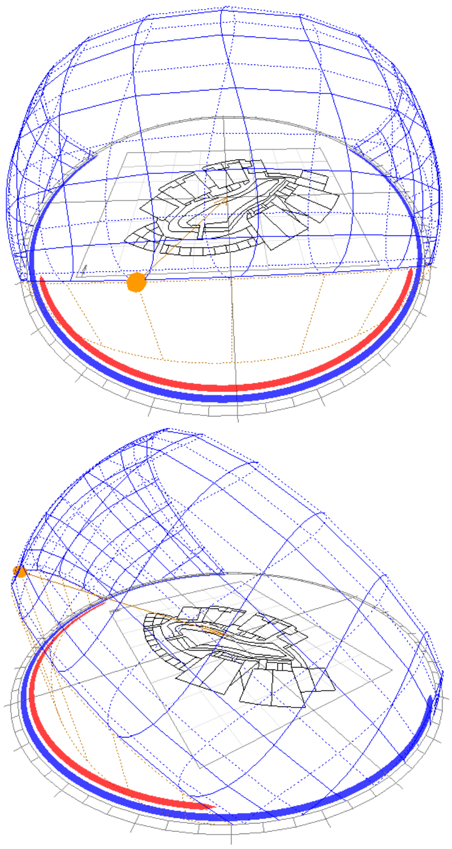


Figure 2: Winter solstice (Urmia), Dec. 21, 12:00

3. Concept and Architectural Design

This skyscraper building designed to be compact and dense to catch maximum solar radiation in cold winter, also utilizing the effective natural ventilation for cooling in summer [9]. While integrated solar water heaters and photovoltaic panels (PV) with buildings, provide considerable energy for heating and electricity [10].

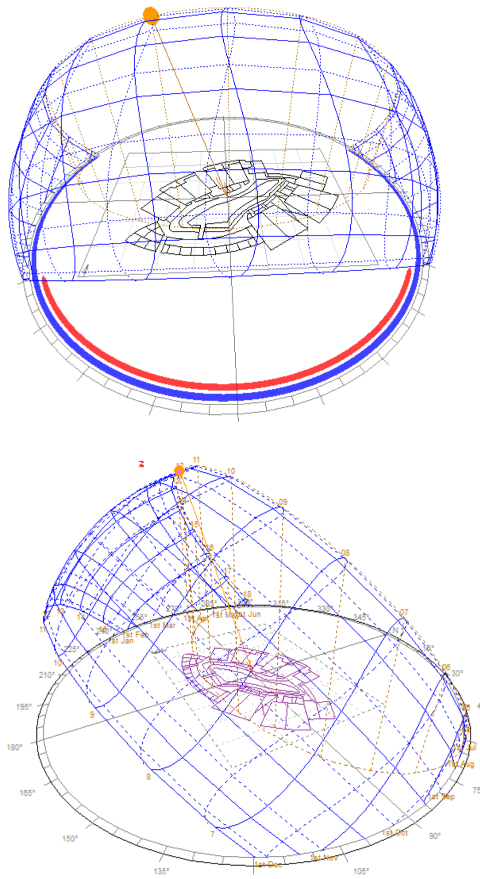


Figure 3: Summer solstice (Urmia), June 21, 12:00

3.1. Design Goals

To create such a complex the following goals are considered in the first step:

•Reunion and rehabilitation of central part of Urmia by designing affordable solar skyscraper in a sustainable humane habitat

•Creating pleasant spaces for different groups of people to bring comfortably to the homeowners

•Evolving a sustainable solar community with improving neighborhood relations and neighborhood centers in a vertical city [11]

•Application of passive/active solar architecture principles for the whole to take maximum advantageous of free source of solar energy

•Low energy architecture and attempt to produce solar electricity via building integrated photovoltaics as much as possible [12]

•Creating of architectural tourism and establishment a new environmentally friendly architecture for visitors of the complex

•Maximum utilization of solar energy in winter and minimum utilization of solar energy in summer for internal space

3.2. Photovoltaics

Photovoltaics can be used to achieve greater energy self-sufficiency. An assessment of the energetic-environmental options for the 60-story mixed use residential towers are as follow:

3.2.1. Installation of PV Cells in Façade

• Optimal positioning of PV cells: South oriented, tilted at an angle of 30º

• For this project: either cover the whole sw façade of the inclining ramp or cover the whole se vertical face of the building envelope, tilted at a 30º angle, as shown on the diagram provide (panel strips placed on low level of each story for the whole façade).

