Sustainable neighborhoods. An energy analysis at urban scale on 5 different typical districts of Abu Dhabi Main Island.

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1- The abstract

By the passing of the years, the world population is concentrating in the cities converting natural areas into urbanized areas by modifying also the thermal properties of the area. The local climate is under continuous change while the cities evolve. And this change is shown perfectly in the Urban Heat Island (UHI) phenomenon. The cooling load inside the buildings is increased indirectly by the UHI phenomenon. This would bring additional cost and bring one step back into the main target of having a sustainable city. Sustainable city start with sustainable neighborhoods.
This paper provides an overview on how with the help of different tools such as ENVI-met, UMI, Energyplus and Ecotect we can have the results of the energy consumption of 5 different districts in Abu Dhabi, a city with hot arid climate. The idea is to analyze each district that is characterized by different building typology. On a second step, after using Ecotect to locate the areas that were exposed to the sun within the district there is an intervention proposal. Placing urban shading devices and vegetation in form of parks not only would improve the outdoor quality but also can reduce the cooling load in the building by reducing the temperatures and improving the airflow. This is the main aim of this study. Several simulations before and after the proposals will show this energy saving.
The shading devices proposed are complying with the traditional concept but adapted to a new technology. The main material would be wood and a specific type of fabric. Even though for the tools used in the energy simulations the important parameters are connected to the materials only. Special openings and details are not recognized. Even though, thru the two main tools we can show that requalifying the neighbors bring direct and indirect savings and helps in having a sustainable neighborhoods.

2 - Introduction

The Middle Eastern Cities have had a high speed development in terms of construction with few possibilities to make the necessary tests before applying. Like other cities in other parts of the world, they are experiencing an unprecedented wave of urbanization. For the next 10 years is expected that the number of citizens will reach over 40 million.
The speed of growth brings out a great challenge for all those involved in the design, planning, construction, and the case study taken into consideration will make a difference into this critical analysis. The Main Island of Abu Dhabi has had a growth that didn't take into consideration many aspects contributing the increase of the UHI levels. There must be interventions in order to make the city more sustainable, such as: cool roof, innovative pavement materials, shading trees and urban shading fixtures. Technically, analyzing such proposals takes a long time, but thru new software's it can be possible to monitor the suggested intervention. From the economical point of view there should be an analysis if such suggested intervention is sustainable cost wise.

The city of Abu Dhabi is being transformed day by day. Despite the architectural and construction studies the urban planning analysis is crucial. In a hot arid climate city such as Abu Dhabi, the decisions made in the urban planning scale influences the building scale. Decision making must analyze many factors and one of them is the Heat Island Effect. In this case study we aim to prove that by making such interventions at urban scale there can be a significant impact at an urban scale. Urban Shading Devices as UHI mitigation strategy can improve buildings energy consumption. This is a result beside others such as improving the outdoor comfort and walkability.
The highest range of the cooling load is in the evening time due to the occupancy of the buildings.
Also part of the building is an elementary school and a mosque. The district is characterized of open parking lots along to the buildings line. The biggest ones are oriented in the south and north part of the district. in the south part the building line creates shading over the parking lots. This can be defined better with Ecotect as mentioned below. The pavement used in the district is a standard one and the asphalt also doesn't have special characteristics in mitigating the UHI.
In this paper we aim to show that by making small interventions in each district there can be a considerable improvement in the quality of life of the citizens, outdoor comfort, anergy saving.
By adding additional shading devices the scale of sustainability can be increased and the city reach its goals.

3 - The case study – Abu Dhabi

Abu Dhabi, an interesting city in transformation was the first location that we had in mind for such research. It all started by leaving for few years in the main island where the city started to develop.
Even though currently the new residential areas are expanding in the suburb, such as Mohamed Bin Zyed City, Khalifa A, Khalifa B, there is still place for improvement in the center. The new residential areas have another approach in terms of the urban planning, outdoor comfort and other parameters.
Our focus is in the main Island where the UHI is notable. Walking in the streets of Abu Dhabi immediately can be noticed the different construction sites. Old buildings built during the first construction wave 60s-80s are being demolished and instead of them skyscrapers are taking place, such as the area of the WTC- World Trade Centre and many other block in the Corniche. This one was the first zone to be developed and it's in the end of the island with a beautiful out coming at the shore.
Demolishing many of this building might be interesting for the real estate, as the cost of the residential buildings is increasing every year, but some of this building have already a piece of history.
In a conference held at New Your University in Abu Dhabi, a French Photographer, were shown different buildings from the 60s-80s that already made a part of the urban history of the city, such as the central bus station.
The above intro is done to show that history can be created every decade. The decisions we take today improve the life of tomorrow.

