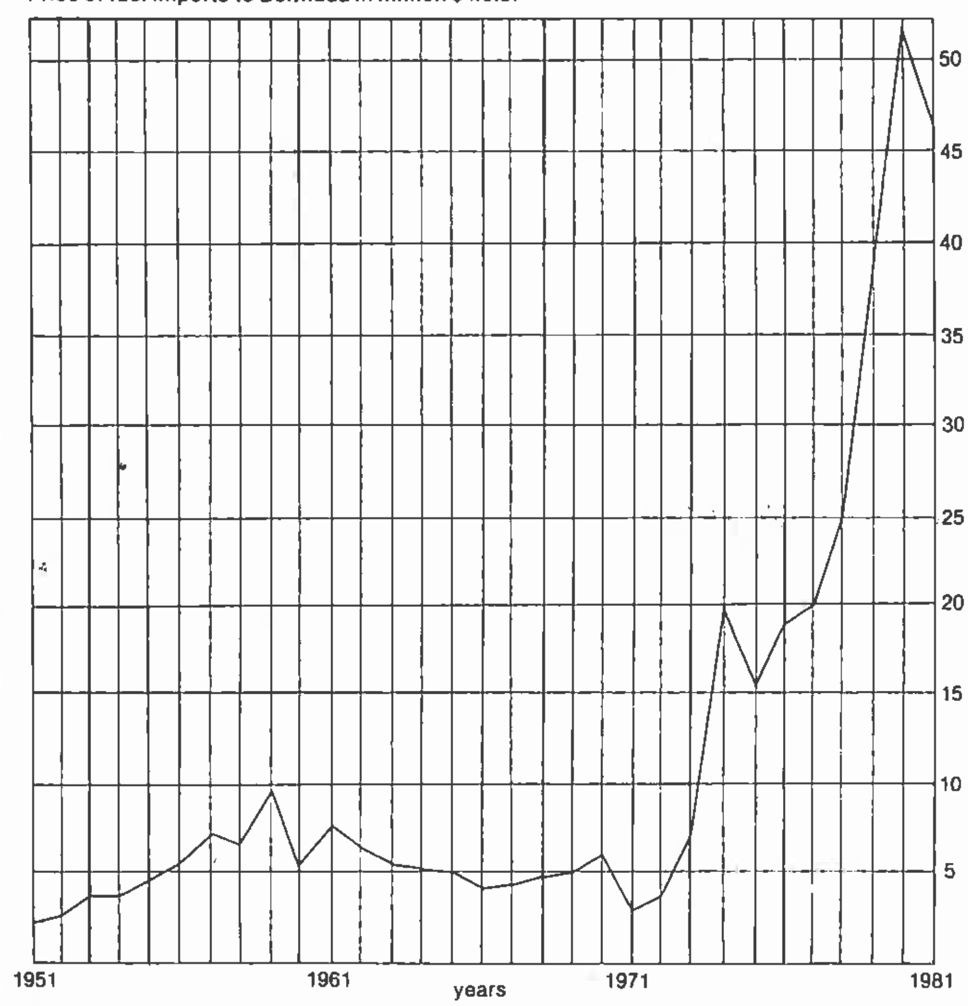
Bermuda's Energy Future

Proceedings of a Conference hosted by the Bermuda Biological Station

Edited by Wolfgang Sterrer
Jonathan Sands
Gary C. Barbour

Price of fuel imports to Bermuda in millien $ f.o.b.



Bermuda's Energy Future

Proceedings of a
Conference hosted by the
Bermuda Biological Station,
April—May, 1981

Edited by

WOLFGANG STERRER
JONATHAN SANDS
GARY C. BARBOUR

Bermuda Biological Station for Research, Inc.
Ferry Reach 1-15, Bermuda

Special Publication #23 from the Bermuda Biological Station for Research, Inc. ISBN 0-917642-23-6.

PREFACE

Twice in the recent past, in December 1980 and in March 1981, Bermuda was on the brink of supply shortages, both caused by bad weather that prevented ships from delivering their cargo in time. While the first shortage, Christmas trees, caused a great deal of public anxiety and almost hand-to-hand combat, the second, fuel oil, went more or less unnoticed, largely because of the professional way in which a crisis was averted. To many of us, however, both incidents were reminders of how totally dependent Bermuda is on outside resources.

This need not be so. Not all of the energy we use on the Island is essential for our survival. Our climate is such that heating and cooling are more often a convenience than a necessity; we do not have an energy-thirsty manufacturing industry; and distances on the Island are so small that they could conceivably still be covered on pedal bike or horseback if necessary. And we have not begun to exploit whatever local energy sources may be available to us.

As evidenced by a number of recent initiatives such as Government's Energy Conservation Committee, the Bermuda Electric Light Company's energy study, the Jaycees' energy fair, and others, the time may have come to investigate the potential for at least some degree of energy self-sufficiency.

A workshop-type conference, it was felt, would provide the forum for local and foreign energy experts to exchange views and evaluate the current situation. Sponsored by the Energy Conservation Committee, with support from a number of donors, a Conference on "Bermuda's Energy Future" was convened by Wolfgang Sterrer and Jonathan Sands at the Bermuda Biological Station on April 29, 30 and May 1, 1981. Thirteen energy experts from abroad joined some 25 local experts for the three-day Conference.

Day One was devoted to a presentation of Bermuda's current energy situation, in the context of the world and U.S. situation. On Day Two, experts from abroad summarized current technology and policy in ten areas of energy generation and conservation. Day Three produced the Findings and Recommendations of the Conference, through the work of committees made up of local and foreign participants. While one committee, chaired by John Houghton, developed guidelines for Energy Contingency Planning, a larger group, coordinated by Gary Barbour and organized into sub-committees on alternate technologies, conservation, buildings, and transportation, assembled the material for Energy Resource Planning. The editors subsequently gathered, revised and coordinated all manuscripts for publication.

As the healthy mix of representatives from industry, government and academe suggests, the Conference was neither a scientific symposium nor a trade fair, nor was it a meeting of consultants called in to make firm recommendations or develop policies. The main emphasis was on exchange of information. We should also caution that the Conference could not attempt to cover the entire field of energy technology; by design, it left out technologies that are either not applicable to Bermuda (e.g. hydroelectric) or environmentally damaging (e.g. coal), and was therefore somewhat biased toward solar technologies. Because of the rapid changes both in the price of oil and the performance of alternative technologies, a quantitative evaluation of the technologies discussed was beyond the scope of the Conference. Finally, the views expressed by the authors of this volume are not necessarily shared by the editors, nor do the many references in this publication to commercial products, processes or services by trade name, manufacturer or otherwise necessarily imply endorsement or recommendation by the participants, their employers, or any of the sponsors of the Conference.

Wolfgang Sterrer
Jonathan Sands
Gary C. Barbour

Bermuda, August 1982

CONTENTS

FINDINGS AND RECOMMENDATIONS OF THE CONFERENCE

A - SUMMARY

1. <u>Bermuda is totally dependent on imported petroleum products</u>.

This dependence applies to both "external" consumption (especially air and ship traffic) and "internal" consumption. Virtually 100% of Bermuda's internal energy supplies are imported in the form of refined petroleum products. Purchases in 1980 totalled 1.1 million barrels of oil equivalent (heavy oils 700,000 BOE; gasoline 200,000 BOE; fuel oil 100,000 BOE; liquid petroleum gas 100,000 BOE) costing $37.5 million in 1980 dollars, or $4.9 million in 1973 dollars. The major consumer of imported petroleum was the Bermuda Electric Light Company (BELCo) which in 1980 purchased 65 percent (700,000 BOE) of Bermuda's total petroleum imports to generate electricity. In 1970, BELCo's share of total imports was only 50 percent or 420,000 BOE.

Bermuda's dependence on imported oil is threefold: in securing refined products, in paying whatever their price may be, and in assuring delivery to the Island. Throughout its journey, from the well to Bermuda's docks, oil is vulnerable to disruption from natural (resource depletion, weather), financial and political causes.

