heat transfer and have obtained some unanticipated results.

A body loses heat to its surroundings at a rate proportional to their temperature difference. The quantity of heat required to maintain the difference, and therefore the heating fuel costs, is directly proportional to the difference between the indoor and outdoor temperatures. This is the basis of the well-known "degree-day" concept.

Reducing the indoor temperature for a long period of time saves heating fuel because of the direct dependence on the temperature difference; as long as the outdoor temperature does not exceed the indoor temperature, the saving is independent of the outdoor temperature (*1*). Thus, an indoor temperature reduction from 70°F (21.1°C) to a minimum of 55°F (12.8°C) will always accrue the same saving when the outdoor temperature is below 55°F. The most important consequence of this is that arguments based on heating fuel savings which would trade deep winter days for days requiring heating later on are, for all outdoor temperatures below the minimum thermostat settings, wrong (*2*).

Further, two types of fuel saving can be distinguished: those with constant minimum thermostat settings, and those during which higher temperatures are reestablished (warm-ups). Warm-up periods clearly subtract from the reduced-temperature savings, and their number should be minimized (*3*). Thus, as long as the temperatures and total times remain the same, restructuring holiday periods will only result in a net saving of heating fuel if the total number of warm-ups is reduced. Thus, consolidation of holiday periods to reduce the number of warm-ups will effect net heating fuel savings (*4*).

Finally, heating fuel savings will be effected by lowering thermostat settings wherever possible, consistent with human needs and the prevention of damage to physical plant through freezing (*5*). This implies rescheduling holidays to take advantage of safe periods for complete shutdown. Such opportunities for major savings occur in the late fall and early spring in most regions where minimum temperatures above 32°F (0°C) are expected and there is no danger of very low temperatures which would result in freezing conditions in service areas carrying water (*6*). Thus, the greatest heating fuel savings may accrue in facilities which are in continuous operation during the coldest portion of the year (*7*)—when heating to a relatively high temperature is necessary in any case to avoid damage through freezing—and which are completely shut down in fall and spring periods that are very cold, but above freezing.

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References and Notes

1. Heat loss from buildings by infiltration of outside air is also directly proportional to the temperature difference, and can be treated in the same way with the same result; see C. MacPhee, Ed., *Handbook of Fundamentals* (American Society of Heating, Refrigeration and Airconditioning Engineers, New York, 1972), p. 452, table 16.
2. This analysis is invalidated for periods during which the outdoor temperature exceeds the indoor temperature. Trading heated days for days in the later spring when heating plants would normally be shut down will, of course, effect net heating fuel savings. Also, the risks involved in running out of fuel in cool but not cold seasons are considerably lower, and minimizing risk may still call for the exchange indicated if fuel supplies are low enough.
3. Every warm-up period is paired with a cool-down period during which the extra heat stored in the structure and contents reduces the heating requirement as cooling to the new, lower temperature takes place. We have assumed that thermostat settings are reduced so that no further heat is called for until the lower temperature is reached, and that the facility is not in use during the cool-down period. In a zero order approximation, warm-up and cool-down are irrelevant to heating fuel costs.
4. As a specific illustration, distributing the customary 5 days of school spring recess among 5 midwinter weekends serves to create an additional warm-up period. For climates in which heating during the spring holiday period is necessary, this calendar shift will result in a net heating fuel loss.
5. The determining temperature is, of course, that measured in service areas containing water pipes.
6. Building surveys indicate that under some conditions freezing temperatures can be reached in service areas even when working areas are at 55°F (12.8°C). Our treatment ignores heating by sunshine, which may make significant contributions in some areas during the fall and spring.
7. Heating equipment is typically more efficient when run at full load rather than intermittently [C. A. Berg, *Science* **181**, 128 (1973)]

8. We thank H. L. Frisch and R. MacCrone for helpful discussions.

The Density Concept

The article by Day and Day "Cross-national comparison of population density" (14 Sept. 1973, p. 1016) is a commendable challenge to those who oversimply issues of population pressure, but the conclusion that density figures are frequently misleading and often useless has been stated many times before in scholarly work. The authors obviously consulted a variety of literature, but they overlooked geographic literature. Geography as a discipline has been traditionally and centrally concerned with "spatial arrangement" and "spatial distribution." The first geographer to grapple with the problems of density data for mapping purposes was working for a commission on railways in Ireland in 1837 (*1*). It is surprising to us that some sociologists are only recently coming to discover the limitations of density data and of conclusions based upon them. Geographers for decades have been discussing such things as "misuses of the [density] concept" and the "inadequacies" of using the man : land ratio as a measure of population pressure.