4- District 3 - Medium Rise Buildings (E3)

The case study we took into consideration for our research due to more available data measured on site is in the main island of Abu Dhabi, surrounded from the streets of: Zayed the First Street, Sultan Bin Zayed the First Street, Fatima Bint Mubarak Street and 5th Street. This a representative district among others with similar properties, characterized of high rise residential, hotels and office buildings on the borders of the area and low rise residential buildings inside the area. We visited the site, took measures met the residents in order to understand the internal life. Based on the information we had from the Abu Dhabi Municipality and from the site verifications we elaborated the table below that was a base for the templates that were created later on in the UMI program for the energy evaluations.
The district is surrounded by high residential and office buildings creating a barrier to the external conditions. This influenced the temperature values on ENVI-met. Will see below that the change of the temperature is visible because also of this influence. The internal part of the district has Medium Rise residential buildings. From the material we had and the façade architecture the different building edge is easy to be recognized. In the older buildings build round the 1990 the windows are smaller and inserted inside the façade wall. In the buildings post 2000 the buildings have full glazed façade. In the perimeter 2 of the older buildings were demolished and new Office/Residential building will take place. The same process is happening also in other similar districts.
In the above 3 images are shown the codes on each building matching the one defined from the Municipality Survey. By making this categorization it was easier to define the rest of the information. The 3D view elaborated from 3D max helped understand the intervention scale. Other 3D will be done to give a better view to stakeholders of the importance of such intervention. The last fig. shows a façade evaluation when studying the façade glazing. This was a study done to compare the results we already had and also to evaluate the Building architecture in order to define the design of the proposed shading design on a second phase.

Description	***District 3***
Typology	Medium and High Rise Buildings
No. of Buildings	70
Max Floor No.	20
Min Floor No.	5
Max. Border Dimensions	582x331
Total Area	193,819.00
Building Area	46,651.00
Building Area in %	24.07
No. of existing parking lots	
Asphalt Area	93,992.00
Asphalt Area in %	48.49
Paved Area	53,176.00
Paved Area in %	27.44
Green Area	NA
Green Area in %	NA
Existing Shaded Area	
Proposed Shaded Area	NA
Existing No of Trees	24
Proposed No of Trees	

Table 1. District 3 area information.

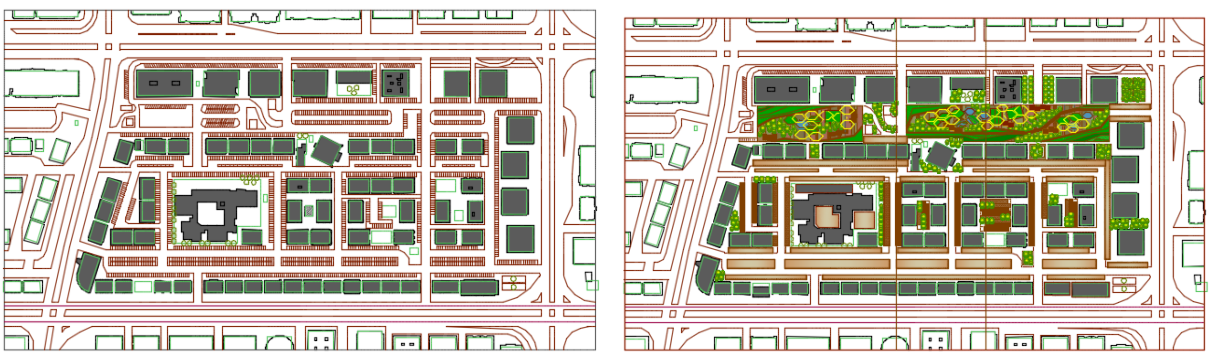

Figure 1. District 3 plan before the intervention.

