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# Effects of Setbacks on Solar Accessibility In Abu Nseir, Amman, Jordan Abstract

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**Abstract**
Climate change has become the primary environmental threat of the 21st century. It is now on the global political agenda as never before. The current solutions based on mechanical and Industrial a product that's lead to design uniform buildings without any concern to its environment.
This paper aims to predict the relationship between buildings setbacks and climate. Through analytical case study at Abu Nseir, Jordan, it tries to investigate current building regulations of Greater Amman Municipality (GAM), According to climate characteristics. The study will ensure that distances between apartment blocks in Amman have to be set up according to climatic change in summer and winter.
To achieve the goal of this study, the current buildings setbacks regulations in Jordan have to be modified according to climate change.

**Keywords:** Setbacks, solar position, profile angel, energy saving.

## Introduction

From the beginning of creation, there was a great conflict between human and nature, where man faces harsh living conditions and tries to cooperate with them. Everybody have an instinct that leads him/her to live in environment where he can interact and feel satisfied. Real architecture promotes harmony between human and natural environment through design approach so sympathetic and well integrated with its site.
But most architects design their buildings without any concern to site forces (location, orientation, nature or climate).that leads to produce uniform buildings without any relation to its surroundings therefore these kind of design will affect on human comfort, behavior and health. The creative designer who can achieve human comfort through smart solutions which emerged from building site and climate.
Mediterranean architecture was considered as a good example in respecting nature and providing human comfort through analytical study to building location and climate difference between summer and winter within full area level or at the level specified for the building site, which varies from one place to another. Where Mediterranean architects tend design compact cities(La Tripologia en linea ),at the same time buildings were opened to the North and South, where south facades allow the natural daylight penetration and north facades allow natural ventilation.
Amman's position on the mountains near the Mediterranean places it is under the cold semi-arid climate (Köppen climate classification: BSk) The city has warm to hot and usually dry summers, whereas the winters are quite wet and range from mild to cool(1). [1]Spring is brief, mild and lasts a little less than a month. Amman has moderate summers starting from mid June to mid September. Summer's high temperatures range from 25 °C (77 °F) to 30 °C (86 °F), usually with low to moderate humidity and frequent cool breezes. Winter usually starts in late November or early December and continues to late April. Temperatures are usually near or below 10 °C (50 °F), with snow usually falling a few times each year.
It should be noted that Amman has extreme examples of microclimate, and almost every district exhibits its own weather (2[2]). It is known among locals that some boroughs such as the northern suburb of Abu Nseir are among the coldest in the city, and can be experiencing frost while other warmer districts such as Marka can be providing much warmer temperatures to its inhabitants at the same times.
According to geographical study about "The Impact of Climate on Construction and Human Comfort in Hashemite Kingdom of Jordan", where the study addressed the climate as the most important factor which directly affect on the patterns of buildings and human comfort. Where the researcher recommended to legislate buildings regulation that achieve human comfort according to climate change (3)[3]. From here the importance of this study emerged to rethink of building regulations according to climate and natural environment to support human comfort. Therefore, It is important to know how building regulations of GAM deal with climatic differences in order to legislate setbacks between apartment blocks.

## What are setbacks?

Setbacks are building restrictions imposed on property owners. Local governments create setbacks through ordinances and Building Codes, usually for reasons of public policy such as safety, privacy, and environmental protection.

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[1] "World Weather Information Service – Amman". World Meteorological Organization. Retrieved February 22, 2013.
[2] "Ever-growing Amman", Jordan: Urban expansion, social polarization ands contemporary urban planning issues". Arlt-lectures.com. Retrieved 2013-11-24.
[3] Momen .M.R.Naser, The Impact of climate on construction and human comfort in Hashemite Kingdom of Jordan.

Building setback has been defined by building regulation policy in the city of Amman, code No(67)for the year 1979; as buildings yard which are unallowable to construct within, where construction line and land boundaries from all sides (4)[4].

According to history, The Ottoman Empire determined building setback as one-sixth of the street width or (one to two meters) depending on the location of the city. But cities which implemented this system had been suffered from several problems, where concrete homes transformed in to ovens in summer season; because most of building walls exposed to sun space and windows which have been developed for ventilation are always closed in order to provide privacy. On other hand, building setback regulations contributed in eliminating "AL-SAHN" from houses which considered the most important element aesthetically, socially and climatically (4).

The Egyptian civil law (819) says that setbacks distance have to be at least one meter, where it is developed on the basis of privacy. Where resident will not be able to have a view with opening on his neighbor side if distance was less than one meter (4).

From this point we note that laws and regulations of construction in Jordan or in neighboring Arab countries don't take in account the analysis of climate and site.

Hence, we observed the negative impact of random setbacks on construction, especially the southern façade which supposed to allow sunlight to pass through building during winter but this arbitrary setbacks prevent sunlight from entering the building. Where sometimes buildings located without any view to Main Street or Sub Street, so these apartments don't get enough sunlight.

From this perspective we find that building setbacks have to be modified according to climate change. and Buildings should be placed on an east-west axis with the longest wall facing south or south-east to maximize light penetration and passive solar heating · The north and west facing walls should contain fewer windows because these walls generally face winter winds. where setbacks and orientation have to be developed in the right way in order to take the advantage of existing shadow patterns created from nearby structures.

