Energy Vol. 5, pp. 101–103
Pergamon Press Ltd., 1980. Printed in Great Britain

NOTES

ERRORS IN A RISK ASSESSMENT OF RENEWABLE RESOURCES

D. W. O. ROGERS and R. J. TEMPLIN
National Research Council of Canada,
Ottawa, Canada K1A OR6

(*Received* 4 *April*, 1979)

Abstract—A discussion is given of some of the serious biases and mistakes presented in an article in this journal entitled "Risk in hydroelectricity production" by H. Inhaber.

In Table 8 of his paper entitled "Risk in hydroelectricity production",[1] H. Inhaber compared the "risks" of hydroelectricity to the "risks" associated with other energy sources (as presented in another report, "Risks of Energy Production"[2]). For several reasons, this table presents a grossly distorted picture of the risks associated with at least several of the renewable energy technologies studied.

In the first place, the author has failed to point out that, in several cases, up to 85% of the risk shown in Table 8 (which refers only to the maximum values of large ranges) is actually associated with the backup energy supply needed for the 25% of the time that "the sun doesn't shine or the wind doesn't blow" and storage is exhausted (for solar thermal, 86% of risk is from backup; for solar photovoltaic, 75%; for wind, 64%). Although one may legitimately make a case (weak in our opinion) for the practice of including the risk of energy backup in the calculations, it is inexcusable to do so without pointing it out. Inhaber failed to do this, both in his article in this journal and in the widely circulated press release for Ref. 2 (although it is discussed in Ref. 2 itself). The fact that Inhaber chose his "riskiest" energy supply for backup has strongly affected the results. One is forced to ask what other distorting factors have been buried in the calculations?

As well as this case of misrepresentation, we are concerned about the accuracy of Inhaber's figures because we have found substantial errors in those two aspects of the report in which we have experience (NRCC has responsibility for coordinating solar and wind energy R&D programs in Canada). We have neither the time nor the desire to attempt to work out correct values or to elucidate on all the problems we have found, but we do feel that, due to its wide policy implications, Table 8 must not go unchallenged.

In the case of solar space heating, Inhaber has created a system to analyse which appears to have been designed to maximize material use and hence risk. It was based on a 70% solar system (which Inhaber treats as a seasonal storage system) proposed in an early study by an Ontario Hydro research group.[3] The system uses 100 m^2 of collector and a 91 m^3 steel water storage tank to provide 57 GJ of heat per year to a house in Toronto. This grossly overestimates material requirements for several reasons:

(i) The ratio of storage volume to collector area is high by a factor of 10 compared to widely accepted design criteria[4,5] and even the study Inhaber referenced said this design had "excessive storage capacity".[6] In later studies,[7] the same Ontario Hydro study team uses the system design we suggest below.

(ii) Output per unit area of collector is low by nearly a factor of two, both because the system is too large and because the collector used is much less efficient than even moderately good flat-plate collectors.

(iii) Inhaber arbitrarily assumes the system will deliver only 70% of its designed output. This is an absurdity in the Canadian climate. If active solar energy becomes viable, then it will have virtually no downtime (as is the case with current oil and gas heating systems). Since

Inhaber's risk values are quoted per unit output, this 43% increase in output for the system (with no other changes) implies there will be a 43% decrease in the associated risk per unit output.

(iv) The use of steel for a large annual storage volume would be a cost and risk maximizing choice. Most current plans call for concrete tanks and Inhaber's figures imply concrete (cement?) requires 0.2% as much labour per tonne as fabricated steel products and hence has a much lower risk.

If one uses a system which is designed to provide 50% of the heat to a home in Toronto, then 36 m^2 of "pedestrian" flat plate collectors are needed along with 3.2 m^3 of water storage to provide 57 GJ of heat per year.[4] Using Inhaber's steel requirements per unit area of collector and per unit volume of storage, this well-designed system would require a factor of 5.5 less steel per unit output than Inhaber's system. Since steel is the major contributor to risk in Inhaber's system, the risk level drops substantially. It should be pointed out that the exact same system located in Edmonton would provide 50% more energy since Edmonton is much sunnier than cloudy Toronto. The use of advanced collectors and/or concrete storage could easily further reduce materials and risks by another factor of two. Based on these figures, a solar enthusiast could conclude that solar space heating is less risky than nuclear power [103 (Inhaber's solar "risk")/$(5.5 \times 1.5 \times 2) = 6.2$ man days lost per MWyr < 10.1 (for nuclear)]. The proper inference is that the method has too many uncertainties to draw a conclusion.

