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DJIBOUTI URBAN DEVELOPMENT PROJECT

Energy Conserving Design for Salines-Ouest Housing

Prepared for

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I. SUMMARY

This consultancy, supported by VITA/USAID, represents an attempt to utilize the climate studies and the building experience gained by the VITA/ISERST Renewable Energy Project in Djibouti. The purpose was to provide practical assistance in climatic and energy conserving design during the planning of the housing which will be built as part of the Djibouti Urban Development Project.

The consultancy represented a type of international, inter-agency cooperation that was new in the Djiboutian context. For this reason, it was made sufficiently flexible to accomodate problems and take advantage of opportunities as they presented themselves. American experts in climatic design and energy conservation are being made available to assist in the planning of housing units and in the preparation of energy efficient details. Their contribution will include material which makes possible an analysis of the initial costs that might be involved in improving the project's overall energy performance.

The consultancy was designed to take place in four distinct phases. The consultant worked initially in Paris with the architectural firm (Groupe Huit/SEDES) that was preparing preliminary designs and cost estimates for the project. This was followed by a visit to Djibouti in which discussions and appraisals of the preliminary plans were made with Djiboutian authorities, VITA, and USAID personnel. A return visit to the Paris firm permitted the consultant to assist with the incorporation of required structural and climatic modifications into the preliminary designs before working drawings were started. A final phase, that of studying the effect of possible "add-on" energy conserving elements, took place in the USA after final drawings were prepared by the architectural firm in Paris. This phase involved the participation of a consultant, Seymour Jarmul, who specializes in the cost-effectiveness of energy conserving features.

The first design phase involved the development of type-plans, space dimensions, and the placement of housing units on their plots. It included decisions as to the type of construction and architectural details that could be provided within the specified budget. The results were preliminary plans for the core units to be built during the project. These will have the potential for later energy conserving adaptions, such as improved ventilation, appropriate insulation, etc. The climatic and energy features not included in the core units built during the project could be installed later by those purchasing the housing.

II. BACKGROUND

The need for housing in Djibouti is acute. Between 2,000 and 3,000 units are needed annually to provide for natural population increase, for new inhabitants and for the replacement of existing sub-standard buildings. In recent years little new housing has been built. The resulting shortfall has been made up by semi-legal construction or remodeling of wooden houses and by increased crowding into existing structures.

In 1983 a World Bank Project Report for a Djibouti Urban Development Project was prepared by Groupe Huit/SEDES. Along with plans for upgrading and improving conditions in existing housing areas in the city, it proposed providing new housing sites for the city's low and medium income inhabitants. According to the plan, housing infrastructure was to be prepared for 7300 inhabitants on 1084 plots at Salines-Ouest (an undeveloped 20 hectare site in the southwest section of the city adjacent to Arta Road). As well as providing infrastructure (roads, sewers, water and electricity), it envisaged the construction of 257 core houses as a pilot program. An estimate of the expected construction cost per house was included.

The Salines-Ouest component of the Urban Development Project was substantially modified in the World Bank Staff Appraisal (April 1984) which defined the housing program as it is now being designed. Although the general plan for the Salines-Ouest area is to be respected, the construction of only a small portion of the original scheme is scheduled to be included in the present Urban Development Project. The plan prescribes developing 176 serviced housing plots on 2.8 hectares. Housing units of four types are to be constructed on 106 lots, the remaining lots will be sold vacant.

The originally estimated price per unit was increased by approximately fifty per cent in the 1984 Staff Assessment. This was due in part to inflation during the intervening period and also to more realistic cost estimates which recognized the high construction costs characteristic of Djibouti. In October 1984, the French design firm, Groupe Huit/SEDES, began work on the type-designs. Following the completion of final plans in December 1984, they will be reviewed in Djibouti. Construction is scheduled to begin in the last quarter of 1985. The major part of the construction will take place in 1986. The housing is expected to be complete by mid-1987.

World Bank and USAID funds that support the project will be used to provide the infrastructure at Salines-Ouest. The land is presently owned by the Société Immobilière de Djibouti (SID) which will bear the cost of construction of the housing

units. The SID will ultimately be responsible for the sale of the units and financial management of the finished project.

Consultant's Observations

Any proposed low income housing project in Djibouti must recognize certain fundamental problems. First, as elsewhere in the developing world, costs must be minimized to place the units within the range of the economic group targeted. In Djibouti this problem is especially severe because of the high cost of material and labor. With the exception of earth products, all building materials must be imported. Pay for skilled workmen must compete with the high salaries available in the nearby Gulf states. The necessity for reduced costs is recognized in the original World Bank Report where it is reflected in the minimum standards that are proposed for the house units. These simple basic core-houses are smaller in size and without the amenities that have been provided in older housing projects in Djibouti which were heavily subsidized by French aid. The new Salines-Ouest housing will reflect the reduced housing standards that present resources can support. These minimal standards, now common in other developing nations, will be new to Djibouti, and may represent a significant compromise both on the part of Djiboutian agencies responsible for the project and for those purchasing the housing units.

