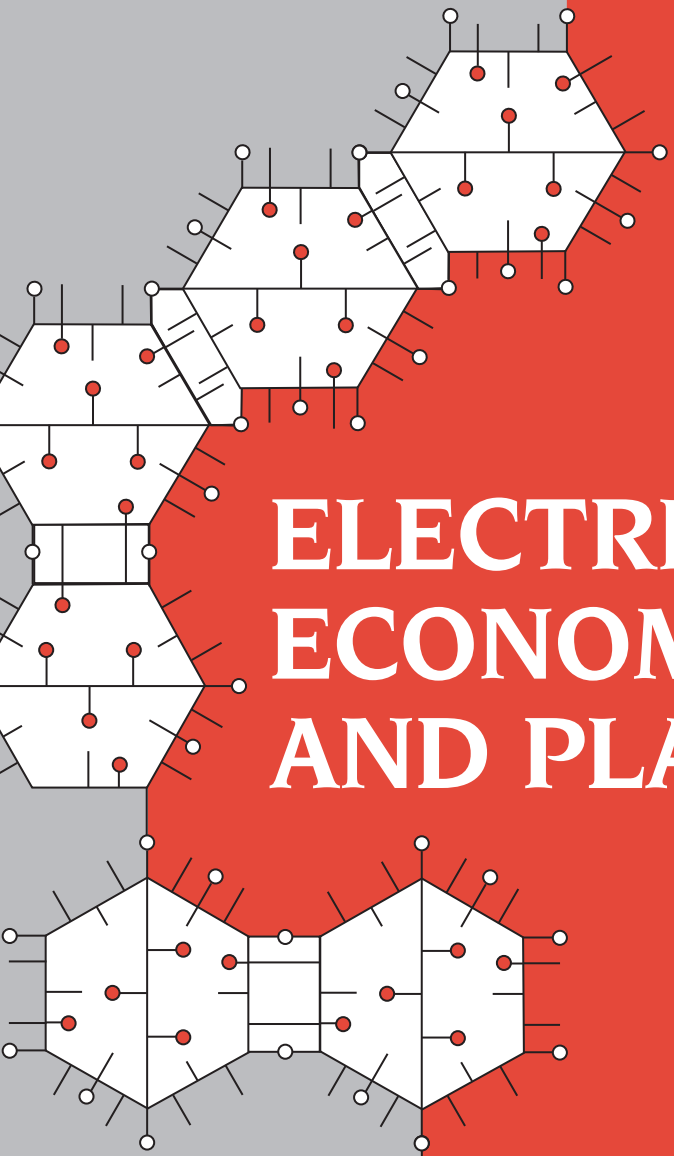
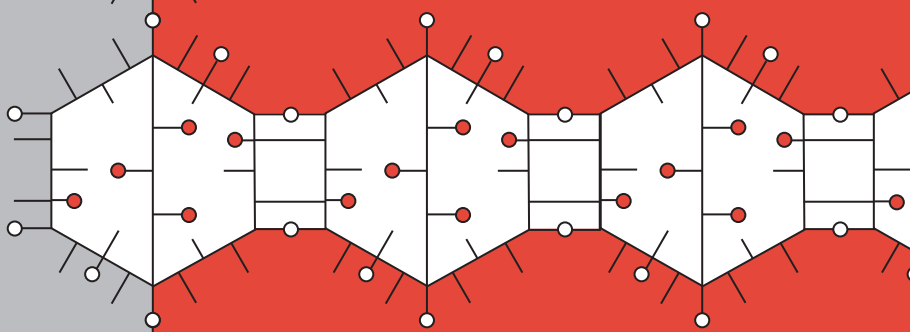
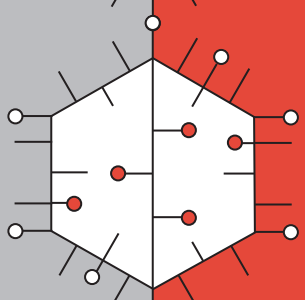