Inhaber has also made several substantial errors in his wind system. Inhaber estimates about 760 tonne of materials/MWyr of energy produced by a wind system. This represents a major error in interpreting the cited reference. Recent NASA-Boeing estimates[8] for a 2.5 MW plant now under construction convert to 9.9 tonne per MWyr over a 30 year lifetime with a design load factor close to 37%. A recent Canadian design study for a large-scale vertical axis machine yielded 6.9 tonne/MWyr for a 2.5 MW machine. While these large machines are not yet built, prototype machines provide clear experimental evidence[9] of one's ability to estimate a system's output given its design and local conditions. In short, Inhaber overestimates the materials required by a factor of 100!

Inhaber also uses estimates for operations and maintenance which would require eight people to staff the NASA/Boeing MOD-2 machine. These machines are in fact designed for automatic, unattended operation. An estimate of maintenance requirements is hard to make but they are likely at least a factor of 10 less than estimated by Inhaber. This would still make maintenance the most harzardous part of the system. Inhaber appears to have obtained his high estimates by using values for kW scale machines which are expected to have much higher operations and maintenance requirements per unit output than large scale systems (his approach is like estimating maintenance on a 200 MW generating station based on a car-sized gas generator).

Finally, Inhaber has proposed energy storage and energy backup systems for use with wind machines. This proposal is based on a fundamental misconception of the type of large-scale wind-energy systems actually being studied in Canada and the U.S. These are so-called fuel-saving systems in which multiple wind plants are connected to existing utility grids. No storage is used unless it happens to be in the system. Similarily, assigning risk to the wind system on account of a coal "backup" system is misleading. Thus, to correct Inhaber's risk estimates for wind machines, we must reduce materials (and presumably transport and construction) requirements by a factor of 100, reduce maintenance requirements by a factor of 10, and ignore the use of backup and storage (and correct the output for this factor). If we do this and use the rest of Inhaber's figures, we find 11 man days lost per MWyr of wind produced electricity compared to Inhaber's value of 822!

We must emphasize that we do not believe the risk figures we have derived above because we do not trust the rest of Inhaber's analysis. They have been deduced to demonstrate that by concentrating on one aspect of Inhaber's study, namely, its choice of systems, we have found errors which lead to order of magnitude changes in the results. On the basis of these errors and the strong biasing of the results introduced by the unmentioned inclusion of energy backup systems, one must question the reliability of *any* of Inhaber's results. We would not use them as even a preliminary indication of the relative risks involved in the various systems studied.

REFERENCES

1. H. Inhaber, *Energy* 3, 769 (1978).
2. H. Inhaber, "Risk of Energy Production", Atomic Energy Control Board, AECB-1119/Rev-1, Ottawa, Ontario (May 1978).
3. A. G. Barnstaple, "An Examination of the Potential for Solar Energy Utilization in Ontario", *Ontario Hydro Rep.* 75092, Toronto, Ontario (Dec. 1975).
4. K. G. T. Hollands and J. F. Orgill, "Potential for Solar Heating in Canada". *University of Waterloo Rep.* 77-01, Waterloo, Ontario (Feb. 1977).
5. W. Beckman, S. A. Klein, and J. A. Duffie, *Solar Heating Design*, p. 66. Wiley, New York (1977).
6. M. K. Berkowitz, "Implementing Solar Energy Technology in Canada". *EMR Canada Rep.* EI77-7, Ottawa (1977).
7. P. L. Drewes and A. G. Barnstaple, "Cost Comparison of Total Utility and Homeowner Costs for Residential Space and Hot Water Heating Systems Including Solar Heating Systems". *Ontario Hydro Rep.* 77197, Toronto, Ontario (April 1978).
8. J. P. Couch, "Mod-2 Wind Generator Program". In *Proc. of 3rd Wind Energy Workshop*, Washington, D.C., CONF770921 (Sept. 1977).
9. P. South and A. Watts, "Magdalin Island Vertical Axis Wind Turbine Field Test". Presented at a *DoE sponsored Workshop on "Economical and Operational Requirements and Status of Large Scale Wind Systems"*, Monterey, California (March 1979); the proceedings are to be published.