## Literature Review

Over the last decade, an extensive literature emerged charting the shift from land-use planning, characterized by regulatory approaches, towards spatial planning, whereby the role of planners and planning was re-cast to one of coordinator, integrator and mediator of the spatial dimensions of wider policy streams through negotiated governance, partnership working, and horizontal as well as multi-scalar actions (5) [5]. While 'sustainability' has been central to these debates, the emergence of spatial planning has been largely driven by the competitiveness agenda, which seeks to position regions in a European and global economic space (6) [6]. However, faced with growing environmental risks, uncertainties and dilemmas, in this paper they argue for the need to fully embed ecosystem approaches into spatial planning theory and practice, proposing the notion of an ecological turn in planning. they suggest that planning has the potential to contribute towards a transition to more resilient places to better cope with complex environmental risks and disturbances. To address this, they emphasize the need to reflect on the interactions between the 'principles' guiding spatial planning activity, the 'practice' that both informs and is informed by these principles, and the 'procedures' employed to operationalise such principles and practice-informed knowledge in land use governance.

With the much documented 'spatial turn' in planning debates in the 1990s/2000s, planning systems shifted beyond narrow land-use concerns to embrace a role of spatial coordination, characterized by flexible policy approaches and multi-scalar interventions (7)[7].

Counsell and Haughton (8)[8], said that sustainable development provided a flexible discourse for formulating spatial strategies, the growing focus on climate change and the heightened sense of risk from anticipated climate change impacts has provided an important emerging context for spatial ECO-Plan:. While there has been limited progress in developing international agreements designed to mitigate climate change.

Spatial planning therefore has a crucial role to play in terms of reducing vulnerability and transforming the footprint of the places people live and work in to become more resilient to climate-related hazards so that they can cope with and recover more quickly from extreme disturbances such as flooding or heat stress (9) [9]. Through influencing the location, layout and design of development, spatial planning has the capacity to adapt the built environment to climate change by delivering a more multifunctional built environment that is safe and resilient to climatic extremes.

The green infrastructure approach moves beyond traditional site-based approaches of 'protect and preserve' towards a more holistic ecosystems approach, which includes not only protection but also enhancing, restoring, creating and designing new ecological networks characterized by multi functionality and connectivity

[4] Jameel.A.A.Akbar, The earth construction in Islam, 1992.

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[6] ALLMENDINGER, P. & HAUGHTON, G. 2009. Critical reflections on spatial planning. *Environment and Planning A,* 41**,** 2544-2549.

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[8] COUNSELL, D. & HAUGHTON, G. 2003. Regional planning tensions: planning for economic growth and sustainable development in two contrasting English regions. *Environment and Planning C: Government and Policy,* 21**,** 225-239.

[9] O'NEILL, E. & SCOTT, M. 2011. Policy & Planning Brief. *Planning Theory and Practice,* 12**,** 312-317.

A lot of researches are rooted in the concept of 'ecological networks' (10) [10]. While evident across a range of jurisdictions, there is a notable focus on such ecologically focused practices within the European Union (11) [11]. A significant proportion of this literature regards the coordination of national and international initiatives to address ecosystems fragmentation (12) [12], although recent years have witnessed a growing desire for a parallel focus on more localized ecological networks in urban environments (13) [13]. This work seeks to demonstrate the scientific procedures and planning practices required to deliver effective ecological connectivity (14)[14].

several scholars (15) [15]have raised concerns about the need for serious examinations of climate change integrated with the planning and urban design process, the only work in urban planning that directly addresses the design of cities in relation to climate change disasters is that of Donald Geis (2000). Geis' work consists of a general urban design, planning, and local government guideline to design such communities, although more detailed and graphic urban design guidelines that may serve as blueprints for designing disaster resistant communities are still missing in his published work.

In Dr. Abdulsalam A. Alshboul and Dr. Hussain H. Alzoubi research about Low energy architecture and solar rights (16)[16], the study discussed solar rights and solar envelope in order to evaluate the solar rights in apartment buildings; however the study focused on the developed areas in Amman. The study asses the relationship between setback and building geometry to ensure adequate solar radiation on building facades.

**Statement of the problem**

Climate change is one of the most significant threats facing the world today, and considered as great challenge for designers, urban planners and policy makers. This research try to find a mechanism to reduce the impact of hazardous planning through analytical study for current setbacks regulations and reform them according to climatic parameters in order to enhance sustainability in urban planning.

**Statement of purpose**

Many studies had examined effective procedures to ensure more ecologically outcomes in the planning process. But this research try to give a radical solutions by reconstructing new regulations based on environmental factors of the specific neighborhood where this research examines an analytical study in Abu Nseir region (class C apartments).

**Case study**

This research focused on Abu Nseir district according to GAM building regulations, the residential zones are classified in to four classes (see table (2)): residential zone A, B,C and D. For each type there are special regulations. Where this research will analyze residential zone C. In order to rethink of setbacks regulations according to climatic factors.

**Methodology**

Solar analysis has been applied to the district of Abu Nseir in order to understand deeply the effect of climate on building design and regulations. Based on the equation of the sun's position in the sky throughout the year, the maximum amount of solar insolation on a surface at a particular tilt angle can be calculated as a function of latitude and day of the year. The following figures and tables calculate the daily solar irradiance, the solar insolation and the number of hours during the day which the sun is shining.

The following graph shows the intensity of direct radiation in W/m² throughout the day.

It is the amount of power that would be received by a tracking concentrator in the absence of cloud. The time is the local solar time.