A cursory review of literature in general geography, in population geography, and in cartography reveals that geographers have long given attention to the difficulties of using population density as an indicator of (to use the terms of Day and Day) "comparative conditions of life" or to make "inference about physical and social conditions."

In 1937, Wright applied the Lorenz curve to international comparisons of "degrees of evenness of different distributions," including that of population density (*2*). The meaninglessness of arithmetic population density is well documented in geographic literature. James noted in 1954 that, "where total numbers of people are enumerated within large expanses of national territory, much of which is unoccupied, the resulting figure is not only meaningless, but is sometimes dangerously misleading as to the true situation" (*3*). Furthermore, it is obvious to Murphey that "measures of population density or of overpopulation mean nothing unless they can be related to usable resources" (*4*). Smythe, Brown, and Fors cautioned that "people who are unaware of geographical controls are prone to misuse such information [statistics of population density]" (*5*), and Clarke outlined the difficulties he encountered when he used density indices (*1*, pp. 28–29).

The questionable relationship of population density to economic well-being is the central theme of Broek's idea that, once the role of cultural achievements in creating natural resources through new technology or altered economic system is understood, it is wrong "to link population density directly with economic well-being" (*6*). A few years later, Carey and Schwartzberg also warned that "students should not infer facts about economic well-being from population density alone, for it is only through an understanding of the dynamic interrelationship of all the ecological factors that we can understand the nature of a region" (*7*). The need for other indices to accompany that of arithmetic density is possibly the oldest issue concerning the value of density indices. Over 50 years ago, Aurousseau decided that "our representations of density . . . are somewhat artificial methods of expressing the variation of grouping" (*8*). Broek and Webb recently have stressed the importance of adding the study of dispersion and pattern to density in order to give a complete description of the distribution of population in an area (*9*). As well as Monkhouse and Wilkinson (*10*), to whom Day and Day refer, other cartographer-geographers have commented on the misleading use of density data in population mapping. Among these are Robinson and Sale, who point out the frequently inadequate and deceptive nature of the density map (*11*).

These examples are representative of a body of work that has existed and been augmented over the years in the field of geography. It is disappointing to realize that these contributions by geographers have been ignored by other scholars.

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References

1. J. I. Clarke, *Population Geography* (Pergamon, London, 1965), p. 28.
2. J. K. Wright, *Ann. Assoc. Am. Geogr.* **27**, 177 (1937).
3. P. E. James, in *American Geography: Inventory and Prospect*, P. E. James and C. F. Jones, Eds. (Syracuse Univ. Press, Syracuse, N.Y., 1954), p. 117.
4. R. Murphey, *An Introduction to Geography* (Rand McNally, Chicago, ed. 3, 1971), p. 61.
5. J. M. Smythe, C. G. Brown, E. H. Fors, *Elements of Geography* (St. Martins, New York, 1966), p. 444.
6. J. O. M. Broek, *Geography, Its Scope and Spirit* (Merrill, Columbus, Ohio, 1965), pp. 41–42.
7. G. W. Carey and J. Schwartzberg, *Teaching Population Geography* (Teachers College Press, New York, 1969), p. 113.
8. M. Aurousseau, *Geogr. Rev.* **11**, 567 (1921).
9. J. O. M. Broek and J. W. Webb, *A Geography of Mankind* (McGraw-Hill, New York, 1968), pp. 10–12.
10. F. J. Monkhouse and H. R. Wilkinson, *Maps and Diagrams: Their Compilation and Construction* (Methuen, London, ed. 3, 1971), p. 321.
11. A. H. Robinson and R. D. Sale, *Elements of Cartography* (Wiley, New York, ed. 3, 1969), p. 147.