2. <u>Bermuda consumes as much energy per capita as the United States</u>.

Bermuda's energy consumption is estimated at 12.7 kilowatts per person (kwp), slightly more than the U.S. (12 kwp). Since Bermuda enjoys about the same standard of living as the U.S. this could be expected. Of this per capita consumption, 70% (8.8 kwp) can be considered "external", i.e. expended in the manufacture abroad of goods, and the transportation of people (particularly tourists) and goods to and from Bermuda. The remaining 30% (3.9 kwp) is consumed on the Island, mainly in generating electricity and as fuel for local transportation. While Bermuda's external energy needs are largely out of the Island's control, internal consumption is estimated to be only 20% efficient. This is partly due to inevitable losses inherent in all energy generation, but to a large part it can be traced to factors such as heavy reliance on electricity, absence of adequate building energy performance standards, generous use of air-conditioning, and inefficient steam and water boilers.

3. Bermuda has not yet reduced its dependence on imported oil.

Increased purchasing power with which to pay for higher petroleum prices, inadequate economic incentives for oil alternatives and limited public awareness programs have inhibited Bermuda's response to market signals that have led other western nations to significantly reduce their dependence on foreign oil.

While Bermudians are extremely conservation-minded about fresh water supplies, Bermuda's 7.4 percent annual increase in demand for electricity has gone relatively unnoticed as BELCo has increased capacity to satisfy this demand (see Figure 4.1).

By comparison, the U.S., by 1981, had reduced its oil imports by 21.8 percent and cut total energy usage by 3.4 percent from 1979 levels. Demand for electricity in the U.S. has also stabilised to an annual growth rate of 2.9-3.9 percent over the past five years. Since tourism in Bermuda and the rate of telephone installations have each increased at rates similar to the 7.4 percent increase in energy demand (see Figure 4.1) it is suggested that the rising standard of living and the ability to pass higher energy costs along to non-residents may account for the sluggish conservation efforts in response to higher energy prices. Furthermore, it is possible

that public awareness about energy and potential savings have not been sufficiently promoted through public-sponsored programs and could account for the disparity in consciousness between the two important island resources, water and energy.

4. Bermuda does not have adequate plans for contingency situations nor for orderly resource development.

Although discussion of an emergency petroleum reserve is underway, heavy reliance is likely to continue on the ability of private oil companies to secure imports to Bermuda in the event of a contingency situation. Government has also adopted a policy which relies heavily on increased prices to stimulate the pace of private development for alternative energy supplies, accompanied by sympathetic loosening of import penalties placed on alternative energy devices which are brought into the country.

The summary of a study recently commissioned by BELCo suggests that large-scale alternatives to electricity generation from oil are not feasible as yet; the study does not assess the potential for small-scale alternatives.

While a market-oriented energy policy is desirable, certain contingency planning and resource assessment measures must be developed under Government auspices in conjunction with private industry. Relinquishing this authority entirely to private enterprise exacerbates the real threat of "public vulnerability" to energy price and supply disruptions for which Government will eventually be held accountable.

5. The Conference recommends inplementation of an Energy Contingency Plan and an Energy Resource Plan to prepare Bermuda for short-term and long-term changes in energy supply.

The ENERGY CONTINGENCY PLAN aimed at meeting short-term supply disruptions, will have to combine the following:

- Stockpiling of petroleum products by Government to supplement reserves held and agreements worked out by oil companies.
- Preparation of simple, fair, decentralised, preferably free market procedures for energy rationing including a "white market" option (i.e. free selling and buying of coupons by consumers).
- Emergency conservation measures to reduce energy demand in the face of an oil shortage.
- Provision for withdrawal from all emergency measures as soon as the emergency is over.

The ENERGY RESOURCE PLAN, aimed at the orderly development of indigenous energy resouces and a reduction of the country's dependence on petroleum imports, should be based on the following:

- An ongoing program for implementing, demonstrating and monitoring alternative energy technologies. It is suggested that, at this time, technologies for solar thermal energy, waste heat recovery and solid waste recovery are ready for implementation; wind power and photovoltaics are ready for demonstration, whereas Ocean Thermal Energy Conversion (OTEC), wave and nuclear technologies should be monitored for potential applicability to Bermuda.
- Continuation of the current policy of limiting the size and number of cars, and similar steps to increase fuel efficiency in transport while monitoring emerging technologies (e.g. electric cars, public rail transit) that would be both energy-saving and environmentally acceptable.
- Creation of a "Buildings and Communities Committee" which, along with a technical advisory panel, would provide advice to Government and private industry on ways to improve energy use in this sector.
- A vigorous program to promote energy awareness and conservation, with the aim of teaching Bermudians to view energy the same way they have tradionally viewed freshwater: as an expensive, limited resource.
- A broader charter (and new name) for the existing "Energy Conservation Committee" including formulation and implementation of the policies suggested above.

B - ENERGY CONTINGENCY PLANNING

The aim of any contingency planning is to meet problems that emerge at short notice and are due to factors that are essentially unpredictable and beyond immediate control. Short run energy problems, arise from supply disruptions. In this section we discuss the nature of these problems and strategies to mitigate the cost of such a disruption. Planning for these contingencies is based on intermediate-level events. For slight disruptions, for example 10% of the usual supply, there is enough slack in the system that it would be best just to "muddle through." On the other hand, if the supply disruption is too large, for example 50% or more, whatever contingency planning was accomplished ahead of time might be largely irrelevant. Such an extreme event would have impact not only on Bermuda, but on the world, on the tourist patterns, and probably would involve at least limited warfare. The planning options discussed below are not designed for such an event.

As background for short run policies, it is important to assess the current situation. Bermuda imports nearly 100% of the energy consumed on the Island in the form of petroleum products, at the rate of 1.5 million barrels per year. The combined storage capacity for refined products provides for six months consumption when full, but averages half full at any particular time. That means that the average storage of products on the Island is on the order of three months. However, at any given time, the stocks could drop to as low as ten days' consumption.

Bermuda is a member of the International Energy Agency (IEA) apportioning scheme, a voluntary arrangement administered by many of the major oil companies. Should a significant supply disruption appear in the world market, the proposed scheme provides for oil

companies to allocate product to each of the consumers on an equal percentage basis. That is, if the world-wide supply shortage is 15%, then Bermuda could be expected to get 85% of its usual supply of products. Assuming Bermuda can rely on this arrangement, it has significant implications for stockpiling strategy. No matter how large the stocks held by Shell and Esso Bermuda, the IEA arrangement acts to even the flow and therefore would affect only the delivery date of the first shipment. This means that additional storage by Shell and Esso would serve no more than to extend the first date of delivery, at which point Bermuda would start the steady state 85% regime.

A possible way to circumvent this lack of incentive is to have stocks that are owned by the Bermudian government, and therefore external to the IEA apportioning scheme. The cost of government-held stocks is a relatively small proportion of the price of oil imported. If one were to sum all annualised costs for an additional thirty days consumption in above-ground storage, assuming suitable storage sites could be found, the sum is equivalent to a 50 cent per barrel premium on imported oil, or 1 cent per gallon. This additional thirty day storage is equivalent to about 10% of the annual consumption, and the 50 cent per barrel premium for such an additional 10% would be applied to the entire amount imported. There are, of course, many issues regarding the method of raising such a revenue. One could apply an additional tariff to imported products; however, some products might be treated differently from others, in which case the tariff on certain products would be higher than the 1 cent per gallon.

Bermuda's relatively small size and low consumption make its energy policy different from North American and European countries. It is so small that one can argue the oil required to maintain it could be hidden by bureaucratic maneuvering and thus protected by friendly nations for strategic or other reasons. This indicates that one solution to any short-term energy supply problem is through bilateral or international agreements in addition to the IEA association.

The other half of the contingency planning problem is allocation in the event of a disruption. The United States have been through two serious disruptions and have instituted much of the allocation infrastructure. Several lessons have been learned.