• PV panel output: 0.15 kWh/m2

• Average sunny hours per day: 7 hour

• Total Output for one PV panel per day: 0.15 * 7= 1.05

• Total PV area on facades: 1450 m2

• Total PV's daily energy production: 1.05*1450=1522 kWh

• Energy demand for covered spaces: 0.097kWh/m2

• Energy demand for semi-covered spaces: 0.387kWh/m2

• Daily energy demand of skyscraper: (3567*0.097) + (2465*0.038)*10=4397 kWh

• Energy self-sufficiency of skyscraper: 1522/4397=35%

• The payback period of the PV installation is far in excess of the life expectancy of the units, making their installation an uneconomic solution.

• However, this is provided as a demonstration of the productive mode option for this building.

Moreover, photovoltaic panels integrated with huge south façade of this high-rise building for power generation which meets the 35% of its electricity demand. Underground pipelines will carry hot water to the complex and consumers. Used water will redirect for infiltration to reuse in green roofs, flexible sunspace and gardens in front of the houses.

Figure 4: Site location & design in Urmia

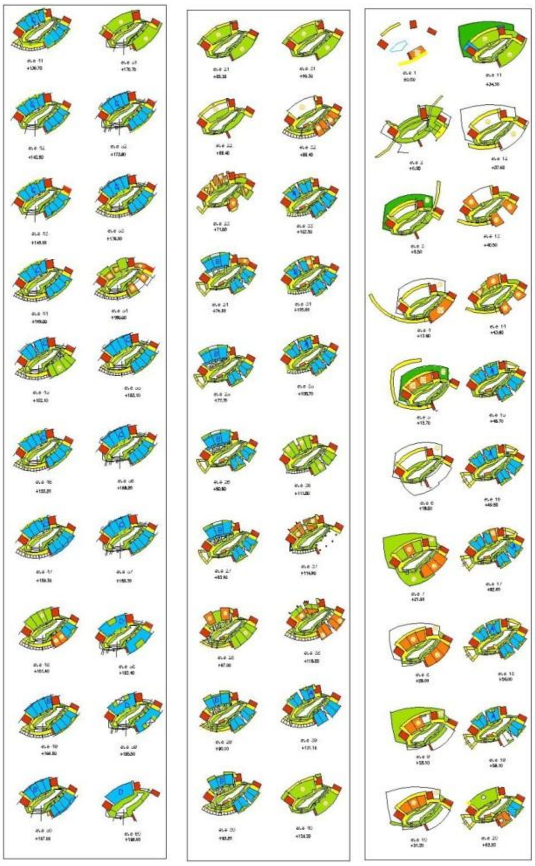
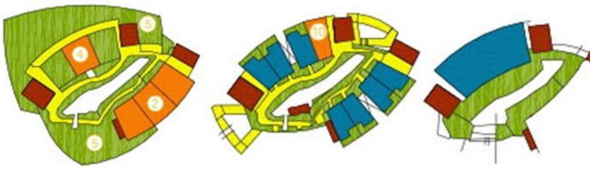
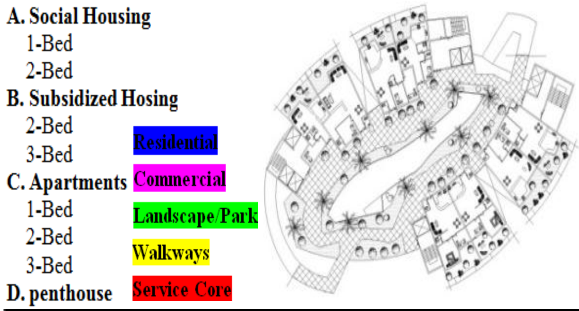


Figure 5: Plans for different stories of 60 story skyscraper





1. Open Aviary/Bird Sanctuary	13. Sandwich Shop
2. Aviary complex Shop	14.Post Office
3. Research Laboratory	15.Bank
4. Observation Deck	16.Bank Tellers
5. Urban Agriculture	17.Wiliam Hills
6. Commons/ Squares Gardens	18.Hardware Store
7. Pub	19.Electronics/IT
8. Creche	20.IT Knowledge Centre
9. Language School	21.Retail General
10. News agents	22.Library /Bookshop
11. Laundrette	23.Resturant
12. Café 24.Mini-Market	25.charity Shop