The severity of Djibouti's climate is well known. The combination of high heat and humidity at certain seasons has few parallels in the tropical world. As a result, building designs and systems successful elsewhere in the tropics may be less successful or unacceptable in Djibouti's situation. Climatic considerations demanded special attention in the design of the original core units. They must be planned to accomodate possible changes and future construction by those purchasing the units.

These fundamental problems were addressed during the consultancy. In the early stages of building design, climate and energy requirements must be considered simultaneously with the cost, the construction methods, and the functional and social aspects. The basic form of housing had been dictated by the 1983 report. It had specificed the layout and sizes of the lots, the area and type of rooms that were to be built, and to which of the four house-types amenities such as electricity and water were to be provided. The estimated costs contained in that report underestimated the expenses involved in building houses on filled land and the structural requirements of construction in a seismic zone. Even the adjusted costs of the 1984 report made it difficult to follow the program requirements in regards to room sizes, etc.

The construction details of the four house-types will be fundamentally the same, responding to the structural requirements of the site, and to climatic conditions that are identical. Necessary structural adjustments are being incorporated in the design by the architects. Adjustments maximizing natural cooling and comfort are included in the core house design when it is possible within the budget.

Climatic Modifications in House-Type A-1

During the period of the consultancy prime attention was given to the smallest unit (Type A-1) which will represent the majority of the units to be built and more than fifty percent of the total cost of construction.

The specifications for this basic core house are given in the original 1983 World Bank Project report which also contains diagrams for its possible configuration. The unit is composed of a single room 12.75m^2 (approx. 137 ft.^{2}) and a sanitary block 3.2m^2 (approx. 35 ft.^{2}). No running water or electricity is provided by project funds. The structure is to be of masonry with a wood-supported corrugated iron roof. The house will be neither plastered nor painted and only one window is specified. The cost of construction for this unit was estimated to be DF 1,048,300 (approx. USD 6,000) in April 1984.

Certain changes and additions to the original design program were necessary. These included earthquake resisting wall and foundation reinforcement which were not included in the original program or estimate. Other modifications have been included in the plan in order to make the building more responsive to Djibouti's seasons of severe heat. These changes include the placing of the room units on the street side of each plot. This frontal position, combined with an entrance space shared by two adjacent houses, permits openings for ventilation on three sides of the main living unit. This location also allows direct through ventilation in the main room. It permits the house to be separated, to the greatest extent possible, from the unit built on the adjoining lots to the rear. This placement allows breeze to circulate freely between houses.

The average roof height has been adjusted to permit the later installation of a false ceiling. A ceiling, when installed by the owner, can provide insulation from the hot air and radiant heat which comes from the metal roof during the day. The planned roof height will permit the safe and efficient operation of electric ceiling fans if they are installed. Other additions include openings for ventilation beneath the roof and the possibility for specially detailed doors which will allow them to be used for ventilation while partially

closed. The accomodations noted above can be included at little or no extra inital expense.

Although during the inital consultancy the emphasis was on A-1 house units, the patterns successful there are applied to the larger house types. The smallest unit is the most difficult to design efficiently. The larger, more expensive units have more amenities originally, and can be protected more easily from the extremes of climate.

Add-On Energy Conserving Features

Further climatic innovations will require extra expenditure either by the project sponsors, if they are to included originally, or by the house owner if they are to be added later. These might include extra windows to permit maximum ventilation, painting the structure to reflect more of the solar radiant heat, installing overhangs and verandas to shade exposed sections of wall, redesigning windows, doors and ventilators, provision of insulation in walls, floors and ceilings, etc. The effect of such features on human comfort and the energy balance of the structures were addressed in the final phase of the consultancy. Their study includes their effect on the cost of electric energy used by the householders.

III. ANALYSIS OF ADD-ON FEATURES TO BASIC HOUSING DESIGN

Data Sources

The following comments concern additions to Salines-Ouest housing units which are designed to improve climatic effectiveness and energy efficiency. They are based on the plans, elevations, sections and cost estimates provided in January 1985 by the French consulting firm (Groupe Huit-SEDES). These plans and documents will be presented in February 1985 to World Bank, USAID, and local authorities in Djibouti.