IEE POWER SERIES 16

# ELECTRICITY ECONOMICS AND PLANNING







T.W. Berrie

Peter Peregrinus Ltd. on behalf of
the Institution of Electrical Engineers

IEE POWER SERIES 16

Series Editors: Professor A. T. Johns
J. R. Platts
Dr. D. Aubrey

# ELECTRICITY ECONOMICS AND PLANNING

**Other volumes in this series:**

Volume 1 **Power circuits breaker theory and design** C. H. Flurscheim (Editor)
Volume 2 **Electric fuses** A. Wright and P. G. Newbery
Volume 3 **Z-transform electromagnetic transient analysis in high-voltage networks** W. Derek Humpage
Volume 4 **Industrial microwave heating** A. C. Metaxas and R. J. Meredith
Volume 5 **Power system economics** T. W. Berrie
Volume 6 **High voltage direct current transmission** J. Arrillaga
Volume 7 **Insulators for high voltages** J. S. T. Looms
Volume 8 **Variable frequency AC motor drive systems** D. Finney
Volume 9 **Electricity distribution network design** E. Lakervi and E. J. Holmes
Volume 10 **$SF_6$ Switchgear** H. M. Ryan and G. R. Jones
Volume 11 **Conduction and induction heating** E. J. Davies
Volume 12 **Overvoltage protection of low-voltage systems** P. Hasse
Volume 13 **Statistical techniques for high-voltage engineering** W. Hauschild and W. Mosch
Volume 14 **Uninterruptible power supplies** J. D. St. Aubyn and J. Platts (Editors)
Volume 15 **Principles of digital protection** A. T. Johns and S. K. Salmon

# ELECTRICITY ECONOMICS AND PLANNING

T. W. Berrie

Peter Peregrinus Ltd. on behalf of the Institution of Electrical Engineers

Published by: Peter Peregrinus Ltd., London, United Kingdom



Peter Peregrinus Ltd.,
Michael Faraday House,
Six Hills Way, Stevenage,
Herts. SG1 2AY, United Kingdom



**British Library Cataloguing in Publication Data**

A CIP catalogue record for this book
is available from the British Library

**ISBN 0 86341 282 3**

Printed in England by Short Run Press Ltd., Exeter

# Contents

# Foreword

I have known Tom Berrie and his work for many years. He portrays the type of engineer, much needed but not often found, who has absorbed the discipline of economics and can hold his own in that discipline as well as being acknowledged as a fully qualified engineer. Tom's first book on electricity economics entitled *Power system economics* was published by the Institution of Electrical Engineers in 1983 and has proved very useful to a wide variety of people. However, times have changed since then; many principles and methods described in that first book, that seemed well founded then, have either been largely replaced or at least drastically modified. Now, like all utilities, electricity must face up to competition, deregulation, privatisation, spot pricing, demand management, conservation, efficiency and environmental maintenance. New principles and methods are needed to cope with these changes. These new principles are described in this book, together with those traditional methods still applicable, such as load forecasting, prescribed pricing and many aspects of plant selection and reliability. It is interesting to read this book in conjunction with Tom's first and to note the socioeconomic developments that have occurred in less than ten years.

The Institution sees it has an important role in keeping practitioners up to date in their profession, and is publishing this new edition in the belief that engineers will find much of use.

Dr David A. Jones
President 1990–91

# Prologue

Since the author published his book on Power System Economics in 1983 fundamental changes have taken place worldwide in electricity economics and planning. The methods developed in the 1960s and 1970s, outlined in that book, emphasised national economic development programmes and prescribed pricing from such programmes, optimising over the long-term. These methods were based upon long-term demand forecasts, elaborate probabilistic risk analysis for reliability, a discounted cash flow approach to project costs and benefits, and long-run marginal cost pricing. Almost everywhere, in developed and developing countries alike, this approach is giving way in planning emphasis to methods based on short-term, short payback development programmes, together with actual time-of-use, dynamic and 'spot' pricing, possibly set in real time. Furthermore, much greater emphasis is given today in electricity supply to the following: consumer response; private capital; private utilities; demand management; energy efficiency; conservation, and environmental maintenance.

The new book makes full use of the subject matter of the previous book, and takes into account the change of emphasis described above. It also introduces the issues and options likely to arise in power system economics and planning in the late 1990s and beyond.

