# A SYSTEMS APPROACH TO ENERGY PLANNING IN INDIA

BY

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# C E R T I F I C A T E

This is to certify that the thesis entitled, " A SYSTEMS APPROACH TO ENERGY PLANNING IN INDIA" which is being submitted by Mr. E.A.S. Sarma to the Centre for Energy Studies, Indian Institute of Technology, Delhi for the award of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of this thesis, which has attained the standard required for a Ph.D. degree of this Institute. The results presented in this thesis have not been submitted elsewhere for the award of any degree or diploma.

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## ABSTRACT

The objective of this study is to develop a systems approach to energy planning with particular focus on the Indian scene. A number of supply and demand side options including certain foreign trade choices are considered and analysed together. The supply side options include the modal choices in electricity generation, the use of different grades of coal, the availability of crude from different sources, the use of different types of refining facilities, the availability of natural gas both in its free and associated forms and the supply of fuelwood from the low-productivity forest growth that occurs naturally in comparison with high-cost high-productivity fuelwood plantations. The availability of draught animal energy, animal waste and crop residue in relation to the livestock-agriculture sub-system and the traditional use of animal waste as dung cakes and manure in comparison with its alternate use as a source of biogas and slurry are some of the other supply options considered in the study. The use of solar photovoltaic energy is considered as an emerging technology in addition to the implications of a few energy conservation devices/processes. The demand sectors considered in the study include agricultural operations, lift irrigation, transportation, industry, the production of nitrogenous fertilisers and aluminium, cooking and lighting. Foreign trade options are considered in the case of crude and petroleum products on the supply side and fertilisers and aluminium on the demand side.

The quantitative framework of this study is based on a linear programming model with cost optimisation as its objective. The sensitivity of the optimal result is analysed with reference to changes in important assumptions regarding the shadow prices of unskilled labour and foreign exchange, the world market price of oil, the availability of resources and the sectoral goals for the different demand sectors. The model is used further to evaluate new energy technologies such as the use of solar thermal energy for cooking. In addition to analysing the investment alternatives in the energy sector, the model provides a valuable insight into the pricing of different forms of energy on an integrated basis.

The study suggests for the reference year i.e. the year 2000-01, a primary energy supply pattern that places greater emphasis on the development of coal, natural gas and hydro-electricity as compared with the prevailing pattern and the future policy. The study highlights the important inter-relationships that exist among the different sub-systems of energy and suggests the need to consider these interrelationships simultaneously. Further, an integrated framework for the pricing of energy is evolved.

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