The average daily solar insolation as a function of latitude. The three curves are the incident solar insolation; the horizontal solar insolation the daily insolation is numerically equal to the number of sun hours in a day. The module is assumed to face the equator so that it faces South in the northern hemisphere in North in the southern hemisphere.(see appendix 1)

The number of hours the sun is shining each day that is the number of hours between sunrise and sunset each day. In latitudes above 67° the sun shines for 24 hours during part of the year. Surprisingly, when averaged over the year, the sun shines an average of 12 hours per day everywhere in the world. In the northern latitudes the average *intensity* is lower than at the southern latitudes.(see appendix 2)

$$Sunrise = 12 - \frac{1}{15^0}\cos^{-1}\left(\frac{-\sin\varphi\sin\delta}{\cos\varphi\cos\delta}\right)$$

and sunset:

$$Sunset = 12 + \frac{1}{15^0}\cos^{-1}\left(\frac{-\sin\varphi\sin\delta}{\cos\varphi\cos\delta}\right)$$

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[10] HASSE, D. 2010. Multicriteria assessment of green infrastructure and green space patterns in shrinking cities - a challenge for planning and design of an urban ecological network. *Proceeding of the 2nd International Conference of Urban Biodiversity and Design*. Nagoya, Japan: URBIO 2010.

[11] EC 2012. *The Multifunctionality of Green Infrastructure*, Brussels, Belgium, European Commission.

[12] BONNIN, M., BRUSZIK, A., DELBAERE, B., LETHIER, H., RICHARD, D., RIENTJES, S., VAN UDEN, G. & TERRY, A. 2007. *The Pan-European Ecological Network: Taking Stock: Nature and Environment No.146,* Strasbourg, Belgium, Council of Europe.

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[15] BEATLEY, T. 2010. *Biophilic Cities: Integrating Nature Into Urban Design and Planning*, Island Press.

[16] Abdulsalam A. Alshboul and Hussain H. Alzoubi research about Low energy architecture and solar rights, Renewable Energy 35 (2010) 333–342.

The equations to generate the above plots are given below. These equations are calculated in solar time, and not in local time.
The number of sun hours is simply the time between sunrise:
The direct component of the solar radiation is determined from the air mass:

$ID=1.353\times0.7^{(AM0.678)}$

Solar calculations based on location and date.(see appendix 3)
According to literature above (Dr. Abdulsalam A. Alshboul and Dr. Hussain H. Alzoubi research about Low energy architecture and solar rights), A design table for cold season was prepared to help planners and architectural designers maximize solar energy utilization in buildings. It identifies the most appropriate setbacks that planners
And designers should allow to maximize the insolation. Table shows the best combination between the two main variables, setback (S), and building height (H), to reach the highest percentages of solar insolation on southern facades. They were categorized into four segments of percentages, 25%, 50%, 75%, and 100%, which represent total received insolation by building facades. Following this table allows solar accessibility for all adjacent apartment blocks in the cold season.
The relation between the setback (S) and the height (H) was estimated based on the solar altitude (b), solar azimuth (F), and the profile angle PA. The solar profile is necessary to determine the solar availability from left and right sides of apartment blocks.
The relationship between solar altitude, solar azimuth, and solar profile is given by the following equations:

$\text{Tan PA}= H/S$

$S= H (\cos \phi)/\tan(\beta)$

**Results and discussion**
Based on analytical study for residential zone type (B) on Abu Nseir district and through studying the relationship between building height and setback to achieve the targeted insolation percentage. The researcher found that current building regulations have to be modified to enhance natural light and ventilation for occupants.where Architect and planners have to design their buildings and city planning according to the climate characteristics.where regulations have to be modified according to sustainable planning not on land use planning.

| Defining Attributes | Land use planning | Spatial planning | An ecological turn in spatial planning |
|---|---|---|---|
| **Purpose** | Planning for the 'public interest' | Planning for 'sustainable development' | Planning for 'resilient' places |
| **Aims** | Providing a land use framework to facilitate economic development | Ensuring the competitiveness of city regions within a globalised economy | Working with natural processes to enhance ecosystems services provision |
| **Approach** | Land use regulation | Spatial coordination | Social-ecological integration |
| **Scope** | Narrow and defined spatial and functional boundaries | Broad and 'fuzzy' spatial and functional boundaries | Inclusive and overlapping spatial and functional boundaries with particular attention to biogeographically delineations |
| **Logic** | Static | Flexible | Reflexive, adaptive and transformative |
| **Administration** | Functional silos | Increased communication and cooperation | Full integration |
| **Urban Perspectives** | Defined land uses | The compact city and urban renaissance | Landscape urbanism and ecological urbanism |
| **Design Concepts** | Domination of nature. Intensive civil and mechanical engineering of solutions | Management and manipulation of nature. Engineering solutions predominate. | Biomimicry and less intensive methods favored. Working with nature. |

**Conclusions**
This research has a great significance on assessing current setbacks regulations.Where these regulations have to be modified according to the characteristics and specifications of the region climate and it recommend designers, planners and decision makers to rethink in city planning to enhance human comfort by providing natural light and natural ventilation, therefore Greater Amman Municipality (GAM) should reconsider building regulations according to climate change.

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16. "World Weather Information Service – Amman". World Meteorological Organization. Retrieved February 22, 2013.


