Journal of Engineering and Applied Sciences 11 (6): 1317-1332, 2016
ISSN: 1816-949X

The Effect of Urban Regulations and Codes on Energy Cycle in Residential Apartment Buildings of Iran's Cold Dry Climate of Tabriz

[1]Fariborz Mahdavi, [1]Tabatabaei Fard and [2]Fagan Aliyev
[1]Faculty of Architecture, Azerbaijan University of Architecture and Construction, Baku, Azerbaijan
[2]Azerbaijan University of Architecture and Construction,
The president of the International Eco-Energy Academy, Baku, Azerbaijan

Abstract: The study's aim is to study the effect of slight orientation deviations from the South in cold-dry climate of Tabriz. Choosing Tabriz as the case of study create a better comparison possibility and more tangible results. A hypothetical residential block based on contextual studies being modeled and simulated by the climatic, BIM based software of ECOTECTTM and analysed for examining, the effect of optimum orientation of residential building blocks on annual energy gains, losses and consumption versus prevalent common orientation regulations. Results show that although the annual temperature distribution or interior felt temperatures through a year are approximately the same but monthly degree days and passive gains breakdown figures indicate more energy loads and more energy consumption need to provide the human thermal comfort conditions inside the determined zones.

Key words: Residential blocks, urban regulations, optimum orientation, cold dry climate, bim simulation, energy cycle

INTRODUCTION

Modelling being done in EcotectTM software with Tabriz's weather data file being mounted on software. For the cases of study, hypothetical residential blocks which it's technical and design specifications being extracted from local municipality regulations and is now broadly used in city-being chosen.

The orientation, total area of each floor, the fenestration sizes and ratio to the total area of floor, materials and etc. all being chosen and modelled correspondent with the contextual studies of regulations in Iran's north west city planning and urban studies in municipalities. Based on these studies in each residential block five south faced and five north faced plots being chosen for modelling, because it was aimed to see the reciprocal shading effects of buildings which couldn't be seen in individual apartment blocks.

The hypothesis of this study is that the main orientation of a building (or residential blocks in this case) can substantially affect the total energy consumption of buildings and the decisions and policies of city planners, municipalities and governments directly affects the total energy consumption of cities. Here's what being done through this research in three stages: First stage, testing the influence of orientation on energy consumption, secondly finding the optimum orientation for Tabriz and lastly comparing the ratio and finding percentage of fluctuations of energy consumption between current situation and optimum orientation conditions.

Literature review: The energy sector worldwide faces evidently significant challenges that everyday become even more acute, energy efficiency measures are nowadays well known and the main issue is to identify those that will be proven to be the more effective and reliable in the long term (Diakaki *et al*., 2008). In Iran, the portion of residential sector in energy consumption is 37% having the most portion compare with other sectors as shown in. On the other hand, in the recent years the energy consumption in housing unit has increased in Iran and it has been doubled during 1998-2008 as shown in (Faizi *et al*., 2011), (Fig. 1).

Most of studies and papers related with climatic designs being done based on specific or local climatic zones in different countries and cities and each of them studied the effect of different parameters on interior conditions (Murgul *et al*., 2015;

Corresponding Author: Fariborz Mahdavi, Faculty of Architecture, Azerbaijan University of Architecture and Construction, Baku, Azerbaijan

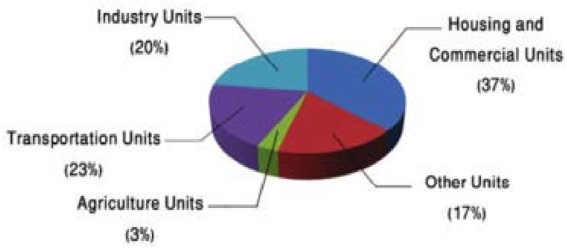


Fig. 1: The proportion of housing and commercial sector in total energy distribuition (Faizi *et al.*, 2011)

Perlova *et al.*, 2015). Also researchers found some good and helping studies related to Iran, in different subjects and Iran's different climatic zones (Bahadori, 1978; Faizi *et al.*, 2011; Foruzanmehr and Nicol, 2008; Heidari and Sharples, 2002; Shirzadi and Nagashzadeghan, 2015) but mostly the subject and approach of the Faizi *et al.* (2011) helps the researchers in this study.

Some previous researches, studies the effect of orientation on cooling and heating loads in residential and non-residential in scale buildings (Agrawal, 1992; Andersson *et al.*, 1985; Futrell *et al.*, 2015; Gagliano *et al.*, 2014; Han *et al.*, 2015; Morrissey *et al.*, 2011; Pacheco *et al.*, 2012; Singh *et al.*, 2011) and some of these studies are in bigger scales like urban scales (Ali-Toudert and Mayer, 2006; Amado and Poggi, 2012). Also, it can be found studies that investigate the effect of orientation on energy consumption in different cities or different climatic regions (Tamimi *et al.*, 2011; Faizi *et al.*, 2011; Haase and Amato, 2009; Koranteng and Abaitey, 2010; Numan *et al.*, 1999; Raychaudhuri *et al.*, 1965; Sedki *et al.*, 2013; Skibin and Noach, 1982; Yohanis and Norton, 2002) or different faced surfaces with different shading devices (Bekkouche *et al.*, 2011; Felske, 1978; Garcia *et al.*, 2002; Gopinathan, 1991; Hadavand and Yaghoubi, 2008; Kontoleon and Bikas, 2002; Kontoleon and Eumorfopoulou, 2008, 2010; Tzempelikos and Athienitis, 2007) or different insulation methods and optimum thicknesses (Al-Sanea and Zedan, 2002; Daouas, 2011; Ozel, 2011, 2013a, b). Within these papers, study of Poel *et al.* (2007), "Energy performance assessment of existing dwellings" had a shared approach with analysis and evaluation of existed dwellings in the first stage of this study.

For analysing comfort and climatic conditions simulation with BIM based software method being chosen. BIM software analysis is one of the methods that being used in so many research and development projects, from small scale architectural projects to large scale urban projects, with vast capabilities for various conditions which can make complex analysis (Cemesova *et al.*, 2011; Krygiel and Nies, 2008; Moon *et al.*, 2011; Motawa and Carter, 2013; O'Brien *et al.*, 2008; Papadopoulos and Giama, 2007; Yi *et al.*, 2015; Zeng, 2012).

Therefore, researchers based on researches in the field of different BIM base software, selected Ecotect™ Software formodelling, simulating and analysis. The advantage of Ecotect™ in this study was vast material library for choosing right and accurate materials, easy and accurate modelling capabilities, the ability to mounting the correspondent city's weather data file and presenting graphical, illustrative and Comparable results. The other reason for choosing software Simulation method was the complexity of quantitative calculations for total U-value of materials, thermal equations and not availability of good and accurate devices for all the analysis.

Ecotect™, owned by Autodesk, Inc. is "a complete building design and environmental analysis tool that covers the full range of simulation and analysis functions required to truly understand how a building design will operate and perform". The primary program analysis capabilities include energy analysis, thermal analysis and lighting/shading analyses. The energy and thermal analysis features take into account factors such as resource management, heating and cooling loads and ventilation and airflow. The lighting/shading analysis tools allow for solar analysis, right-to-light analysis, daylighting assessment, shading design and lighting design.

Ecotect™ Software is an environmental analysis tool that allows designers to simulate building performance right in conceptual phase. It includes a wide array of detailed analysis functions with a highly visual and interactive display that make analytical results can be directly presented within the context of the building model. Thus, complex concepts and extensive datasets can be communicated in surprisingly intuitive and effective ways (Yang *et al.*, 2014).

MATERIALS AND METHODS

Methodology of modelling and simulation

General information: Modelling and simulation being done in Ecotect™ Software. Simulations were mostly thermal simulations but a natural lighting analysis also being instructed on final analysis stage. As choosing the right cases with right specifications has an crucial importance in credibility of study, a vast literature review in cold climate cities being done and also local and contextual studies on Tabriz and general climates of Iran municipal and regulations being done to extract right and common specifications and regulations for these type of cities in common residential blocks buildings. In this stage collaborations through interviewing and meetings with different district municipalities and officials took place and based on these data and also data from most residential apartment projects which was currently under construction, the exact specification and building information codes being extracted for modelling and simulation.