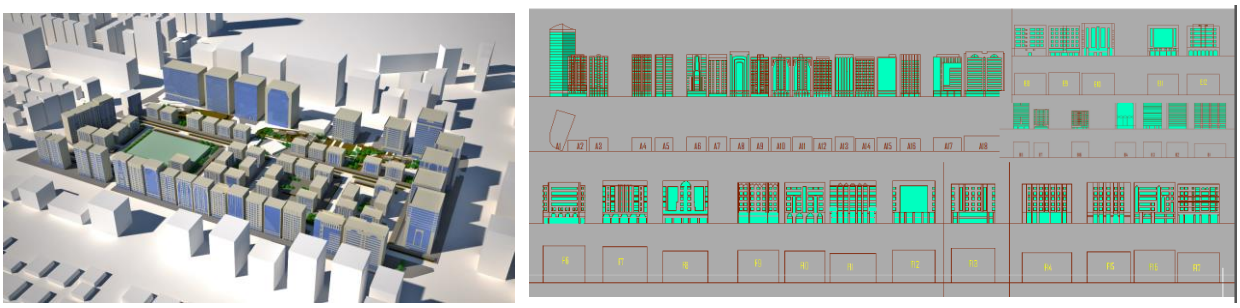

Figure 2. 3D aerial view of the district.

This district has as its main characteristic the high rise buildings surrounding the medium rise buildings in the center. It's a general characteristic in Abu Dhabi this type of urban planning. Although in the new areas the planners are placing a homogenous height in the districts. In the north part of the district there is an open parking that in our proposal can be an underground one and the area can be used as an internal park with shading on the paths where people can walk and run, trees in the main points and play areas. This can improve the life of the citizens. By adding one requalification at a time the city of Abu Dhabi can offer a healthier and sustainable leaving to its citizens. In the southern part there is also another open parking that is our suggestion is covered by smart shading devices. In such way that not only it can be shaded but also can be recovered energy for the lights within the district.

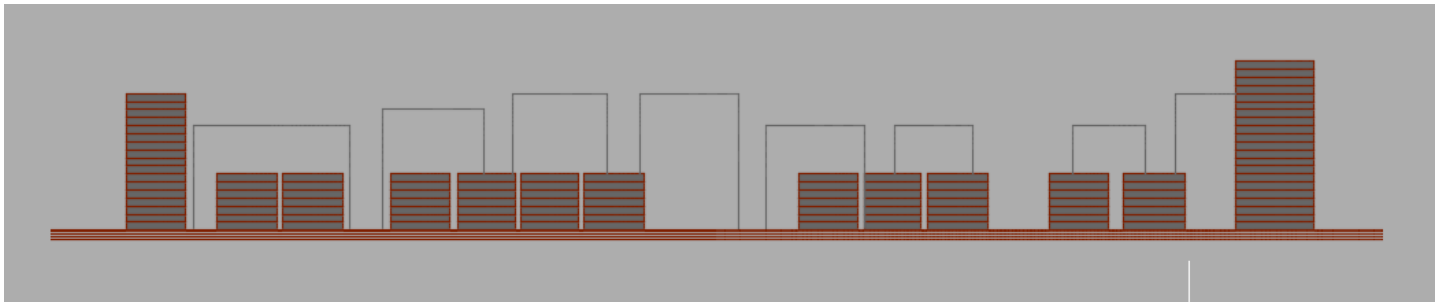

Figure 3. Cross Section.

5- District 2 –High rise buildings.

This district is framed from the Hamdan Bin Mohammed Street, Sultan Bin Zayed Street, Liwa street and Khalifa Bin Zayed the First. The area in part of the Corniche, a very attractive area from the real estate point of view. The total number of buildings is 48 varying to a height of a maximum 49 floors. We are in down town Abu Dhabi. This is the new developed areas with an edge of 15 years. The WTC is very near to this districts. The district has a square shape and the buildings are spreaded in a uniform way respect to the other districts seen earlier. But also in this case we have a central square that is transformed in an underground and 2 floors parking. There is no cover at the roof of the parking.
This district is has the lowest quality of life respect to the others. This due to the new buildings that are being built. Almost 4 old buildings were demolished and instead of them are being build skyscrapers. There a considerable amount of dust in the area. This is the only district among the 5 taken into study that there is no tree.
In our proposal, the parking lot is only underground and this area becomes a park with shading and trees. It's the only area that can be used for leisure for the citizens living in the towers.
The section of the district shows the movement in it. Almost homogenous height, besides the tallest building. The Envi Met model was a little complicated due to the height of the buildings where was applied a scale factor to fit the 3d inside the framework of the program.
And as can be seen below, the average temperature reduction is of 0.112 degrees. This might be due to the height of the buildings making very difficult the air to flow and also because already they shade the district with their height. The distance between some of this buildings might reach several meters despite their height.
The margin of error in this temperature reduction calculation is still ongoing and it's going to be part of a future paper. In any case, despite the very limited spaces between this buildings there is place for improvement with different small recreate areas with benches, shading providing energy to recharge electronic equipment and place some local trees to improve the outdoor comfort and make this particular district more sustainable.

