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Green roofs under hot and dry climate in south-west of Algeria: Study of the implementation conditions

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Abstract
The Algerian Sahara occupies over 80% of the Algerian surface. Green roofs and facades will contribute to transforming the desert into ecological green cities. This work addresses the possibility of realization ofing such green buildings under the climatic conditions of the Saharan cities of Algeria by highlighting the need for gray water irrigation in order to overcome the water problem in these arid regions. A collection of different native and non-native plants that can be planted in hot arid climate by carrying out bibliographic research on their applications in other regions and climates is presented. Carpobrotus acinaciformis is the most recommended, among the succulent species plants, for its great success in the study area. Regarding herbaceous plants, the basil, rosemaryand canna are best adapted to the harsh climatic conditions. A chemical analysis of grey-water was conducted to examine the feasibility of reusing generated water from domestic activities. The results show that slaked lime can be added to purify water, and filtration on sand is recommended. Furthermore, simulations were carried out using TRNSYS to analyze the cooling effect of green roofs and facades compared to conventional roofs. The results show that green roofs help significantly in decreasing the number of hours of discomfort and the cooling energy use compared to the green facades.

Keywords
Desert plants, Green roofs, Greywater, Hot and dry climate, Simulation.

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1. Introduction

The building sector is a great contributor to global energy consumption; it is responsible for approximately 40% of the total annual world consumption. The massive magnitude of energy consumption in buildings is for cooling and heating (Tushar, Bhuiyan, Sandanayake, & Zhang, 2019) Building envelopes are one of the most challenging and interdisciplinary components of a building (Perini & Rosasco, 2016). An efficiently designed building envelope improves comfort and reduces energy needs. In recent decades, green roofs are widely built in several countries around the world as an innovative concept that increases the sustainability of buildings and cities. Previous studies have shown the role of these vegetated envelopes in the improvement of building energy efficiency (Jim, 2014), the mitigation of urban heat island effect in sequester carbon dioxide and reduction of air pollution [(Perini, Ottelé, Giulini, Magliocco, & Roccotiello, 2017) ; (Nagase & Dunnett, 2013)], aesthetics reactions (Jungels, Rakow, Allred, & Skelly, 2013), enhancement of the biodiversity and reduction of habitat losses (Coma et al., 2017) and decrease urban noise pollution ((Jungels et al., 2013); (Coma et al., 2017)). In addition to the aesthetic impact on the urban landscape, green roof systems also called an 'eco-roof' or roof garden are an impressive remedy for creation of more green areas. Numerous investigations have studied the performance of vegetated buildings in different climate zones. Some authors have shown the effectiveness of the green roof in hot summer in the Mediterranean climate (Cristina M. Silva, Gomes, & Silva, 2016); (Cristina Matos Silva, Flores-Colen, & Coelho, 2015)). However, other authors have indicated that the effect of these envelopes is more significant on heat flux in summer than in winter, a conclusion that was also proved by (Cristina M. Silva et al., 2016) for mild climate (Cristina Matos Silva et al., 2015). The most important points in all these results is that the impact of these green roofs on the heating and cooling needs and on the variation of the temperature varies with the season, the region, and the climate ((Jaffal, Ouldboukhitine, & Belarbi, 2012); (Coma et al., 2017)).

Water is an essential element in the success of vegetated envelopes; for this reason, xeriscape landscaping and xeriscape plants, which require less water and maintenance, have been successful recently. Some studies are focused on the presentation of plants which can intervene in these designs for certain regions (Sari & Karaşah, 2015).

The use of green roofs will depend on the properties of the plant and substrate in hot and dry climates. In fact, extreme heat requires the use of plants with certain properties, especially species with high leaf succulence and low water use, in order to survive these difficult conditions. Southern Algeria covers approximately 84 % of the Algerian surface. It is characterized by a harsh climate, low annual rainfall, water scarcity, and a hot weather. One of the problems that face Southern people is water deficiency. By integrating the "green roof", energy consumption in building will be reduced. Moreover, they will contribute to the preservation of the Saharan natural ecosystems by creating more green areas and giving an aesthetic touch to the urban landscapes. Further, using greywater as an irrigation source for the realization of these green envelopes is considered as great way for sustainable development and an important strategy in the sustainable water management schemes in this water-stressed region. Some researchers demonstrate that it is safe to use lightly treated greywater for irrigation ((Pinto, Maheshwari, & Grewal, 2010). However, (Rodda, Salukazana, Jackson, & Smith, 2011) indicate in their investigation that greywater gives a potential source of water for household crop irrigation which additionally shows some fertilizer properties, but its use requires more precaution due to its disadvantage which is present in salt and metal accumulation in irrigated soils over time, in addition to an increase in sodium and metal concentrations in crops.