1. In a disruption, one seldom knows the extent and duration until it is over. An important principle is to prepare for a disruption by buying as much flexibility as possible. Given more time to evaluate the situation and to gather consensus, one can presumably make better decisions and allay panic.

2. Decentralise decision-making as much as possible. Free markets usually work better than government allocation schemes.

3. Be fair. The more predictable and equitable (at least perceived), the better the public reaction and the less hoarding.

4. Should the rationing of petrol or other products be instituted, the scheme should include a "white market" option. That is, consumers should be able to buy and sell coupons on an open market. This allows for a much greater economic efficiency and equity.

5. Plan ahead as much as possible. Constructing emergency measures ahead of time and delegating authority to a person or group in charge of energy releases the Premier from energy management decisions, insulates him from quarrels over allotments, and frees him to place his effort on other fronts such as

international arrangements.

6. Institute transportation policy carefully. This is discussed in more detail in the section on long run options.

7. Withdraw gracefully from whatever emergency actions have been taken once the supply disruption is over. It is tempting for governments to continue control over what previously had been market processes, even when the emergency has passed.

Conclusion

Bermuda is fortunate to have many assets that affect its energy policy. Its climate and geographic size make the demand for heating, cooling and transportation less stringent than for other countries. Its small size means that government, public interest, and private representatives know each other and are in better communication. Decisions are made with fewer people, and bureaucratic structure is simplified. These advantages mean that Bermuda need not rush into formalised government action; however, energy supply is a serious concern, and some planning for potential disruptions should be initiated now as has been suggested above.

C - ENERGY RESOURCE PLANNING

The aim of energy resource planning is to provide for orderly development of alternative resources as they become technically and economically viable, with the long-range goal of diminishing the country's dependence on petroleum imports and the accompanying vulnerability to supply disruption. Ideally, energy resource planning would lead to a sustainable balance between demand and supply, the latter largely from indigenous sources, and would significantly reduce the need for contingency planning.

Conference participants considered eight alternative energy sources, in addition to energy conservation and energy use in buildings and transportation. The main criteria and recommendations are summarised in

Table 1
<u>Availability & Applicability</u>

Supply Alternative	Commercial availability	Applicability to Bermuda		
		Now	5 years	long term
Solar Thermal	yes	*		
Waste Heat Rcvry.	yes	*		
Resource Recovery (solid waste)	yes	*		
Wind	yes		*	
Photovoltaics	yes		*	
Wave	no			*
OTEC	no			*
Nuclear	no			*

Tables 1-3. Technologies were evaluated primarily on the basis of technical maturity and commercial availability rather than cost since it was felt that a detailed cost-benefit analysis was beyond the scope of the Conference. Applicability of a specific technology to Bermuda was then expressed in three time frames ("Now", "In 5 years", and "Long-term", see Table 1).

Potential problems and barriers associated with the use of alternative energy sources were reviewed (see Table 2) to determine whether these options should be recommended for:

- o Implementation -- primary purpose to remove institutional barriers and create incentives; secondary purpose to evaluate performance
- o Demonstration -- primary purpose to evaluate performance; secondary purpose to remove initial barriers if applicable, or
- o Monitoring -- primary purpose to maintain options for future demonstration or implementation through a continuing review of the performance and applicability of technologies

Table 2
Problems & Barriers

Energy Options	Cost	Technical	Planning	Servicing	Acceptance	Other
Solar thermal	**		*		*	
Waste heat recovery	*	*		*		(1)
Resource recovery	*	*	**	**	*	
Wind	*	*	**	**	**	
Photo-voltaics	**		*		*	
Wave	**	**	*	*	*	
OTEC	**	**	*	*	*	
Nuclear	**	*	**	*	**	(2)

Problems: ** Major * Minor

Notes:

(1) Unresolved policy for potable water production

(2) Perceived resistance by Bermuda to nuclear energy

In making the recommendations and approaches to alternative energy sources (see Table 3) specific consideration was given to the associated energy costs; the state of system development; existing institutional barriers; existence of a potential servicing infrastructure; and public awareness.

Table 3
Recommendations & Approaches

Energy Option	Recommendation	Approach
Solar thermal	Implement	Commercialisation & promotion Housing co-op. loans Tax incentives Govt. sponsored projects Revised building codes Rental commission Rate structure Education
Waste heat recovery		
- water production	Implement	Establish policy Proceed with project
- power generation	Implement	Recommend plant design
Resource recovery	Implement	Solve planning problem Monitor state of re-cycling
Wind	Demonstration	Obtain planning/zoning approval Install/monitor 100 kw system
Photo-voltaics	Demonstration	Install/monitor 5kw residential system Monitor state of re-cycling
Wave)		
OTEC)	Monitor	Review state of the art and performance
Nuclear)		

Energy Conservation. Energy savings produced through conservation are abundant (only 20 percent of all Bermuda's available energy is put to useful work), inexpensive ($10-25 less than an equivalent barrel of oil), and have been shown to make an enormous contribution to economic growth (97 percent of all growth in the U.S. between 1973 and 1978). Because energy produced through conservation necessitates the involvement of a relatively large, disaggregated group of energy users, to maximise conservation savings requires continuous and innovative programs. Promoting energy efficiency (=conservation) is dependent on a number of social, economic and political variables, however, of which two fundamental elements must be considered.

First, private citizens and business must be made aware of energy mismanagement; of the potential that exists to improve energy use; and that improving efficiency will, directly or indirectly, result in savings of both energy resources and money.

Second, energy users must be informed of specific remedies or actions they can take to achieve these savings. Public awareness and information campaigns can take several forms using many different media. Most effective are those programs which address major energy users and uses and which are dramatic enough to leave a lasting impression on the viewer, listener or reader. Like any advertising campaign, promoting energy conservation must be specially tailored to the audience as well as to the product.

Raising public consciousness and the level of education regarding optimal energy use is often not enough to induce energy users to make simple changes in lifestyle or investments in conservation measures. The question of "conservation incentives" or "use penalties" is then raised as the means not only to promote but implement energy production through conservation. Because the

most significant and painless energy savings are realized through the initial public awareness and information campaigns, the conferees believe that "incentives" or "penalties" may be deferred at this time but that the Bermuda Energy Committee should not rule out such approaches and should in fact thoroughly investigate their need and potential for leveraging additional energy savings at some later date.

In the meantime, it is the specific recommendation of the conferees that the name of the "Energy Conservation Committee" be changed to the "Bermuda Energy Committee (B.E.C.)" and that the Energy Committee vigorously implement a program of public awareness and information while studying the possibility of later recommending incentives or penalties.

Buildings and Communities. Because of the high proportion of energy used in buildings and community systems and the real potential within this sector to make substantial energy savings, the conferees recommend that a 7 member "Buildings and Community Committee" be organized to provide professional and technical assistance for optimising energy use in these areas. It is suggested that the committee consist of private sector representatives and include architects (2), mechanical engineers (2), a builder /contractor, a community leader, and a building energy specialist who should act as chairperson.

It is further recommended that a panel of three foreign experts be retained to advise the Buildings Committee on the latest international developments in architectural and community design, engineering, and building materials specifically as they relate to increased energy efficiency.

It should be the specific task of the Buildings Committee and the advisory panel to educate the public about energy saving processes and technologies for all buildings and community systems; promote the design and construction of energy-responsive new buildings; encourage the retrofitting of existing buildings with energy-saving techniques and devices; promote the establishment of support services for maintenance and development of appropriate energy systems; survey, analyse and recommend cost-effective energy systems which may be used by private developers; solicit assistance of key agencies and personnel in the private and public sectors; and coordinate all such programs and activities with those of the Bermuda Energy Committee.