Parking and public transport.

There are many similar districts in this area, such as the one of the WTC – world trade center where recently, in the last 10-15 years all the old buildings have been demolished and the new ones are the one to be developed. Of course the parking problem has to be addressed by adding faster buses in a separate line for buses. In Dubai the transportation system has been improved in the last 2 years. The same is happening in Abu Dhabi. This will solve the parking problem within the districts and one family might have a limited number of cars. In any case this is a very large topic so has to be treated separately.

Description	***District 2***
Typology	High Rise Buildings
No. of Buildings	48
Max Floor No.	49
Min Floor No.	9
Max. Border Dimensions	464x328
Total Area	151,839.00
Building Area	27,256.00
Building Area in %	17.95
No. of existing parking lots	
Asphalt Area	85,949.00
Asphalt Area in %	56.61
Paved Area	38,634.00
Paved Area in %	25.44
Green Area	NA
Green Area in %	NA
Existing Shaded Area	
Proposed Shaded Area	NA
Existing No of Trees	NA
Proposed No of Trees	

Table 2. District 2 area information.

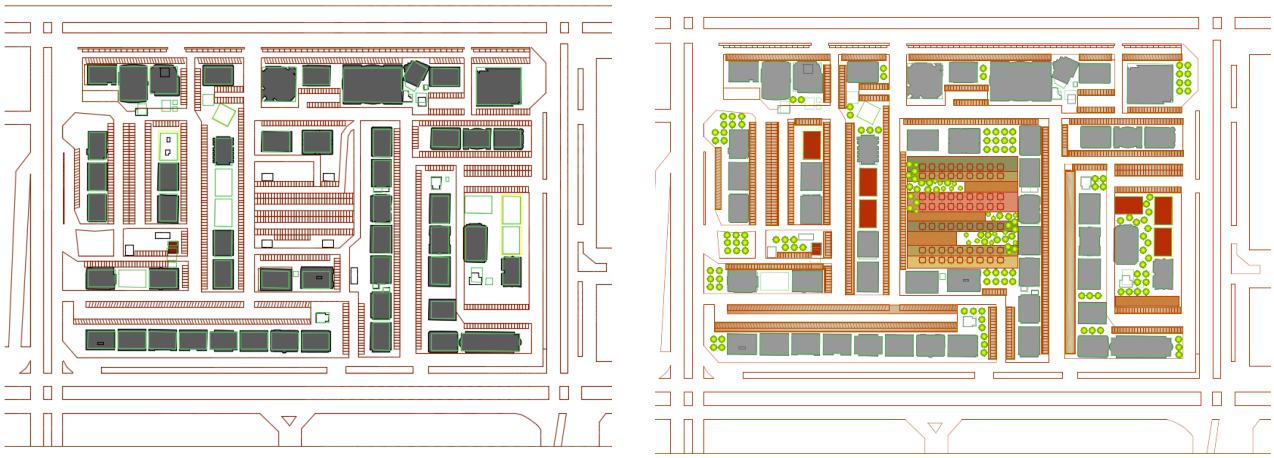

Figure 4. The plan

DISTRICT 2	HIGH RISE BUILDINGS
T REDUCTION	0.112

5- District 4 – Medium rise buildings.

This district is framed from Al Kaleej Al Arab Street, Delma Street, Al Bateen Street. The shape of the districts is rectangular with straight line street patter. In this district the number of buildings is 81. More than 50% of them are five floors. This area is categorized from internal small parking lots non-covered.
The buildings have an age of 30-40 years old. Most of them are rented to foreigners. In comparison to the other districts there are internal trees placed between the buildings.