Extracted patterns and specification for buildings both in large-city scale and small-free standing building scale, mutually being studied and compared in order to form simulation models correspondent and possibly most close cases to more than seventy percent of what are being built currently in these region cities and especially in Tabriz. Here researchers acknowledged all the individuals and officials that help throughout the study and interview process in all stages of this study.

Residential building models data: At the stage of literature review and comparing different districts' master plan, it's being concluded that linear pattern, in Tabriz and most of adjacent cities is common and especially in latest urban plans for residential blocks, it's most common type. Also, the orientation of buildings mostly are face to South-North and circulations between buildings and streets are Eastern-Western.

Also, most of the regular plots for each building have an area around 200-350 m^2 and an average width at 12-18 m in and 20-30 m of length. Lastly studies shows that an average width of a crossing or alley in these cases of block size is around 6-15 m. Therefore, based on these studies, the block size was chosen 15×30 m and based on the codes of municipality 60% of it from north can be occupied and built which makes the building occupied size 12×l5 m. As the aim of the study was beyond the study of a singular building, some alternative block samples being modelled through the first simulation sessions which led the researchers to the final alternative with specifications that cited below. Also it's important to mention that because the main question of this study was the "amount of orientation effect in residential apartment blocks in cold dry climate of Tabriz", all the modelling and simulation stages being done on two blocks with all the same specifications with just one difference which was the general orientations of buildings which in one type, orientation was Southern-Northern what is common and used in most of the blocks which is and in other type, buildings' general orientation is faced to optimal orientation of Tabriz extracted from Ecotect™ software based on Tabriz's climatic data which is slightly angled (16.5°) to the North-Western to south eastern. Thus final specifications models are as being cited below.

A small size neighbourhood being created with two blocks of parallel buildings with a crossing alley between, with width of 12 m. In each block five buildings being modelled to examine the effect of shadowing and wind close to the reality. As being mentioned based on the contextual studies each building's plot is 15×30 m and occupied area is 15×18 m.

Based on municipalities' codes in most of lran's cities, northern buildings can be build higher than the southern ones due to overshadowing problem. Thus, based on this code, northern buildings modelled in six floors and Southern buildings modelled on four floors. Also based on most of current residential building's height of each floor set to 3.20 (2.80 from floor to ceiling) overall the whole block consist of 10 buildings which at the end final height of northern buildings was 19.20 and Southern buildings was 12.8° and are in two groups with a crossing between.

Final important detail about modelling stage was fenestration which was different in southern and northern blocks .Based on codes in almost all cities of Iran, due to limiting the visual communication between buildings, northern buildings have windows in both facades, one faced to the court and other to the alley but Southern buildings have windows just to their court which is in their northern part of plot. This is one of the main variants of the experiment which is mostly because of the cultural factors and urban codes. Windows OKB and height are the same for all buildings and correspondent with actual codes.

Human thermal comfort range was chosen between 18-26°C, people's clothing level Chosen to light clothing with intensity index of 0.1-0.2 as the function was residential. Also the range of space occupation chosen 7× 24 and Windows being chosen to airtight.

Method of analysis: The 5 Southern blocks with 4 floors and 5 Northern block with 6 floors being modelled which each of these considered as one apartment unit and if all of than being considered as thermal zones, we were

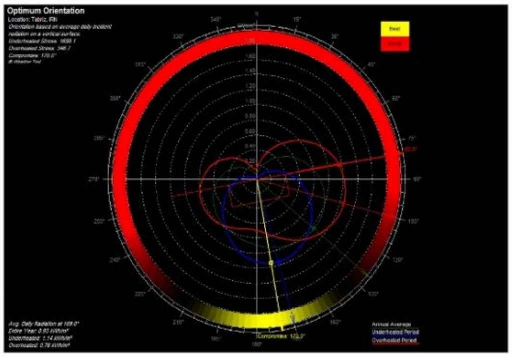


Fig. 2: Optimum orientation for Tabriz extracted from Ecotect™

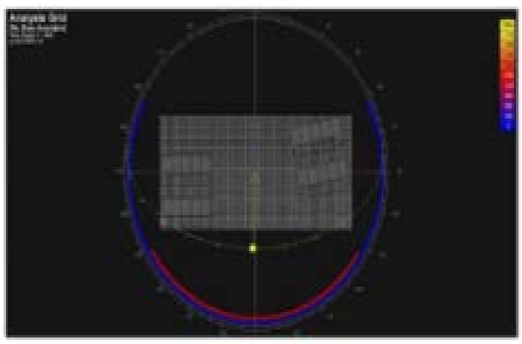


Fig. 3: Two modelled block plan, Northern-Southern oriented and optimum oriented

encountered with 100 thermal zones which leads to very long calculation and run time for analysis and also makes it hard to compare and analyse them. So it's been decided to consider some of them as samples in a way that at least two sample from each of floor were available to compare with each other and check that if everything and also results are the same which it makes our thermal samples to 36 zones. Other zones remain non-thermal to show their effect on other zones in one hand and on the other hand didn't overload calculation stage (Fig. 2- 4).

RESULTS AND DISCUSSION

Analysed results

Direct solar gains: As one of the main questions of this paper was how much orientation can affect the thermal conditions of interior, direct solar gain results can directly being effected by orientation and finally these results came out: Northern buildings gain more direct solar gain than the southern buildings and higher floors get more direct solar gain. Also buildings that placed in two ends of the rows have more fluctuations of internal temperature and also in their annual energy gain and lose cycle much

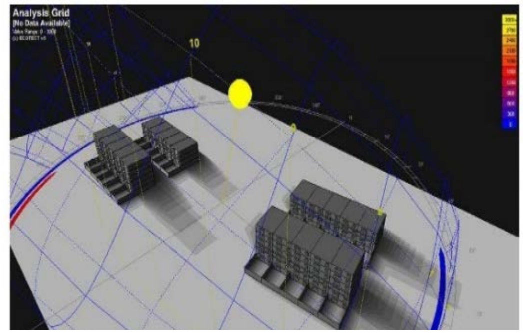


Fig. 4: Two modelled blocks

more total energy transfer can be seen in most of the results, especially on passive gain breakdown graphs. This issue is valid also for the last floor of each apartment. Last floors have less stable conditions, both in a singular day and also in annual life cycle (Fig. 5a,b).

Direct solar gains on buildings of optimum oriented buildings are not much different than current Northern-Southern buildings, neither indirect solar gains are not much different but analysing and comparing fabric gains figures and data which have a substantial effect on stabilizing and improvement of interior conditions shows that in optimum oriented buildings is much more and shows its effect on other parameters of comfort (Fig. 6 and 7).

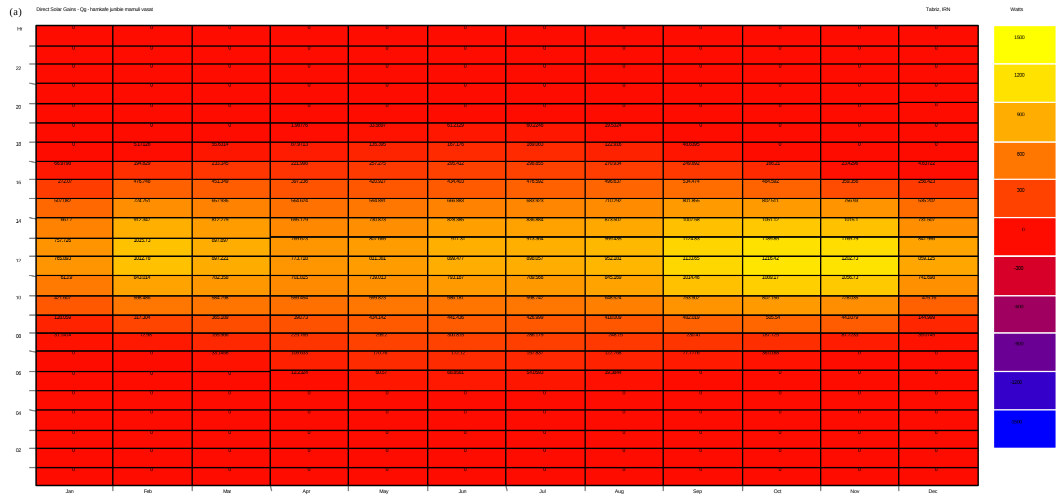
The last important result which is related to Right to Light, shows that the ground floor of northern apartments almost gain no direct sunlight which is a direct result of buildings height regulations (Fig. 8).