Transportation. Because of the Island's reliance on motorbikes and small cars, the limitations on the number of cars, and the short driving distances, Bermuda's transportation system is already relatively fuel-efficient. Since all transportation fuel is imported, however, it would be desirable to reduce the system's dependence on oil. While rail transit and electrified vehicles provide increases in fuel efficiency, much of the benefits from these transportation alternatives have environmental rather than energy-related benefits. The application of non-technological strategies such as excise taxes, use incentives and consumer awareness programs should also be considered for the transportation sector. Whatever approach is taken, it should be cautious and enhance rather than interfere with the Island's main source of foreign exchange: its attractiveness as a tourist resort.

THE WORLD AND U.S. SITUATION

1- WORLD ENERGY OUTLOOK

Gary C. Barbour

To begin this investigation of Bermuda's energy future, it is appropriate to look first at the history of world energy supplies, and then to review the major energy options for the 1980's. In that any discussion of future petroleum price and supply scenarios must be approached with caution, this statement is necessarily simplistic in its treatment of some of the more complicated yet important aspects of world energy supplies. Nevertheless, a basic understanding of trends in the world energy scene is important not because Bermuda is a major player in the politics of international energy, but rather because Bermuda needs to develop a degree of energy security within an economic setting which otherwise finds the nation heavily dependent on foreign goods and capital. A more complete and detailed description of policies and technical aspects of energy in the 1980's will be presented in following sections.

Shortly after World War II, petroleum replaced coal as the predominant source of energy for developing nations of the world and increased steadily in use for nearly 20 years. Between 1947 and 1960 world petroleum consumption rose from 8.2 million barrels a day to 21 million barrels, ultimately comprising 34 percent of the entire demand for energy (from a percentage share of about 15 percent in 1947). Consumption of petroleum during this period escalated from an annual growth rate of 6.6 percent during the population boom of the 1940's and 1950's, to a growth rate as high as 8.0 percent during the 1960's.

Our growing appetite for petroleum raised the concern of geologists who in 1970 reported that the world was approaching a period in which available supplies would not satisfy growing demand, creating isolated, and later more extensive, petroleum shortages. To illustrate the concept of petroleum as a depletable resource, geologists pointed out that half of the oil that was ever produced, 200 billion barrels, was taken from the ground in the past ten years whereas the first 200 billion barrels of world oil had required 111 years (1857-1968) of production.

Despite the uncertainty in calculating the exact amount of potential reserves, it was clear by 1970 that petroleum was a finite resource and that our remaining reserves should be carefully consumed to "buy time" for the eventual discovery of an oil alternative.

While supply scarcities due to resource depletion were admittedly a long-term concern of geologists, a more immediate problem emerged in 1973 when political leaders within several Arab oil producing countries staged a boycott of petroleum sales to the U.S. through the formation of an international oil cartel. Since the formation of OPEC, The Organization of Petroleum Exporting Countries, the chief concern of oil consuming countries has not been demand restraint due to resource depletion; instead, price and supply interruptions have dictated energy use and directed world energy policy.

OPEC still controls 68 percent of the free world's petroleum reserves and has, since its formation, increased crude oil prices from $1-3 per barrel in 1973 to $30-35 per barrel in 1980. The economic ramifications of these price increases, along with subsequent supply disruptions from Iran (1979), imposed severe economic hardship not only on industrialised nations but on developing countries of the world as well. Price increases of over 1000 percent in a seven year period contributed substantially to spiraling inflation world-wide, increased international balance of payment deficits in favour of OPEC countries, and exacerbated unemployment in energy-intensive communities. Although demand for OPEC oil leveled during the 1970's and, at this writing, is declining further, energy experts remain concerned that record-setting oil exploration in the U.S. has failed to yield petroleum reserves in quantities large enough to cover production expenses, let alone in quantities significant enough to displace the Middle East as the world's leading oil supplier. Nevertheless, aggressive oil and natural gas exploration is being pursued in all parts of the globe, yielding fewer and fewer major oil discoveries.

Moreover, oil experts believe that regardless of the prices established by OPEC, their production capability (approximately 34 million barrels per day) cannot satisfy world demand if the growth rates of the 1960's re-occur in the 1980's. To do so would require the discovery of another Kuwait or Iran roughly every three years, or another Texas or Alaska every six months. What then do the 1980's portend for the world energy outlook?

Energy analysts are nearly unanimous in their belief that petroleum will continue to comprise the bulk of our energy supply, but that reduction in the demand for all energy, particularly petroleum, is imperative. Experts concur as well that coal, nuclear and renewable energy sources such as solar, wind and hydroelectricity will gain as contributors to the world energy supply, but are not likely, in this decade, to make up the supply deficit.

The production of synthetic fuels from coal provides enormous potential for utilising the U.S.' most abundant energy resource (coal) for more diversified use as a liquid fuel. Commercial quantities of synthetic gas are already available (about 500,000 BOE), as are limited quantites of heavy oils. Significant environmental problems regarding the processing and disposal of toxic by-products have recently raised concern, however, and threaten to delay production targets in the

U.S. of 2 million barrels of crude oil by 1992. The availability of water with which to refine synthetic coal products is another unresolved impediment facing synthetic fuels production. To cloud the future further, a growing number of energy insiders believe that while environmental concerns may delay production, economic and technical limitations also make these synfuel goals optimistic at best. For nations not possessing indigenous coal resources, synthetically produced oil is not an alternative as U.S. production is likely to be consumed domestically.

Nuclear energy, highly touted during development in the 1950's and 1960's, suffered several setbacks with commercial applications in the U.S. but expanded significantly in France, Spain and several other countries. Facility construction and siting, increasing cost of materials and labour, along with concerns about waste disposal and international nuclear proliferation halted construction of conventional fission reactors in the U.S. and severely reduced progress in other countries such as Japan, Canada and West Germany. Fission energy, as used in existing power plants should, nevertheless, provide a stable increment of power in the 1980's and may increase slightly depending on the economic status of energy utilities and the political climate surrounding nuclear proliferation issues. In those nations where government agencies have strongly encouraged nuclear development ambitious goals of 50-80% of total energy supply are likely to be achieved by nuclear technologies in the 1980's.

Renewable energy technologies such as direct and passive solar thermal energy, electrical generation from the sun (photovoltaics), wind energy and hydroelectricity have all reached relative technological "maturity" in the laboratory and await economic incentives to catalyse full-scale market deployment. Virtually every industrial nation,

particularly the U.S., Canada, Japan and West Germany, already have invested heavily in renewable energy sources and have now nurtured domestic and international industries for these non-conventional energy technologies. Other nations such as Norway, Sweden, Mexico, Great Britain, Saudi Arabia and many developing countries are assessing their own resource potential for renewable power applications which promise to provide economically attractive and, more importantly, indigenous sources of energy. These technologies will be discussed in more detail in later sections.

Perhaps the most immediate, abundant and economic source of energy in the 1980's will be in the form of energy saved through conservation. Inexpensive home improvements and the utilisation of energy-efficient automobiles and industrial devices can produce energy at an equivalent per barrel cost of $8 to $25 compared to the current average world oil price of $35 a barrel. Energy experts are beginning to concede that the individual conservation actions taken by energy consumers at work and in the home will easily out-produce any other central energy supply in the coming decade. Such may be the case in the U.S. where between 1973 and 1978 twice as much energy was produced through conservation than will be provided by synthetic fuels by 1985. Moreover, 97 percent of the U.S. economic growth during this five year period was fueled by energy savings, and only 3 percent by new energy supplies. Still, impediments do exist in utility rate-making and public awareness which limit the potential for energy conservation.

In all, the basic trends in world energy point to a future of continuing uncertainty and potential adverse economic ramifications fueled by overdependence on foreign-controlled energy sources. Although crude oil is likely to continue as the world's predominant energy source, adverse impacts from foreign dependence can be lessened if we reduce the growth of energy demand, particularly consumption of petroleum, and promote the application of indigenous supplies which provide convenient and economical sources of energy. To ignore the realities of continued dependence on a diminishing and foreign-controlled source of energy invites financial and social chaos for which we will have only ourselves to blame.