## Appendix

### Appendix (1)

| | **Power on the Horizontal (kWh/m2/day)Module Power (kWh/m2/day)** | **Incident Power (kWh/m2/day)** | **Day** |
|---|---|---|---|
| 6.198594 | 3.603436613 | 6.295889154 | 0 |
| 6.270595 | 3.680318285 | 6.360532005 | 5 |
| 6.366362 | 3.785507283 | 6.446427406 | 10 |
| 6.481894 | 3.917240154 | 6.549996705 | 15 |
| 6.617145 | 4.076156874 | 6.671845503 | 20 |
| 6.784129 | 4.270580709 | 6.824870386 | 25 |
| 6.985408 | 4.503568776 | 7.012550811 | 30 |
| 7.207783 | 4.768126339 | 7.222743742 | 35 |
| 7.434912 | 5.05436014 | 7.440447942 | 40 |
| 7.653922 | 5.353594662 | 7.654369408 | 45 |
| 7.856178 | 5.659073324 | 7.857552729 | 50 |
| 8.03688 | 5.965985865 | 8.04684272 | 55 |
| 8.225858 | 6.295412005 | 8.253686802 | 60 |
| 8.444262 | 6.6642472 | 8.500985398 | 65 |
| 8.652144 | 7.041728383 | 8.75021004 | 70 |
| 8.825854 | 7.406759631 | 8.978558857 | 75 |
| 8.95856 | 7.750198619 | 9.179504804 | 80 |
| 9.050929 | 8.068641695 | 9.353513846 | 85 |
| 9.139719 | 8.391666748 | 9.53812618 | 90 |
| 9.248657 | 8.740273316 | 9.758172506 | 95 |
| 9.337815 | 9.075967333 | 9.971338073 | 100 |
| 9.390552 | 9.379003723 | 10.1580216 | 105 |
| 9.406781 | 9.644617875 | 10.31522474 | 110 |
| 9.391825 | 9.873556668 | 10.44533038 | 115 |
| 9.364592 | 10.08162892 | 10.56583544 | 120 |
| 9.355993 | 10.29965227 | 10.70877302 | 125 |
| 9.350242 | 10.50872561 | 10.8536583 | 130 |
| 9.334588 | 10.69177667 | 10.98229482 | 135 |
| 9.308 | 10.84427284 | 11.08950246 | 140 |
| 9.274109 | 10.96725308 | 11.17568386 | 145 |
| 9.237629 | 11.06353665 | 11.24293631 | 150 |
| 9.202999 | 11.13619853 | 11.29357501 | 155 |
| 9.173917 | 11.18797134 | 11.32961442 | 160 |
| 9.153178 | 11.22100223 | 11.35259904 | 165 |
| 9.142641 | 11.23675019 | 11.36355822 | 170 |
| 9.143203 | 11.23592682 | 11.36298514 | 175 |
| 9.154816 | 11.21849528 | 11.35085461 | 180 |
| 9.176488 | 11.18366769 | 11.32661944 | 185 |
| 9.206267 | 11.12991334 | 11.28919793 | 190 |
| 9.241262 | 11.0550205 | 11.23699543 | 195 |
| 9.277693 | 10.95620787 | 11.16795653 | 200 |
| 9.311062 | 10.83039009 | 11.07975532 | 205 |
| 9.336683 | 10.67483375 | 10.97037285 | 210 |
| 9.351172 | 10.48883204 | 10.83973128 | 215 |
| 9.356374 | 10.27782766 | 10.69393981 | 220 |
| 9.366501 | 10.06038322 | 10.55276961 | 225 |
| 9.394525 | 9.852232623 | 10.43342286 | 230 |
| 9.406667 | 9.619740493 | 10.30078036 | 235 |
| 9.386984 | 9.350367509 | 10.1406942 | 240 |
| 9.330448 | 9.043704247 | 9.951074374 | 245 |
| 9.238138 | 8.705458525 | 9.735912827 | 250 |

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|---|---|---|---|
| 9.129287 | 8.357627446 | 9.51740301 | 255 |
| 9.043217 | 8.037781174 | 9.337043541 | 260 |
| 8.947157 | 7.716957264 | 9.160667286 | 265 |
| 8.810293 | 7.371134923 | 8.956922909 | 270 |
| 8.632677 | 7.004313871 | 8.72602055 | 275 |
| 8.422289 | 6.626478919 | 8.47558239 | 280 |
| 8.205089 | 6.26030675 | 8.230662932 | 285 |
| 8.019609 | 5.935151934 | 8.028323163 | 290 |
| 7.83688 | 5.628403343 | 7.837843683 | 295 |
| 7.632661 | 5.323292404 | 7.63337519 | 300 |
| 7.412388 | 5.025024238 | 7.418698117 | 305 |
| 7.185081 | 4.7405354 | 7.201159669 | 310 |
| 6.964051 | 4.478689018 | 6.992509797 | 315 |
| 6.765766 | 4.249353707 | 6.807902782 | 320 |
| 6.602411 | 4.058823135 | 6.658491662 | 325 |
| 6.469555 | 3.902917164 | 6.538932755 | 330 |
| 6.355826 | 3.773762322 | 6.436980695 | 335 |
| 6.262265 | 3.671330703 | 6.353057088 | 340 |
| 6.192831 | 3.597360094 | 6.29071192 | 345 |
| 6.150537 | 3.553103974 | 6.252702257 | 350 |
| 6.137228 | 3.539297677 | 6.24073512 | 355 |
| 6.153483 | 3.556167446 | 6.255350563 | 360 |