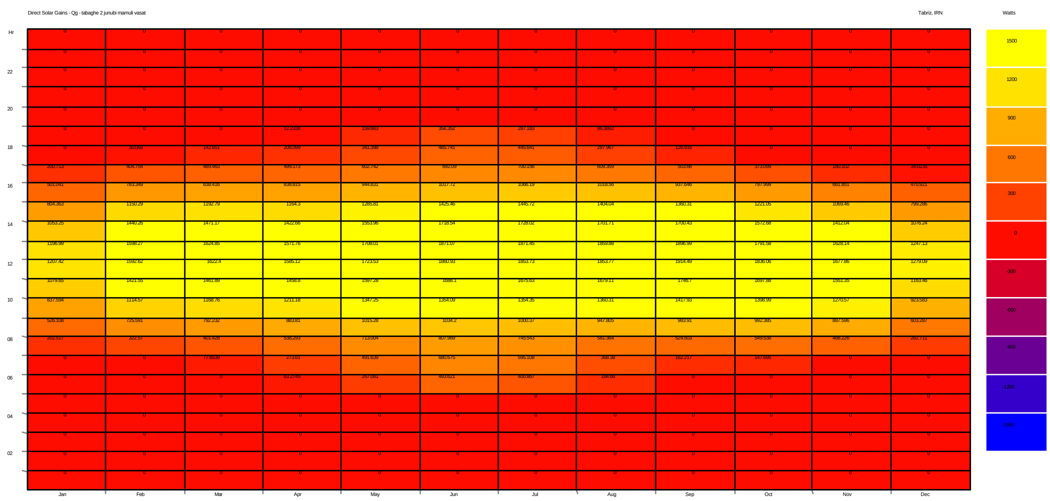
Monthly degree days and discomfort degree hours: These series of analyses shows that with optimum orientation, up to 15% less heating load especially in peak months of energy needs, December and January is needed which is a big difference for residential uses (Fig. 9 a, b).

Passive gains breakdown analysis: As a result of frequent windy days and Due to Tabriz's cold dry climate with severe wind blows a substantial amount of energy losses happens from infiltration of cold air from outside and ventilation, mostly because of poor airtight windows which indicates urgent need for regulations in this field (Initial studies showed that in <50% of current constructions are double glazed windows).

Southern apartments have more energy gains and losses which lead to more fluctuations of energy and ultimately less Stable interior thermal conditions compared to northern apartments. This part is valid for both optimum oriented and current oriented blocks (Fig. 10a, b).

(a)





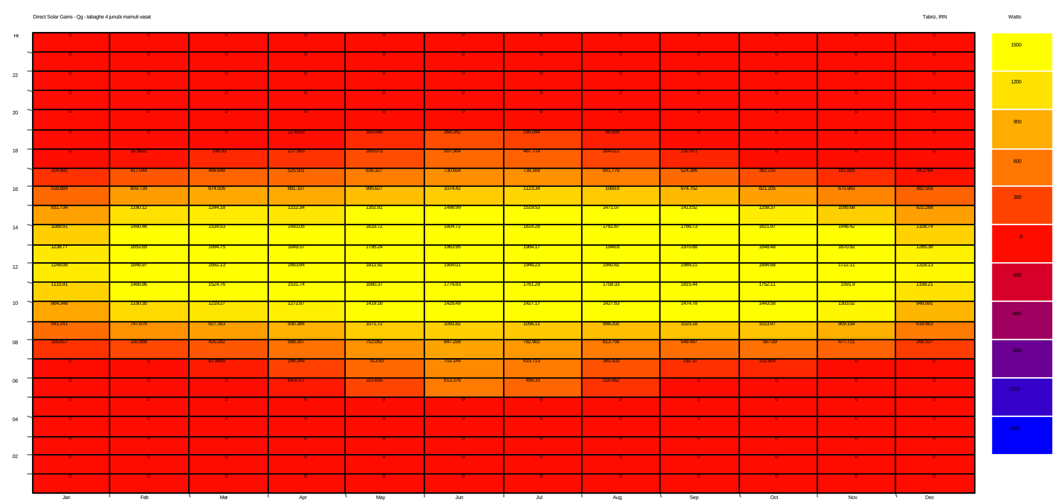


Fig. 5: Countinue

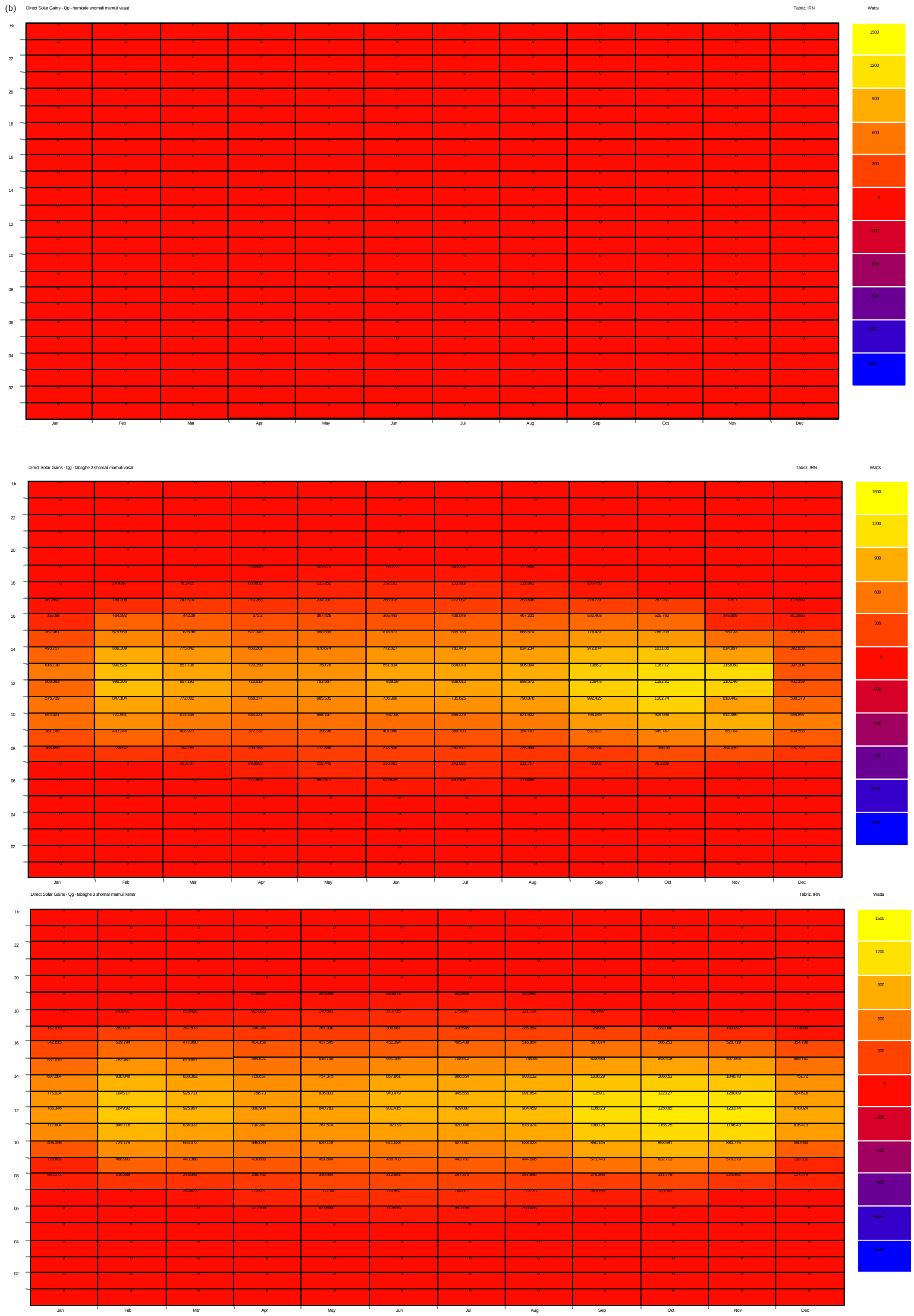
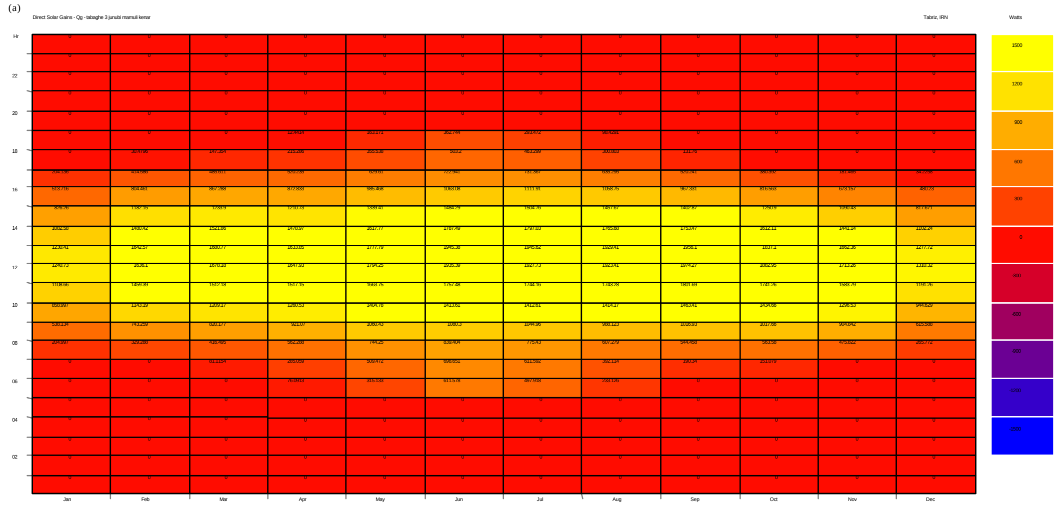
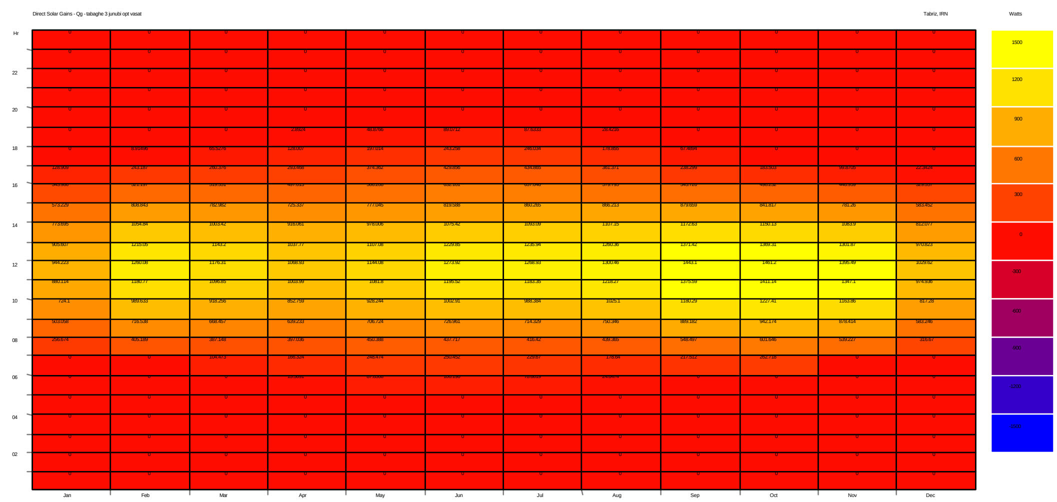