The present documents and drawings which were consulted include:

<u>General</u>
1. Location Plan, Overall Site Plan
2. Housing Cost Summary

<u>House Type A-1</u>
3. Foundation Plans, Room Plans, Site Plan
4. Elevations, Sections
5. Quantity Survey, Cost Estimate

<u>House Type B-1</u>
6. Foundation Plans, Room Plans, Site Plan

7. Elevations, Sections
8. Quantity Survey, Cost Estimate

House Type B-2
9. Foundation Plans, Room Plans, Site Plan
10. Elevations, Sections (including Type C-2)
11. Quantity Survey, Cost Estimate

House Type C-2
12. Foundation Plans, Room Plans, Site Plan
13. Quantity Survey, Cost Estimate

Accurate costs of construction materials and labor for Djibouti are difficult to obtain in advance. Those used in the calculations are based on costs obtained by Groupe Huit/ SEDES and used in their documents, and on costs recorded by VITA/ISERST staff and consultants in Djibouti. They represent the most accurate estimates possible, but, as in the case of the quantity survey/costs submitted by Groupe Huit, they should be adjusted for actual on-site costs as they become available.

Cost of Modifications Incorporated in Present Design

The house-types designed for Salines Ouest follow the guidelines for basic core housing outlined in the original 1983 Project Report. The 1985 estimated housing costs show an increase of 19.75 percent over the April 1984 estimate (Staff Appraisal Report) for several reasons. As well as the inevitable increase because of inflation, other costs result from the necessity to introduce certain important features that had not been included in the original estimate. It was, for example, essential to provide reinforced concrete foundations, columns and beams to resist earthquakes. The new costs also include the changes made to accommodate Djibouti's extreme heat. Within the minimal budget every effort was made to guarantee that the original house units were structurally sound and appropriately designed for Djibouti's climate. Only those additions considered essential by the design firm and the VITA/ISERST consultant were included in the present basic designs.

Some climatic adjustments were made without extra cost. Others required some additional expense but are consistent with current building practices in Djibouti and would be expected by authorities and potential purchasers. Consideration was given to provide for additions the owners might make later to the original units or in new structures they will build.

Modifications that required no extra expense include the siting and orientation of the core units on each plot. They

were located to provide sufficient open space between neighboring structures to permit maximum natural air movement to occur. As eastern and western walls receive the greatest solar radiation, buildings were oriented so that the exposure of these walls was minimal in order to reduce heat gains in the rooms. Where east and west walls occur, they are shaded from the sun during critical periods with exterior verandas or neighboring walls.

Other climatic modifications to the designs specified in the 1983 Project Report involved increased expense. They are a logical response to climate and already normal in Djibouti building practice. These additions are listed below along with their cost for each unit and for the project as a whole. They included:

1. Provision of a minimum roof height (2.92m) adequate to allow for the later addition of a ceiling (height 2.8m) which will reduce radiant heat gain from the roof. The height was determined by the space necessary to allow for ventilation and to operate an electric ceiling fan safely and efficiently.

2. Construction of openings for ventilation below the roof surface to allow for the escape of the hot air that collects there.

3. Inclusion of window and door openings adequate to guarantee cross ventilation and air movement in the living spaces.

The cost of these climatic modifications is included below along with the percentage they represent of the overall cost of each unit and for the project as a whole.

House-Type	Cost (DF) for Climate Features
House-Type A-1 (1,210,240 DF)	
Increase in roof height	24,484
Roof ventilation blocks	2,970
Extra window (over door cost)	5,000
Total	32,454 per house 2.6% of construction cost
House-Type B-1 (1,570,280 DF)	
Increase in roof height	26,993
Roof ventilation blocks	2,180
Total	29,173 1.9% of construction cost

House-Type	Cost (DF) for Climate Features
House-Type B-2 (2,269,320 DF)	
Increase in roof height	35,694
Roof ventilation blocks	2,180
Extra window	25,000
Total	62,874 per house 2.7% of construction cost
House-Type C-2 (2,272,920 DF)	
Increase in roof height	35,694
Roof ventilation blocks	2,180
Total	37,874 1.6% of construction cost

The total cost of the modifications listed above for the 106 units to be built is 3,895,950 DF. This represents 2.4 percent of the total projected cost of the housing (163,030,640 DF).

Inflation and the structural additions to resist earthquakes account for a major part of the expected 19.75 percent increase in costs over the April 1984 estimate. Additions designed to decrease cooling loads in the basic units account for less than one-sixth of the increase. There is no doubt in the mind of the architects and the consultants that these increases are justified. They will guarantee only the livability, not the comfort, of the housing units the project is providing and will reduce energy consumption in those units which use electric devices for cooling.

