The Application of Cogeneration Systems to the Cooling of Food and Buildings in East Timor

A thesis presented in partial fulfilment of the requirements for The Degree of Master of Technology at Massey University New Zealand

Estanislau De Sousa Saldanha

2001

ABSTRACT

Cogeneration is generation of both heat and power simultaneously using a single primary energy input. Cogeneration recovers "waste heat" from a conventional power generation plant to produce useful energy, leading to the increased overall efficiency of fuel input. This also achieves cost savings, and reduces greenhouse gas emissions where fossil fuels are used.

The objectives of this study are to assess the technical and economic viability of a cogeneration system for the cooling of food and buildings in East Timor. The findings of this research provide a basis for recommending action and further research to East Timor's decision-makers on energy issues. Technical assessments in this study focus on cooling, electricity demand, and fuel supply as the basis for choosing the type and size of a cogeneration system. The financial viability of the cogeneration system is assessed using net present value (NPV) and sensitivity analysis. The NPV of the cogeneration system is compared with the NPV of conventional energy supply for cooling and electricity.

There is low demand for cooling for comfort and food preservation in East Timor, due to low levels of industrial and commercial investment, and the vast majority of people still living in poverty. Although cooling demand is low overall, numerous government and commercial buildings have installed cooling systems. In this study, six buildings (2 office buildings, a bank, a hotel, a university and a mini-market) were selected based on their relatively high cooling demand and their geographic proximity to one another.

The cooling demand of these six buildings was modeled based on a room-by-room approach. The results showed that their overall hourly cooling demand averages 600 kilowatt-cooling, while peak load was 707 kilowatt-cooling. This cooling demand was primarily driven by ambient temperature, number of people present and lighting load.

Power demand in East Timor is low. The total operable power supply capacity for the entire country is 22 megawatts, of which more than half is located in Dili. Electricity demand is predominantly driven by residential consumption, rather than commercial and industrial consumption. Although there is low electricity demand, East

Timor faces an immediate electricity deficit of 24 megawatts, which is higher than the existing operable capacity. In the six selected buildings, the overall peak and average electricity loads were 489 kW and 422 kW respectively. This load was mainly driven by air conditioning, computers, and lighting applications during working hours.

Electricity generation relies on diesel, which is imported from Indonesia. Diesel will remain the main source to generate electricity due to a lack of feasible alternatives. East Timor is rich in natural gas both offshore and onshore. However, until now there has been no plan to provide natural gas distribution pipelines to East Timor.

Based on the cooling and electricity demand and fuel availability, diesel was chosen to drive the cogeneration systems. The size of the cogeneration system was selected so as to fulfill both the electricity demand in the six selected buildings and be able to export surplus to the local grid. There are two reasons for employing a larger engine capacity. Firstly, a small engine will not be able to generate sufficient heat to drive an absorption cooling system with a capacity of 600 kilowatt. Secondly, export electricity will increase revenues generated from the cogeneration plant.

Financially, the net present value (NPV) of both the cogeneration system and the conventional energy supply system were lower than zero, which means that neither system can be viable financially. The cogeneration system's NPV was lower than that for the conventional energy supply system, due to its higher capital and operating costs. High operating costs were due to fuel costs, with low revenues being due to heavy subsidies on electricity. If fuel and electricity subsidies were removed, a cogeneration system could become a more attractive option compared to a conventional system. However, removing the electricity subsidy would result in the large majority of people being unable to afford electricity.

AKNOWLEDGMENTS

The author would like to thank the following staff of Massey University for advice and assistance during the course of this research project:

Dr Stephen White, Department of Chemical Technology, Former Chief Supervisor.

Dr John Holland, Institute of Natural Resource Management, Chief Supervisor.

Professor Don Cleland, Institute of Technology and Engineering.

Professor Rao Badimidari, Institute of Technology and Engineering.

Dr. Linus Opera, Institute of Technology and Engineering.

Mr. Charles Chua, International Student Office.