This work is an exploratory search for solutions to realize green roofs in the Saharan climate such as the climate of Bechar.

This study was initiated for three purposes:

- To collect the different plants species that can be implemented in the vegetated envelope as well as those that can be applied in the green roofs and which survive in the hot dry climatic conditions.
- To support the development of greywater irrigation initiatives.
- To analyse and assess the effect of vegetated roofs and walls on the dynamic thermal behaviour of the building. Besides, this investigation is carried out during the cooling and heating periods using TRNSYS.

2. Methodology

First, a selection of different plants that can grow on the roofs of buildings in regions with hot and dry climates is presented through a bibliographic review. Afterwards, and given the aridity of the climate in the studied area, gray water irrigation is proposed as a solution, testing by chemical analysis the possibility of using this water without risk. Finally, a numerical simulation with the TRNSYS software coupled with COMIS was established in order to verify the impact of green walls and roofs on the thermal comfort and the energy consumption of the building in the studied area.

3. Which vegetation on the roofs?

Saharan flora appears to be very scarce when comparing the small number of species that live in this desert to the large surface it covers. Some authors collected plants adapted to hot and dry climates and that can be applied to green roof. However, these plants cannot be adapted to all the climates in the world. Species from one part of the world may not be suitable for other regions if climates differ.

The success of the green envelope depends essentially on the growing medium (substrate) and on vegetation that constitutes it, on the orientation of the building and weather conditions. Several studies have recommended evergreen and native plants for an extended life of green roof ((Tran et al., 2019); (Schindler, Blaustein, Vasl, Kadas, & Seifan, 2019)). Indeed, for southern Algeria with its hot and dry climate, these conditions trigger plant mortality.

3.1. Plants for roofs realization

According to our literature search, green roof studies that were carried out in hot and dry climates are less important compared to other climates (Kazemi & Mohorko, 2017). Australia has taken the lion's share in these studies (Du, Arndt, & Farrell, 2019; Rayner, Farrell, Raynor, Murphy, & Williams, 2016). However, no work dealing with the behavior of plants in the Algerian Saharan region has been carried out.

First, Botanists were consulted to list the plant species that can grow on the roofs in hot dry climates. Then, a bibliographic research on the studies already made using these plants was also performed. The main conclusion is that the choice of these plants is based on several parameters:

- high lifespan,
- rapid coverage,
- ability to self-sustain,
- grow aggressively (not invasive),
- store water.

For existing buildings, it is preferable to use extensive green roofs that are lightweight systems to avoid any increase in the structural load of the building. Plants with relatively shallow roots is very recommended.

Succulents are the most suitable for hot and dry climates, as drought-tolerant plants since they are low consumers of water, more than their large capacity to store water in their leaves (Rayner et al., 2016).

Sedum species are the most appropriate due to their wide use around the world in the extensive green roof installations, and due to their shallow root system (MacIvor & Lundholm, 2011). They are not invasive and may grow well in shallow and dry substrates, where most other species cannot survive.

Among the sedum species, sedum sediforme has been the subject of several studies (Bevilacqua et al., 2015; Coma et al., 2017; Azeñas et al., 2018; Dirks et al., 2016) who has shown the adaptation of this kind of succulent to hot and dry conditions of summer. In Algeria, Sedum sediform is very common in the Algerian Tell as well as in the Aurès massif. (Nektarios et al., 2015) examined the effect of substrate depth on sedum sediform growth. Their results show that even with a depth of 7.5 cm these plants can be used successfully in the Mediterranean climate but require irrigation. However, (Rowe, Getter, & Durhman, 2012) have shown that this species can survive no more than two years for a depth of 5cm in a humid continental climate in Michigan. (VanWoert et al., 2005) have shown that some genotypes of this plant can withstand minimal or no irrigation. This plant can survive without irrigation for 14 days as demonstrated by (Nektarios et al., 2015). In addition, (Van Mechelen, Dutoit, & Hermy, 2014) indicated that sedum sediform increases the insulation capacity of the roof to more than 82%. A similar result was provided by the work of (Coma et al., 2017) under dry Mediterranean continental climate.

