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PASSIVE SOLAR DESIGN IN LESOTHO:

A CONSULTANCY REPORT

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PREFACE

This report details the work carried out in Lesotho by David Norris, a consultant for Associates in Rural Development, Inc. (ARD), from May 13 to July 28, 1982. His solar design work is part of an ongoing effort by ARD and the Lesotho Renewable Energy Technology (RET) project to develop and disseminate ideas, information and designs for improved housing in Lesotho. The scope of work undertaken by Mr. Norris follows.

1. Gather readily available climatic data for Lesotho, appropriate for the performance of heat-loss calculations and Pascalc solar analysis.

2. Instruct a RET staff member in the execution of heat-loss and Pascalc solar performance analyses.

3. Gather information on rural and urban house types, use patterns, construction techniques and building materials.

4. Develop drawings and cost estimates for four specific energy-conserving house types. Drawings to contain plan, section, elevations and details of innovative energy techniques. Cost estimates to be performed by local quantity surveyor. The single-family house types are:

    - LEH Co-op low-income house (rural),
    - LEH Co-op low-income house (urban or peri-urban),
    - LHC middle-income house, and
    - Ministry of Works (MOW) upper-income house.

5. Meet with appropriate private- and public-sector individuals in the preliminary and developmental design stages to get their observations and criticisms.

6. Prepare a folder for each house type containing a description and benefit/cost analysis of its energy-conserving and passive-solar features, along with a brief summary of the analytical method and techniques used to perform the benefit/cost analysis.

7. Conduct a one-day seminar at the conclusion of the consultancy to present the designs and results of the benefit/cost analyses.

Outputs of the consultancy were to include drawings and folders for each of the four house types, the one-day seminar and a final report.

I. BACKGROUND

The present consultancy should be viewed in the context of a number of related initiatives undertaken by ARD, directed toward reducing fossil fuel use in housing in Lesotho and Botswana. First, this work in Lesotho was preceded by a similar consultancy (with engineer Peter Temple) in Botswana, involving, in part, an energy-conserving design for the RET project manager's home. This earlier consultancy served as an introduction to many of the climatic, energy, programmatic design and building technology issues that are also of concern in Lesotho. Further, it confirmed the wisdom of modifying an existing Government of Lesotho (GOL) house design using energy criteria, rather than proposing a radical design.

Second, the groundwork for this consultancy was laid by ARD consultants Blair Hamilton and Ron Alward, who gave a well-attended seminar in Maseru and distributed a pamphlet--"Energy Use in Building." Their efforts, directed primarily at insulation, energy conservation and retrofits, dovetailed nicely with this consultancy, which focused mainly on passive solar heating and new home construction.

Third, this consultancy reviewed the economics of energy conservation and passive solar heating, primarily from the standpoint(s) of the designer and/or occupants. It was complemented and expanded upon by another ARD consultant, Frederic March, who effectively related it to regional energy markets and government policy.

Fourth, the RET staff in Lesotho has considerable ongoing work, primarily under the direction of Gary Klein (ARD's laboratory supervisor), exploring housing-related energy problems and their solutions. This in-country experience and expertise was invaluable during all phases of the consultancy.

II. TASKS AND ACCOMPLISHMENTS

A. Scope of Work

This section describes the activities and outputs related to each task outlined in the scope of work. The complete scope of work has already been presented.

1. Gather readily available climatic data for Lesotho appropriate for the performance of heat-loss calculations and Pascalc solar analysis.

All solar performance analyses were carried out using Total Environmental Action's (TEA) Pascalc program on a Texas Instruments' TI-59 programmable calculator. Pascalc predicts the annual performance of a passive system or combination of systems by measuring the amount of auxiliary heat required to keep a building at a given internal temperature. The climatic inputs required for Pascalc are monthly solar radiation and degree-day figures. Compared to similar work done in Botswana, climatic data for Lesotho were abundant, varied and in a close-to-usable form.