The author would also like to thank the New Zealand Government for granting a New Zealand Overseas Development Assistance (NZODA) scholarship, which made this study possible.

The author gratefully acknowledges the assistance of the following people in gathering data that was used to assess cogeneration viability in East Timor.

Mr. Trevor Fry, Eletricidade de Timor Leste (EDTL), Dili, East Timor.

Mr. Graham Easton, Waukesha New Zealand, Auckland.

Finally, sincere thanks go to the East Timorese community in Palmerston North, New Zealand, especially to Anacleto Ribeiro and Edmundo Viegas. Especial thanks go to my wife Betty, and sons Jovi and Nino for their tireless support throughout the project.

This research project is dedicated to East Timor, the newly born country, where the author was born and grew up.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1
INTRODUCTION

1.1. General Background

East Timor is located about 750 km north of Australia. It shares boundaries with Indonesia in the west, east and north, while in the south is the Timor Sea. The territory of East Timor consists of the half-part of Timor Island, including the offshore Islands of Atauro and Jaco, and an enclave, Oecusse, on the north coast of the Indonesian territory of West Timor. East Timor has an overall land area of approximately 14,609 square kilometres. The population in the territory is estimated to be around 800,000 people in 2001, who are mostly settled in the north coast.

East Timor is a former colony of Portugal. In 1976, Indonesia unilaterally annexed East Timor as its 27th province. However, the United Nations Organisation rejected this annexation and considered Portugal as the administrative authority of the territory. The UN demanded that Indonesia withdraw its troops from East Timor and let the East Timorese people exercise their own right to self-determination freely and without any interference, as stated in the Security Council and the General Assembly Resolution 389, 1976 and 31/53, Paragraph 5, 1976 respectively.

In April 1999, the Indonesian government under President Habibie offered two options to the East Timorese people, namely to vote to accept the proposal of special autonomous region under Indonesian rule; or to reject the proposal leading to independence. The vote was held on 30th August 1999, and the result showed that 78.5 percent of East Timorese people rejected the autonomy proposal offered by the Indonesian Government. Post-referendum, militias and Indonesian soldiers expressed their dissatisfaction by destroying a large part of the country, leaving the economic infrastructure of the territory severely damaged.

In October 1999, the Indonesian government ratified the results of the East Timorese vote and acknowledged the establishment of the United Nations Transitional Administration in East Timor (UNTAET), which is mandated by the United Nations Security Council to establish a democratic government in East

Timor. The first democratic election in the territory post-colonial occupation was held in August 2001 in order to elect members of the constituent assembly leading to the territory's fully independence in May 2002.

1.2. Economy

The economy of East Timor relies primarily on the agricultural sector, which contributes almost 40 percent to the gross domestic product (GDP) and absorbs nearly 85 percent of its workforce. The main agricultural products are coffee, rice and maize. Coffee is the only export crop (Pedersen and Arneberg, 1999).

The violence of September 1999 severely damaged 50 percent of the economic infrastructure, such as commercial and government buildings and the power sector. Consequently, the GDP dropped from US$375 million in the year 1998 to US$228 million in the year 1999 (World Bank, 1999 and Valdivieso, 2000).

In the year 2000, the GDP of the country rose 15%, which was driven by construction, commerce, trade and basic services. This growth was largely contributed by the presence of United Nations (UN) staff and other expatriates, who have stimulated consumption and some private investment. However, these investments were predominantly short-term within the services sector (Valdivieso and Lopez-Mejia, 2001).

The future economy of East Timor will depend on a number of main sectors: agriculture, oil and gas, mining (i.e. marble and manganese), fisheries and tourism. The agricultural sector will provide large numbers of jobs, while coffee remains the main exporting commodity (Saldanha and Da Costa, 1998).

Oil and gas will contribute more than half of East Timor's income. In 2000, East Timor received the first royalty from oil and gas exploitation in the Timor Gap, of US$3 million. This amount is predicted to increase more than ten times per annum by the year 2007, when the Bayu-Udan project operated by Phillips Petroleum is expected to start full production.