Sedum Rubens: is an annual plant of the family Crassulaceae of 3-12 cm, this plant grows in the Algerian Tell. No work that integrated it into a green roof was found.

Sedum acre: Perennial plant of 4-8 cm. (Vahdati, Tehranifar, & Kazemi, 2017) examined its planting in green roof in Mached in Iran. On the other hand, (Rowe et al., 2012) studied the effect of substrate depth of green roof on more than 24 succulents. Sedum acre was able to maintain from 4 to 7 years and survive in a depth of 2.5cm in Michigan. Additionally, it was able to resist without water for 10 days in the hot and dry climate of Melbourne in Australia (Farrell, Mitchell, Szota, Rayner, & Williams, 2012). This plant has stronger stem, larger flowers and yellowish leaves in Algeria, much larger than the one being planted in Europe.

Sedum caeruleum L. Crassulaceae, Saxifragales: is very common in the Algerian Tell as well as in the Aurès massif. It is found on rocky slabs and rockeries.

Aloe vera is famous as herbal medicine. This plant is widely used in the study area especially for a decor. Yet, there are no previous studies on it. However, (Jalali, 2011) recommended it in green roof for Dubai climate. The plant contributes to the reduction of air pollution as it was mentioned in the work of (Tan & Sia, 2005).

Carpobrotus acinaciformis: or "Witch's Claw»; is widely used in the study area for decor and gardening. It survives for years and supports the great wave of heat. No previous work has been done before; however (Razzaghmanesh, Beecham, & Kazemi, 2014) examined Carpobrotus rossii a plant of the same family as 'Carpobrotus acinaciformis' that grow in southern Australia. Their result shows that this species is resistant to hot and dry climate, it also has given a large horizontal extension of the cover. (Vahdati et al., 2017) studied another species of the same family "Carpobrotus edulis". According to them, it is a good choice for hot climate of summer in Mashhad, because it has a good resistance even for most stressful months.

Prickly pear (Opuntia ficus-indica): This plant is well adapted to the hot and dry climate. This perennial plant, persistent type can reach up to 3 to 5m. Previous studies have shown that the integration of taller plants on green roofs could be a strategy for optimizing green roofs. Higher plants better reduce the temperature in the substrate (Sailor, 2008).

Sansevieria trifasciata: is a subtropical species of succulents. It has an anti-pollution ability to clean the air by eliminating the fumes of toxic substances. The original plant of Africa can reach 170 cm. it grows well in the south-east of Algeria. While in the south west, its use is limited to decoration. In literature, and for its integration in green roof, (Lin & Lin, 2011) illustrated that this species is drought-resistant and offers good coverage of extensive green roofs with large areas. The authors conducted their study in a tropical climate of the south of Taiwan. Although no study has been carried out on this plant in dry areas, the success of this plant in the hot and dry climate in Biskra city (south-east Algeria) encourages its use in extensive green roof throughout the south of Algeria.

Aptenia cordifolia: a small perennial plant with succulent foliage. It grows very quickly and carpets large areas. This species can withstand extreme heat, cold, and salinity. This plant has been tested in the work of (Schweitzer & Erell, 2014) in Tel Aviv. Their results showed that this plant can undergo long dry periods, its good contribution to reducing the temperature of the building thanks to its good cover of the roof and it requires less irrigation.

3.2. Herbaceous plant

Gazania rigens: native to southern Africa about 50 cm, is well adapted to the Mediterranean climate. This species has been the subject of several studies in different climates. In Algeria, this species grows well in the Tell and some South- eastern cities.

Sauge (Salvia): a native plant of the edges of the Mediterranean, but recently largely naturalized around the world (Savi et al., 2014), it grows well in southwestern Algeria, it is easy to cultivate, and it does not require enough irrigation. It has been the subject of research particularly in Italy ((Savi et al., 2014); (Vaz Monteiro et al., 2017)) where the ability of this plant to increase the cooling of green buildings even in substrates of 8 to 12cm deep.