In our model the shading devices are surrounding the open parking lots and in the internal areas it's connecting the buildings. The type of the shading proposed is mashrabiya, since the buildings are medium rise. This would give to the district a sense of connection with the heritage and the history of the country.
In the southern part it's suggested to have an underground parking and instead of the current parking to have an open park. This is the only area in the district that can have this use. By creating one park at a time, within each district the level of sustainability might increase in a notable way. And by walking in this direction one neighborhood at a time the results might be impressive and significantly important to the level of the sustainability that the Abu Dhabi Municipality is aiming to reach.
The ENVI met model was quite fast and also the simulation within this program took less time that the other districts. In our proposal the amount of trees is increased in total by creating small leisure areas in the borders of the buildings.
The cross section shows the idea of the district and the homogenous spread of the buildings in this district.
Also the 3D that was previously prepared for the energy simulation shows the development within the district.
Among all the 5 case studied we took into consideration this one has a more active life of the citizens.
The temperature reduction shown from the Matlab, after elaborating the table coming from ENVI met is 0.393 degrees that is higher from the other districts. This probably due to the shading between the buildings that has a bigger impact also on the buildings itself.

Description	***District 4***
Typology	Medium Rise Buildings.
No. of Buildings	81
Max Floor No.	5
Min Floor No.	3
Max. Border Dimensions	401x341
Total Area	136,709.00
Building Area	31,878.00
Building Area in %	23.32
No. of existing parking lots	
Asphalt Area	52,486.00
Asphalt Area in %	38.39
Paved Area	52,345.00
Paved Area in %	38.29
Green Area	1783
Green Area in %	1.30
Existing Shaded Area	
Proposed Shaded Area	NA
Existing No of Trees	54
Proposed No of Trees	

Table 3. District 4 area information.

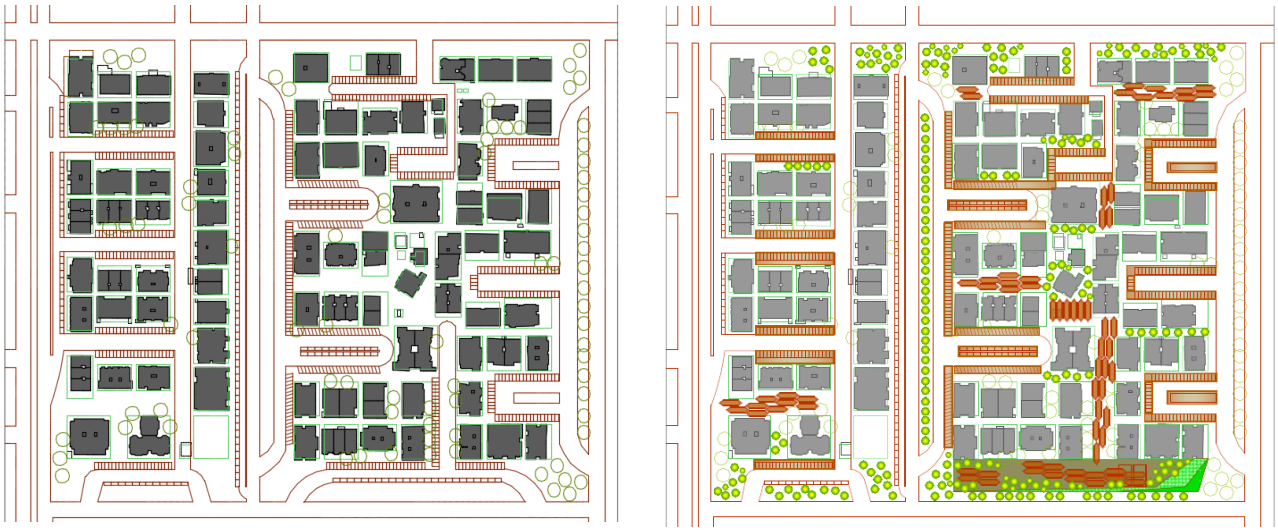

Figure 5. The plan.

DISTRICT 4	MEDIUM RISE BUILDINGS
T REDUCTION	0.393

6 - District 5 – Villas and high rise buildings.