**Appendix (2)**

| Hours of Sunlight | Sunset | Sunrise | Day |
|---|---|---|---|
| 9.940392913 | 16.9702 | 7.0298035 | 0 |
| 9.985084085 | 16.99254 | 7.007458 | 5 |
| 10.04625063 | 17.02313 | 6.9768747 | 10 |
| 10.12293062 | 17.06147 | 6.9385347 | 15 |
| 10.21398264 | 17.10699 | 6.8930087 | 20 |
| 10.31813974 | 17.15907 | 6.8409301 | 25 |
| 10.43406273 | 17.21703 | 6.7829686 | 30 |
| 10.56038912 | 17.28019 | 6.7198054 | 35 |
| 10.69577442 | 17.34789 | 6.6521128 | 40 |
| 10.83892424 | 17.41946 | 6.5805379 | 45 |
| 10.98861655 | 17.49431 | 6.5056917 | 50 |
| 11.14371431 | 17.57186 | 6.4281428 | 55 |
| 11.30316948 | 17.65158 | 6.3484153 | 60 |
| 11.46601959 | 17.73301 | 6.2669902 | 65 |
| 11.63137827 | 17.81569 | 6.1843109 | 70 |
| 11.79842118 | 17.89921 | 6.1007894 | 75 |
| 11.9663686 | 17.98318 | 6.0168157 | 80 |
| 12.13446579 | 18.06723 | 5.9327671 | 85 |
| 12.30196222 | 18.15098 | 5.8490189 | 90 |
| 12.46809059 | 18.23405 | 5.7659547 | 95 |
| 12.63204666 | 18.31602 | 5.6839767 | 100 |
| 12.79297078 | 18.39649 | 5.6035146 | 105 |
| 12.94993233 | 18.47497 | 5.5250338 | 110 |
| 13.10191828 | 18.55096 | 5.4490409 | 115 |
| 13.24782716 | 18.62391 | 5.3760864 | 120 |
| 13.38646994 | 18.69323 | 5.306765 | 125 |
| 13.51657904 | 18.75829 | 5.2417105 | 130 |
| 13.63682671 | 18.81841 | 5.1815866 | 135 |
| 13.7458532 | 18.87293 | 5.1270734 | 140 |
| 13.84230449 | 18.92115 | 5.0788478 | 145 |
| 13.92487852 | 18.96244 | 5.0375607 | 150 |
| 13.9923771 | 18.99619 | 5.0038114 | 155 |
| 14.04376023 | 19.02188 | 4.9781199 | 160 |
| 14.07819788 | 19.0391 | 4.9609011 | 165 |
| 14.09511461 | 19.04756 | 4.9524427 | 170 |
| 14.09422196 | 19.04711 | 4.952889 | 175 |
| 14.07553523 | 19.03777 | 4.9622324 | 180 |
| 14.03937263 | 19.01969 | 4.9803137 | 185 |
| 13.98633676 | 18.99317 | 5.0068316 | 190 |
| 13.9172808 | 18.95864 | 5.0413596 | 195 |
| 13.83326299 | 18.91663 | 5.0833685 | 200 |
| 13.73549433 | 18.86775 | 5.1322528 | 205 |
| 13.62528437 | 18.81264 | 5.1873578 | 210 |
| 13.50398962 | 18.75199 | 5.2480052 | 215 |
| 13.37296821 | 18.68648 | 5.3135159 | 220 |
| 13.23354297 | 18.61677 | 5.3832285 | 225 |
| 13.08697427 | 18.54349 | 5.4565129 | 230 |
| 12.93444268 | 18.46722 | 5.5327787 | 235 |
| 12.77704071 | 18.38852 | 5.6114796 | 240 |
| 12.6157728 | 18.30789 | 5.6921136 | 245 |
| 12.45156186 | 18.22578 | 5.7742191 | 250 |
| 12.28526125 | 18.14263 | 5.8573694 | 255 |
| 12.11767066 | 18.05884 | 5.9411647 | 260 |
| 11.94955477 | 17.97478 | 6.0252226 | 265 |
| 11.78166358 | 17.89083 | 6.1091682 | 270 |
| 11.61475342 | 17.80738 | 6.1926233 | 275 |
| 11.44960761 | 17.7248 | 6.2751962 | 280 |
| 11.28705595 | 17.64353 | 6.356472 | 285 |
| 11.12799185 | 17.564 | 6.4360041 | 290 |
| 10.97338601 | 17.48669 | 6.513307 | 295 |
| 10.82429532 | 17.41215 | 6.5878523 | 300 |
| 10.68186564 | 17.34093 | 6.6590672 | 305 |
| 10.54732695 | 17.27366 | 6.7263365 | 310 |
| 10.42197981 | 17.21099 | 6.7890101 | 315 |
| 10.30717213 | 17.15359 | 6.8464139 | 320 |
| 10.20426607 | 17.10213 | 6.897867 | 325 |
| 10.11459588 | 17.0573 | 6.9427021 | 330 |
| 10.03941842 | 17.01971 | 6.9802908 | 335 |
| 9.979859537 | 16.98993 | 7.0100702 | 340 |
| 9.93686038 | 16.96843 | 7.0315698 | 345 |
| 9.911128599 | 16.95556 | 7.0444357 | 350 |
| 9.903099301 | 16.95155 | 7.0484503 | 355 |
| 9.91291007 | 16.95646 | 7.043545 | 360 |
| 9.940392913 | 16.9702 | 7.0298035 | 365 |