Monthly solar radiation data for Maseru and Oxbow were gathered from the Thaba-Tseka Report, by Gary Klein and Alan Wyatt, who developed data from daily readings made by Lesotho Hydromet Services in those locations. No attempt was made to verify the accuracy of the solar data as time was limited, the data reasonable and the investigators qualified.

The degree-day figures for Oxbow and Maseru were derived from mean daily temperature readings averaged by month by the government's Hydromet Services. The number of years data were

collected to arrive at the averages is unknown. The degree days used in Pascalc runs were obtained by subtracting the average monthly temperature from the base of 65°F and multiplying by the number of days in the month. This resulted in first-level, usable, degree-day data. More accurate data await the recording of degree days derived daily. (See post-consultancy initiative 1.)

2. Instruct a RET staff member in the execution of heat-loss and Pascalc solar performance analyses.

Originally, the RET project expected to employ two Basotho university student engineers over their winter break, one of whom was to help with the work of this consultancy. Unfortunately, neither student came to the project. Batalatsang Kanetsi, who is team leader Jay Stryker's counterpart, is an engineer and so was an ideal choice as the apprentice thermal engineer. But, he was too busy with project administration and other duties to be able to allocate enough time to learn the techiques and perform the analyses required. Therefore, it was decided that John Nicholson, a physicist, science teacher and American volunteer working for the Campus Crusade for Christ, assigned to the RET staff, would be instructed in and learn how to execute heat-loss and Pascalc analyses. Though not Basotho, Mr. Nicholson's selection as the thermal apprentice may ultimately be of greater benefit to the project and the GOL.

Mr. Nicholson analyzed almost all of the typical house plans available from the Ministry of Works, Lesotho Housing Corporation (LHC) and Lower Income Housing Company (LEH Co-op) to establish an energy conservation ranking for existing plans. (See post-consultancy initiative 6.) He also executed the lengthy iterative analyses required to establish the most cost-effective path in the selection of energy conservation and passive solar techniques. (See "Energy: The Economics" in PASSIVE SOLAR HEATING IN LESOTHO HOUSING, available from the RET project in Maseru.)

Conservatively, this work required Mr. Nicholson to execute 10 heat-loss and 20 Pascalc analyses, so he is now eminently qualified to do both. In the course of performing numerous Pascalc runs, he became familiar with TI-59 programming (see section B. "Other Outputs"). In addition, he taught physical science for two years at Butha-Buthe high school. Given his newly acquired energy expertise and extensive teaching experience, he is in a very good position to teach heat loss and Pascalc to one of the Basotho engineers recently hired by the RET project. (Post-consultancy initiative 2 recommends that such a program be undertaken.)

In addition to the instruction of Mr. Nicholson, two brief familiarization sessions were held with other RET staff members. At the request of Judy Gay (ARD's field supervisor), one afternoon was spent instructing nontechnical staff in the fundamentals of energy conservation and solar design. Also,

time was spent with RET project volunteers in Malefiloane reviewing their office plans and discussing energy design principles and techniques.

3. Gather information on rural and urban house types, use patterns, construction techniques and building materials.

Architectural information was gathered from a number of sources, and dwellings in Mokhotlong, Malefiloane, Thaba-Tseka, Roma and Maseru were visited. In Mokhotlong, the home of a middle-income civil servant was seen and the occupant interviewed. Low-cost insulation techniques were discussed with RET project volunteers in Mokhotlong and plans for the RET project offices currently under construction there were reviewed. In a Malefiloane village, six rondavels were visited and about a dozen villagers interviewed with the assistance of an interpreter. During an overnight stay in a Canadian-funded housing project in Thaba-Tseka, its virtues and drawbacks were discussed with the American volunteer occupant. Closer to Maseru, a visit was made to the Roma campus with Dr. Gay and detailed discussions held about the various upper-income house types built over the years for faculty. Alan Hutcheon, a faculty member and amateur energy enthusiast, was interviewed regarding the varicus Roma house types from both energy and user perspectives.

