Living cool: An approach for Architectural “COOL ROOF” to Decrease the Electricity Consumption in Iraq

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Abstract. One of the most important problems in Iraq is the insufficient and inefficiency of the electrical power generating station, that is causing many problems in the availability of electricity in public and private buildings. This problem is leading to use privet power generators, causing air pollution and highly energy consumption. The second exploratory symposium "the reality of power in Iraq and its impact on the society" which had been held on May 2011 in Iraq proposed a large number of recommendations, a standout amongst these proposals was: urge the utilization of the thermal insulation in the building's roofs to reduce the energy consumption. This study will prompt to the new idea of “living cool” in the Iraqi houses and different types of buildings throughout the day without the electricity's power using by utilizing the new thermal insulation technology. This study eventually examines the idea of the “COOL ROOF” innovation to Iraqi's houses and public buildings. The problem of the energy consumption might be the critical issue over the world generally, what's more done Iraq specially. The transmission of the energy through top roofs might be more than (50%) starting with those general transmission energies through the other surfaces. Roofs with "high solar reflection", high daylight reflection and high thermal emittance "high heat radiant" are remaining unflappable throughout the day. Previous researches approved that "the roof surfaces with low thermal emittances properties and high solar reflection might also remain cool in the sun and throughout the day. Use this type of roofs (cool roof) will reduce cooling electricity power in the different types of buildings in Iraq. Cool roofs can also reduce the citywide encompassing air temperature over summer by decreasing those gigantic number for air-conditioning equipment, abating ozone framing furthermore, eventually expanding human comfort demands by using the nature and minimum requirements to reach human comfortable zones. This research has been used practical details to apply the cool roof technology in Iraq.

1. Introduction

To discuss energy transmission over the building's skin surely will be find that the roofs surface is the majority significant component those general transmission energies through the surface. That is the reason to look into that reality which says that: - “Roofs that could great reflect the daylight (high capability to reflect the sunlight) what’s more secondary qualify to warm emittance issue (high capacity with emanate heat) would be staying cool in the sun”; same time the roofs, which have, lower thermal emittance yet all the exceptionally sun based reflection secondary might also stay cool in the sun. The utilizing of electricity’s power in the sunny season and hot days (for ventilating issue) might make drops down, in case of changing normal roof with a cool roof "the citywide ambient air temperature in summer can be lower by using Cool roofs, slowing ozone formation and increasing human comfort” [1].
The study of [2] approved that “the differences between the surface and ambient air temperatures for highly absorptive (low-albedo) roofs, may be as high as 50K. While for less absorptive (high-albedo) surfaces with similar insulated properties, such as roofs covered with a white coating, the difference is only about 10K”. For this cause, roofs that rivet little insulation make indicated as “cool surfaces” What's more might affect to diminish those necessary cooling-energy. Same time those warming of the air might make helping to profoundly absorptive surfaces that by implication increase the buildings’ cooling needs. Different studies to [3] affirmed; “Dark roofing materials are efficient in absorbing incident solar radiation. For example, black single-ply roofing has a typical albedo of 0.06. Gravel roofs have albedos between 0.12 and 0.34, depending on the color of the gravel, but most tend to be around 0.15”.

Generally, the dim roofs colored's temperature will be climbing bigger also speedier over reflective roofs. For example, some researches like [2] Also [3], indicate that light-shaded roofs warm dependent upon at 1/3 the rate of their dim equivalents parts. Those hotter roofs transmit more heat into the buildings than cooler ones, supposing that the level of insulation and construction are the same. In addition, the Contrast of the top surface (roofs) temperature, furthermore that of the overlying air chance to be concerning as high as 45-55K (80-100°F) to dull roofs, furthermore similarly as high as 10-15K (20-30°F) to cool roofs, supposing comparable underlying materials [3]. According to the Iraqi environment, Iraq's environment needs to utilize the (cool roof) concept, to decrease depending on energy demands furthermore lessen the energy consumption. This causing to coming low for outside air temperatures can slow urban pollution formation temperatures Also approved human health and outdoor comfort. Decreased thermal stress might additionally increment the lifetime about cool roofs, decreasing preservation and waste [2].