2 - THE WORLD OIL MARKET

John C. Houghton

One of the major events in the United States in 1970's was the realisation of its vulnerability to the world oil market. Two supply disruptions increased the price by several multiples, affecting unemployment, inflation, Federal government organisation (creation of the Department of Energy), and the design and purchase pattern of a vast array of products and services. The potential problems with oil supply are perhaps worse for the 1980's than the 1970's. A recent report by the Congressional Budget Office estimates that if Saudi Arabian production were to be halted completely for one year, it could cost the economy of the United States over 250 billion (thousand million) dollars, increase unemployment by 2%, and boost inflation by 20%. The seriousness of the problem is reflected by another source: Jimmy Carter, while President, spoke openly of possibilities of war to secure oil routes in the Gulf, and President Reagan appears at least as adamant. These facts should be of equal concern to Bermuda. The United States imports roughly half of the oil it consumes and has extensive holdings of other fuel resources, including coal. By contrast, Bermuda is nearly totally dependent on oil imports for its energy needs. It must be said, however, that Bermuda is very small and can survive on small quantities of oil, compared with the United States.

The structure of the world oil market, the impact of disruptions and price rises on the U.S. economy, and other related topics are reviewed in recent publications. This paper will treat current predictions of oil price projections in order to establish a reference against which some of the alternative energy sources can be evaluated. The implications for Bermuda's energy strategy will be discussed briefly; some of the issues also appear in the section on Contingency Planning.

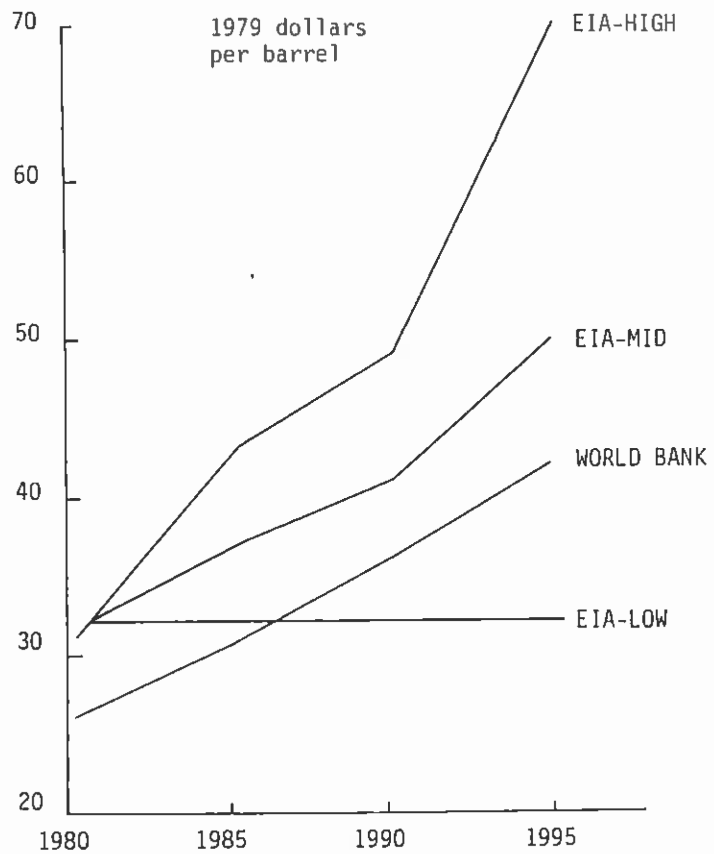


Figure 2.1. WORLD OIL PRICE PROJECTIONS (source: U.S. Department of Energy, Energy Information Agency, Annual Report to Congress 1980).

World price for oil is not determined on the basis of cost. Production cost for oil in the Middle East is on the order of a few dollars per barrel, considerably less than the more than 30 dollars per barrel currently received. The price is high due to monopoly pricing; OPEC is able to constrain production so that

marginal demand and marginal supply are out of equilibrium. This cartel behaviour makes prices especially difficult to predict. If the cartel collapses, the price of oil could drop precipitously. However, the cartel has continued to remain remarkably stable for nearly a decade, and many of the internal incentives to disrupt it seem to be weakening. The world oil price, although very uncertain and difficult to forecast, is likely to increase.

Figure 2.1 shows price projections made by both the U.S. Department of Energy and the World Bank. Both institutions would claim that these projections should be considered more as 'operating assumptions' than as results of strict modeling efforts. Both institutions' projections are based on constant 1979 dollars and start with a 1980 price of around $30 per barrel. Both the Department of Energy mid-projection and World Bank projection rise at a rate of around 3% a year for at least 10 years. The high DOE projection predicts $70 per barrel in 1995 and the low projection predicts no change. One should note the Department of Energy has offered an odd number of scenarios. This is a customary trade-off in Washington analysis. Analysts indicate uncertainty by displaying several scenarios even though decision-makers often choose the central scenario for actual decision-making. In fact, there is a great deal of variation in world price projections. The variation is a function not only of the modeler, but also of assumptions about other factors such as economic growth, effectiveness of conservation, non-OPEC production, nuclear power, and future disruptions.

There are other forecasts of world oil price. The institutions that perhaps know the future price of oil better than anyone else are the major oil companies. They are, unfortunately, unable to even informally discuss such projections due to anti-trust considerations in the United States. Another collection of price projections is presented by the Energy Modeling Forum, which is a process by which energy modelers are able to compare modeling methods and results. Although the latest results of world oil prices are still in draft form, using identical assumptions about geologic reserves, sensitivity of demand to price, lack of disruptions, and so forth, the ten different models produced results that ranged from a real price in 1980 dollars of $30 to $80 per barrel in the year 2000.

With all of the information from the Department of Energy, the World Bank, and the ten modelers associated with the Energy Modeling Forum, it is fair to make conclusions. One is that there is a high variation in the estimates, and if one were to choose the modeler and the assumptions properly, one could find practically any projection desired. The second is that, having emphasised the variation, a middle ground can be generated that predicts $30 oil in 1980 rising to $50 oil in 1995. Most would assume that this would not be a smooth increase, but would happen in quantum jumps with perhaps decreasing real prices in between.

There is an additional problem in setting a reference price against which the alternative energy strategy should be compared. Everything else being equal, one would prefer to generate energy using local sources and Bermuda dollars rather than importing foreign oil and spending dollars that flow directly out of the country. The advantages local sources provide are that Bermuda, as a country, can be more self-reliant, and that balance of payments is improved, with corollary improvements in inflation and unemployment. While analysis has been done on import premiums in the United States, such an analysis would be difficult to perform for Bermuda. One might speculate, however, that the value of the import premium would be a substantial fraction of the price of oil -

perhaps as much as a half of the price of a barrel.

What, then, are Bermuda's energy policy alternatives? In the long run, the real price of energy is going to rise and stress the economy. This should be counteracted by supply augmentation and demand reduction. Both of these issues are discussed in detail in the sections on Energy Resource Planning.

In the short run, the problem is not price increase, but supply disruptions. Policy alternatives center around a manipulation of oil stocks and allocation, and they are discussed in the section regarding Contingency Planning.

3 U.S. ENERGY POLICY AND GENERAL PRINCIPLES

Lynda L. Brothers

U.S. energy policy serves as a good example for Bermuda because of America's role as a major energy consumer; therefore, its actions affect world energy activities. Secondly, the similarities between Bermuda and the U.S. while not complete may outweigh the differences. Let me outline what I'll call "enduring principles" in U.S. energy policy.

The first enduring principle is to reduce oil imports, reduce vulnerability to supply interruptions or work toward domestically controlled supply sources. This recognizes that oil, as a nonrenewable resource of finite supply, cannot forever be the mainstay of energy production. The policy is essentially bipartisan in the U.S. having been embodied in the Project Independence under President Ford and in the National Energy Plans I and II under President Carter.

The magnitude of the problem of over-reliance on imports is shown by the following chart.