The Khubetsoana development was visited twice--once with Mr. Klein to see the site and a typical, low-income, LEH Co-op C4 core house (with an atypical, retrofit, insulated ceiling

installed by the RET project); a second time with Mike Wilson, LHC's chief architect, to visit a number of middle-income units under construction. The first major "self-help" housing project in Maseru, White City, was also visited.

In Maseru, the upper-income dwelling of the senior RET project staff member was seen. An afternoon was spent interviewing 'Mamello Khoboko, Dr. Gay's counterpart, and visiting her family's middle-income dwelling and those of some of her neighbors. Another afternoon was devoted to interviewing the female RET project staff members to assess the needs of low- to middle-income Basotho home-owners. Mrs. Khaketla of the Maseru high school was also interviewed. She outlined the various forms, traditions and building practices associated with the rondavel.

In-depth interviews were conducted with representatives of all the major institutional housing suppliers--Chris Lebona, acting chief architect of the MOW, which does upper-income civil servant and expatriate housing; Mr. Wilson of LHC, which does middle-income housing; and Craig Huckuluk, chief engineer for LEH Co-op, which does low-income, self-help housing. Also interviewed were John Mullin and John Edgar, private-sector architects for Household Associates and Design Group, respectively. Eva Havelka, the chief engineer of Maseru, was also interviewed concerning existing zoning requirements and the impact of energy considerations on zoning.

Written sources of information included Mollo o Kae? (Where is the Fire?) and the Thaba-Tseka Report, both by Gary Klein and Alan Wyatt, available at the RET project library. Most critical in any assessment of housing needs is the Housing in Maseru Study, undertaken in 1979 and 1980 by the Ministry of the Interior, which effectively outlines Maseru's housing needs, determined by income group. It should also be noted that this survey included questions regarding annual fuel costs and types by income level. The raw computer data were obtained and analyzed in an effort to assess real fuel costs in Lesotho. Though this effort was unsuccessful, it did provide new insight into total annual fuel costs and distribution by income. (This information is available from the RET project in Maseru.)

At the request of Mr. Hamilton and Mr. Alward, the RET project had gathered about a dozen plans of existing upper-, middle- and low-income house types from the MOW, LHC and LEH Co-op. An assessment of all drawings was made concerning program, total area, room sizes, mechanical and plumbing features, materials, details and cost. All "base" buildings used in this consultancy were selected from these drawings (see the next section concerning fourth task from the scope of work). Primarily as a part of RET project staff training, heat-loss and Pascalc solar performance analyses were conducted for all house types reviewed to determine an energy ranking for existing plans.

Product information was obtained from a variety of sources. First, Mr. Klein was familiar with much of what is both of use and available. He also made an expedition to Bloemfontein to collect insulation, weather-stripping and stove data. Second, Household Associates made their product library available along with Mr. Mullin, one of their project architects, to answer questions. Third, a number of trips to the Maseru outlet of Frasers, Inc., country-wide retail suppliers, provided insight into standard, locally available building supplies. Fourth, a meeting was held with Mike Bevis, manager of LEH Co-op's P and S woodworking division, to discuss the possible production of wood windows, as opposed to the steel windows typically available (see post-consultancy initiative 10.)

Some price information was obtained in the course of gathering product information, but most of it was provided by the MOW's Quantity Survey (QS) Unit, which analyzed the cost(s) of a number of standard energy conservation and solar options during the initial phase of this consultancy. They also executed the final quantity surveys and cost estimates for all the "base" and "energy conservation" designs in order to avoid any accusations of biased cost analyses.

4. Develop drawings and cost estimates for four specific energy-conserving house types. Drawings to contain plan, section, elevations and details of innovative energy techniques. Cost estimates to be performed by local quantity surveyor. The single-family house types are LEH Co-op rural low-income house, LEH Co-op urban or peri-urban low-income home, LHC middle-income dwelling and MOW upper-income house.