2. Previous Studies to extract the research problem
The research is discussing many different articles and researches, which are reviewing the literature collected by (ASHRAE); literature listed on the web sites of (FSEC), (ORNL), (NREL), (LBNL), (ACEEE), and the publications of Elsevier to extracting the research problem. Several keywords were search like "cool roofs, high-albedo, roof space ventilation, radiant barrier and else…” Around half of those papers exhibited cool roofs impact on the quantitative cooling energy savings. Those cooling energy savings differed starting with 2% up to 44% and averaged over 20%. In addition, there are around 10papers introduced peak cooling energy utilize and the quantitative savings, and there are two papers said saving for heating energy, or extra sums from claiming warming obliged. The researchers shown that "the peak cooling energy savings from cool roofs are between 3% up to 35%, which depends on ceiling insulation levels, duct placement and roof space structure. More than fifteen papers presenting energy savings from cool roofs applied white colored top roof structures. Such as: [4-8] researches depend on "radiant barrier systems for cool roofs". The researches that fixated on the urban heat island effect revealed the cooling energy savings. The (Figure 1) shows the temperature transfer interactions at the roof’s surface vitality equalization for top surface
An investigation for Akbari et al. Recorded that Eventually the top reflection from claiming two identical transportable classrooms done Sacramento those cooling-energy will a chance to be saved 46%, while the peak electricity will be saved 20%. An additional examine to Konopacki et al. Accounted for two commercial buildings in California measured saved about 12–18%. Furthermore, parker et al. Measured a normal for 19% vitality investment saved in eleven Florida residences eventually by reflective coatings once roofs [9]. There are many other investigations recreated about urban-wide cooling over Los Angeles once smog; those outcomes indicate a huge decrease in ozone fixation. Those simulations anticipate a diminishment of 10–20% in population-weighted exhaust cloud (ozone).

From those previous studied they approved that “the roof surfaces with low thermal emittances properties and high solar reflection might also remain cool in the sun and throughout the day, So the researchers extracting that using this type of roofs (cool roof) will diminishing cooling electricity power in the different types of buildings in Iraq. Cool roofs can also reduce the citywide encompassing air temperature over summer by decreasing those gigantic number for air-conditioning equipment, abating ozone framing furthermore, eventually expanding human comfort demands by using the nature and minimum requirements to reach human comfortable zones.

According to that, the research has been extracting the research problem, which that: “find best practical (suitable and economical) architectural detail for cool roof in Iraq as one of the effective solutions to decrease the electricity consumption”

3. The idea about cool Roof

A standout amongst those clearest definitions to cool roof is materials that have low thermal emittance and high solar reflection, or high warm emittance with high solar reflection that diminishes heat increase through those tops [10].

In turn, portrayal might a chance to be utilizing to the idea of “cool roof” which will be the surfaces with high solar reflection with more emissivity. Based on ASHRAE standard 90. 1 in 2001 those cool roofs were describing “the materials which have a base reflection of 0. 70 [10], more an exploration for "cool roof" based on sustainable studies even in Islamic inhere-tense houses such as the study of [17] and the study of [1] viewed as roofs that sit tight cool in the sun by minimizing solar absorption What’s more expanding warm emanation need aid „cool roofs“ [1]. As appear in (Figure 2). These substances demonstrated that:

A. All asphalt colors (black-top) have very poor reflection (0. 03–0. 26), same time those White color top will be somewhat superior (0. 31).
B. White elastomeric coatings have high emittance Also reflection (0. 65–0. 78).
C. White single-ply membranes have higher emittance and reflection (0.69–0.81). Different covered white material frameworks (such concerning illustration white metal top and painted concrete) have reflection (0.67–0.85). Therefore, as stated by Iraqi nature’s domain and development conditions; the concrete painted with white color will provide for better impact of the top significantly finer that point clear out it concerning illustration if it leaves without any covering.