The Potential for "Add-On" Energy Saving Features

Any calculation of savings in energy costs presupposes the use of electric energy to make interior environment more livable with lights, electric ceiling fans or air-conditioning units.

According to project specifications originally only 42 of the 106 units to be constructed will be provided with electricity. There is little doubt that new owners of those homes without electricity will be connected soon to the power lines that are being provided by the project on the site. Present practice indicates that families will undergo considerable financial sacrifice to obtain and operate electric cooling devices.

The type of mechanical cooling, fans or AC units that will be installed will depend on the income level of the occupant. The extent of their use will depend on a room's "effective temperature". That is the temperature to which human beings respond, a combination of air temperature, radiant temperature, humidity, and air movement. Any reduction in interior "effective temperatures" will be reflected in a reduction of the time that the electric cooling device must be used, or in the force with which it operates.

Air temperature and relative humidity within the house can only be reduced below outside conditions by air-conditioning. Reducing radiant temperature within a room and increasing natural air movement through it can be influenced by the architectural and site detailing. The energy savings realized by reducing air-conditioning loads during the seasons in which it is required is discussed fully in the following section. The design elements discussed below will increase the periods in which the house is comfortable without mechanical cooling and would reduce the cooling loads, and therefore the energy demands at the times it is necessary.

Add-On Features to Reduce Radiant Temperatures

Reducing the average temperatures of the surfaces of a room, the walls, floor, and ceiling, by one degree has the same effect as reducing the air temperature of the room by 1.4 degrees. Therefore by lowering the average temperature surrounding solid surfaces by 10 degrees would affect the occupants of the room in the same way as a reduction of 14 degrees in air temperature. The floor of a room will have a temperature approaching the seasonal average. Interior walls and exterior walls in shade will have temperatures reflecting the average of air temperature over a given 24 hour period. The outer surfaces of walls or roof exposed to the sun can easily rise 20 degrees or more above ambient air temperature. Their interior surface temperature can be nearly the same, as in the case of metals or thin wood, or will be somewhat reduced as in the case of masonry walls. For example, during April, which has an average noon exterior air temperature of 29°C, the effective temperature of a typical Salines Ouest Project room would equal 34°C if the roof and one wall are exposed to the sun and their temperatures rose to 49°C and 39°C respectively. This would be above the exterior temperature that might be expected two months later, in May or early June, and would require mechanical cooling for comfort. Protection for these surfaces can keep the room surfaces near the actual April air temperature and eliminate or reduce the need for mechanical cooling.

The Cost of Protection from Radiant Heat

Walls: As was pointed out in the earlier section, two, or in some cases, three walls of each room have been protected from the sun by the siting and planning of the presently designed house units. Shading the remaining walls from exposure to the sun could be done by constructing a protective overhang or by vegetation.

A shading device cutting the solar radiation on one wall by approximately 50 percent would result in a decrease in interior effective temperature of slightly less than one degree during the part of the day that the sun's heat penetrates the wall. There would be no effect from overhangs at night or on walls not in sunlight. The cost of building overhangs would be between 18,000 DF and 33,500 DF per room, based on estimated roof costs. This slight reduction in temperature does not justify the cost of specially constructing permanent shading elements for this project.

Nearly the same shading effect could be accomplished by vegetation at less cost. Judging from other housing projects within the city, home owners will take considerable time and trouble to grow and maintain small trees within their courtyards. Properly placed these trees can shade the room walls which face the courtyards at critical times and seasons. The project should be responsible for "street trees" placed to have the same shading effect on the front facades. The cost of this planting is difficult to estimate, but would certainly be less than protection with building elements. Trees, when mature, would have the added advantages of improving the visual aspect of the project and reducing exterior air temperatures. The project area currently supports a growth of small acacia trees. Investigation should be carried out into the type of trees that might be successful on the filled project land.

Roofs: There is no simple way to protect roofs from the sun's radiation. Protection for the inhabitants of the house from the hot air and radiation that comes from the underside of a metal roof can be provided with light weight ceilings over each room. Properly insulated such a barrier can reduce the ceiling temperature during the hottest part of the day to 3 or 4 degrees above room air temperature. This should be contrasted with the 20 degrees or more above air temperature that the roof can reach.

Provision was made in the basic designs for a roof height adequate to accommodate the installation of a ceiling by the house owner. The additional expense which was entailed is included in the present cost estimates for each house unit. The insulating value of various ceiling materials the owner

might use, and their effectiveness in reducing the energy used for cooling is analyzed in the following section on cost-effectiveness.