1.3. Power Sector

In 1998, East Timor's power sector consisted of 60 power stations with total operable capacities of 26.5 megawatts. More than half (14.7 megawatts) of these operable capacities were generated from two main power stations in Dili. The total annual electricity generation was 77 gigawatt-hours and total electricity sold was 68 gigawatt-hours. The number of customers for all power centres totalled about 43,000 (Perusahan Listrik Negara Cabang Dili, 1998 and Asian Development Bank, 2001).

Following the violence in September 1999, 50 percent of the power stations were seriously damaged. Such destruction mainly occurred in district and sub-district centres, where power stations were driven by small capacity diesel engines with the range of 25 kilowatts to 800 kilowatts (Eletricidade De Timor Leste, 2001 and Asian Development Bank, 2001).

It is estimated that electricity demands in the territory will increase by about 5.5 percent per annum relative to the existing power supply (Eletricidade De Timor Leste, 2001). However, this estimate may only be based on the existing electricity demand, which is driven by small-scale business and residential load. If there is large-scale business investment, energy demand could exceed this annual electricity growth.

Facing poor electricity supply, the ETTA (East Timor Transitional Authority) has worked closely with numerous governments (such as Australian, Portuguese and Japanese) and the Asian Development Bank to restore power stations in East Timor. The Transitional Administration also allocated US$11,793,000 during the period of January 2000 - March 2002 (Asian Development Bank, 2001). The restoration of the power stations will increase electricity supply back to 1999 levels. However, this increase could not cover overall energy demand, which is estimated to exceed 30 megawatts in 2002 (Eletricidade De Timor Leste, 2001).

The Asian Development Bank (2001) has programmes in place to identify the potential of rural energy resources and alternative energy sources to diesel generation. This is particularly important as East Timor faces increasing energy demand, which is in contrast with the financial ability to build new power

generation facilities. Under such circumstances, the government could increase attention to finding alternative technologies to meet energy demand and save natural resources and finances.

1.4. Cogeneration System

Conventional power generation only converts a third of primary energy input to useful energy, while a large amount of energy input is unconverted and released as "waste heat". Cogeneration systems recover this "waste heat" leading to increased overall efficient energy use.

Cogeneration is defined as the sequential generation of electricity and useful heat from the same primary fuel, thus making use of heat that would otherwise be wasted (Taylor and Labson, 1997:1). Cogeneration systems can generate two or more useful energies (i.e. cooling, heat and power) simultaneously using a single primary energy input. Cogeneration will convert large amounts of "waste heat" from conventional power generation to produce useful energy for numerous applications such as heating and cooling for industry, buildings and food possessing. It could offer potential energy savings of approximately 35% leading to operating cost saving from fuel use. The overall efficiency of cogeneration is around 80-90% (CADDET, 1995 and Hart and Rosen, 1996). Combined cooling and power also save primary energy of about 24.5% (United Nations Economic and Social Commission for Asia and the Pacific, 2000).

In East Timor, cogeneration could be used to generate cooling for buildings and for food preservation. It could offer a reliable energy supply, primary energy (diesel) savings, transfer of technology, and job creation. Absorption cooling from a cogeneration system can be a substitute electric cooling system, which then increases the availability of electricity generated to supply other consumers. However, cogeneration systems require suitable energy demand, fuel supply and skilled people to operate and maintain them effectively. Therefore, it is necessary to determine the technical and economic viability of cogeneration applications in East Timor.

1.5. Project Aims and Objectives

1.5.1. The Aim of the Project

The aim of this project is to assess the applicability and economic viability of cogeneration systems to provide refrigeration and air conditioning in East Timor. The findings of the research will provide information for East Timorese decision-makers for energy planning.

1.5.2. The Objectives of the Study

The objectives of this research are:

1. To undertake a literature study on cogeneration systems.
2. To assess the technical and economic viability of cogeneration systems to the cooling of food and buildings in East Timor.
3. To provide recommendations to East Timorese decision-makers regarding the suitability of adopting cogeneration systems.