Fig. 5: a) Three left figures show direct solar gain in northern buildings in ground floor (top), second floor (middle) and last floor (down); b) other three right figures show the direct solar gains of southern correspondent blocks in the same order

(a)





(b)

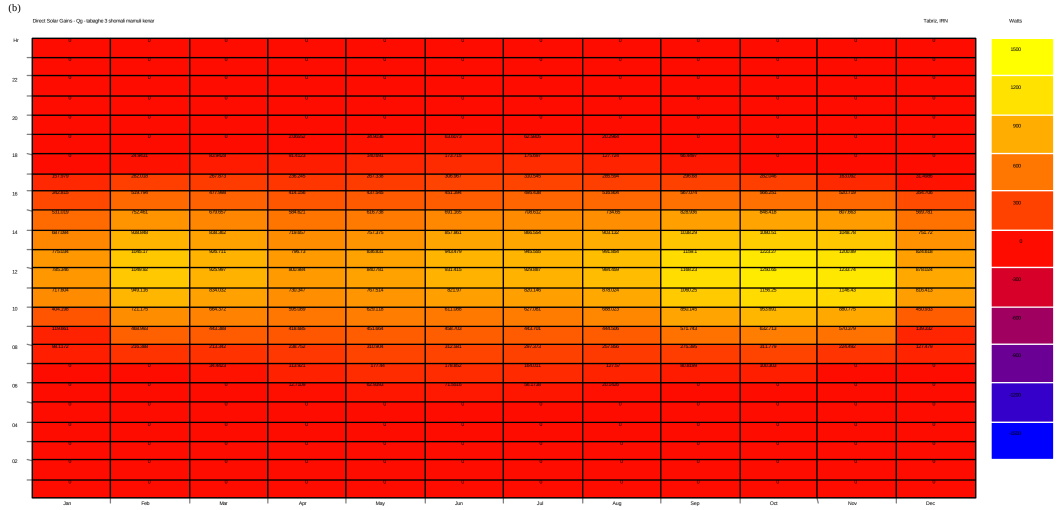


Fig. 6: Continue

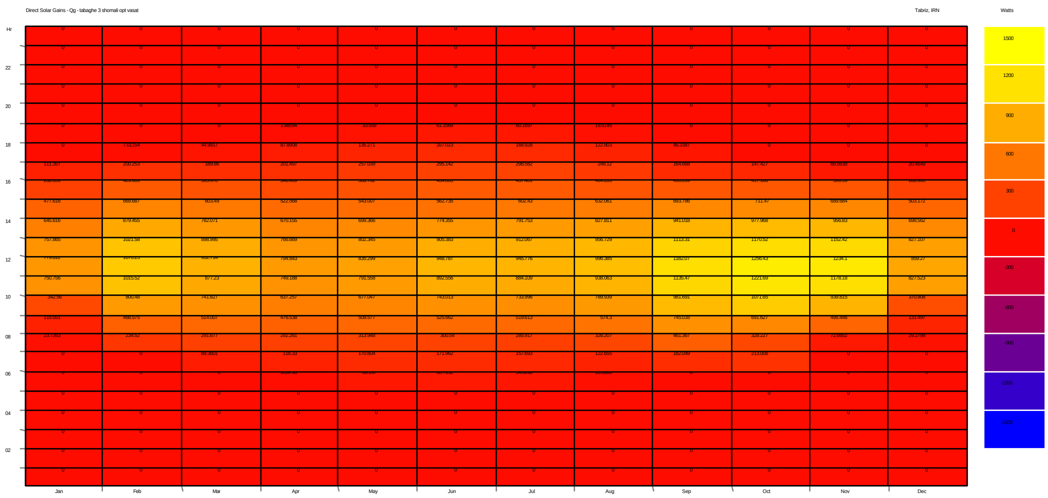
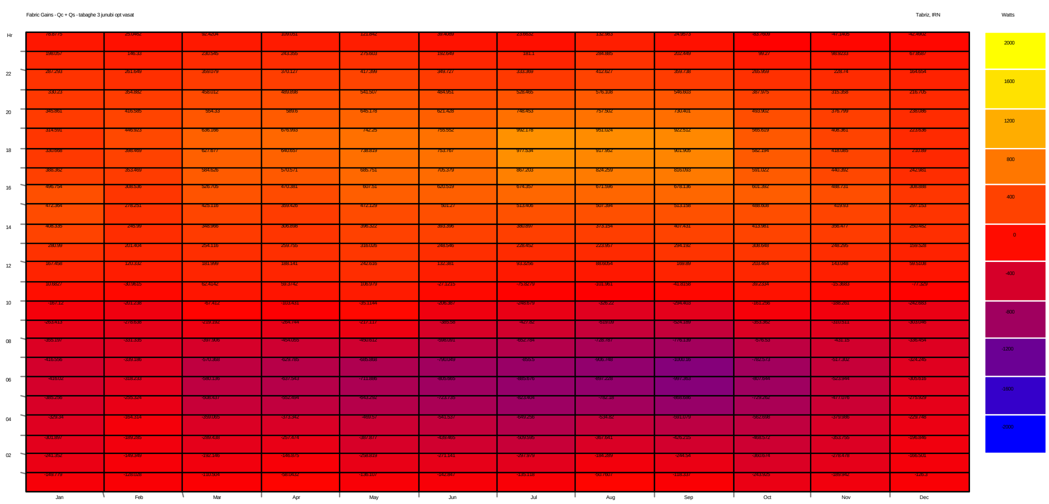