Research Potential: There is considerable scope to evaluate the thermal qualities of typical Djibouti building materials in relation to their cost. Both the conductance and time lag that occurs in the usual materials, e.g. the typical cement blocks, and the same characteristics in other possible wall, roof and ceiling materials, should be tested under Djibouti conditions. Special emphasis should be placed on light weight panels and locally produced materials. In addition, a catalogue of the characteristics and maintenance requirements of climate modifying plant materials should be prepared and made available to city officials and home owners.

Add-On Features to Augment Ventilation and Air Movement

Ventilation (the removal of hot air from structures) and air movement (the passage of cooling breezes through rooms) reduce not only the actual air temperature in the house, but also the effective temperatures felt by the inhabitants. These principles have been recognized in the present design to the extent possible within the extremely limited budget. They could be further developed within the project, if funding is available, or can be considered by the owners for inclusion in later buildings on the plots.

Ventilation Openings: Holes to allow hot air to escape from the upper regions of the house are essential. Simple perforated blocks have been included in the present design. These openings could be enlarged and could provide a considerable advantage. Unless openings are sizable the gentle force of rising hot air is not sufficient to cause air to exit from the house; successful ventilation demands openings as large and as free from obstruction as possible.

Ideally ventilation openings should be placed at two levels, one just under the highest section of the roof, another slightly below the proposed ceiling level. There it can be used to evacuate hot air from the room after a ceiling has been put in place by the occupant.

The experience with ventilation openings in other housing projects in the city has not been universally successful. In many, if not most, cases the occupants have blocked the openings to retard the entrance of dust, insects, or animals. Their decision to bear the increased heat within the room rather than undesirable side-effects of unprotected openings should be respected and recognized in the design.

Improving ventilation in Salines-Ouest housing would require two modifications in the present designs. The first would be an adjustment in the size and placement of the openings themselves; a doubling of the actual open space could easily be justified. The second would be a new design for openings which would inhibit the entrance of unwanted elements. In some cases, this would mean openings that could be closed completely by the occupants at certain times of year, for example, when dust is a problem. They would be left open when heat is a problem. Ventilators would be closed during those times when air-conditioning was being used. These ventilators would need to be simple, sturdy and easily operated. Openings between roof and ceiling need only be protected from rain and can remain open. Those located in the room must be capable of complete closure. No simple designs exist for this type of device but the problem is not complicated.

The cost of increasing the opening size can be calculated. The cost of providing protected ventilators capable of being closed can only be estimated at the present time. A rough approximation of the cost increase for each house-type unit is listed below. It is based on doubling the opening size and assuming adjusted window unit costs for closable ventilators.

House Type	Redesigned Ventilator Cost (DF)
A-1	13,386
B-1	12,596
B-2 & C-2	23,013

Proper ventilation will extend the period in which rooms can be used without mechanical cooling devices, and therefore, extend the times of the year in which no electric energy would be required. It would expand the times in which fans alone would suffice, and reduce the speed at which it would be necessary to operate them. If air-conditioning is contemplated, a well ventilated roof space above the ceiling, one which remains near the ambient air temperature, will significantly reduce cooling load.

Air Movement: Natural air movement through a room is controlled and directed by the size and placement of windows and doors. Although the number and size of windows has been adjusted in certain house types (see description of present design) because of the limited budget, the number of openings provided in each room remains minimal.

Placing at least one extra window (cost approx. 25,000 DF) in each room (two per room is the standard in most rooms in the present design), and the provision of openings (doors or windows) between rooms within the house would facilitate air movement within the structure. As was described in the case

of ventilators, the proper sizing and placing of windows would facilitate natural cooling for much of the year. Too few, or poorly placed openings, demand that mechanical consuming cooling devices be used in seasons when they should not be required. Although the cost of extra windows (25,000 DF each) is easy to calculate, their proper design is an extremely complicated problem.

Windows have a variety of functions as well as that of encouraging air movement. They permit light and view within the room and are a basic esthetic element of the facade. As an opening in a protective wall, their design must reflect the society's requirements for privacy, and must provide security for the occupants and their possessions. They should be designed so that unwanted sunlight does not penetrate the house during the hot season. These multiple functions are served successfully only if windows are specifically designed considering their function, materials, maintenance and cost.

The multi-louver design shown in the architectural drawings of the present house designs satisfies most of the climatic requirements. Two vertical louver/shutters will shade the windows from lateral radiation. The upper horizontal louver will permit some air circulation even if the lower section is closed for privacy or security. A horizontal overhang (not provided) would have better protected the opening from vertical sun and rain. Doors are subject to the same multi-functional requirements.