YEAR	IMPORTS million barrels per day	%of Consumption
1960	1.8	19
1962	2.1	21
1970	3.4	24
1972	4.7	29
1974	6.1	38
1976	7.3	43
1979	8.4	47

(Costing about 2% of GNP-$50 billion)

(Source: Strobaugh, Yergin, Energy Future)

This chart shows the trend in the 1970's, in spite of the 1973-74 oil embargo, toward increasing dependence on imported oil both as

a percentage of consumption and in the average volume of oil imported.

A more recent statistic, however, shows a decrease in the level of imports.

Weekly Petroleum Status Report

April 17, 1981

Week ending April 10, 1979 8.27 million BPD (Barrels per day)

Week ending April 10, 1980 7.5 million BPD

Week ending April 10, 1981 5.375 million BPD

U.S. Department of Energy

Source: Energy Information Administration

Also, average 1981 oil imports are down 32 percent from 1980 comparable time periods.

Why is it so important to reduce oil imports? The U.S. is spending approximately $10 million an hour on oil imports. It is difficult to have any balance of trade or budget with such an economic strain. Also, because of concentrated control of oil by a few countries, stability of supply is uncertain and closely related to political stability. Military defense in U.S. also requires a sure source of oil.

The second enduring principle of U.S. energy policy relates to energy conservation. Conservation is generally considered the cheapest, fastest and easiest energy alternative. Conservation actions include improvements in energy efficiency of buildings, vehicles and industrial equipment. Some conservation requires capital expenditure while some requires only behavioural changes. For example, replacing a turbine or a boiler for increased efficiency could be deemed conservation and requires a capital expenditure, whereas turning down the thermostat on room heating and putting on a sweater are behavioural actions. In other words, conservation involves cutting energy waste wherever possible.

Generally, energy conservation has required public awareness in the U.S. The oil embargo in 1973-74 is frequently credited with increasing public awareness. Coupled with the attention of national leaders this has resulted in significant energy conservation in the U.S. For example, U.S. Department of Energy (DOE) figures from the National Energy Plan II (1979) show that energy consumption growth rates are substantially reduced when averaged over the five years after the oil embargo, compared to previous periods.

Energy Consumption Growth Rates
% per year average

	1950 - 1973	1973 - 1978
Overall	+3.5%	+0.9%
Residential/ Commercial	+4.1	+2.6
Industrial	+3.1	-1.2
Transportation	+3.3	+1.7

These figures illustrate the rapidity with which conservation measures can be felt throughout the American economy.

The approaches to conservation are numerous and will be addressed in other chapters. In the U.S., public awareness has been an important factor but also creation of cost incentives and removal of various

disincentives and institutional barriers have been important.

The third enduring principle relates to energy supply and is called diversification of energy supplies. In the U.S. this policy is actually revealed in numerous activities. We are attempting to take advantage of our abundant natural resource, coal. Conversion to coal is embodied in various statutes and regulatory actions aimed at converting oil burning power plants to coal burning. Also, we are attempting, through the alternate liquid Fuel Corporation and other mechanisms, to encourage the development of synthetic fuels. We have oil shale reserves in the U.S. which will be developed very soon. Recent legislation established the goals for synthetic fuels at 500,000 barrels per day in 1987 and 2,000,000 in 1992.

The principle of diversification is also embodied in the U.S. goal for solar energy. The previous administration established a goal of 20% of U.S. energy use to be provided from solar sources by the year 2000. This includes all solar sources including biomass and hydroelectric as well as direct solar, photovoltaic, wind power, energy from waste, ocean thermal energy conversion and others. In 1977, 4.2 quads (quadrillion BTU's), or 6 percent of U.S. energy, was supplied by solar (mostly hydropower and biomass). DOE estimates that a base case of 9.9 quads and a maximum of 18.5 quads could be achieved by 2000, and considers 28.5 quads the technically limited possibility.

Other forms of diversification in the U.S. include some role for nuclear energy and attempts to enhance domestic oil and gas production. Many aspects of diversification are regional.

Bermuda, of course, has a much smaller natural resource base. Obviously, sun is abundant here, as is wind. Some use of what would otherwise be waste might also be indicated. As the technologies develop Bermuda's most abundant resource will be the surrounding ocean with waves and thermal energy options.

The implementation of a policy aimed at diversification of energy supplies is dependent upon which resource is being encouraged. In the U.S., because of the extreme size, diversity and different jurisdictions, numerous approaches are being applied. Federal (and industrial) funds for research and commercialisation are helping to speed the development of new and emerging technologies. The imposition and, where appropriate, removal of regulatory controls is also important. Gasoline price decontrol is a recent example of this approach. Tax incentives for business and individuals are also proving effective. Financial support can also take the form of loan guarantees, purchase commitments, price supports and a variety of other approaches.

The <u>fourth and last enduring principle</u> is more difficult to trace directly to U.S. policy and <u>is called</u> "<u>matching</u>", that is to match the energy quality to the end use. It is indirectly tied to numerous components of U.S. energy policy. Matching means at least three things. First, and most obvious, it includes the appropriate match of thermodynamic quality of energy to end use. Second it means matching local resources to local uses. If, as in New England, one has abundant firewood and abundant need for home heating, then match the wood resource to the use. Third, type, kind, or quality matching is included: if you need liquid fuels, no surplus of solid fuel or electricity will suffice.

The <u>final point</u> I would like to discuss <u>is implementation</u>. Implementation of energy policies in the U.S. has some very obvious components, and some more subtle aspects. Obvious approaches in the U.S. include use of research funds to accelerate development of

new technologies, such as fusion energy, or electric vehicles. A second major tactic is the use of income tax incentives and the removal of disincentives. An important approach in the U.S. is in the area of public information. For example, major efforts in conservation have already proven quite successful. Other incentives relating to costs and prices are available and some of these are used by government. Implementation of energy policy in the U.S. is often left to the states. State options, which often differ from Federal actions, include local zoning rules, permit approvals etc. Ensuring that all the levels of government, Federal, state and local, and all types of incentives, taxes, pricing, and public pressure lead to the fulfillment of an energy policy is a difficult but vital task.

THE BERMUDA SITUATION

4 - ENERGY USE IN BERMUDA

A. C. Hollis Hallett

The Bermuda Islands contain some 21 square miles of land at 32° 18' north latitude, 568 nautical miles east of Cape Hatteras, North Carolina, the nearest point of the North American coastline. The Gulf Stream which passes between Bermuda and the continent is a moderating influence on the Island's climate characterised by high humidity, mild winters and only moderately hot summers. The Census of 1980 gave the resident population as 54,670 (corresponding to a very high population density of about 2,600 per square mile). In addition, approximately 600,000 tourists visit the Island each year.

Bermuda's only natural resources of consequence are its beauty, its climate and the friendliness of its people, which combination is marketed abroad through its tourist industry. The Island has a network of hotels and guest houses to cater to this industry and attempts to provide high quality resort service for its visitors. The second mainstay of the economy is the so-called exempted companies, predominantly financial management houses and insurance companies which do business outside the Island from an office within. These require the support of sophisticated banking, accounting, legal and communication services.

On occasion the Island's small farming capacity will produce a sufficient quantity of a vegetable or a fruit for a short-term supply of the local needs resulting in a temporary embargo on importation of the particular item. The local fisheries industry rarely satisfies more than a fraction of the demand. Several quarries provide stone for building purposes, and there is sufficient wood for fireplaces which often are the only form of residential heating.

Aside from this, Bermuda relies completely on imports for all local needs in food, clothing, building materials and fuels, to say nothing of appliances, transportation equipment, luxury items and other goods and services. These imports are paid for by the foreign currency earnings of the tourist industry and exempt company business.

Bermuda has been very successful in managing its economy, and has recently been placed 18th in the World Bank's list of nations in descending order of Gross National Product on a per capita basis. This success has resulted in a very high standard of living, and virtually no unemployment.