The ultimate purpose of the drawings is to introduce energy-conserving new housing into the Lesotho market. To do so, they target a number of key operators in the housing market--the major institutional suppliers (MOW, LHC and LEH Co-op), private-sector designers, draftsmen working in either public- or private-sector offices (who are responsible for a significant percentage of new construction through "moonlighting"), builders and, finally, home buyers.

Implicit in the scope of work was a two-part strategy which sought to affect this broad range of interest groups. The first part involved teaching the fundamentals of energy design by means of the seminar, the primer PASSIVE SOLAR HEATING IN LESOTHO HOUSING, drawings and individual consultations, while the second aimed at the publishing and wide distribution of the "EC" (energy-conserving) drawings series as either learning tools (in conjunction with the primer) for designers or draftsmen, or actual building documents for interested builders, contractors or home buyers. It should be noted that the projected cost of the RET project "EC" series of plans will be significantly lower than "moonlight" plans--M10 to 20 versus M75 to 150.

Considerable time was spent developing the format for the "EC" series, prior to actually developing the drawings, and the following layout was settled on--a color-coded folder with pockets on each side. The inside left pocket was to contain the folded, single-sheet, 24" X 36", architectural drawing which presents the measured plan, section, elevations and site plan. The inside right pocket was to hold:

- the appropriate "building pamphlet," which explains the energy-conserving and solar modifications, and discusses straight-line pay-back;
- general construction notes which are the same for all plans;
- "EC Details" which are appropriate to each particular set of plans; and
- "EC Materials," a package of building materials, cut from catalogs, which are considered commendable by the RET project staff.

(The "EC" plan packages are available at the RET project in Maseru.)

Each design in the "EC" series was developed from an existing MOW, LHC or LEH Co-op design and specifically refers to that design in the title. The Pitso-EC was adapted from the MOW's Pitso Mark 5, the A3-EC from the LHC A3 and the C4-EC from the LEH Co-op C4 core house. The reasons for selecting existing designs for modification are outlined in PASSIVE SOLAR HEATING IN LESOTHO HOUSING (page 38).

The scope of work called for an energy-conserving variant of the C4 that would respond specifically to "rural" climate fuel-use patterns, building techniques and occupation. Upon

execution of the urban/peri-urban C4-EC, it was clear that the same basic plan would also be appropriate for rural communities with no modification other than increased insulation. Upon consultation with Mr. Stryker, Mr. Klein and Dr. Gay, the scope of work was modified to include an energy-conserving rondavel as the fourth building option. This was something that the RET project volunteers in Malefiloane had suggested they could use to promote energy conservation at the village level. After a number of discussions with Mr. Klein, a pamphlet was produced which singled out and reinforced energy-conserving techniques <u>within</u> the presently endangered rondavel tradition.

The pamphlet, TOWARD A WARMER RONDAVEL (available from the RET project in Maseru), is comprised of simple graphics accompanied by an explanatory text in both English and Sesotho. (The translation of the text is currently underway. Also, see post-consultancy initiative 8.) It does <u>not</u> recommend novel techniques or materials because as Mr. Kanetsi put it, albeit somewhat elliptically, "If they know what insulation is, or what it will do for them, and can afford it, they will build a concrete block building with a metal roof." Novel materials and techniques were also avoided because of problems with their cost and availability in very rural areas. Further, it is recommended that, in any event, such techniques and materials be thoroughly tested before they see widespread use in rondavels (see post-consultancy initiative 9).

5. <u>Meet with appropriate private- and public-sector individuals during the preliminary and developmental design stages for their observations and criticisms.</u>

Critical to the ultimate acceptance of the "EC" design series was the sense of participation in their development by their "parent" agencies. To ensure this, two meetings were held with key design operatives of the MOW, LHC and LEH Co-op. The first was to introduce the project and the goals of this consultancy, discuss their available "base" building options, seek their perceptions and suggestions prior to initiating the "EC" designs, and request their assistance in all phases of the consultancy which they all agreed to provide.