Figure 6: Plan levels: left to right: level 7 (+21.90m), level 17 (+52.90m), level 60 (+198.6m)

Figure 7: 3D view to the skyscraper and surrounded site (consider to the volume and green elements on facades and roof)

Figure 8: 3D views of southern façade with integrated photovoltaics and sustainable elements

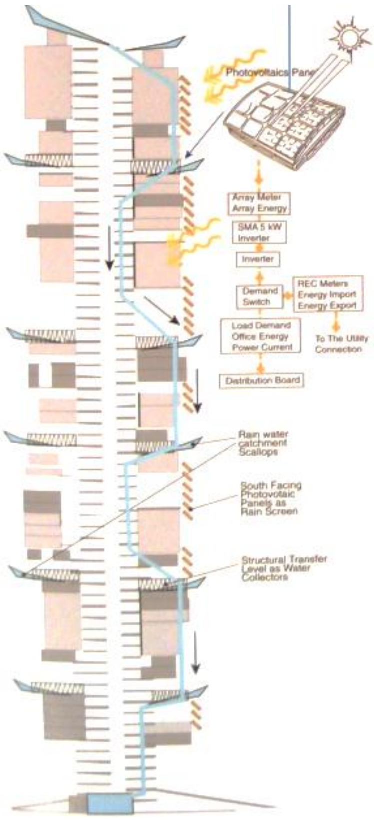


Figure 9: PV panels integrated in the building for solar electricity generation

Figure 10: 3D section of the sustainable solar skyscraper utilizes daylighting and vertical ventilation at the central core

As said before, direct solar radiation also is a great source of heat in the winter as a thermal passive system for the site [13]. Optimized designed windows will pass the available solar radiation as well as designed trombe-walls and sunspaces.

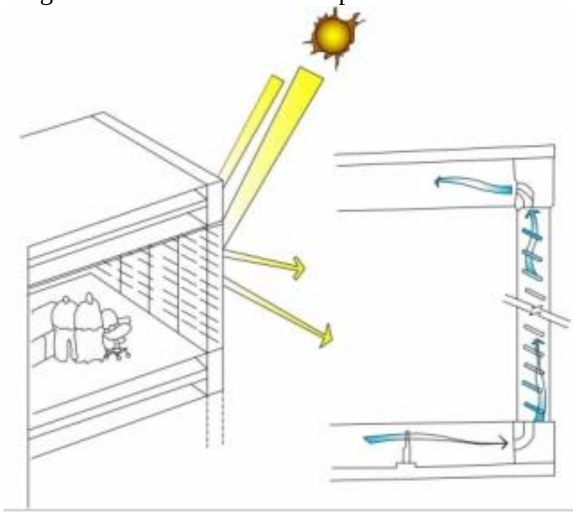


Figure 12: Triple glazed ventilated wall with plane blinds (east & west elevation)

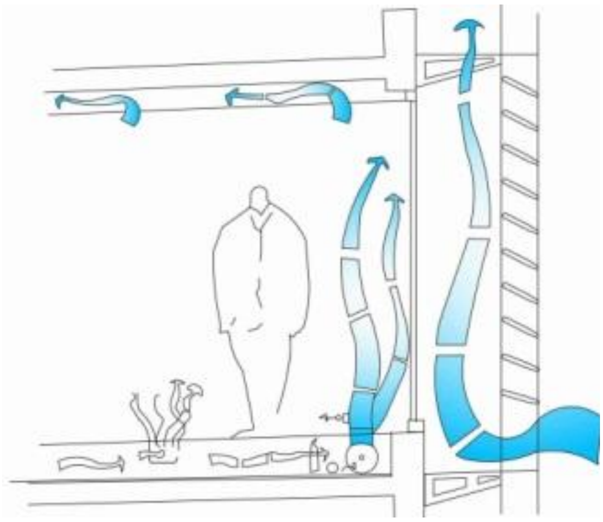
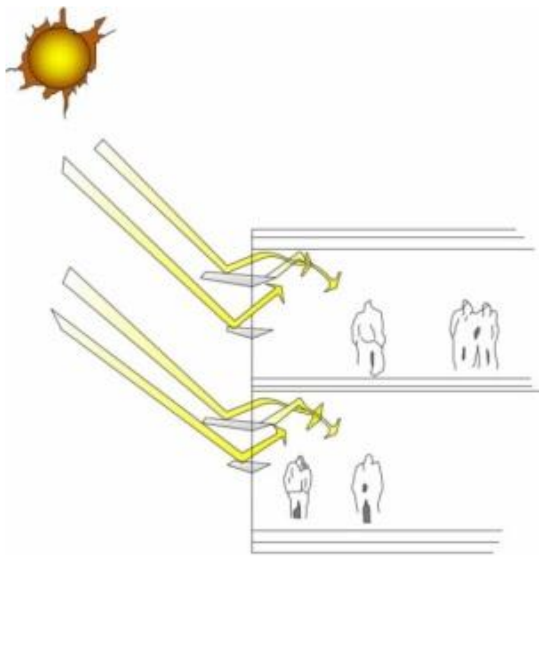