The cost proposed for windows and doors (15,00 to 30,00 DF) would permit a variety of types. Appropriate designs would result only from specific studies tailored to local conditions that are beyond the responsibility of the usual architectural contract. For example, the design of windows facing an enclosed courtyard should be different from those facing the public street where privacy can be an overriding consideration. Those protected by veranda roofs would be expected to differ from those exposed to full sun. Doors can be designed to allow air movement when partially closed. The material from which panels are made should respond to local costs and maintenance procedures. Properly designed fenestration should not increase building costs. It can be expected to increase comfort and convenience, and to result in energy savings during transitional seasons.

Research Potential

A program designed to provide appropriate designs for ventilation openings and for economic, efficient window and door types could be important to this project. They would have considerable value to future construction of housing in the region. Studies should be devoted to providing designs

especially appropriate to low income housing. Type-designs should be capable of being constructed and maintained within the resources of buyers. They should be constructed to resist the rigors of Djibouti's climate. They should be planned, sized and located to provide maximum protection for interior spaces, to encourage natural cooling and to reduce energy consumption of mechanical cooling devices.

IV. COST BENEFIT ANALYSIS OF ELECTRIC CONSUMPTION

Introduction

The following analysis deals with:

1. Lighting
2. Refrigerators
3. Air Conditioners
4. Ceiling Fans

Other than lighting, none of this equipment is called for in the construction documents. The best way to save energy is not to install any of this additional equipment.

Nonetheless, with the passage of time, it is quite possible that in fact the appliances will be purchased. Therefore, it seems appropriate to see what steps can be taken in improving the Salines-Ouest buildings to reduce that future consumption.

It would be simplistic to say that the energy conservation work should not be done until the appliances operate; since many of the steps will improve comfort even in the absence of the appliances.

In general, the conservation measures described have the potential of reducing energy consumption below half of what it will otherwise run without them. Costs for doing the work are such that savings in the first year alone will pay back the expenditure.

Lighting

The construction documents call for the following number of 60 watt incandescent frosted glass fixtures for each of the units:

Unit Type	Number of Fixtures
A_1	None in basic unit. 3 if electricity option is exercised; the analysis assumes that the option is exercised.

Unit Type	Number of Fixtures
B_1	3
B_2	4
C_2	4

Assuming that each fixture burns, on average over the course of one year, five hours a day, electric consumption for each unit will total:

Unit Type	KWH Per Year
A_1	328.5
B_1	328.5
B_2	438.0
C_2	438.0

The cost of this lighting consumption will vary with the type of electric hook-up, i.e. whether a 1KVA or a 3KVA rate applies:

Unit Type	Annual Cost - 1 KVA	Annual Cost - 3 KVA
A_1	9,231 FD ($52.15)	11,990 FD ($67.74)
B_1	9,231 FD ($52.15)	11,990 FD ($67.74)
B_2	12,308 FD ($69.54)	15,987 FD ($90.32)
C_2	12,308 FD ($69.54)	15,987 FD ($90.32)

Recommendation:

Substitute 15 watt fluorescent fixtures for the specified incandescents. With ballast, the fluorescent draws 23 watts as opposed to the 60 watt incandescent. Energy and costs are proportionately reduced.

Light output for the fluorescent is 870 lumens; for the incandescent it is 855 lumens.

For the fluorescents, annual electric consumption for each unit will total:

Unit Type	KWH per year
A_1	125.9
B_1	125.9
B_2	167.9
C_2	167.9

Annual cost for the fluorescents will be:

Unit Type	Annual Cost - 1 KVA	Annual Cost - 3 KVA
A_1	3,539 FD ($19.99)	4,596 FD ($25.97)
B_1	3,539 FD ($19.99)	4,596 FD ($25.97)
B_2	4,718 FD ($26.66)	6,128 FD ($34.62)
C_2	4,718 FD ($26.66)	6,128 FD ($34.62)

Although each fluorescent lamp costs about 2.5 times the incandescent, it lasts about 10 times as long. Therefore, annual lamp cost is much more favorable for the fluorescent:

Unit Type	Incandescent	Fluorescent
A_1	849 FD ($4.80)	213 FD ($1.20)
B_1	849 FD ($4.80)	213 FD ($1.20)
B_2	1,132 FD ($6.40)	284 FD ($1.60)
C_2	1,132 FD ($6.40)	284 FD ($1.60)

Combining both energy and lamp costs, the following comparison of annual lighting savings results from use of the fluorescents:

Unit Type	Annual Savings - 1 KVA	Annual Savings - 3 KVA
A_1	6,328 FD ($35.76)	8,030 FD ($45.37)
B_1	6,328 FD ($35.76)	8,030 FD ($45.37)
B_2	8,438 FD ($47.68)	10,707 FD ($60.50)
C_2	8,438 FD ($47.68)	10,707 FD ($60.50)

One additional point with respect to the use of fluorescents in Djibouti is that they throw off less heat than do incan-

descents. The 60 watt incandescent throws off 54 watts of heat; the fluorescent and its ballast 18 watts.