## Reading the book

The various groups of readers are recommended to read the following sections of the book:

1 *Decision takers, senior price setters, top academics*
The executive summary, especially the appropriate sections for their special interest

2 *Decision makers, middle price setters, senior academics and researchers*
The executive summary as a whole

3 *Decision analysts, junior price setters, middle academics and researchers*
The executive summary plus first section, and commentary summaries in each chapter

4 *Specialists and junior academics and researchers, also senior students*
Each individual specialised chapter

The executive summary is meant as an outline precis of the book for readers who should be made acquainted with the material therein, but for whom the time taken to read further is unwarranted.

*Chapter 1* sets the scene, giving the background to all planning in the energy sector by discussing the world economic and energy outlook for the 1990s and beyond.
*Chapter 2* deals with how governments' departments, electricity utilities (public and private), cogenerators, autoproducers and large electricity consumers, should make a national electricity sector assessment, this being needed from time to time to give background to their own planning.
*Chapter 3* describes how the above organisations should assess the likely demand upon them for electricity; it bears in mind today's emphasis on demand management and the connected subject of reliability.
*Chapter 4* outlines methods in coping in electricity planning with the factors of improving efficiency, conservation and the environment.
*Chapter 5* lists the arguments for and against public versus private utilities, funding and regulation in electricity supply, together with current trends and likely future pressures.
*Chapter 6* gives an up to date picture of prescribed pricing, i.e. the traditional setting of prices well in advance of the actual time of use; it then deals with dynamic pricing, i.e. setting prices near to, or actually at, their time of use, including 'spot' electricity pricing, buying electricity forward, futures electricity markets, agents, brokers and insurers.
*Chapter 7* deals with how to determine, in the world of today and tomorrow, generation, transmission, distribution and utilisation plant programmes, bearing in mind competition, marketmakers and price setters, controllable demand and the need for short-term returns; also how large, medium and even small consumers should today optimise their utilisation programme, i.e. both their electricity plant and the usage of their plant. There is an annex on technology transfer, indicating its special importance to electricity supply in, for example, developing countries.
*Chapter 8* discusses the special problems of developing countries, e.g. high growth in electricity demand, shortage of foreign and local capital, few skilled managers and labour, debt service problems, often vast but untapped fuel resources, balance of payments difficulties, etc.
*The Epilogue* gives a look to the future in electricity supply worldwide, describing the issues likely to arise and the probable options for solving these.

# Executive Summary

## 1 World outlook

National economies are classified as: developed; resource-rich developing; and resource-poor developing. Some have but recently industrialised. Wholesale reclassification is unlikely during the 1990s but developing countries will increase their energy role. World economic and energy growth depend markedly on population growth. In developing countries labour increases are swamped by capital requirements, although population growth may occasionally be a net contributor to economic growth. After population, the second largest unknown throughout the 1990s will be the effectiveness of private funding and ownership for public utilities. Likely world economic outlook in the early 1990s is for $2\frac{1}{2}\%$ growth at best, with uncertainties on: development growth; oil prices and availability; the EEC, CIS (formerly USSR) and Eastern Europe growth prospects; debt servicing, and relieving poverty. The likely world energy outlook depends directly on development growth. Abundant world commercial energy resources are unevenly distributed while renewables such as fuelwood are not. The world energy scene must be periodically assessed, requiring much information on the following: resource bases; exploration rates; extraction–production ratios; production economics; supply risk and political, fiscal and operational restrictions. Periodically, demands need assessing in detail for oil, gas and coal, noting the oil companies' roles, energy pricing, interfuel competition, energy in development, country dependence by fuel. World and country fuel supply–demand balances in detail must be made by all concerned with energy for the short, medium and long term.

Energy management, efficiency, conservation and the environment will play increasing roles, but developing countries have not sufficient resources to cope with these, except with outside help. Fuel prices and availabilities will be cyclic, with developing countries only having a vital role after 2010.