This district is located near the historic castle of Qasn Al Hosn. Its border streets are: Zayed The First Street and Hamdan Bin Mohammed Street. The area in part of the Corniche, a very attractive area from the real estate point of view. It's the first area to be developed in the city of Abu Dhabi. As showed in the table below the total number of buildings is 69, quite dense in the borders. In the plans of the below images can be seen the shape of this district. Its similar to a square surrounded by the high building range on the borders and then the villas in the center. While modeling this district we noted that also in this area one old building was demolished with a perspective to build a new one. In this districts there are a considerable amount of trees as part of the villas internal area. Which help in improving the microclimate by creating shading and thru the other processes.
There is a mosque as a gathering place and the rest of the surrounding high rise buildings are a mix between offices in the first floors and residential in the upper floors. In some of the buildings there is a retail area on the ground floor.
In any case, there was no trace of shading or internal parks. By walking in the street on a normal sunny day (the fogy days in such climate are approximately 10 days per year), There is no shaded passage and the parking lots are non-covered. There is a full area in the southern part of the district where an open parking lot takes place. In the new district proposal this area has an underground parking and an open park full of shade and trees. A combination that can improve the life of the citizens living in this area. The style of the shading proposed is mashrabiya since the villas in the center permits to large families to live in. we thought that connecting children's with history is important in such modern environment and development.

The development of the district in the section is showed in the images below. This section helps understanding the physiognomy of the district. Also the 3d build for the energy simulation reveals the location of the buildings around the square district. Building the models in ENVI met was quite fast, as the models of the buildings are almost squares. The difficulties that encored during the simulation was the time consuming. This penalized the energy simulation.
Even though was managed to have the results of the temperature reduction thru the script in Matlab simplifying the work for the huge amount of values we were getting from ENVI MET. An important point to be mentioned is also the increase of the trees in the new model that will be part of a future paper. In any case in this research is being shown the difference between the existing model and the shaded model. And as can be seen below, the average temperature reduction is of 0.328 degrees.

Description	***District 5***
Typology	Villas and High Rise Buildings.
No. of Buildings	69
Max Floor No.	22
Min Floor No.	3
Max. Border Dimensions	406x414
Total Area	162,473.00
Building Area	27,033.00
Building Area in %	16.64
No. of existing parking lots	
Asphalt Area	95,881.00
Asphalt Area in %	59.01
Paved Area	39,559.00
Paved Area in %	24.35
Green Area	NA
Green Area in %	NA
Existing Shaded Area	
Proposed Shaded Area	NA

Existing No of Trees	79
Proposed No of Trees	

Table 4. District 5 area information.

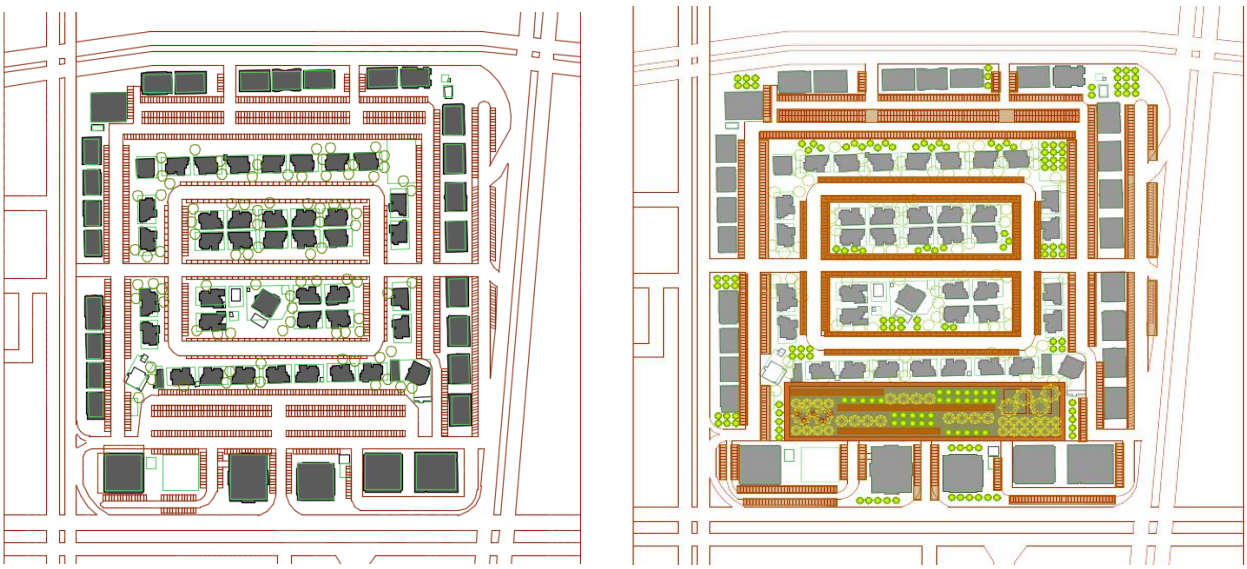

Figure 6. The plan.