**Table 1 Average min and max temperature in Amman, Jordan.**

| | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Max Temperature °C (°F) | 13 (55.4) | 15 (59) | 17 (62.6) | 23 (73.4) | 28 (82.4) | 31 (87.8) | 32 (89.6) | 33 (91.4) | 31 (87.8) | 28 (82.4) | 20 (68) | 15 (59) | 23.8 (74.9) |
| Average Temperature °C (°F) | 7.7 (45.9) | 9 (48.2) | 11.6 (52.9) | 15.8 (60.4) | 20 (68) | 23.6 (74.5) | 25.1 (77.2) | 25.2 (77.4) | 23.4 (74.1) | 19.9 (67.8) | 14.3 (57.7) | 9.4 (48.9) | 17.1 (62.8) |
| Average Min Temperature °C (°F) | 4 (39.2) | 5 (41) | 6 (42.8) | 10 (50) | 13 (55.4) | 16 (60.8) | 18 (64.4) | 19 (66.2) | 16 (60.8) | 14 (57.2) | 9 (48.2) | 5 (41) | 11.3 (52.3) |

**Table 2:Required building setbacks in GAM regulations for residential zones. (Source: Greater Amman Municipality, GAM, 2006).**

| Setbacks in GAM regulations for residential zones | | | | |
|---|---|---|---|---|
| Residential zone | Frontal setback (m) | Side setback (m) | Rear setback (m) | **Allowable block height** |
| Class(A) | 5 | 5 | 7 | **15(m)** |
| Class(B) | 4 | 4 | 6 | **15(m)** |
| Class(C) | 4 | 3 | 4 | **15(m)** |
| Class(D) | 3 | 2.5 | 2.5 | **15(m)** |
| | | | | |

**Table 3: The minimum allowable plot area for residential zone categories in GAM**

| **Residential zone** | **Minimum plot area($m^2$)** |
|---|---|
| Class(A) | **1000** |
| Class(B) | **750** |
| Class(C) | **500** |
| Class(D) | **300** |

**Table 4: Direct solar radiation((kw/$m^2$)**

| 105 | Day:15-Apr |
|---|---|
| **direct radiation (kW/m2)** | **Hour (24h)** |
| 0 | 0 |
| 0 | 0.125 |
| 0 | 0.25 |
| 0 | 0.375 |
| 0 | 0.5 |
| 0 | 0.625 |
| 0 | 0.75 |
| 0 | 0.875 |
| 0 | 1 |
| 0 | 1.125 |
| 0 | 1.25 |
| 0 | 1.375 |
| 0 | 1.5 |
| 0 | 1.625 |
| 0 | 1.75 |
| 0 | 1.875 |
| 0 | 2 |
| 0 | 2.125 |
| 0 | 2.25 |

| | |
|---|---|
| 0 | 2.375 |
| 0 | 2.5 |
| 0 | 2.625 |
| 0 | 2.75 |
| 0 | 2.875 |
| 0 | 3 |

**Table 5: Recommended setbacks to achieve the targeted insolation percentages**

| solar profile | | 38 | 35 | 38 | 46 | 38 | 35 | 38 | 46 | 38 | 35 | 38 | 46 | 38 | 35 | 38 | 46 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Setback | S | 0.95H | 0.99H | 0.95H | 0.72H | 0.64H | 0.72H | 0.64H | 0.48H | 0.31H | 0.36H | 0.31H | 0.24H | 0.0H | 0.0H | 0.0H | 0.OH |
| | | 14.25 | 14.85 | 14.25 | 10.8 | 9.6 | 10.8 | 9.6 | 7.2 | 4.65 | 5.4 | 4.65 | 3.6 | 0 | 0 | 0 | 0 |
| Building height | H | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