The second meeting was to review a preliminary plan of each "EC" design with the appropriate agency to secure their comments and criticisms prior to procceeding with the final design. With all three agencies, the response to the preliminaries was positive. Virtually no changes were recommended for the C4-EC and A3-EC. Of the A3-EC, Mr. Wilson of the LHC said, "It's better than anything we have," and Mr. Huckuluk of LEH Co-op said of the C4-EC, "I wish we had had this three years ago," suggesting that it would have been the design used for the Khubetsoana development. Mr. Lebona of the MOW recommended a modification of the design of the servants' quarters, followed by an invitation to EHISA (the Society of Architects and Engineers) for lunch, where he insisted on the announcement of the seminar.

6. Prepare a folder for each house type containing a description and benefit/cost analysis of its energy-conserving and passive solar features, along with a brief summary of the analytical method and techniques used to perform the benefit/cost analysis.

Each "EC" design package includes a two- to three-page description of the plan's conservation and solar features, and its energy economics. The section "Energy: The Economics," in PASSIVE SOLAR HEATING IN LESOTHO HOUSING, describes the uncertain nature of benefit/cost analysis, given the bias implicit in the Pascalc program and the lack of good fuel use/cost data. That section also decribes Pascalc's working assumptions, its key variables, and the most cost-effective path through the conservation and solar options for both limited and unlimited budgets. The benefit/cost analysis is sufficient to guide an interested designer or home buyer, but does not attack larger policy or economic issues, nor does it present a detailed life-cycle cost analysis because of the tenuous understanding of real space-heating fuel costs and, thus, potential savings.

7. Conduct a one-day seminar at the conclusion of the consultancy to present the designs and results of the benefit/cost analyses.

At the "Energy in Building" seminar, conducted by Mr. Hamilton and Mr. Alward, many participants requested a document which would sum up much of what was presented. Such a document was ultimately produced and distributed by mail. In anticipation of a similar request, a summary was produced for distribution at the seminar held at the close of this

consultancy. The manual, PASSIVE SOLAR HEATING IN LESOTHO HOUSING, served as an outline for the presentation, a reference for those attending the seminar and is a primer on energy-conscious design for those who were not there.

The seminar was attended by an estimated 40 persons overall, including RET project staff. Some change and a drop in attendance occurred between the morning session where the primer's contents were presented, and the afternoon, when the building designs were discussed. Most of those present were associated with the design profession. Many were second-level project architects from private offices. Most were Basotho. Representatives of the LEH Co-op attended, but LHC and MOW did not. All major contractors were notified of the seminar, but no representatives of the building trades appear to have been there. Both the morning and afternoon sessions were well received and generated active interest. Each participant received a copy of the primer, all the "EC Details," the Thermal Mass Pattern Book (a publication of TEA, Inc.) and a package of recommended "EC Materials."

B. Other Outputs

This section describes outputs which were not anticipated in the original scope of work, but which proved necessary and/or advisable to effectively accomplish the prescribed tasks or the RET project's broader agenda for energy-efficient housing.

1. Consultation was provided to John Bohn about his passive solar-heated mission dwelling and Mr. Mullin of

Household Associates about his office's energy-efficient adult education building (to be constructed in part using AID funds). In addition, with the help of Mr. Klein, a consultation was held with authorities of Mokhotlong clinic concerning a passive solar-heated, winter vegetable greenhouse.

2. The Pascalc program required the input of a quantity of building and insulation data. Given the number of Pascalc runs to be executed, it was decided to expedite the input by developing, writing and testing a Pascalc data input program, which is not a standard feature of TEA's Pascalc package. The program is now in the RET project's hands and Mr. Nicholson is fully trained in its use.

3. Mr. Nicholson's shading coefficent program, which facilitates an otherwise lengthy set of Pascalc data entry calculations, was also developed as part of this consultancy, though entirely on his own initiative.

