A significant result of the 1973 energy crisis has been the consideration of solar energy for space heating. The need for future energy sources will again be re-evaluated this year as a result of the devastating storms which swept the interior and eastern seaboard during January, 1977. The increasing need for savings is becoming especially acute as decision makers learn that space heating accounts for 18 percent of the nation's total fossil fuel demand. Likewise, the heating demand for the average residential household is between 55 and 60 percent of the total energy used (see Figure 1).

Widely heralded solar heating potential is based largely around the possibility of capturing the sun's rays by various forms of solar collecting devices. The effectiveness of these devices is a function of size and optimal placing of the device relative to sun angle and direction.

Since optimal orientation to the sun is prescribed in the installation of solar collectors on houses, it follows that any house which faces the sun absorbs a certain amount of natural solar radiation. It further follows that, especially in the winter months with low sun angles, if the daytime activity areas (living room, family room, and kitchen) were to face south they would be warmed enough by natural radiation to permit a reduction in the demand for space heating. A common situation in a post WWII subdivision housing tract is for these daytime activity areas to be on one side of the house, usually the street side, with picture windows facing opposing windows.

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across the street. The question may then be posed: on east-west trending streets where the daytime activity areas face either north or south, do the south-facing houses naturally consume less heating fuel than the north-facing houses? It was the purpose of this investigation to measure fuel consumption data for south-facing versus north-facing houses on opposite sides of the same street to determine whether a savings in fuel consumption exists. Measurements were made for a test site in San Jose, California during the winter of 1974-75.
Site Climate

Radiation intensity is the foremost consideration in determining a site's potential for tapping solar energy. Studies in the late 1950's and 1960's found and delimited three world regions where a good potential for harnessing solar energy exists (see Figure 2). The test site, San Jose, California, at 37°N, is located in the extreme southern portion of the region classified as "good." While this region, unlike the other two, is generally hampered by problems of seasonality causing major variations in the amount of radiation received on a day to day basis, some of the benefits that can be ascribed to the region defined as "highest potential" can be found to exist in the San Jose area due to the locational proximity (37°N vs. 35°N) to the northern boundary of the "highest" region. These benefits that overlap into the "good" region are high sun angles, long cloud-free days, and a considerable amount of solar radiation.

Figure 2. Regions of Solar Energy Potential (after, United Nations & T.G. Ward).
San Jose receives on the average 216 lys/day* of incoming solar radiation during the winter months. The sky is unobstructed from 50 to 60 percent of the time and the sun angles vary from 29.6 degrees to 42.4 degrees above the horizon during the same period.

The climatic conditions which occurred during the test period of November 1974 to February 1975 were within normal ranges. These data, summarized in Table 1, were obtained from the Meteorological Observatory at San Jose State University and the U.S. Naval Weather Observatory at Moffett Field, Naval Air Station California. Wind and temperature were not considered in this study because the winter temperatures were not significantly low enough to cause a wind chill factor.

**TABLE 1**

**CLIMATIC CONDITIONS, SAN JOSE, CALIFORNIA NOVEMBER 1974 TO FEBRUARY 1975**

<table>
<thead>
<tr>
<th></th>
<th>Incoming Radiation</th>
<th>Sun Hours</th>
<th>&lt; Broken Conditions</th>
<th>&gt; Broken Conditions</th>
<th>Days of Precip.</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>185 lys</td>
<td>330 hrs</td>
<td>299 hrs</td>
<td>103 hrs</td>
<td>2</td>
</tr>
<tr>
<td>December</td>
<td>138</td>
<td>341</td>
<td>238</td>
<td>152</td>
<td>5</td>
</tr>
<tr>
<td>January</td>
<td>168</td>
<td>341</td>
<td>276</td>
<td>104</td>
<td>3</td>
</tr>
<tr>
<td>February</td>
<td>211</td>
<td>308</td>
<td>219</td>
<td>168</td>
<td>10</td>
</tr>
<tr>
<td>Totals</td>
<td>702 lys</td>
<td>1330 hrs</td>
<td>1032 hrs</td>
<td>516 hrs</td>
<td>20</td>
</tr>
<tr>
<td>Averages</td>
<td>174</td>
<td></td>
<td>256</td>
<td>129</td>
<td></td>
</tr>
<tr>
<td>Percentages</td>
<td></td>
<td></td>
<td>77%</td>
<td>23%</td>
<td></td>
</tr>
</tbody>
</table>

*Lys - Langley. One langley is equivalent to one calorie of radiation or the amount of heat needed to heat one square centimeter one degree centigrade. 1 ly = 1 cal/cm²/min.
Site Description

The test site is in the extreme southern part of San Jose, located on the flat alluvial plain of the Northern Santa Clara Valley. The test area is surrounded on three sides by mountain ranges (reaching elevation of a few thousand feet) but the houses in the test site are well away from the shading and cooling effects of the mountains.

Uniformity of the test houses was a major factor in selection of the streets and residences to be measured. Houses were selected which were: (1) typical of San Francisco Bay Region housing, (2) not insulated by overgrown vegetation, and (3) old enough not to have construction deficiencies uncorrected. With these considerations in mind, 1000 houses from seven different subdivision tracts, with ages ranging from 5-7 years, were selected from City Planning Department Maps and large scale (1" = 200') air photographs. All of the selected houses were located on east-west trending streets (Figure 3).