![Diagram](image-url)

**Figure 2.** Thermal emittance and the reflection of solar energy [11].

Throughout the daytime, the absorption of solar radiation may be rising the temperature of a top surface. at the same time, it brought down by emanation about warm radiation of the sky. Sun warming may be proportional to solar absorption; while radiative cooling is proportional on warm emittance. Hence, different factors, a top with heist solar reflection Also high warm emittance might remain cooler over a top for a low sun based reflection or low warm emittance. Those white surfaces can have high reflection so that is meaning they are cool, with NIR reflection, also high warm emittance. At the same time, the dark surfaces bring low noticeable Furthermore NIR reflection, so they are warm. However, a low-emittance surface could remain cool though the low-emittance surface needs a fundamentally higher solar reflection. (Table 1) has shown the cool & non-cool alternatives for low-sloped roofs. Demonstrated ranges of commonplace values for starting solar reflection, introductory warm emittance and expense [10].
Table 1. “Cool & non-cool” alternatives for low-sloped roofs. [10]

| Roof Type                      | Reflectance | Emissance | Cost (S/k) |
|--------------------------------|-------------|-----------|------------|
| Built-Up Roof with dark gravel with smooth asphalt surface | 0.08 - 0.15 | 0.80 - 0.90 | 1.2 - 2.1 |
| Built-Up Roof with aluminum coating | 0.25 - 0.35 | 0.20 - 0.50 | 1.2 - 2.1 |
| Single-Ply Membrane black (EPDM, CP, CSPE, PVC) | 0.04 - 0.05 | 0.85 - 0.95 | 1.9 - 2.0 |
| Single-Ply Membrane gray EPDM | 0.15 - 0.20 | 0.85 - 0.95 | 1.9 - 2.0 |
| Modified Bitumen with mineral surface caps (SBS, APP) | 0.10 - 0.20 | 0.85 - 0.95 | 1.5 - 1.9 |
| Metal Roof unpainted, corrugated, dark-painted, corrugated | 0.30 - 0.50 | 0.20 - 0.30 | 1.8 - 3.7 |
| Asphalt Shingle black | 0.04 - 0.06 | 0.80 - 0.90 | 1.1 - 1.4 |
| Asphalt Shingle brown | 0.05 - 0.08 | 0.80 - 0.90 | 1.1 - 1.4 |
| Liquid Applied Coating smooth black | 0.04 - 0.06 | 0.85 - 0.95 | 0.5 - 0.7 |
| Liquid Applied Coating smooth white | 0.70 - 0.85 | 0.85 - 0.95 | 0.6 - 0.8 |
| Liquid Applied Coating smooth white rough white | 0.50 - 0.60 | 0.85 - 0.95 | 0.6 - 0.8 |
| Concrete Tile red | 0.10 - 0.12 | 0.85 - 0.90 | 3 - 4 |
| Concrete Tile white | 0.65 - 0.75 | 0.85 - 0.90 | 3 - 4 |
| Concrete Tile unpainted | 0.16 - 0.22 | 0.85 - 0.90 | 3 - 4 |

For profoundly absorptive (low-albedo) roofs, those surface/ambient air-temperatures difference might achieve 50 K, same time for less absorptive (high-albedo) surfaces with comparable different properties (e. g. White-coated roofs), the Contrast could a chance to be just something like 10 k. As demonstrated done (Figure 3) below.

Figure 3. Temperature Ascent (surface temperature - air temperature) of Different materials measured toward top solar conditions [14]. How "Cool Roof" Works
To clarify the way of how the cool roof technique works we need to know how solar energy has to raise the temperature of the builds surface materials and what's more, the chemical and physical properties of surface finishing materials might help warming.