Fig. 6: a) Left figures are direct solar gains in 2nd floors of northern buildings, and right figures are direct solar gains of 2nd floors of southern buildings. Top figures are for current oriented blocks and bottom figures are for optimum oriented blocks



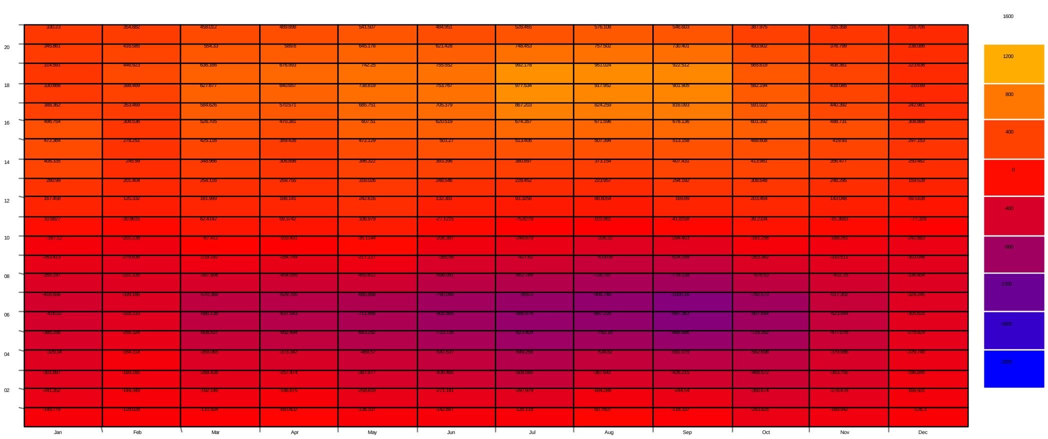
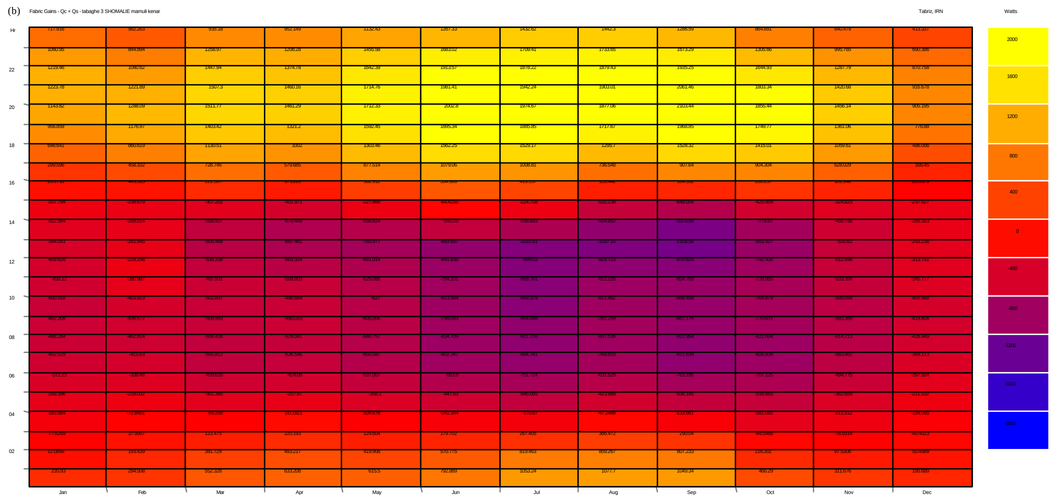


Fig. 7: Continue



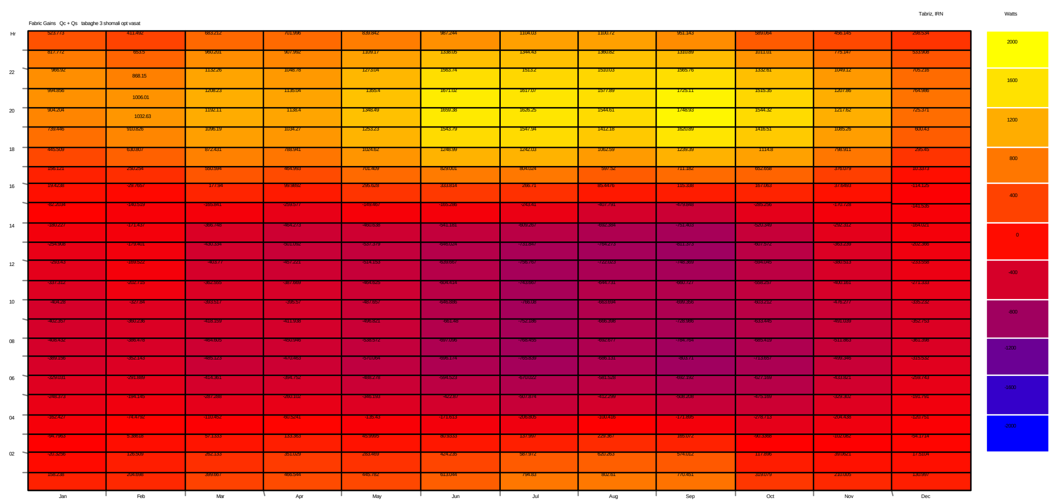


Fig. 7: a) Left figures are Fabric gains in 2nd floors of northern buildings and right figures are fabric gains of 2nd floors of southern buildings. Top figures are for normal oriented blocks and bottom figures are for optimum oriented blocks

Fig. 8: Ground floor of Northern

(b)