Figure 13: Full-height glazing with external adjustable blinds and perimeter coil units

4. Conclusion

The re-densification of cities will become a central issue of the 21st century, alongside cultural integration and flexible living and working concepts that address the issues of global migration.

The challenge of sustainable development in the building sector presents opportunities in a business sector that for a long time has not been particularly renowned for new ideas-including scientific, technical and design innovations, new export opportunities and once again as an impulse generator for long- term social developments. Today we should make these results affective across the board, instead of flirting with so-called “zero energy buildings”. So we must apply the way we look at energy for a single building to whole towns and cities, and take a similar approach to that used in the single building field: note all the relevant factors, understand how they interact, and develop new methods that can be integrated into the existing system.



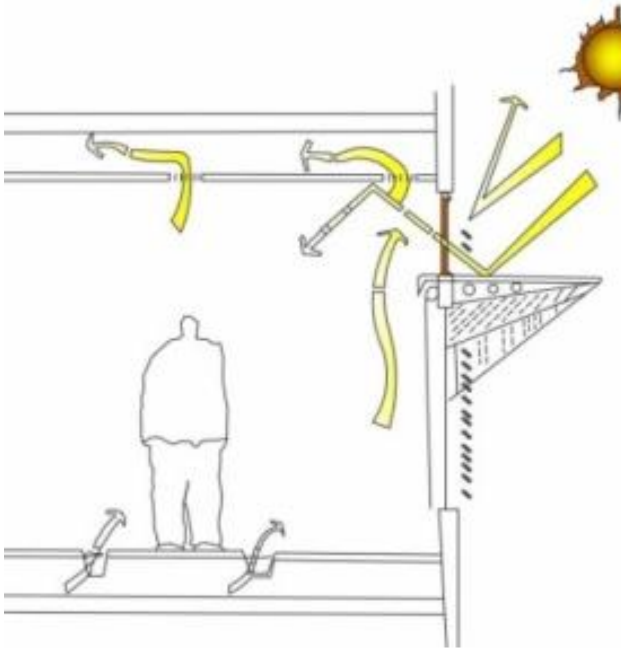


Figure 14: Left: Double Light-shelf for smart control of Solar penetration inside; Right: Light-shelf and blinds with clear double-glazing

Skyscraper and other major urban building types require to be designed to an ecologically responsive standard as a matter of urgency for a sustainable future. However, the limitations are also defined and recognized. From the other hand, low energy design and ecological design are applicable regardless of architectural style.

This project aimed at designing affordable housing and evolving a sustainable community with diverse neighborhoods. In this semi-large vertical complex that includes required services for living, regards to the natural potentials in the site and local culture of Urmia, architectural spaces are designed according to the sustainability and solar architecture to create comfortable, quiet, pleasant environment for occupants.

However, it is aimed to reach the high standard of sustainability and affordability by incorporation of sustainable technologies such as water harvesting, energy efficient design, waste recycling and other principles of sustainable humane architecture. In addition, Energy efficiency is the key item in designing these buildings utilized proper insulation and maximum usage of solar radiation for heating (by passive solar principles and thermal collectors) and electricity production via PV panels. Since the best opportunity for improving a building’s environmental performance occurs early in the design process, it is clear then that we must at the onset make our skyscrapers and other large buildings not only ecologically responsive but aesthetically pleasing as well if green design is to be a durable proposition.

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