The chart below indicates the excess heat thrown off by the incandescents over the course of one year. Also shown is the number of hours a good sized room air conditioner (12,000 BTU/hour) would have to run to remove this heat.

Unit Type	Excess Heat (BTU's)	Hours of Air Conditioner Operation
A_1	672,702	56
B_1	672,702	56
B_2	896,936	75
C_2	896,936	75

Installation Cost and Payback: Fixture cost will vary with the quality of the fixtures chosen. Using medium quality fixtures, there is little difference in construction cost. Therefore, payback is immediate.

Refrigerators

Since refrigerators, if any, will be installed by the occupant, it is impossible to know what particular appliance will be consuming electricity. Accordingly, the discussion which follows below will have to be adapted to particular circumstances.

The amount of electricity used by a refrigerator varies with its size construction, energy efficiency, and how and where it is used. Based on audits conducted in Djibouti in 1983, average annual refrigerator consumption approximates 2,000 KWH. For this electricity, a 1 KVA subscriber paid about 56,200 FD ($317), while a 3 KVA user paid 73,000 FD ($412). In a single year, therefore, electricity to run the refrigerator costs about half what it did to buy the appliance.

There are two major opportunities to cut this consumption.

1. Insulation

The insulation installed in Djibouti's refrigerators at present is simply not enough to withstand the climate's high temperatures.*

* See Chapter VI "Household Refrigerators" in Reducing Energy Consumption in Buildings by Seymour Jarmul, published by VITA, 1984.

By simply placing a jacket of 40mm thick urethane foam slabs across the top and down the sides of a refrigerator, its annual consumption will be cut by 20 percent, saving the user between 11,240 FD ($63) and 14,600 FD ($82) a year. The insulation costs about 2,500 FD ($14), resulting in a payback of under three months.

Even greater savings are available, of course, if material could be added to the door and part of the rear of the refrigerator shell, but the average user may find this difficult to do and to live with.

2. High Efficiency Refrigerators

When used with respect to refrigerators, the word "efficiency" refers to the amount of cooling produced by a fixed amount of electricity. Thus, a refrigerator with a high efficiency rating, uses less electricity to produce a given amount of cooling than does a refrigerator with a low efficiency rating.

Methods of rating efficiency vary from country to country and from manufacturer to manufacturer. Nonetheless, at the moment of purchase, a buyer should carefully compare the relative efficiencies of the refrigerators he is considering.

Even though high efficiency models might cost as much as 20 percent more than standard ones, they can cut consumption by up to half that of standard models.

Suppose, for example, that a premium of 20,000 FD ($113) is charged for a high efficiency model which is, otherwise, comparable to a standard version. Suppose, further, that the higher efficiency cuts annual consumption by 30 percent. This benefits the 1 KVA user by 16,860 FD ($95) a year and the 3KVA consumer by 21,900 FD ($124) per year. The investment for higher efficiency is returned in about a year and continues to cut consumption thereafter.

If the consumer has the money to buy the higher efficiency appliance, its additional cost is an expense that makes sense.

There is one further point to be made concerning refrigerator maintenance. When the condenser coils at the back of the refrigerator get covered with dirt it becomes difficult to remove heat from the refrigerator, and its operating efficiency suffers accordingly. For about 1,000 FD ($5.65), one can buy a brush made especially for cleaning these coils easily. The brush has a tapered design and special bristles that loosen the dirt that a vacuum cannot reach and ordinary brushes would miss.

Taken together, the above three measures can reduce electric consumption by refrigerators to half of what it might otherwise continue to be.

Air Conditioners

No air conditioners are called for in the construction documents, nor is any provision made to supply electricity for them. Nonetheless, future years may well see an installation if the occupant somehow gets the money to buy and operate one. Should that happen, it is most likely that it will be used in the bedroom during sleeping hours, although individuals will vary this.

Based on observations made during VITA's 1983 energy audit in Djibouti, annual consumption for such an air conditioner would approximate 3,600 KWH at a cost of 131,400 FD ($742). The cost is based on the 3 KVA rate, since an air conditioner is not likely with a 1 KVA supply.

A discussion of ways to cut this energy consumption is contained in Chapter VII, "Air Conditioners and Ceiling Fans" of Reducing Energy Consumption in Buildings, by Seymour Jarmul. That chapter's recommendations apply to the work proposed for Salines Ouest.

As an example of the cost effectiveness of some of these measures, the use of insulation and of a radiant ceiling barrier is examined below.