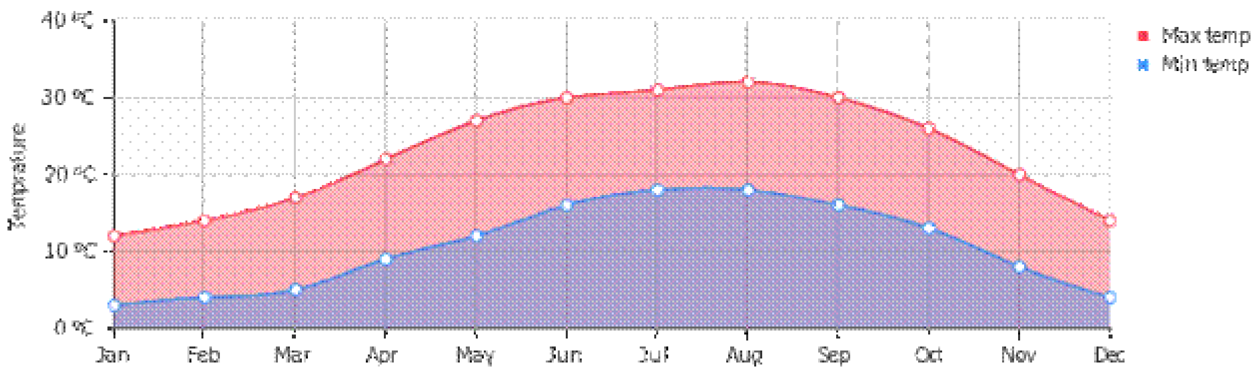


**Figure 1 Average min and max temperature in Amman, Jordan.**

**Figure 2: Land division in Abu Nseir district.( source: www.ammancitygis.gov.jo)**

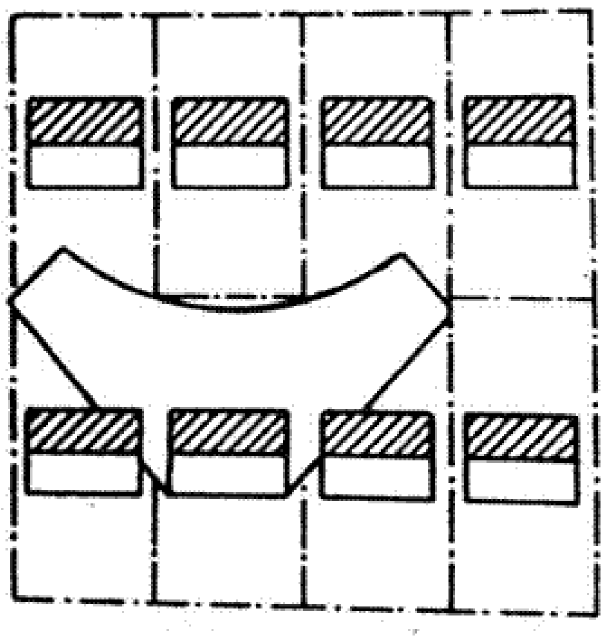

**Figure 3: Regular setbacks effect.( source: leader in architectural design based on climate/ Ministry of energy and renewable resources)**

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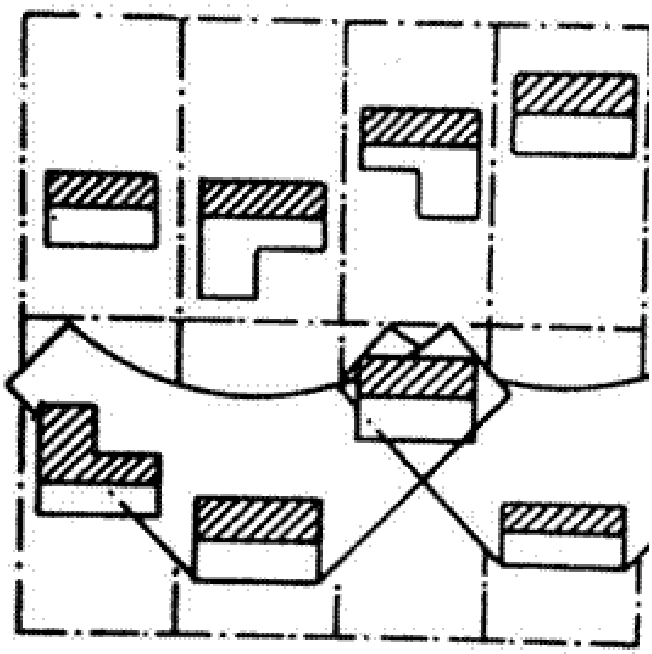


**Figure 4: Random setbacks effect.( source: leader in architectural design based on climate/ Ministry of energy and renewable resources.)**

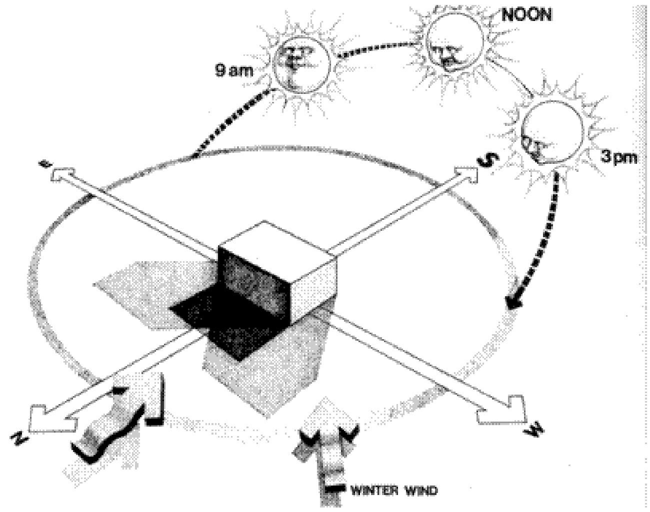
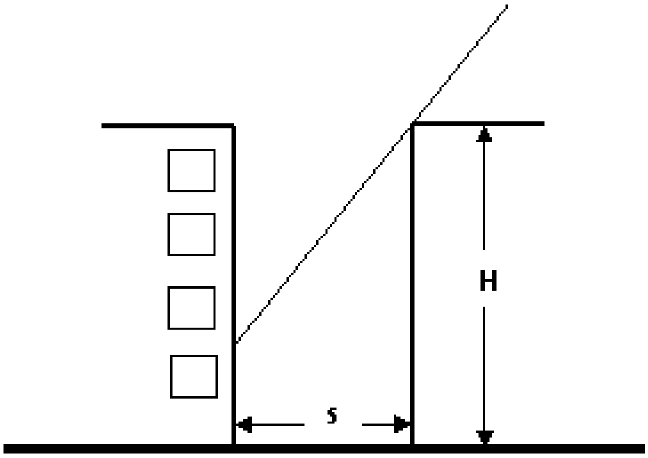