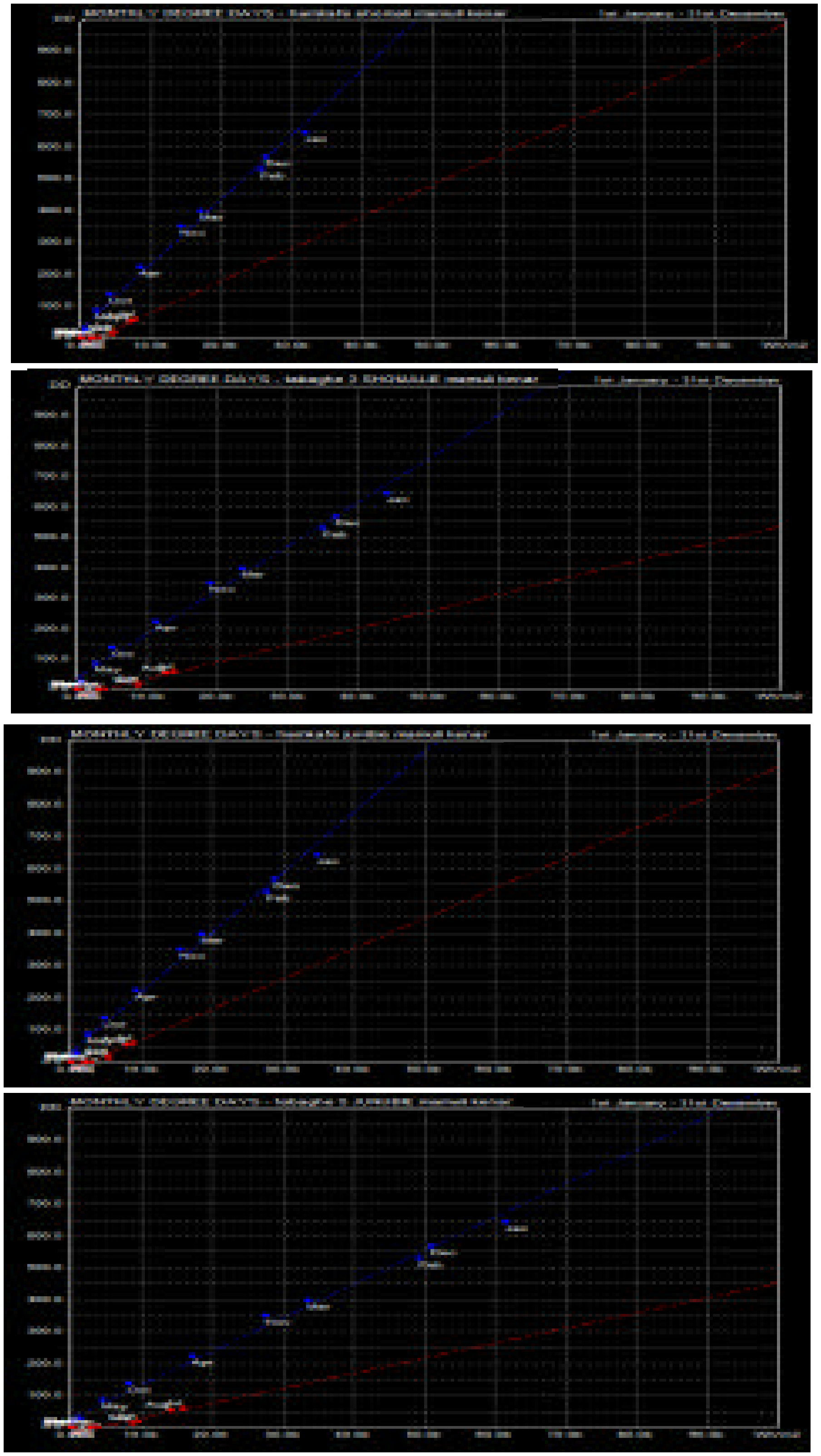


Fig. 9: Continue

(b)

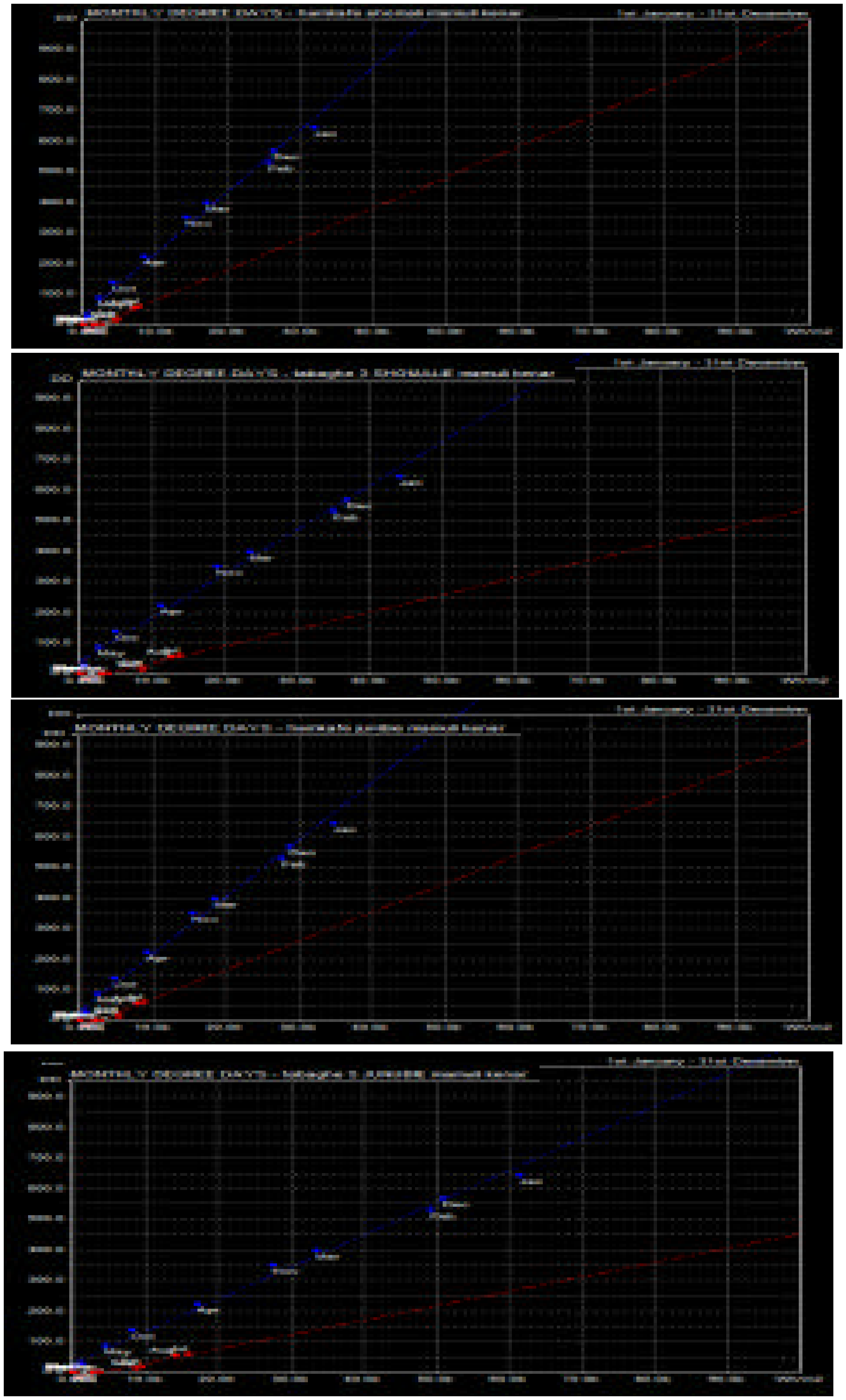


Fig. 9: a) Left figures are in order from top to bottom, monthly degree day graphs of ground and last floor (3rd floor) of southern and ground and last floor (5th floor) of Northern buildings with normal orientation; b) right graphs are in order, the correspondent figures for monthly degree days of optimum oriented floors of same floors. As horizontal row indicates the energy demands, less deviation from vertical angle means less energy loads in buildings