The Salines Ouest construction documents indicate the following:

Surface Areas (Square Meters)

Unit Type	Floor Area		Ceiling Area		Wall Area (Net of door/windows)	
	Piece #1	Piece #2	Piece #1	Piece #2	Piece #1	Piece #2
A_1	12.23	--	12.23	--	39.93	--
B_1	15.20	--	15.20	--	44.02	--
B_2	15.20	12.80	15.20	12.18	44.98	40.61
C_2	15.20	12.80	15.20	12.18	44.98	40.61

Insulation

Application of urethane foam insulation to the walls (with a thickness of 40 mm) and to the ceiling (50 mm) will reduce

annual consumption by at least 50 percent below original levels. This is based on energy audits at Balbala 2 and at Isotherma, where these measures resulted in reductions of 93 percent* and 75 percent respectively.

A 50 percent reduction represents an annual savings of 65,700 FD ($371). The cost of installing the insulation will be about 1,000 FD per square meter ($5.65). Assuming it is installed in the room with an area of 15.20 meters (see the preceding chart), the application on walls and ceiling will cost 60,180 FD ($340). This represents a payback of slightly less than one year.

Radiant Ceiling Barrier

Radiant ceiling barriers can be very effective when used in hot climates with skin-load-dominated buildings (as opposed to high internal load dominated buildings).**

The Salines Ouest buildings' initial construction assumes a corrugated steel roof. If experience is any guide, most Djiboutians will add a ceiling of some sort below this outer skin as soon as they are able to afford the expense. The incremental cost of adding aluminum foil to the ceiling board, or of tacking the foil--by itself--in the attic plenum, will average about 350 FD per square meter ($2.00).

Where an air conditioner is in use, it is assumed that the door and windows are (hopefully) kept closed. The effect of the radiant barrier is to reduce the inner skin temperature of the ceiling, and thus reduce the amount of heat radiated to the occupant below. If, with nothing but a corrugated steel roof above, the underside of the metal has a temperature some 15 to 20 degrees centigrade above ambient temperature in the room, the use of a ceiling panel of 15 mm fiberboard with aluminum foil will drop the surface temperature to about two or three degrees above ambient. In turn, occupant comfort is substantially improved.

The number of hours of reduced use of air conditioners as a result of using the radiant barrier has no field statistics to quantify the benefit. If one assumes a reduction of only 15 percent, it would represent an annual savings of 13,140 FD

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* This figures includes other measures in addition to the insulation, but the primary benefit derives from the insulation.

** 1. "Roofs in the Warm Humid Tropics", O. Koenigsberger and R. Lynn, published by Lund Humphries, 1965.

2. "Radiant Barriers for Cooler Houses", P. Fairey, Solar Age, July 1984.

($74) against an installation cost for the room with an area of 15.20 square meters of 5,320 FD ($30.06). This is a payback of less than five months.

Ceiling Fans

Based on audit observations, the average ceiling fan draws between 500 KWH and 600 KWH per year. At 550 KWH a year, this represents an outlay of 16,860 FD ($95) for a 1 KVA subscriber, and 20,075 FD ($113) for a 3 KVA subscriber.

Reduction of this consumption is not likely, regardless of any measures taken, as long as people continue to start the fan automatically on entering a room and continue to run it until leaving. The energy conservation measures discussed previously will improve comfort levels, and therefore theoretically might result in people not using the fans as much. A great deal of field observation will have to be done before it can be said with any certainty that a reduction of consumption can be achieved in this area.

V. RESEARCH RECOMMENDATIONS

The Salines-Ouest pilot housing scheme will be the first attempt in Djibouti to provide affordable shelter for low and medium income levels with a minimum of subsidy. It represents the first step towards the solution of Djibouti's housing shortage, and should be used to establish replicable standards of appropriate housing design.

The constraints of limited materials, high costs, and severe climate in Djibouti are grievous. There has as yet been no structured research into the problems of design and construction that builders in Djibouti will continue to face. The modest size of the Salines-Ouest project in relation to the present housing shortage will insure that any unit built will be sold, even if the planning and construction are less than ideal. This should not obscure the fact that the Salines-Ouest housing provides a unique opportunity to test new designs, construction methods, and materials. They will be applicable not only to this project but to future low-income housing.

The need for the results of country-specific building research will increase as building activity increases in Djibouti. The fields that should be investigated include the experimentation leading to the production of building materials from local resources, the tailoring of construction standards and codes to small-scale single story buildings, and studies of architectural planning and detailing designed to mitigate the region's climate. Sufficient time remains to

organize practical research directed specifically to the problems of the Salines-Ouest project. Such a project could be used as a catalyst to organize support for building research for which interest has already been expressed by international agencies involved with aid to Djibouti.

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