Rosemary Rosmarinus officinalis: it is one of the most popular plants in Algeria, able to reach up to 1 m 50 high; this perennial evergreen plant of Mediterranean origin has been acclimatized in different types of climates in the world, its lifespan is 20 years. It enjoys warm or moderately dry climates; it also showed a high survival rate, as some studies have). Under Mediterranean climates, this plant has been suitable for extensive green roof ((Jesús Sánchez-Blanco, Ferrández, Navarro, Bañon, & José Alarcón, 2004); (Coma et al., 2017)), with depth substrate of 15 cm, its root is not shallow. It requires full sun, and it resists well to drought. Its dense foliage and its hairy leave give a very good insulation to the roof and low transpiration. In Algeria, rosemary is one of seven plant species exceeding 50,000 hectares in the national territory (Zoubeidi, 2004). It grows abundantly in the Saharan regions.

Cymbopogon citratus (Lemongrass): it can reach 1 meter high. No work that used it in green roof was found except (Dirks et al., 2016) who recommends it as green roofs that includes horticultural and medicinal products. According to the authors, lemongrass is recommended for hot and dry climatic conditions, water stress and salinity. In southwestern Algeria, the plant has been grown in some green garden and parks. It holds well to extreme climatic conditions according to some observers.

Basil (Ocimum basilicum): it can measure 20 to 60 cm in height. Well known in Algeria and is used for repelling insects especially mosquitoes. It requires irrigation since it does not support water stress. The plant has been used by some authors as extensive green roof ((Eksi & Rowe, 2016); (Van Mechelen, Dutoit, & Hermy, 2015)) who encourage the production of food also from green roof.

Canna: is a tropical plant with its exuberant foliage and which can reach 0.7 m of height. No work has been found that relate green roof to this plant. However ((Fowdar, Hatt, Breen, Cook, & Deletic, 2017; Vijayaraghavan, Reddy, & Yun, 2019) conducted critical views on the quality of water from vegetative roofs, where they cited the positive effect of Canna on runoff quality. It also contributes well in the elimination of pollutants that may exist in wastewater (Fowdar et al., 2017).

Narcissus: Perennial herbaceous plants of the family Liliaceae. Its height varies from 10 to 40 cm. The plant presented a successful performance in the work (Nagase & Dunnett, 2013) where it was able to graft in substrate depth of 10 cm in the UK and without irrigation. It is well known in Tell and its use in green roof in southern Algeria can help add an aesthetic touch to the city.

Marjoram: is delicate, aromatic, fragrant and easily cultivated. It can reach 60 cm in height. (Karachaliou, Santamouris, & Pangalou, 2016); and (Papafotiou et al., 2013)) studied it under a Mediterranean climate.

Leopoldia comosa: Native to Southern Europe, Iran and Turkey. It reaches 20 cm. It has been cited in the work (Van Mechelen et al., 2015).

Geranium: is a genus of herbaceous plants of the family Geraniaceae. This species has been encountered in some studies (Nagase, Dunnett, & Choi, 2017).

Strelitzia reginae (bird of paradise): It is 2 m high. Its production is important in Algeria. Algeria used it as symbol for a stamp in 1969. (Fowdar et al., 2017) examined the effect of certain ornamental plants implanted in a living wall system capable to filtering greywater. The plant has given important results in eliminating certain pollutants. Strelitzia reginae is grown in Bechar for decor, gardening and parks.

4. Greywater as an irrigation solution for green envelopes

Production of Greywater in poor areas may go down to 15-20 liters per day per person, while the inhabitants can waste tenfold of this amount (Sou, 2009).

Greywater is collectively dumped with blackwater in Bechar .

The population of Bechar in 2017 was 205'112 and the water consumed by a person was estimated by 163 l / day (D.P.S.B: Direction of the programming and the follow-up of the budget of Bechar).

Greywater analysis was performed on samples collected from house. It was disposed from sinks, shower, laundry, dishwashing and kitchen; they were collected in basins.

4.1. Greywater analysis

The performed analysis and results are illustrated in Table 1. Noting that each sample was analysed in triplicate.