DISTRICT 5	VILLAS AND HIGH RISE BUILDINGS
T REDUCTION	0.328

7- District 1

This district is located in the entrance of the main island of Abu Dhabi, near the Bateen Airport. This area is categorized by a considerable amount of trees. Most of the families living here are Emirati citizens.
The suggested mashrabiya here is the proposed shading. This district is categorized by a straight line pattern.
We had difficulties in simulating this are in ENVI met, turbulences were created after every temptation.
There were done 3 trials with no results. Probably the spread of the villas creates a pattern not recognized from the program. In any case the future plan is to simulate a low rise district with the same input as this one in order to have some results in terms of the temperature reduction.
There is a central square that hosts a mosque. There is no free place to create an internal park. In any case we proposed the shading over the open parking lots.

Description	***District 1***
Typology	Villas
No. of Buildings	68
Max Floor No.	4
Min Floor No.	1
Max. Border Dimensions	414x289
Total Area	119,555.00
Building Area	28,212.00
Building Area in %	23.60
No. of existing parking lots	
Asphalt Area	27,859.00

Asphalt Area in %	23.30
Paved Area	63,484.00
Paved Area in %	53.10
Green Area	3963
Green Area in %	3.31
Existing Shaded Area	
Proposed Shaded Area	NA
Existing No of Trees	151
Proposed No of Trees	

Table 5. District 1 area information.

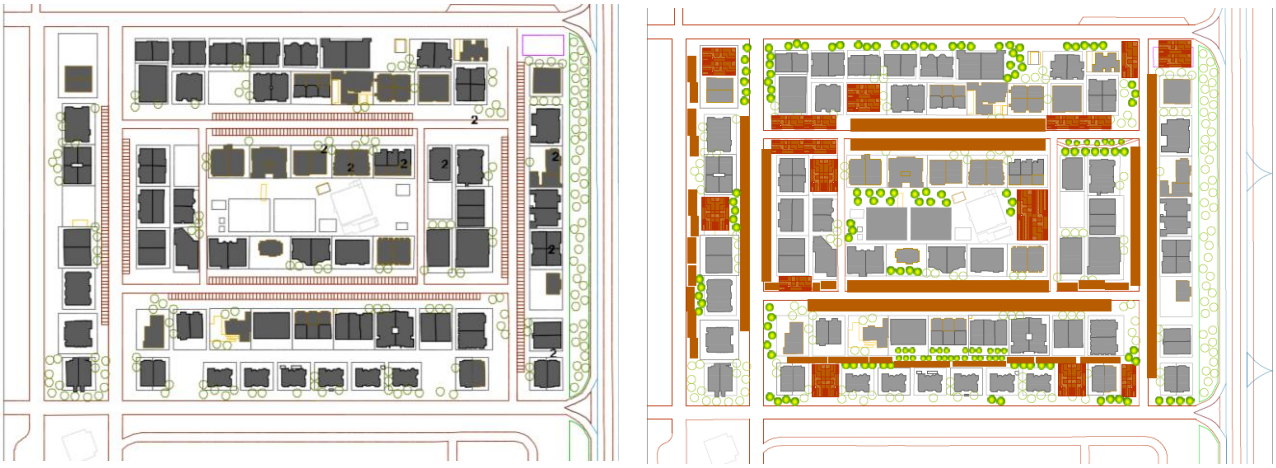

Figure 7. The plan.