3.1. A “Solar Energy”
There are three main types of rays are forming the solar energy and which reached the earth in different percentage. These rays are:
- UV spectrum “ultra violet”: is about (5%) of solar energy counting the rays that causes the sunburns.
- Visible light, in colors ranging from violet to red is about (43%) of solar energy.
- Remaining (52%) of solar energy is infrared, felt as heat.
In the following, the research will be showing the main features on the energy act for the roof materials:

![Albedo effects on surface energy](image)

**Figure 4.** Albedo effects on surface energy [14].

3.1.1. “Solar Reflection”. The solar reflection or “Albedo” means the rate of that surface capacity to reflect that sun-powered energy which achieves that surface. (Figure 4) is demonstrating the albedo impacts from claiming surface vitality [14].

3.1.2. “Thermal Emittance”. Any surface laid open to the sun will get hotter until it achieves warm balance (i.e., it provides off as much heat as it obtains). The thermal emittance of the material has to controls what amount of high temperature it will emanate for every unit range during an provided for temperature, that is, how promptly a surface provides for dependent upon high temperature. The point when presented on sunlight, surface with high emittance will achieve warm balance in an easier temperature over a surface for low emittance.
3.2. “Temperature Effects”

It could be one of the main feathers that pretentious on the solar reflection and heat emittance, also it is perceptible effects on surface temperature. A study looks three different roof types (as shown in fig. 5) illustrates these differences [14]. “ASU National Center” of Quality top-roof surfaces had small reflection however great thermal emittance; “typical black asphalt” roofs range about 74-85°C (165-185°F) at noontime through summer season. Metal roof has “high-reflection” and “low-thermal emittance” and keep warm about (150-15°F) 66-77°C, some studies such as [10]. Has been exposed that “cool roofs” with both high-reflection and high-emittance spread greatest temperatures in the summer sun about 43-46°C (110-115°F).

4. Advantageous “Cool Roof’s” materials used in Iraq

There are many types of roofing materials that would use in the top roof finishing in Iraq, these are prepared of greatly reflective and emissive materials which can stay (28-33)°C or (50 to 60) ºF cooler than other regular materials during the peak of the summer season. (Fig. 6) may be indicating those suitable covering cool top material that could a chance to be utilize easily in Iraq.

Cool top Coatings for surface would be the best-applied technology that can be use usefully in Iraq especially for low-sloped roofs. Cool top coatings could be spray over an extensive variety about existing surfaces, such as (asphalt, concrete, gravel Furthermore metal). The cool top covering contained of heavy paints constancy, and have numerous additives that give advance specifications to
their joining with the top roof materials, solidness suppressions from claiming green growth. What's more contagious growth this materials covering have the aptitude to self-wash, or shed soil under typical precipitation.

There are two types of cool roof coating which could be use efficiency in our country Iraq. Because of its efficiency in providing thermal insulation, reflection and the flexibility needed to maintain surfaces. These types are: “Elastomeric and Cementitious”: “Elastomeric coatings” have numerous polymers to decrease weakness what's more to increase the bonding between layers, while “cementitious coatings” have cement elements. The research found another covering kind, which holds cement elements and polymers, both kind has a sun oriented re-fection about (65%) and may be more when it became new, also have a “thermal emittance” about more than (80-90%). The “elastomeric coatings” are responsible of waterproofing membrane; same time “cementitious coatings” trusting on the underlying material for waterproofing.

The (Figure 6) is demonstrating the advantageous layers for cool covering spread, which might be, utilize for roofing sections in Iraq. The researchers designed two details of coating the top roof with cool spray layer; the first one can use the “cementitious” covering following utilizing the last top completing (concrete tiles 80X80X4 cm) which utilization to commonplace Iraqi material (as demonstrated over Figure 7, A). However; the second method for cool spray covering roof layer might utilize the “cementitious coating” after completing those top surface for the regular (terrazzo tiles 30X30X2.5cm), which utilization generally for completing those buildings’ roofs. (As demonstrated in Figure 7, B).

![Figure 7. A. practical detail of coating the top roof with cool spray layer (Researchers).](image)

Single membranes could be in a pre-fabricated sheet. It can be applying in a single layer for roofs with very low slope. Generally, the material glued or mechanically fastened on the roof [10] (Figure 8) is display the insulation methods for the “single-ply membrane” that which be a good option for typical roofs in Iraqi buildings.
Figure 7. B. Cool coatings spray on a rooftop in Iraq (Researchers).