Bermuda had reached this elusive state by a process of growth as shown in Figure 4.1 Here, a number of factors have been plotted on a logarithmic scale against time, from 1920 to 1980. Such a plot has the advantage that if a quantity increases annually by the same percentage, the graph is a straight line. It can be seen that the capacity of the Bermuda Electric Light Co. (BELCo) has increased at the rate of about 7.4% per annum (which means a doubling in 10 years) and now stands at about 100 megawatts. The other major public utility (The Bermuda Telephone Company) has increased the number of telephones in service by about 8.5% per annum and now stands at about 45,000.

On the revenue-producing side, the number of tourists have increased by 7.8% per annum (now at about 600,000 per year), and the Government's revenue from customs duties (the largest single contributor and estimated for 1981 to 1982 to be about 45% of the total) has grown by 9.1% per annum to close to $40 million (uncorrected for currency value changes).

By contrast, the resident population has only increased at a rate of 1.6% per annum. There are signs in the curves that the high rates of

growth are now slackening, or have been slackening since the mid 1970's, and an important unknown in planning the future is the growth rate that can be expected for the

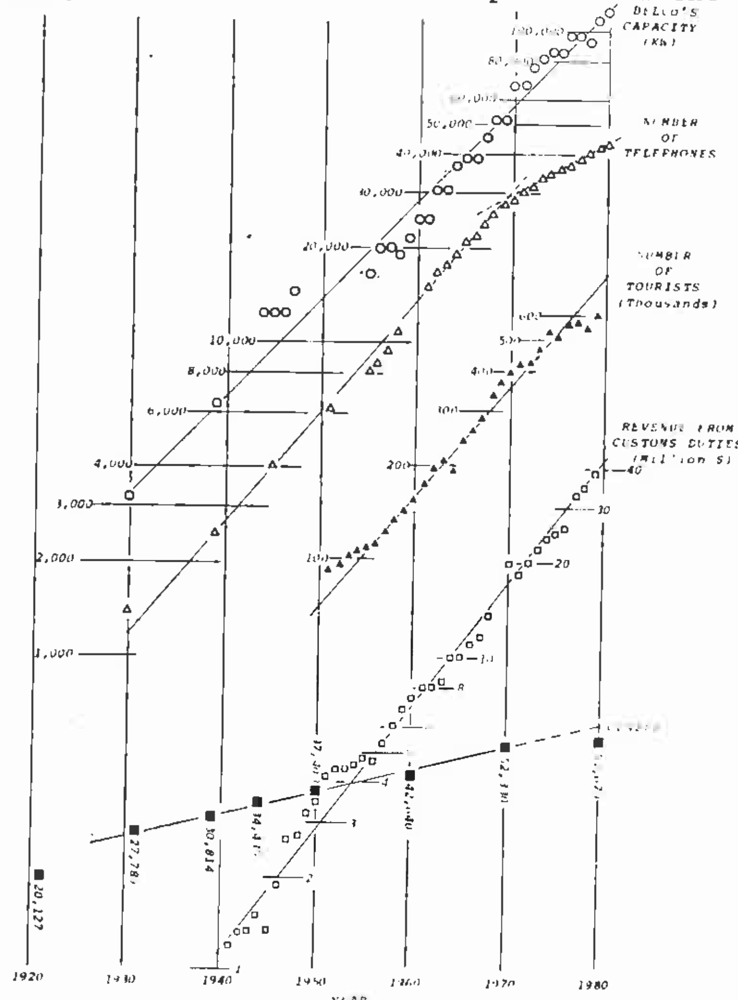


Figure 4.1. Economic indicators compared to population, 1920-1980 (from Hayward et al., eds., Bermuda's Delicate Balance).

eighties. BELCo itself (as reported in this conference) is planning on a future growth rate of about 2% per annum, and the natural limits on the size of the Island may well limit other factors similarly.

It is possible to make estimates of the rate of energy consumption of Bermuda residents. The energy consumed falls into two categories: the internal represents the amount used by residents within the Island as they go about their daily business; the external represents the equivalent rate of consumption arising from the manufacture of goods and services which must be imported, and the transportation necessary to bring to the Island both these goods, and the tourists on which the economy so largely depends. The figures, expressed in kilowatts per capita (kwp), are as follows:

INTERNAL:

Food	0.5 kwp
Wood, Charcoal etc.	trace
Petroleum Fuels	3.3 kwp
LPG (liquified petroleum gas)	0.1 kwp
Total	3.9 kwp

EXTERNAL:

Manufacture	4.7 kwp
Transport	4.1 kwp
Total	8.8 kwp
OVERALL TOTAL	12.7 kwp

The figure for food is based on the U.S. figure. Those for petroleum fuels and LPG (liquified petroleum gas) are taken from the 1977 Report of the Bermuda Government's Energy Conservation Committee, and do not include the amounts which are brought in and re-exported by sale to aircraft, ships etc. In the external category, the figure for transport should

be reasonably accurate since it is a calculation based on the regular schedules of ships and commercial airlines and includes the energy used to bring a vessel or plane from its port of origin and return. The figure for manufacture is the most uncertain on the list as it is a very crude guess based on a similar break-down for the U.S. It needs further study.

The final total of 12.7 kwp compares with the U.S. total which is very nearly 12 kwp and is very much higher than the world average of 2 kwp. Bermuda is thus an enormous energy consumer per capita of its population.

The energy which is used locally and internally is almost all in the form of fossil fuels and is imported. Diesel fuel, gasoline and fuel oil together amount to an importation of about 1.1 million barrels per year. The other significant quantity is Liquified Petroleum Gas (LPG), amounting to about 40 thousand barrels equivalent per year. The oil total is about 72% Diesel Fuel, 17% Gasoline, and 11% Fuel Oil. In terms of end use, the distribution of these fuels is as follows:

Diesel Fuel		Gasoline		Fuel Oil	
BELCo	91%	Retail	69%	Commercial	100%
Retail	2%	Commerical	25%		
Commercial	7%	Marine	6%		
	100%		100%		100%

The Fuel Oil is almost exclusively used by the larger hotels and the hospital to fire the boilers for hot water and steam.

From the above figures it is clear that BELCo is by far the largest user of imported oil, and Bermuda residents rely on electricity for most of their energy needs. BELCo's electricity is distributed as follows:

Residential use	41%
Commercial use	32%
Hotels	19%
Government	8%
	100%

The total flow of imported fuels into the main areas of Household, Commercial (including the Hotels) and Transportation is shown diagramatically in the "pipe-line" drawing of Figure 4.2. Here the imported fuels are shown on the left in units of equivalent kilowatts per capita (Diesel Fuel 2.15, Fuel Oil 0.35, and Gasoline 0.8 totalling 3.3 kwp). The size of the "pipes" is proportional to the quantity of fuel, and they are drawn to show the flow of the fuel to the different sectors.

Another feature has been added to Figure 4.2, namely the amount of the entering fuel which is actually used to do the job intended - called on the diagram "Useful Work" - and the amount which is wasted - labeled as "Waste". Every process which uses fuel to obtain mechanical work has its characteristic efficiency of conversion and the efficiency for most processes is distressingly low. A car, for example, uses only about 25% of the energy content of the fuel for actual propulsion; the remaining 75% is wasted through the exhaust and heating the engine. The drawing has been constructed using the following typical efficiency figures: BELCo 30%, Transportation 25%, Heating in Boilers 75%, Household Use 33%. These may well be still too high for Bermuda's conditions.

A striking characteristic of Bermuda's use of fuels is that most of the processes used here have low efficiency. Thus Bermuda suffers a

larger than usual waste factor - 79% is wasted compared with about 49% for the U.S. Since by far the largest waste is concentrated in one industry, BELCo, it would be sensible to try and extract more useful work out of the waste heat generated from that plant.

A comparison between Bermuda and the U.S. on the end uses of the primary fuel is instructive.