The conclusions that can be drawn according to Table 1 are:

- Analysed grey water is acidic (pH = 4.08) due to presence of detergents (bleach, shampoo, soap,) and surfactants. For irrigation, the pH should be increased by adding the slaked lime (Ca (OH) 2, up to the value of pH 9.5.
- The turbidity measurement gave a first indication on colloidal matter of mineral or organic origin. Suspended solids are organic and mineral materials. A simple filtration with sieves up to 0.2 mm can help in reducing the turbidity and suspended matter, which could be further reduced by simple decanting.
- The conductivity values are very high (4.71 ms/cm); the limits being 1.90-2.36 ms/cm. The greywater contains mineral salts from detergents. In his thesis, (Metahri, 2012) gave a table (page 64) indicating the tolerance to the salinity of some cultivated plants (adapted from FAO, 1985). According to results in Table 1, the conductivity remains high.
- The waters of industrial effluent with high COD decrease the oxygen concentration in water, yet such water can be used for irrigation.

5. Simulation: Impact of green roof and walls on thermal comfort and energy consumption of buildings

TRSNSY-COMIS software was applied to evaluate the impact of green roofs and facades on thermal comfort and energy consumption of buildings. A housing cell of 120 m2 of space and 3.5 m high, as shown in the figure 1, built on the ground floor with a surface window of 1.2 m2 and a door facing south is chosen for this study.

The rectangular shaped living cell is simulated in TRnbuild at a thermal zone, where all the multilayer walls have been defined with their heat transfer coefficients. Type 77 (the ground temperature model) was used to calculate the temperature below ground as boundary condition for the floor on solid ground. In parallel, this cell was simulated in COMIS by introducing all the coeffi-

Table 1. *Results of the analysis of the sampled waste water.*

Parameter	Devices	Method	Unity	Values obtained
pH	multi analyseur pH meter	NF T 90-008	/	4.08
Conductivity	multi paramètre pH meter	NF EN 27888	s/cm	4710
TSS (total suspended solids)	gravimetric method [77]	NF EN 872 filtre fibre verre Sartor	%	10
CAT (Complete Alkalimetric Title)	Titrimetry	NF EN ISO 9963-1	g $CaCo_3$/l	0
COD (Chemical oxygen demand)	open reflux method [77]	NF T 90-101	mg O_2 /l	218,18
Turbidity	Turbidimeter 2100N IS	ISO METHOD 7027	NTU	1031

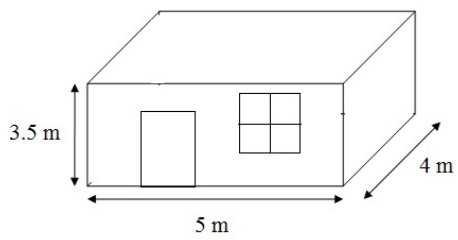

Figure 1. The housing cell used for the simulations.

Table 2. Description of the external walls and the low floor of the studied cell as well as their thermal transmission coefficients U.

Wall	Materials	Thickness(m)	U (W/m²K)
	Tile paving	0.020	
Floor on ground	Concrete	0.200	0.864
	Stones	0.400	
Wall	Internal finish	0.030	
	Clay brick	0.10	
	Air gap	0.03	
	Clay brick	0.15	0.767
	External finish	0.030	
Flat roof	Internal finish	0.030	2.487
	Flooring block	0.160	
	Mortar	0.030	

Table 3. Description of the green roof.

Wall	Materials	Thickness(m)	U (W/m²K)
Green roof	Internal finish	0.030	0.998
	Flooring block	0.160	
	Mortar	0.040	
	Vegetable substrate	0.120	

Table 4. Studied case.

Studied case	Abbreviation
Common roof, used as reference	Ref.
South wall covered with vine plants	Green S
West wall covered with vine plants	Green W
Green roof (grass)	Green R
Combination Both south wall and roof vegetized.	Green S R
Combination Both south and west walls as well as roof vegetized.	Green SWR

cients necessary for the aeraulic simulation: Cp "Wind pressure coefficients" for all the direction of walls and for eight directions of wind that were calculated by Cp Generator; discharge coefficients (Cd) and coefficient for the cracks (Cs)) of the vertical openings. The Green roof and green walls simulation was carried out using Green envelope model developed by (Rabah, 2013), this model proposed a modified thermal resistance which takes into account heat transfer and vapor transfers and their evolution according to the water availability. The model assumes the revegetation model as a system composed of two separate layers: The leaf canopy (the foliage) and the substrate considered as porous medium defined by its thickness, by its maximum water retention capacity and by its thermophysical properties which depend on its water content. The model is written in Matlab programming language and is coupled to TRNSYS. From the meteorological data and the heat flux through the building walls, it calculates the sensible heat fluxes, the latent heat fluxes and the radiative fluxes on the foliage and on the substrate surfaces.