## 2 Electricity sector

With respect to *energy planning*, before 1973 infinite, cheap, abundant oil necessitated no serious national energy planning, only fuel strategies. Many countries today use less commercial and largely unplanned non-commercial energy, with disastrous effects. Today many claim that market forces replace planning, yet many countries were not able, by the late 1980s, to balance energy–fuels inputs–outputs after the oil price rises of the 1970s. Energy sector and subsector planning is here to stay in the 1990s, dealing with supplies,

demands, pricing, ownership, investment, energy management, regulation, efficiency, conservation and environmental maintenance.

Concerning *energy usage*, considerable improvement in energy efficiency is possible worldwide, especially by pricing. Most oil importing countries pass price rises on to consumers, whilst oil exporting countries continue pricing domestically below border values. Any earlier moves towards border pricing reverse when oil prices fall. Improvement in energy efficiency is most rewarding for large energy consumers, e.g. electricity suppliers and transport. Yet governmental or regulatory body incentives, financial or otherwise, are usually needed, also for encouraging energy conservation. Simple remedies are often more effective than capital-intensive ones, e.g. energy plant refurbishment, not complete replacement. For medium to small consumers, direct conservation measures work best, i.e. just to achieve less energy usage.

Regarding *energy supply*, World Bank reviews of energy sector and subsector supply positions suggest developing countries' commercial energy production rising from actual 1·7 billion tonnes of oil equivalent (btoe) in 1980 to over 3 btoe mid-1990s, 33% of the increase from oil production improvements, 27% from coal improvements, 22% from natural gas improvement, 18% through hydropower, these requiring efforts and actions by developed – developing countries' partnerships. The first action is always to accelerate identification, evaluation, development, and marketing of indigenous energy.

Large *investment* is needed to achieve sufficient energy for satisfactory world economic growth, despite improvements made in demand management, efficiency, conservation, etc., a working hypothesis being ten to twenty times the gross investment needed for developing countries, the latter being known with some accuracy and consistency. This means a doubling of energy's share of total investment in GDP growth from 2% to 3% of GDP, achieved in the early 1980s, to an average 5% of GDP over the years up to 1993/95. Funding world energy is thus a major problem for the 1990s, emphasising the need for: mobilising finance from all sources; simplifying financial availability and procedures, especially cofinancing; strengthening governmental and neutral guarantees; providing finance especially for technology transfer, particularly for developing countries.

Types of energy finance are: official, i.e. from governments, applied multilaterally or bilaterally; private, i.e. from commercial banks, finance institutions, etc.; suppliers' or buyers' credits, i.e. from equipment suppliers or manufacturers; and equity, especially with private utilities. All financing must fit within national accounting planning, and the US$ 130 billion requirement for energy investment for developing countries would be much higher without this requirement, especially if most financing were on hard commercial terms. Only small energy investment for developed countries is foreign, but for developing countries this type is much larger, possibly one half, or US$ 65 billion, over the ten years to 1993/95, compared with the World Bank's US$ 25 billion for the actual investment for energy in 1982, both measured in 1982 dollars. Mobilising adequate local capital for developing countries' energy will also prove most difficult, the favourite method to date being by direct treasury transfers to subsectors, thereby destroying the utilities' autonomy and accountability, and distorting their operations. Many economists now believe alternative methods will only work if energy pricing is all at border values and if private capital is

always welcome. Effective finance needs strong institutions plus adequate regulation against monopolies and monopsonies. Each subsector, e.g. electricity, must optimally fit into national economic and energy programmes.

Periodically, assessment of national electricity must be done by all utilities in order to retain a proper perspective. If electricity supply means one single government-funded, owned and regulated utility, the national electricity is part of that utility's national economic and energy surveys. With many private or public utilities for production and/or distribution a separate national electricity assessment is needed, for each such assessment starts by considering national economy and energy. Privately owned utilities may need to hire expertise to do this. A more detailed look is then needed at the national electricity sector—e.g. number and types of utility, trends towards privatisation, deregulation—sufficiently detailed for utilities to make meaningful forecasts of national electricity growth rate, funding, etc. Electricity reviews must examine current and likely markets, their efficiency and degree of competition, also how electricity prices are set, who regulates the market and how well. Each utility must then examine its own position within national electricity market shares and future prospects; utility fuels' position and prices, examining its current and future pricing; likely introduction of consumer 'clever' meters, microprocessors, microcontrollers, microcomputers, enabling demand management, time-of-use tariffs, dynamic and 'spot' pricing to be introduced, wholesale and retail, plus the expected future of competitive fuels. Electricity marketplaces will dominate the sector in the 1990s, especially when demand management plus spot pricing become normal.

