



ON SCIENCE AND
TECHNOLOGY

Geothermal Energy Projects Planning and Management

Edited by
Louis J. Goodman
Ralph N. Love

Published in cooperation with the
East-West Center, Hawaii

Pergamon Press

NEW YORK • OXFORD • TORONTO • SYDNEY • FRANKFURT • PARIS

Contents

List of Tables	vii	
List of Figures	ix	
List of Symbols	xi	
Preface and Acknowledgments	xiii	
Chapter		
1	AN INTRODUCTION TO GEOTHERMAL ENERGY	
	Louis J. Goodman and Ralph N. Love	1
	Earth Heat	1
	Classification of Geothermal Resources	4
	Uses of the Earth's Heat	6
	Present Use of Geothermal Energy	9
	The Integrated Project Planning and Management Cycle and Geothermal Development Projects	12
2	WAIRAKEI GEOTHERMAL POWER PROJECT: NEW ZEALAND	
	Ralph N. Love and Richard Bolton	24
	Project Background	24
	Phase 1: Planning, Appraisal, and Design	26
	Phase 2: Selection, Approval, and Activation	63
	Phase 3: Operation, Control, and Handover	67
	Phase 4: Evaluation and Refinement	72

3	HAWAII GEOTHERMAL PROJECT: UNITED STATES Louis J. Goodman, Tetsuo Miyabara, and Barbara Yount	95
	Project Background	95
	Phase 1: Planning, Appraisal, and Design	99
	Phase 2: Selection, Approval, and Activation	118
	Phase 3: Operation, Control, and Handover	136
	Phase 4: Evaluation and Refinement	157
4	TIWI GEOTHERMAL PROJECT: THE PHILIPPINES Rosemary Aquino and Salvador Aquino with the technical assistance of Arturo Alcaraz	168
	Project Background	168
	Phase 1: Planning, Appraisal, and Design	169
	Phase 2: Selection, Approval, and Activation	190
	Phase 3: Operation, Control, and Handover	191
	Phase 4: Evaluation and Refinement	197
5	POLICIES OF GEOTHERMAL DEVELOPMENT Louis J. Goodman and Ralph N. Love	206
	The Case History Record	206
	The Broad Issues	211
	Conclusion	221
	Index	223
	About the Authors	229

List of Tables

Table

1.1	Areas of Known or Probable Geothermal Potential	5
1.2	United States Historical Comparative Costs	9
1.3	Electricity-Generating Capacity from Geothermal Resources	11
2.1	Summary of Test Results	40
2.2	Power Only Proposal: Summary of Estimate of Cost	60
2.3	Allocation of Capital Costs for 6- and 12-Ton-per-Year Heavy Water Plant with Power Generating Equipment	61
2.4	Itemized Costs	62
2.5	Comparison of Prices for 1954 and 1955	65
2.6	Electricity Generation at Wairakei	74
2.7	Utilization Factor, 1964-1974	75
2.8	Major Division of Costs	82
2.9	Capital Costs	83
2.10	Annual Working Expenses for 1965-1969	84
2.11	Chemical Analyses of Effluents from Wairakei and Broodlands Fields	88
3.1	Comparison of Data Between Area A and Area B	126
3.2	Budget Allocations for HGP Drilling Phase, 1975-1976	127
3.3	HGP Casing Program for Geothermal Well	129
3.4	Subcontract for Drilling Operations	133
3.5	Summary of Pumpdown Test	142
3.6	Throttled Flow Data for January 26-February 10, 1977	150
3.7	Hawaii Geothermal Research Test Facility Estimated Plant Equipment Costs	155
3.8	HGP-A Discharge Results	157
3.9	Long-Range Power Projections for HGP-A	159
3.10	Geologic Analysis and Interpretation of Possible Production Zones	160

viii LIST OF TABLES

3.11	Aerometric Data for HGP	162
3.12	Comparison of Chemical Content of HGP-A of Nearby Wells and Springs	163
3.13	Level of Noise Near Well Site	164
3.14	Financial Summary for HGP, 1973-1978	165
4.1	Data on Drill Holes, Tiwi, Albay	179
4.2	Oil Imports and the National Balance of Trade	200
4.3	Tentative Assessment of Indigenous Energy Resources	202
4.4	Geothermal Development Program	202
5.1	Small Power Plants Presently Existing, under Construction, or Planned in Participating Countries	214
5.2	Comparison of Fossil-Fuel, Nuclear, and Geothermal Estimated Generating Costs	216