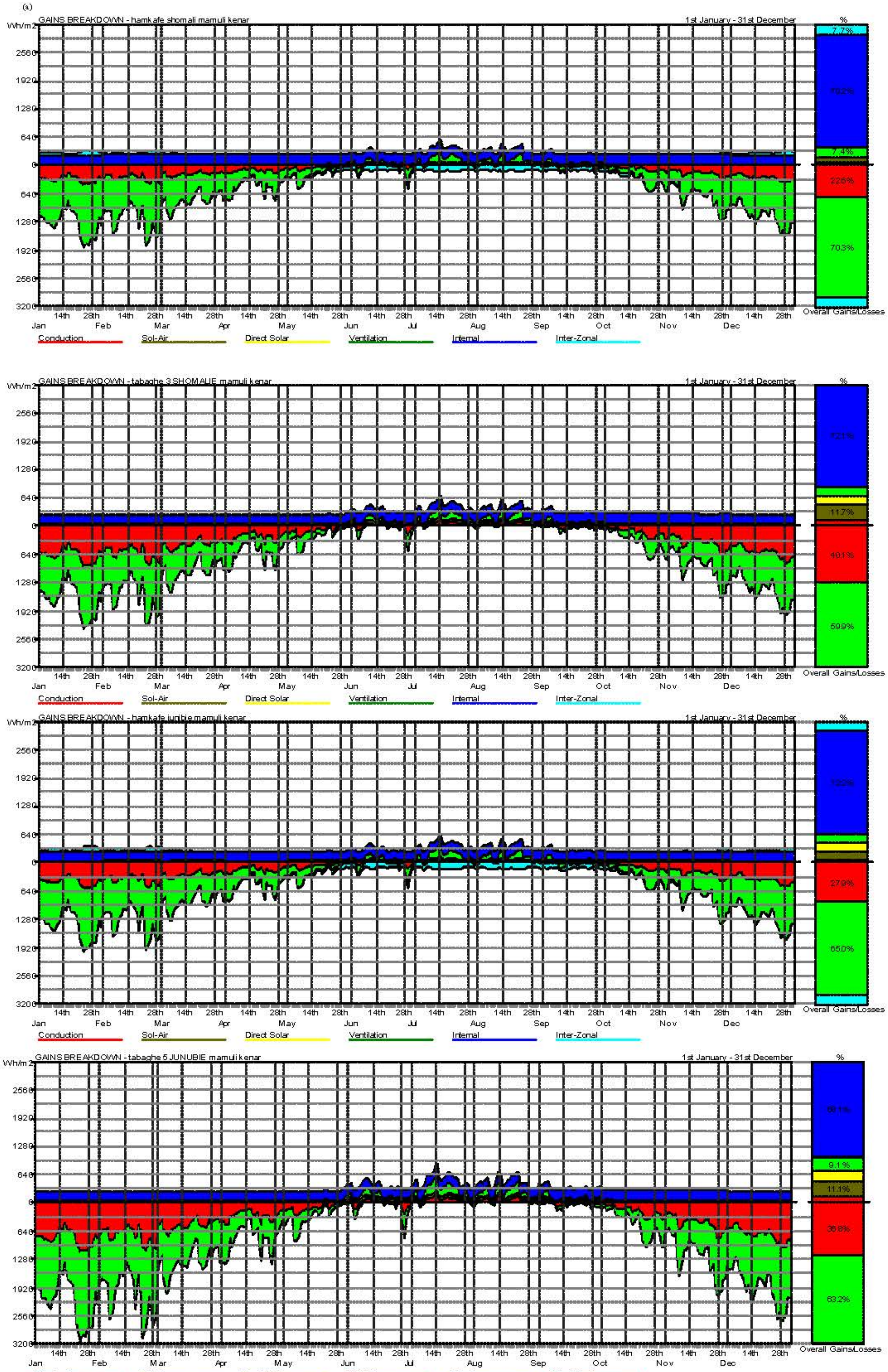


Fig. 10: Continue

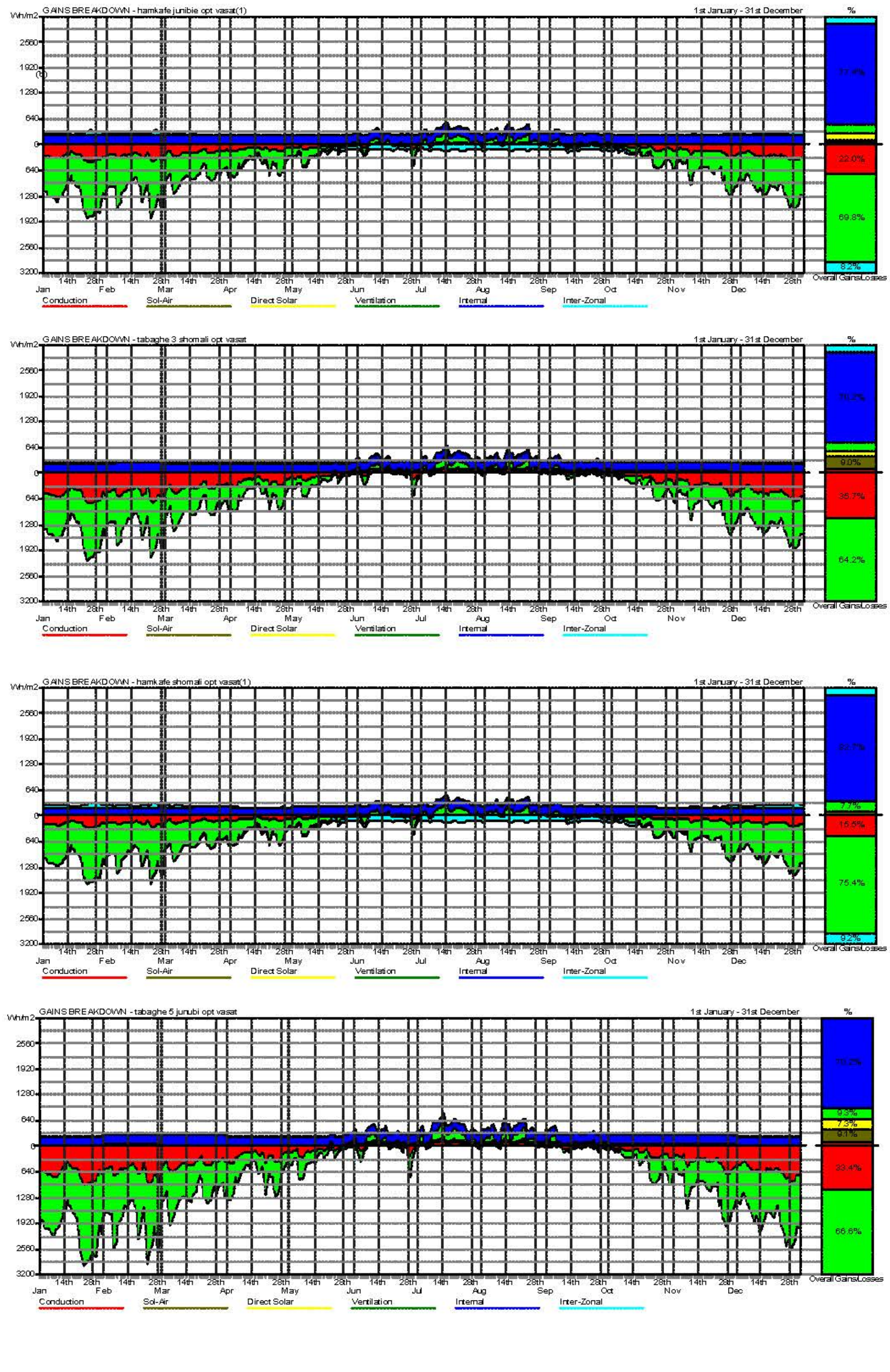


Fig. 10: a) Left figures are in order from top to bottom, passive breakdown graphs of ground and last floor (3rd floor) of southern and ground and last floor (5th floor) of northern buildings with current orientation; b) right graphs are in order, the correspondent graphs for passive breakdown of optimum oriented floors. Less deviation from the middle line in right graphs indicates less fluctuations of energy losses in optimum oriented buildings

CONCLUSION

The main hypothesis of this research was that large-scale regulations and urban decisions can directly affect total energy need and consumption of a city and as a more specific subject, orientation taken as the main criteria for this approach.

Although, direct solar gains and especially fabric gains indicates small differences in a positive way for optimization and enhancing more energy gains and less energy losses in optimized emended blocks but the best indicators was 'monthly discomfort degree hours' and 'monthly degree days' results which showed that with small orientation changes based on the specific cities geographical and climatic information, large amounts of energy conservation would be made. In this case, in Tabriz with a change of 16.5 in orientation of residential blocks and circulation streets and alleys between them, >15% of energy conservations would be made, especially in peak cold months of this city, December and January. This amount in a single unit of apartment with about 100 m^2 area is about 10000 W m^{-2} less energy consumption, in just January which if we calculate this for whole block and through all year, very large scale energy consumption conservation would be made. Further experimental studies with more accurate tools and also more comprehensive software modelling and simulation method with more applicable urban planning will be useful for more accurate and calculable results.

Other important side result of this study which meets the initial proposal of authors about the need for more specific and local, regional regulations in Iran's cities based on their climate and geographical characteristics, came out from passive gains breakdown results. Based on these analysis as the most of energy tosses and gains happen in two ways, one through the conduction method and mostly from the windows' glazed areas and two from the infiltrations of outdoor air through the windows, we may conclude that in most of Iranians cold cities, some regulations for windows sizes are needed which limit their sizes or their percentage area in proportion of whole exposed wall. First initial contextual studies and surveys shows that similar to other cities of Iran-and mostly based on merely cultural factors, the current ratio of window to wall is about 30-40% which needs to be adjusted and refine for at least extreme climates of lran's cities like very cold and dry cities of northwest of lran like Tabriz, Ardabil and etc. or very hot arid cities of central parts at Iran like Yazd, Isfahan and etc. First Findings of this study, correspondent with other studies before this proposes small windows for cold climates, especially when severe winds are prevalent in that region. More accurate, numerical and specific studies are needed in this field, both experimental and numerical method and also software based simulation methods.

REFERENCES

Agrawal, P.C., 1992. Review of passive systems and passive strategies for natural heating and cooling of buildings in Libya. Int. J. Energy Res., 16: 101-117.

Al-Sanea, S.A. and M.F. Zedan, 2002. Optimum Insulation Thickness for Building Walls in a Hot-Dry Climate. Int. J. Ambient Energy, 23: 115-126.

Ali-Toudert, F. and H. Mayer, 2006. Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate. Build. Environ., 41: 94-108.

Amado, M. and F. Poggi, 2012. Towards solar urban planning: A new step for better energy performance. Energy Procedia, 30: 1261-1273.

Andersson, B., W. Place, R. Kammerud and M.P. Scofield, 1985. The impact of building orientation on residential heating and cooling. Energy Build., 8: 205-224.

Bahadori, M.N., 1978. Passive cooling systems in Iranian architecture. Sci. Am., 238: 144-150.