The characteristics of the different layers of materials constituting envelope elements chosen in this work, as well as the thermal transmission coefficients. See, Table 2.

In the case of a green roof, the value of the vegetal substrate was introduced from the work of (Rabah, 2013) (Table 3).

Six cases were studied (Table 4). It has been assumed that the cell houses 7 occupants.

For the simulation of the walls, the vegetation reflects a part and absorbs the rest of the solar radiation but remains at relatively low temperature due to water evaporation.

6. Results and discussion

The simulation results are presented as hot and cold hours, in Table 5, corresponding to the number of hours when the operative temperature is out of the comfort range for category (III); a range satisfying 85% of residents according to EN 15251 (Figure 2). Results showed that the number of cold hours is increased when the walls are green, and reduced by a green roof.

__Table 5.__ Temperature ranges, annual hours of discomfort and comfort time ratio in the free-running cell.

	Reference	vegetated cases				
		GS	G W	G R	G S R	GSWR
Max. temperature	40.7	40. 5	40.4	36.3	35.9	35.6
Min. temperature	8.8	8.6	8.5	12.0	11.7	11. 5
Cold hours	3133	3243	3267	3053	3222	3373
Hot hours	2081	1954	1942	1823	1614	1360
% comfortable time	40.5	40.7	40.5	44.3	44.8	46.0

During the hot season, and for all the studied cases, the hot hours decrease with integrating plants into building. The association of the green roof with the vegetated West and South walls give the best results with 721 less hot hours and a maximum temperature reduced by 5°C compared to the base case.

The solar radiation received on a horizontal surface is greater than that on the west facade; the latter is larger than that received on a south facade.

Even when neglecting the effect of moisture transport in the studied cell envelope, the vegetation of the roof increases the minimum temperature during the winter by 3°C and decreases the maximum temperature by 4.5°C in summer. Throughout the year, the percentage of comfort time is improved by vegetating the roof but remains unchanged if only walls are vegetated.

The heating and cooling loads calculated for the reference temperatures Tc = 18 ° C in winter and Tc = 28 ° C in summer for the different cases, are illustrated in (Figure 2).

The Algerian rule DTR C 3-4 (Technical Report, 'Regulatory Technical Document,' 'Thermal Regulation of Residential Buildings - Calculation Rules for Heat Loss') on the dimensioning of air conditioning systems fixes domestic basic conditions. Standard comfort requires the air temperature to be 27 °C with a relative humidity of 50 to 60% according to the duration of the stay, while for the improved comfort, the temperature drops to 24 °C with a relative humidity of 45 to 50% according to the duration of the stay. Contrarily, article 4.4 of the DTR C3.2 (Technical Report, 'Regulatory Technical Document,' 'Thermal Regulation of Residential Buildings - Calculation

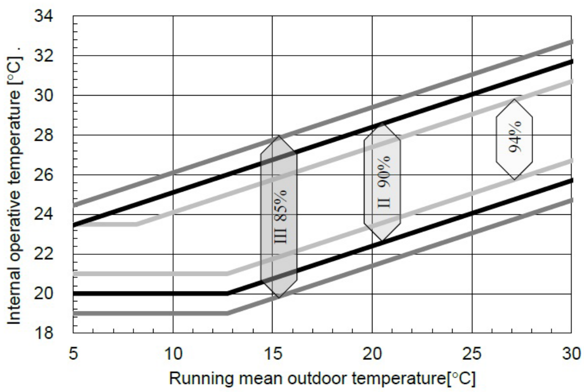

__Figure 2.__ Comfort range in premises with natural ventilation according to EN 15251.

Rules for Heat Loss') gives the temperatures to consider for these calculations. It is 21°C in continuously occupied premises and 18°C for circulation areas (hallways, stairs). The comfort conditions proposed in this study are only as severe as in the industrialized countries. To reduce energy needs, acceptable but realistic comfort conditions were adopted for the simulations. It is well known that occupants of naturally ventilated space tolerate larger margin by adapting their conditions.