Figure 8. “Single-ply membrane”. [12]

“Cool roof technology” have three main categories: one of them is the “single-ply” membrane, another one is “a liquid-applied”, and the third set is “metal panels”. (Table 2) is displaying the three categories of “cool roof”.

| Category       | Product                                           | Reflectance | Emissivity | SRI |
|----------------|---------------------------------------------------|-------------|------------|-----|
| Single-ply     | White polyvinyl chloride (PVC)                    | 0.86        | 0.86       | 107 |
| Single-ply     | White chlorinated polyethylene (CPE)              | 0.86        | 0.88       | 108 |
| Single-ply     | White chlorosulfonated polyethylene (CPSE), e.g., Hypalon | 0.85        | 0.87       | 106 |
| Single-ply     | White thermoplastic polyolefin (TSO)              | 0.77        | 0.87       | 95  |
| Liquid-applied | White elastomeric, polyurethane, acrylic coating  | 0.71        | 0.86       | 86  |
| Liquid-applied | White paint (on metal or concrete)                | 0.71        | 0.85       | 86  |
| Metal panels   | Factory-coated white finish                      | 0.70        | 0.87       | 85  |
5. Coasts of “Cool Roof”
Periodically the top roof of most building need maintenances, the best time to change the albedo during that, “cool-roofs” sustain no extra cost if color-changes combined into routine “re-roofing or re-surfacing schedules”, the roof-tops of the buildings might be coated or covered by a new material. Usually many High albedo-alternatives are available for cool roofing materials, often at cheaper or no added cost [2]. The cost of “an asphalt cap sheet” or amended “bitumen roof” is around $1.00 to $2.00 for each ft² [2]. The best cost of a traditional “single-ply roof membrane” with high reflection, high emittance is around 0.50$/ft² [16]. (Table 1) have displayed examined primary cost ranges for several “cool roof” products. While (Table 2) had been display the indicative comparisons of the tradeoffs in reflection, emittance, cost and factors between traditional materials and cool roof materials options for low-sloped roofs; the table had been note that:

- The cost of “Cool roof coatings” might between ($0.75-$1.50)/ ft² this cost incloud materials and work, that includes repetitive surface preparation like (pressure washing), but that doesn’t include reparation of of leakages, flaws, or fizzy of the present roof surface.
- The costs vary of “Single-ply membrane” is start from ($1.50-$3.00)/ ft² which, includes materials, fixing, and practical preparation labor. However, this cost doesn’t include repairing work’s extensive or elimination and removal of present roof layers.
- The best quality ranges coast is start from (0-5) or reaching to (10 cents) for best products, or start from (10-20) cents for the constructed-up roof with a “cool coating” used in places of flat asphalt or aluminum layer coating.

The costs of any roofing works have depending on the native marketplace and many factors like (magnitude of roofing job, the total roof’s number of diffusions or difficulties, and comfort way to entree to the roof [14].

6. Process and Conservation Productions
Appropriate fixing of a cool roof project is very important to long term achievement. The coating of the top roof or single ply casing on a low sloped roof can work as a good assembly of top-surface of a roofing and could be apply right over a roof level or maybe on topmost of other standing materials. The good fixation of “Cool roof” layers can be durable the top roof within a couple of years. To confirm worthy product performance, the client can seek proper warrants for the product and the installation provision. Furthermore, horizontal tops and higher sloped tops “tend to withstand weathering better”. with good conservation, the coats are capable to preserve maximum of the solar reflection, with reductions of about “20 percent”, generally in the first year after submission of the covering [12].

6.1. Details of cool roof design

- The presentation of cool rooftops is influences by the collection of soil. Soil accumulation can decrease if rooftop surfaces incline at any rate 1⁄4 inch per foot.
- When fluid applied coatings are utilizing, cautiously select coatings that is viable with the fundamental substrate
- Liquid applied cool rooftop coatings ought to consent to “ASTM Standard 6083-97” for sol- idness and lengthening and have a base thickness of “20 mils” [16].
- The significant boundaries to consider while assessing the complete vitality effect of an adjust- ment in rooftop sun-oriented reflection are “insulation R-value”, “climate”, “solar radia- tion”, “building use and type”, and the “efficiencies of heating and cooling equipment”.