C. Post-Consultancy Initiatives

This section details future initiatives which stem directly from this consultancy and seek to improve the general conditions necessary to build energy-efficient housing in Lesotho.

1. In terms of base data, both fuel use and climate data should be improved. For the former, Dr. Gay's survey results will improve the understanding of fuel use and cost in rural areas, while the application of Mr. Hamilton and Mr. Alward's questionnaire in Maseru will add to the data gathered in the

Housing in Maseru Study. Mr. Klein has already initiated discussions with the survey and evaluation unit of LEH Co-op to integrate the energy questionnaire into their survey work. For life-cycle cost analyses of energy benefits/costs, specific, separate figures are needed for the amounts spent annually on cooking, hot water and space heating. With such average annual figures, Pascalc's currently exaggerated predictions of annual auxiliary heat can be pegged to actual fuel use. As for climatic data, the degree-day data which are presently lacking should be gathered daily by Hydromet from the average daily temperature readings in Maseru, Mokhotlong and Oxbow. The possibility of taking such readings should be broached with Mr. Makara of Hydromet Services.

2. It is extremely important for Mr. Nicholson to teach Pascalc analysis to a Basotho engineer(s).

3. The Pascalc program should be modified to take standard international (SI) units to facilitate its use by metric-trained professionals. References with SI-based heat loss techniques and U-values should also be obtained.

4. At present, it is likely that if the RET project provided a Pacalc building energy design evaluation service, an engineer and the TI-59 would suffice to handle the demand. Translation of the Pascalc program to a larger computer could only be justified if there was a significant increase in the demand for such a service, which is not anticipated, or if the exercise were of a purely educational nature.

5. At present, if restricted to heat-loss and Pascalc analyses and providing energy product information, the RET project can provide an energy consulting and design evaluation service for the Lesotho housing community. For simple homes, the present RET project staff can provide valuable design suggestions as well. For larger or more complicated buildings, a professionally trained architect would be required.

6. The building/energy ranking should be explained and distributed to the LHC and MOW (LEH Co-op currently uses only one house type) to ensure that there is a degree of energy awareness in their building selection, particularly if they continue to choose from their existing plans.

7. Two copies each of the primer and design packages should be distributed to LEH Co-op, MOW and LHC. Other free copies should go to the technical schools, national library and American cultural center.

8. The building design packages and TOWARD A WARMER RONDAVEL should be actively distributed to as wide a market as possible. If this is done by the RET project, it may eventually require additional staff and a significant reproduction and distribution budget. Also, the designs make a number of assumptions about the site, primarily that it is flat, and the documents are not complete by U. S. standards. Therefore, it is recommended that a statement be included in the design packages distributed which relieves the RET project of any liability. The rondavel pamphlet should be translated

and distributed to volunteers, the institutions listed in initiative 7 and any rural development project or institution.

9. A testing period is recommended for the "EC" designs and the proposed solar techniques. Some are too novel (e.g., the sun-roof), but most simply need a contact period between design and construction. Mr. Klein has already initiated a modest, but possibly sufficient, testing program as part of the design and construction of a guard-house at the Khubetsoana site. Full-scale testing would be best, and continued pressure on the MOW, LHC and LEH Co-op to build a testable prototype of each "EC" design is advisable. It is likely that they would be interested in doing so, but unwilling to carry the additional cost. Regarding the rondavel, the most critical shortcoming is a safe, effective stovepipe. Discussions with Mr. Klein resulted in a sketch of a pipe which would be integrated into the typical sheet-metal roof cap. This is a promising device, but one which must undergo extensive feasibility and safety testing before <u>any</u> consumer application.

10. As indicated earlier, lengthy discussions were held with Mr. Bevis of LEH Co-op, P and S, on the topic of wood windows. (For an outline of this conversation, see the section on windows in PASSIVE SOLAR HEATING IN LESOTHO HOUSING.) This matter should be pursued, although it involves a major effort which the RET project may not be staffed to carry out at this time.