**Figure 5: Building orientation according to sun angle**

**Figure 6: Land divisions according to residential land use for type (c).source: www.ammancitygis.gov.jo**




**Fig(): shows the relationship between building height and recommended setback with maximum solar insolation.**

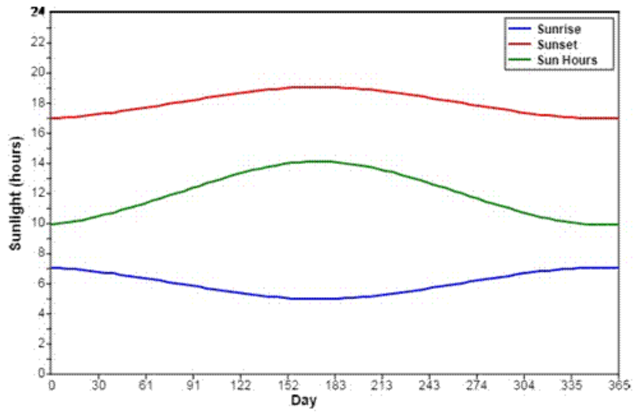



**Figure 7: Direct radiation(kw/m$^2$)**

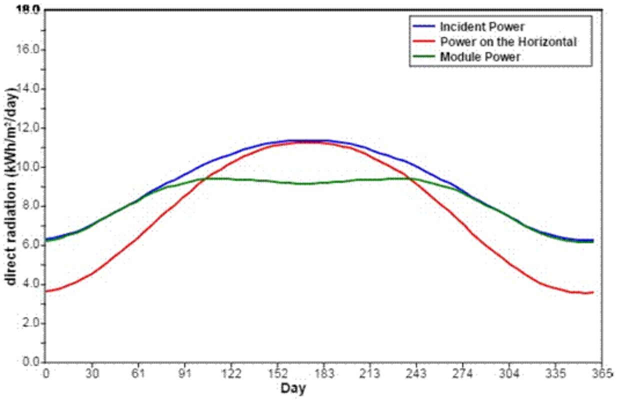



**Figure 8: Daily solar insolation**

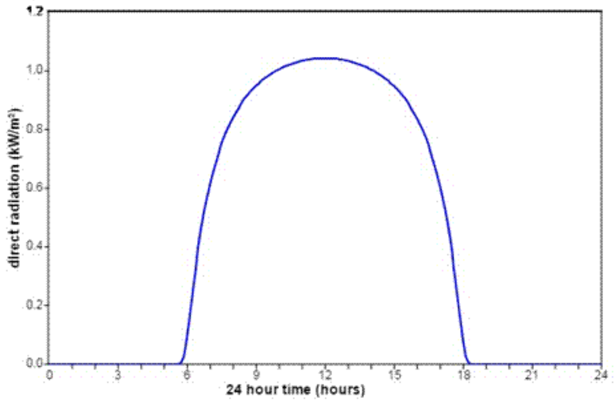



**Figure 9: Sunlight hours**

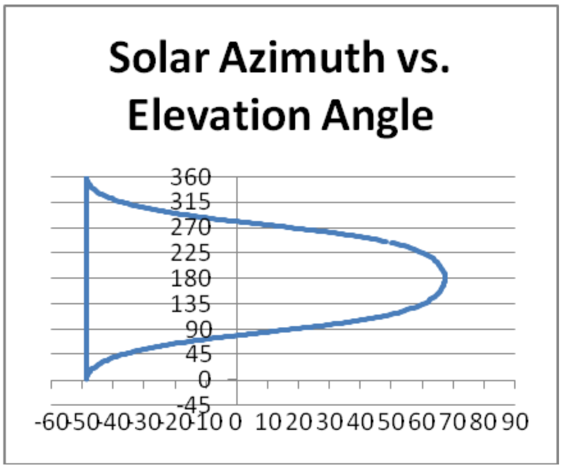



**Figure 10: sun declination degree**

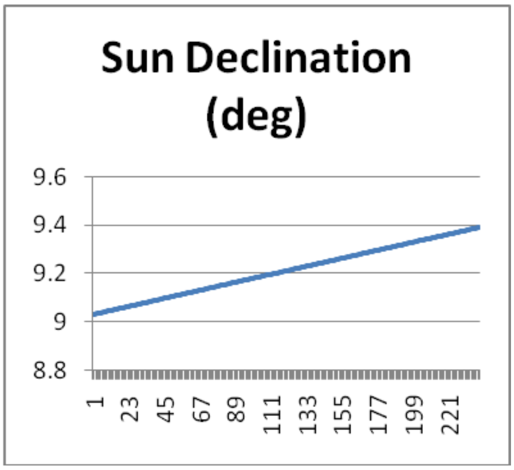



**Figure 11: Solar Azimuth VS elevation angle**

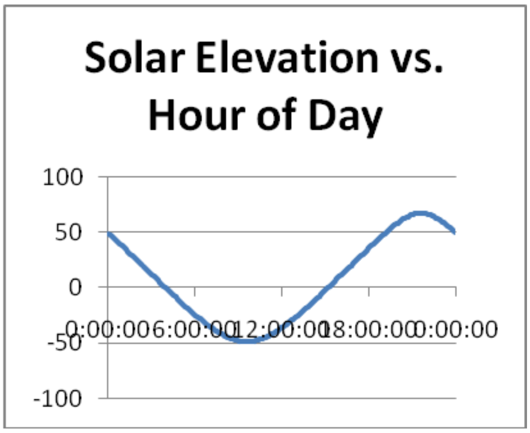



**Figure 12: Solar elevation VS hour of day**