Bekkouche, S.M.A., T. Benouaz, M.R. Yaiche, M.K. Cherier and M. Hamdani *et al.*, 2011. Introduction to control of solar gain and internal temperatures by thermal insulation, proper orientation and eaves. Energy Build., 43: 2414-2421.

Cemesova, A., C.J. Hopfe and Y. Rezgui, 2013. An approach to facilitating data exchange between BIM environments and a low energy design tool. Proceedings of the 13th Conference of International Building Performance Simulation Association, August 26-28, 2013, Cardiff University, Chambery, France, pp: 3234-3241.

Daouas, N., 2011. A study on optimum insulation thickness in walls and energy savings in Tunisian buildings based on analytical calculation of cooling and heating transmission loads. Appl. Energy, 88: 156-164.

Diakaki, C., E. Grigoroudis and D. Kolokotsa, 2008. Towards a multi-objective optimization approach for improving energy efficiency in buildings. Energy Build., 40: 1747-1754.

Faizi, F., M. Noorani, A. Ghaedi and M. Mahdavinejad, 2011. Design an optimum pattern of orientation in residential complexes by analyzing the level of energy consumption (Case study: Maskan Mehr Complexes, Tehran, Iran). Proc. Eng., 21: 1179-1187.

Felske, J.D., 1978. The effect of off-south orientation on the performance of flat-plate solar collectors. Solar Energy, 20: 29-36.

Foruzanmehr, A. and F. Nicol, 2008. Towards new approaches for integrating vernacular passive-cooling system into modern building in warm-dry climates of Iran. Proceedings of Conference on Air Conditioning and the low Carbon Cooling Challenge, July 27-29, 2008, Oxford Brookes University, London, UK., pp: 1-12.

Futrell, B.J., E.C. Ozelkan and D. Brentrup, 2015. Optimizing complex building design for annual daylighting performance and evaluation of optimization algorithms. Energy Build., 92: 234-245.

Gagliano, A., F. Patania, F. Nocera and C. Signorello, 2014. Assessment of the dynamic thermal performance of massive buildings. Energy Build., 72: 361-370.

Garcia, H.V., A. Esteves and A. Pattini, 2002. Passive solar systems for heating, daylighting and ventilation for rooms without an equator-facing facade. Renewable Energy, 26: 91-111.

Gopinathan, K.K., 1991. Solar radiation on variously oriented sloping surfaces. Solar Energy, 47: 173-179.

Haase, M. and A. Amato, 2009. An investigation of the potential for natural ventilation and building orientation to achieve thermal comfort in warm and humid climates. Solar Energy, 83: 389-399.

Hadavand, M. and M. Yaghoubi, 2008. Thermal behavior of curved roof buildings exposed to solar radiation and wind flow for various orientations. Appl. Energy, 85: 663-679.

Han, G., J. Srebric and P.E. Enache, 2015. Different modeling strategies of infiltration rates for an office building to improve accuracy of building energy simulations. Energy Build., 86: 288-295.

Heidari, S. and S. Sharples, 2002. A comparative analysis of short-term and long-term thermal comfort surveys in Iran. Energy Build., 34: 607-614.

Kontoleon, K.J. and D.K. Bikas, 2002. Modeling the influence of glazed openings percentage and type of glazing on the thermal zone behavior. Energy Build., 34: 389-399.

Kontoleon, K.J. and E.A. Eumorfopoulou, 2008. The influence of wall orientation and exterior surface solar absorptivity on time lag and decrement factor in the Greek region. Renewable Energy, 33: 1652-1664.

Kontoleon, K.J. and E.A. Eumorfopoulou, 2010. The effect of the orientation and proportion of a plant-covered wall layer on the thermal performance of a building zone. Build. Environ., 45: 1287-1303.

Koranteng, C. and E.G. Abaitey, 2010. The effects of form and orientation on energy performance of residential buildings in Ghana. J. Sci. Technol., 30: 71-81.

Krygiel, E. and B. Nies, 2008. Green BIM: Successful Sustainable Design with Building Information Modeling. John Wiley and Sons, New York, USA., ISBN-13: 9780470390467, Pages: 241.

Moon, H.J., M.S. Choi, S.K. Kim and S.H. Ryu, 2011. Case studies for the evaluation of interoperability between a bim based architectural model and building performance analysis programs. Proceedings of 12th Conference of International Building Performance Simulation Association, November 14-16, 2011, Dankook University, Yongin, South Korea, pp: 1521-1526.

Morrissey, J., T. Moore and R.E. Horne, 2011. Affordable passive solar design in a temperate climate: An experiment in residential building orientation. Renewable Energy, 36: 568-568.

Motawa, I. and K. Carter, 2013. Sustainable BIM-based evaluation of buildings. Procedia Social Behav. Sci., 74: 419-428.

Murgul, V., D. Komatina, V. Nikolic and N. Vatin, 2015. Passive solar heating: Its role in architectural shaping. Appl. Mech. Mater., 725: 1552-1556.

Numan, M.Y., F.A. Almaziad and A.W.A. Khaja, 1999. Architectural and urban design potentials for residential building energy saving in the Gulf region. Appl. Energy, 64: 401-410.

Ozel, M., 2011. Effect of wall orientation on the optimum insulation thickness by using a dynamic method. Appl. Energy, 88: 2429-2435.

Ozel, M., 2013a. Determination of optimum insulation thickness based on cooling transmission load for building walls in a hot climate. Energy Convers. Manage., 66: 106-114.

Ozel, M., 2013b. Thermal, economical and environmental analysis of insulated building walls in a cold climate. Energy Convers. Manage., 76: 674-684.

O'Brien, W., T. Kesik and A. Athienitis, 2008. The use of solar design days in a passive solar house conceptual design tool. Proceedings of the 3rd Conference on Canadian Solar Buildings, August 20-22, 2008, University of Toronto, Fredericton, New Brunswick, Canada, pp: 164-171.

Pacheco, R., J. Ordonez and G. Martinez, 2012. Energy efficient design of building: A review. Renewable Sustainable Energy Rev., 16: 3559-3573.

Papadopoulos, A.M. and E. Giama, 2007. Environmental performance evaluation of thermal insulation materials and its impact on the building. Build. Environ., 42: 2178-2187.

Perlova, E., S. Karpova, X.M. Rakova, E. Bondarenko and M. Platonova *et al*., 2015. The architectural concept of the building with low energy consumption. Appl. Mech. Mater., 725: 1580-1588.

Poel, B., G. van Cruchten and C.A. Balaras, 2007. Energy performance assessment of existing dwellings. Energy Build., 39: 393-403.

Raychaudhuri, B.C., S. Ali and D.P. Garg, 1965. Indoor climate of residential buildings in hot arid regions: Effect of orientation. Build. Sci., 1: 79-88.

Sedki, A., N. Hamza and T. Zaffagnini, 2013. Effect of orientation on indoor thermal neutrality in winter season in hot arid climates case study: Residential building in greater Cairo. Int. J. Eng. Technol., 5: 712-716.

Shirzadi, M. and M. Nagashzadeghan, 2015. Building energy optimization using sequential search approach for different climates of Iran. Int. J. Renewable Energy Res., 5: 210-216.

Singh, M.K., S. Mahapatra and S.K. Atreya, 2011. Solar passive features in vernacular architecture of North-East India. Solar Energy, 85: 2011-2022.

Skibin, D. and C. Noach, 1982. Optimal oreintation of buildings in the Negev semi-arid conditions. Energy Build., 4: 185-189.

Tzempelikos, A. and A.K. Athienitis, 2007. The impact of shading design and control on building cooling and lighting demand. Solar Energy, 81: 369-382.

Yang, L., B.J. He and M. Ye, 2014. Application research of ECOTECT in residential estate planning. Energy Build., 72: 195-202.

Yi, H., R.S. Srinivasan and W.W. Braham, 2015. An integrated energy-emergy approach to building form optimization: Use of EnergyPlus, emergy analysis and Taguchi-regression method. Build. Environ., 84: 89-104.

Yohanis, Y.G. and B. Norton, 2002. Useful solar heat gains in multi-zone non-domestic buildings as a function of orientation and thermal time constant. Renewable Energy, 27: 87-95.

Zeng, M.N., 2012. Future of green BIM designing and tools. Adv. Mater. Res., 374: 2557-2561.