Numerous examinations utilized cool rooftop innovation for various structure types and in various areas for different rooftop measures, these investigations found that the utilizing of this innovation spared cooling vitality between 10-69% from characteristic cooling vitality that required if the conventional material utilized. Table3 is demonstrating the “energy saving” for various structures types with cool rooftops in various areas.
Table 3. Energy saving for different buildings types with cool roofs in different locations.

| Building  | Location                   | Citation                              | Size (ft²) | Roof Insulation* | Roof Space | Cooling Saved | Demand Savings |
|-----------|----------------------------|---------------------------------------|------------|------------------|------------|---------------|----------------|
| Residence | Merritt Island, FL         | (Parker, et al. 1994)                | 1,800      | R-25             | Attic      | 10%           | 23%            |
| Convenience Recall | Austin, TX | (Konopacki, S. and H. Akbari. 2001)         | 100,000    | R-12             | Ptenum     | 11%           | 14%            |
| Residence | Cocoa Beach, FL            | (Parker, Cummings, et al. 1994)      | 1,795      | R-11             | Attic      | 25%           | 29%            |
| Residence | Nobleton, FL               | (Parker, et al. 1994)                | 900        | R-3              | Attic      | 25%           | 30%            |
| School Trailer | Volusia County, FL | (Calahan, M., D, et al. 2000)       | 1,440      | R-11             | None       | 33%           | 37%            |
| School Trailer | Sacramento, CA         | (Akbari, H., S., Bertz, et al. 1993) | 960        | R-19             | None       | 34%           | 17%            |
| Our Savor's School | Cocoa Beach, FL    | (Parker, D., J., Sherwin, et al. 1996) | 10,000     | R-19             | Attic      | 10%           | 35%            |
| Residence | Cocoa Beach, FL            | (Parker, et al. 1994)                | 1,809      | None             | Attic      | 43%           | 38%            |
| Residence | Sacramento, CA             | (Akbari, H., S., Bertz, et al. 1993) | 1,825      | R-11             | None       | 69            | 32%            |

7. Conclusions
In the Iraqi conditions, the cool roof technology can be very advantageous because it can decrease the electricity usage in hot days, which is more than 6 months in different governorates in Iraq. Using “cool roof technology” that have been designed in the research have to decrease the temperature of the roof about 50%, which have been affect the using of cooling energy and that is used to reach the comfortable zones in hot climate. These details are the simplest and best economic way to reduce the citywide ambient temperature of air in summer’s season. Increasing human comfort demands and slowing ozone formation decreased the thermal stress had been increasing the need to use cool roofs in Iraq. In addition, there are numbers of benefits provided by these cool roof systems, it includes:
A. Decreasing the huge numbers of “air-conditioning unites” equipment depending on natural decreasing of the temperature close to the roofing materials.
B. Reduce the cooling energy costs.
C. The cool roof heat transfers, a lesser amount of heat to the other normal types of roof building, under the building become more comfortable and cooler for longer time.
D. By decreasing cooling system needs, a cool roof helps the users to decrease peak electricity demand.
E. Improved comfort due to cooler ceiling and better human health.
F. Roof life is longer due to decreased thermal contraction and expansion as the roof stays cooler.
G. Reduce the effect of urban heat island. On a bigger scale, if the albedo of the whole region can significantly increase by mounting cool roofs, light colored cemented surfaces etcetera, the effect
of urban heat island can decrease. Raising the average albedo of the areas of the roof and other surfaces that are exposed would result in less temperature increase in the urban microclimate, decreasing overall peak energy demands.

H. Cool roofs transfer a lesser amount of heat to the outdoor environment than do warm roofs.
I. The using of Cool roofs system is improving a lesser pollution to the environment.

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