The orientation of daytime activity areas was determined by interpretation of air photographs (1:24,000) and confirmed, in questionable instances, by visual on-site inspection. The air photo interpretation keys were: chimneys, as indicators to location of living or family rooms, and patios, assuming that access is normally from the family room. If the fireplace and the patio are in close proximity to each other then the determination of the daytime activity area could be inferred with some accuracy. This technique proved to be successful in 60 percent of all the houses where the indicated parameters were visible. The remainder of the houses not visually discernible by the air photo inspection and the remaining 40 percent of unconfirmed housing were visually inspected to verify the location of the daytime activity area. Following the final on-site inspection, 834 units (of the original 1000) were selected for further study.
Figure 3. Test Site, South San Jose.

The Data

Data on natural gas consumption, the nearly universal heating fuel in San Jose, were provided by Pacific Gas and Electric Company with the provision that fuel usage by individual houses would not be revealed. Since the data had to be aggregated by north/south street sides anyway, the imposition of disclosure rules presented no problems.

In Table 2, a summary of the natural gas consumption figures for houses in the test site, data are aggregated by equal numbers of north and south facing houses. Gas consumption rates are in cubic feet per month.
TABLE 2
NATURAL GAS CONSUMPTION RATES, SAN JOSE TEST SITE
WINTER 1974-75

<table>
<thead>
<tr>
<th></th>
<th>November</th>
<th>December</th>
<th>January</th>
<th>February</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>All North-facing</td>
<td>33082</td>
<td>59812</td>
<td>92244</td>
<td>73234</td>
<td>259373</td>
</tr>
<tr>
<td>All South-facing</td>
<td>30678</td>
<td>54153</td>
<td>84585</td>
<td>69980</td>
<td>239405</td>
</tr>
</tbody>
</table>

Percent of North greater than South:

7.23 9.41 8.30 5.73 7.69

*To obtain the monthly difference between the respective directions, the following formula was utilized:

\[
\frac{(\Sigma N - \Sigma S)}{\Sigma N} \times 100 = \% \text{ of } N/S
\]

\(\Sigma N\) = Sum of all north facing
\(\Sigma S\) = Sum of all south facing
N/S = Percentage the north is greater than the south facing

Results

Heating fuel consumption rates (Table 2 and Figure 4) for the south-facing test houses are significantly lower than those for north-facing houses. The monthly differences range from a low of 5.73 percent for February to a high of 9.46 percent for December with an arithmetic average for the test period of 7.69 percent.

Examination of the per-street data on a month to month basis revealed that, for the months of November and February, some of the south-facing blocks of houses used more rather than less natural gas than their north-facing counterparts. Also, for these same months the differences between the blocks were inconsistent rather than clustering around a norm. These anomalies probably resulted from the striking weather variations encountered in November and February, at both ends of the short winter weather season common to the San Francisco Bay Region. In November, for instance, when the first of
winter's rainstorms arrive, there are still numerous clear, warm days. February conditions, when the winter rains abate, are also quite variable. Accordingly, space heating for these months vary from hour to hour, day to day, and from person to person. The difference between sensible temperatures and absolute temperatures is surely important. Another factor explaining fuel consumption irregularity is the varied personal reaction to the changes in the length of day in November with its slow rate of change as the winter solstice approaches, and February with its rapid lengthening of the days as spring progresses.
These calculated monthly differences (Table 2) in fuel use can be converted to terms familiar to the average consumer by applying them to a non-north or south facing house (this conversion is demonstrated in Table 3).

TABLE 3
FUEL SAVING SCHEDULE

<table>
<thead>
<tr>
<th></th>
<th>Monthly Bill for Non-North or South Unit</th>
<th>Conversion Index (from Table 2)</th>
<th>Monthly Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>November</td>
<td>$8.33</td>
<td>0.0723</td>
<td>$0.602</td>
</tr>
<tr>
<td>December</td>
<td>13.79</td>
<td>0.0946</td>
<td>1.305</td>
</tr>
<tr>
<td>January</td>
<td>13.70</td>
<td>0.0830</td>
<td>1.127</td>
</tr>
<tr>
<td>February</td>
<td>11.36</td>
<td>0.0573</td>
<td>0.651</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$47.18</strong></td>
<td></td>
<td><strong>$3.695</strong></td>
</tr>
</tbody>
</table>

From this table it may be seen that if a house were to be oriented in a southerly direction the owner could expect to save at least three to four dollars per season in heating costs. While the savings on the individual house is small, optimal orientation of houses throughout an entire city could reduce the natural gas demands by close to 10 percent.

Recommendations

The results of this study lend themselves to some recommendations. First, further studies should be made to see if the findings of this study replicate elsewhere. Control parameters in further studies should be increased and standardized. In addition to direction, vegetation, and a minimum of size control used in this study, consideration should be given to employing such factors as volume, floor size, insulation, and number of floors since they all affect the demands
placed upon the heating systems of the modern houses. If the positive results of proper daytime orientation are seen to replicate it may be suggested that thought be given by local controlling agencies that, prior to house plan approval, the new residential developments should either orient conventionally planned houses on the lots so that the daytime living space faces the optimal direction for utilization of the sun for its natural heating benefits, or develop new internal house designs to make the maximum use of solar benefits. And, finally, reserve the expensive and not universally proven solar collectors and other gadgets for those areas and conditions where simple orientation would not be sufficient.

NOTES