The influence, jurisdiction and scope, present and future, of *regulators*, needs assessing in all electricity reviews. Regulatory bodies vary between full, direct government control over utility ownership and funding, through 'heavy' regulation with authority to send for development and financing plans, persons and papers, to 'light' regulation, keeping only a low profile and intervening for flagrant abuses, especially against competition, but relying on the market and self-regulation as much as possible. Regulators' jurisdiction and scope are important matters for electricity utilities, generation, transmission and distribution, and for 'wheeling' electricity over the mains, i.e. using the network as common carrier, also for ensuring that autogenerators and cogenerators are given full scope and a fair competitive price for their electricity.

## 3A Demand assessment

Traditionally, *forecasting* is at the heart of planning. Given long plant lead times and lives in electricity, forecasts are made for 5 to 25 years ahead for peak demand (kW), annual kWh, plus demand patterns. However, ex-post evaluation questions tradition and long-term forecasting is suspect for the 1990s. Traditional approaches are: (i) from electricity data, forecasting peak demand (kW), using forecasted load factors to deduce annual kWh; (ii) from electricity data, forecast annual kWh by consumer class and summate, then using forecasted load factors deduce kW peak demand; (iii) from electricity data, forecast peak kW and annual kWh separately, checking derived load factors against past experience; and (iv) from national economic data, forecast annual

GDP and national energy, breaking down the latter into gas, electricity, coal, oil, etc., and converting electricity kWh into kW using forecasted load factors.

Traditional forecasting methodologies are:

(a) Extrapolation, e.g. previous growth continuing until saturation
(b) Examining time series of kW and kWh, rereviewing fuel and plant prices, likely new industries, improved efficiency, demand management, conservation and environmental measures
(c) Synthesising with the factors behind demand, e.g. predicting kW for future economic scenarios, using correlations of electricity with population, per capita income, consumer number, type and class, sales of appliances, industrial production
(d) Market surveys, e.g. electricity consumption examined using various credible tariffs, for existing and new residential communities, industrial or commercial estates, demand estimated from consumer number, type and class.

Electricity planning is not linear but interactive; historically it starts with demand forecasting using semi-exogenous data on cost and price, finding the least-cost way of supplying the forecasted demand, costing this and then pricing those electricity supplies, deciding whether consumers will pay the long-term price, wondering whether the utility can find the capital, obtain enough annual revenue, and finally, when the answer to any of these questions is 'no', repeating the cycle as many times as necessary. Bad load forecasts are economically detrimental because of vast resource cost losses and because pricing changes are always politically difficult. Principles behind forecasting are researching historical statistics and social, economic and political pointers showing how the economy, especially the energy and electricity sectors, are developing. Data sources are government and development agencies' economic reports, their energy reports and electricity sector reviews, and interviews with people in the country and sector concerned. Derived factors such as electricity growth, sales per consumer etc., must be compared with statistics from other countries and sectors. Common pitfalls in forecasting are: (i) extrapolation of trends regardless of altering features; (ii) forecasting influenced by supply-side factors only, i.e. preconceived ideas of size and composition of the plant programmes needed; (iii) not questioning whether the economy or utility has resource costs to meet the forecast, or whether consumers are willing and able to pay the price; (iv) also excessive 'number crunching' for its own sake.

## 3B Demand management and reliability

Demand management (DM) ideally influences consumer demand to optimise joint supply–demand operation, efficiency and cost. It has existed in many forms from the early days of electricity. The oldest form prescribes a maximum electricity flow, above which supplies are automatically cut off. DM is important for the 1990s because, with modern techniques, it is cheaper to control certain demands than to build more generation, transmission and distribution. In the past, supply shortages meant directly controlling selected consumers to limit demand at some periods, e.g. at peak. With limited