DISTRICT 1	VILLAS
T REDUCTION	NA

9 - The shading devices

As shown in the two images below the district before the proposed intervention is characterized by opened parking lots. No shading is applied anywhere and there is only one underground parking in the north-west side of the district. There are few trees placed near the elementary school. The residents don't have a park inserted into the district or a play area for the children. The aim of this proposal is to prove that by having a minimal intervention on the urban shading devices over the parking lots and in the internal parks can bring cost saving in terms of energy consumption of the buildings. And this is one of the results of such proposal. The outdoor comfort and the walkability have a considerable improvement, but this part will not be included in this research.
In the proposed intervention there are different typologies of shading. A detailed description will take place below. There is created an internal park with shading devices integrated with trees that are typical of the Middle Eastern countries. This will help saving irrigation water and maintenance costs but on the mean time will provide shading. The area where the park is located covers all the parking places that are thought to be placed in a second underground parking.
All this landscape and shading, despite being used as UHI mitigation strategy which means decreasing the air temperatures will also bring a better life quality, outdoor comfort that the inhabitants can take advantage of in the free time of the long working days. The idea of having such intervention in each district can improve the city scale sustainability. This area is characterized of straight line streets, as the main island of Abu Dhabi, this helps the design to be standardized that means also to reduce the costs of the intervention. The ark takes place in the north side as this area has more access to the sun and a modification in this part will have a bigger feedback. Also there already an existing underground parking there that can simplify possible construction of a new underground parking.

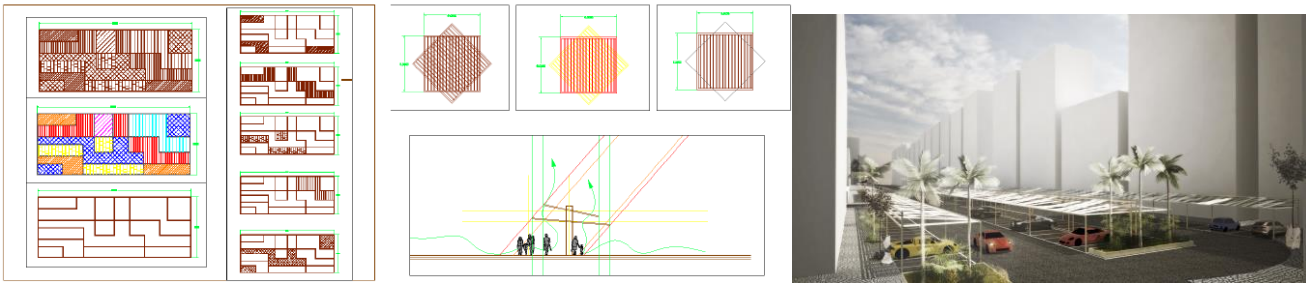

Figure 8. Shading devices.

8The energy evaluation

After all the evaluations in terms of urban scale intervention and shading analysis the main aim of this research as mentioned is to measure this intervention in terms of energy. The whole process is divided in 3 steps:

1- The base files,
2- The link,
3- The simulations.

The above description was part of the previous paper submitted as part of this research. The District E3 was the one that we anylized the most as we had more information about the use of each building, the energy use etc. Below are shown the results that will be used a baseline for the other districts as a comparative case.

Temperature Reduction	Energy Saving
0.17 degrees	0,32 %

Table 6. Energy consumption.

10 - Conclusions

After analyzing each district below are shown the results of the temperature reduction in each district. Without calculating the error %, apparently the biggest temperature reduction is provided in the district 4, medium rise buildings. Which means that the first intervention to be done in case of requalifying the neighborhoods is the medium rise building districts.

DISTRICT 5	VILLAS AND HIGH RISE BUILDINGS
T REDUCTION	0.328

DISTRICT 1	VILLAS
T REDUCTION	NA

DISTRICT 2	HIGH RISE BUILDINGS
T REDUCTION	0.112

DISTRICT 3	MEDIUM AND HIGH RISE BUILDINGS
T REDUCTION	0.174

DISTRICT 4	MEDIUM RISE BUILDINGS
T REDUCTION	0.393

Table 7. Temperature reduction..

11 - The error margin.

This part has yet to be studied and it might modify the results, meaning the district that the intervention should start with. But in any case, the difference between the districts is quite high so the definitions shouldn't change.

During the simulations and the work with the models the district 1 was the one that we were not able to proceed with due to the limitations of ENVI met or any wrong placed parameter during our tree trials.

12 - Future Works

Part of the future works is the optimization of the 2 main shading devises proposed in this paper, the traditional ones and the smart shading devices. This a part of future paper. Another important chapter of this research is the validation of the results. In this case another paper will follow with the results of a validation between the results of the real data measured on site, simulated data with Envi Met and similated data with UWG, another tool to generate weather file.

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