According to these histograms (Figure 3) , the following conclusions are drawn:

- The vegetation of the south or west walls increases the energy need for heating. This is explained by the shadow created by these plants that prevents the solar rays to reach the walls of the building.
- Vegetation of the roof reduces the energy needs in winter. It gives the lowest value among the studied cases.
- The association of the green roof and green south or west wall resulted in heating needs lower than the base case but larger than the green

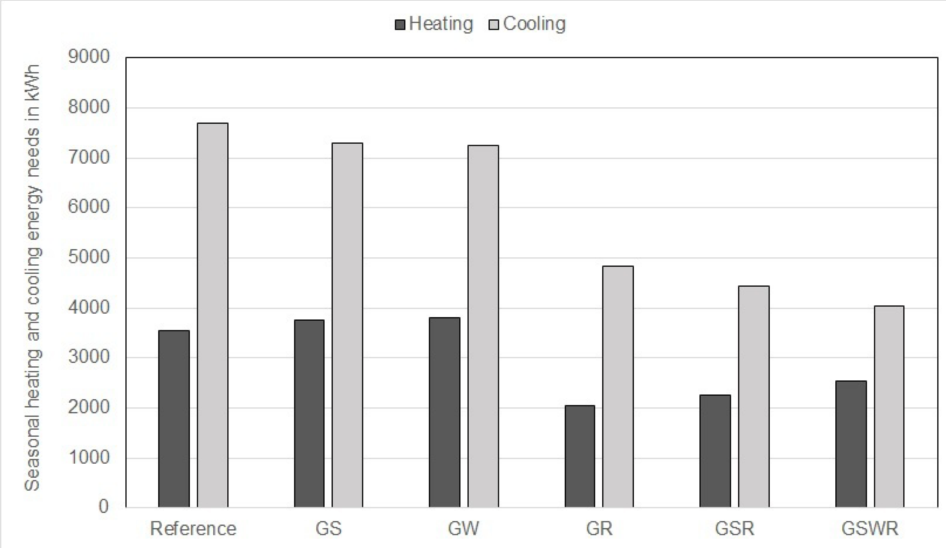

Figure 3. *Heating and cooling need for the different cases.*

roof. This proves the effective contribution of vegetation of the roof in the reduction of these needs.
- For the five studied cases, the cooling needs decrease with walls vegetation.
- Vegetation of the roof and the south and west walls gave the best results in the warm seasons. The calculated reduction of cooling need is more than 3600 kWh compared to the reference case.
- The roof only decreases the cooling need 6 times compared to the south or west vegetating wall.

7. Conclusion

Previous studies have shown the effectiveness of green roofs and walls as sustainable technologies in different climates. The question that was asked is what if these technologies can be realized in Bechar.

In this study, a variety of native and non-native plants from the southwestern region of Algeria were used. These recommended plants were selected based on two parameters:
- their adaptation to study climates by the visual observations made by the authors in the study area.
- research that examined the effect of integrations of these plants on building envelopes,

The proposed database privileges the use of succulent species particularly *Sedum sediform, Aloe vera* and Carpobrotus acinaciformis that can resist the harsh climatic conditions. Carpobrotus acinaciformis is the most recommended for its great success in the study area. As for Herbaceous plant, the basil, romarain, and canna can adapt to Bechar town despite low nutrient supply, drought and strong winds especially in spring. A successful realization of green building lies in the irrigation of plants, although our choice is limited on certain plants that are drought-tolerant, irrigation remains important for long-term survival taking into consideration the scarcity of rainfall.

Greywater is proposed as an alternative water source. An analysis of the water was conducted. The water was too acidic, contained some organic load and had a very high turbidity. It was purified by adding some slaked lime and filtration on sand is recommended. Analysis of thermal and energy performance of green roofs and walls are performed with a comparison with conventional concrete roofs and walls. The results highlight the significant impact cooling energy loads of green roof compared with green walls in this climates. However, west-facing and south-facing orientations have given very similar results in energy needs and of comfort.

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