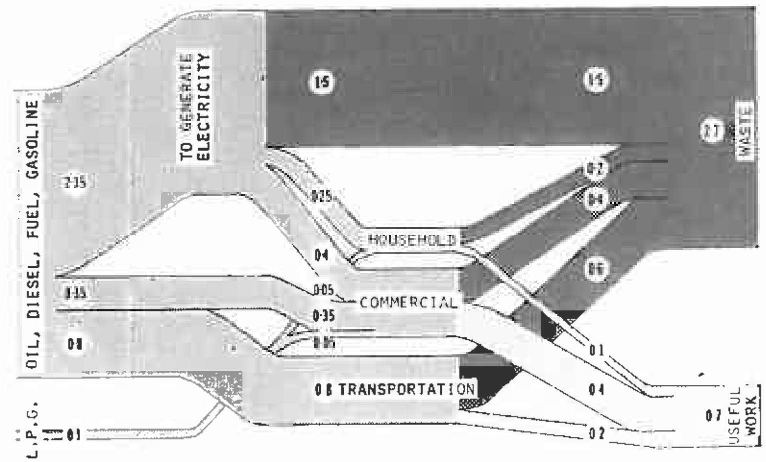


Figure 4.2. Energy conversion from fuels to useful work and waste (from Hayward et al., eds., Bermuda's Delicate Balance).

	U.S.	BERMUDA
Electricity	26%	63%
Household/Commercial	20%	13%
Transportation	25%	24%
Industrial	29%	-
	100%	100%

Of these categories, the Industrial and, to some extent, the Household/Commercial tend to use higher efficiency processes. Industrial blast furnaces (for smelting), heating-treating plants, and boilers can have efficiencies higher than 70% resulting in a more efficient use of fuel, which helps reduce the waste factor in the U.S. but these industries are absent from the Bermuda scene. In the U.S. heating of buildings is a large component of the energy use in the Household/Commercial category and this, again, is virtually absent in Bermuda.

5 - BERMUDA'S OIL IMPORTS

John Carey

This presentation covers the source of Bermuda's oil, the supply of current local demand by major product, a comparison of the cost of current petroleum imports in 1973 terms with today's costs, and finally a look at anticipated 1985 consumption if we do nothing.

Bermuda's bulk petroleum requirements are normally supplied by refineries in Aruba and Curacao, in the Netherlands Antilles. Crude oil sources for these refineries include Venezuela, the Middle East, Nigeria and Mexico. The cost of the crude oil required to produce Bermuda's refined fuels is determined by the producing governments. At the present time, due to the current level of Saudi output, many of the producing states have been forced to remove premiums, or reduce prices, in order to sell their particular crude, in light of the surplus available. Coupled with a perceived worldwide reduction in demand, this has had the effect of maintaining stable prices and reducing the price of fuel oil in Bermuda.

When interpreting the following information it should be kept in mind that (i) the quantities and most of the percentages are rounded off for ease of discussion; (ii) volumes relate to sales and not necessarily consumption, particularly in the case of BELCo; and (iii) volumes used for aircraft and ships bunkers are excluded.

Bermuda's on-island petroleum demand is made up of four basic categories:

- Bermuda Electric Light Company (BELCo)
- Gasoline
- Fuel Oil
- Diesel, L.P.G., Asphalt, Lubricating Oil etc.

COMPARISON OF MAJOR PRODUCT IMPORTS

	1970	1980	%Incr.
BELCo Fuel	420	700	65
Gasoline	200	200	-
Fuel Oil	100	100	-
Diesel, LPG, Misc.	100	100	-
TOTAL	820	1,100	35

While BELCo's volume has increased by 65% over the ten year period, there has been no significant increase in the remaining three categories. It is appropriate, however, to look at the cost of crude over about the same period.

YEARLY OPEC AVERAGE CRUDE OIL
OFFICIAL SALES PRICE

YEAR	U.S. $/BBL. FOB
1973*	3.39
1974	11.28
1975	11.02
1976	11.77
1977	12.88
1978	12.93
1979	18.67
1980	30.87

* The 1973 price is derived from posted prices, which are not official sales prices.

The increase in OPEC crude prices has had a large effect on the cost of products that Bermuda purchased in 1980. The costs exclude taxes, expenses, profit, etc.

COMPARISON OF PRODUCT COSTS (in million $)

1973 vs. 1980
BASED ON 1980 VOLUMES

	1973	1980
BELCo	$3.0	$23.1
Gasoline	1.3	8.5
Fuel Oil	0.3	3.0
Diesel	0.3	2.2
	$4.9	$36.8

This table shows that, prior to the OPEC action and the price increases which followed, our 1980 imports would have cost Bermuda about 5 million dollars based on 1973 prices. The products actually cost an astounding 37 million dollars. By comparison, the Bermuda Government 1980/1981 revised budget was just 127 million dollars.

The next table outlines BELCo's fuel imports, at five year intervals, from 1955 to 1980. During this period Bermuda experienced major expansion in the commercial sector; air conditioning became a necessity for computers and other sophisticated equipment, and we experienced a bouyant economy. BELCo's fuel consumption reflects the tremendous changes that took place in Bermuda over the 25 year period. These numbers, incidentally, do not reflect the fact that BELCo achieved a significant reduction in fuel consumption of 15 percent in 1980 versus 1979.

PRODUCT IMPORTED FOR BELCO
COMPARISON 1955 - 1980

	VOLUME (K.BBLS)	PERCENTAGE INCREASE
1955	90	-
1960	210	130
1965	285	35
1970	420	45
1975	670	60
1980	700	5

Unfortunately, we are unable to ascertain what impact the large increase in motor boats, over the period, has had on these statistics. What is significant is that gasoline consumption increased in proportion to the motor vehicle population.

The remaining categories, fuel oil, diesel oil, etc. are so diverse in end use that it serves no useful purpose to review them in detail.

Looking forward and choosing 1985 as the year for which we can make a reasonably realistic forecast, we envision the demand shown below.

1985 ESTIMATED DEMAND (in k. Bbls.)

	1980	1985	PERCENTAGE INCREASE
BELCo Fuel	700	775	10
Gasoline	200	200	-
Fuel Oil	100	100	-
Diesel, LPG, Misc.	100	150	50
TOTAL	1,000	1,225	10

In summary, BELCo shows a modest growth in consumption, in keeping with the utilisation of more efficient generation equipment as the older less efficient units are replaced. As well, increase in diesel consumption follows the trend away from gasoline in autos, boats and commercial equipment to promote greater fuel efficiency.

6 - ENERGY POLICY IN BERMUDA

Colin Miles

In the following I intend to give an account of Government's energy policy and the considerations that lie behind various actions taken in recent years in regard to energy prices and encouraging conservation.

At the risk of sounding a little complacent I would begin by pointing out that the need and scope for an active energy conservation policy is perhaps less acute in Bermuda than in our North American neighbours. Our size, geographical location, and temperate climate mean that we should have less demand for fossil fuels than many other countries with a similar high standard of living. The nature of our infrastructure and our environmental and economic policies - in particular the absence of heavy industries and restrictions on the number and type of private and commercial vehicles - mean that in comparison with many other economies we are already relatively fuel-efficient, at least as far as internal consumption is concerned (see Chapter 4).

We have no recent history of subsidised energy prices; we always have and will continue to buy our fuel at world prices. Notwithstanding the high cost of fuel, electricity will always be a relatively expensive commodity - the domestic market is just too small to enable us to take advantage of the economies of scale open to utilities in other countries. Neither do we have access to relatively cheap sources of centrally generated electricity such as hydro. Some idea of the tiny size of our domestic market for electricity can be gauged from the fact that BELCo's weekly sales are around 6 <u>million</u> kwh whereas U.S. utilities' weekly output is in the region of 40 <u>billion</u> kwh.

So we already have an environment where our demand for fuel products, given the Island's standard of living, is comparatively modest and where the cost of energy has traditionally been high enough to encourage conservation. This has been particularly apparent in our major industry - the hotels - where competitive pressures from other resorts encourage a high level of efficiency.

In one important respect we will remain dependent on fossil fuels irrespective of any attempt we might make on the conservation front or in converting existing facilities to solar power or new technologies. Our economy's main dependence on air and sea communications and the availability and cost of fuel for international transportation remains totally out of our hands.

What then is the role of an active energy policy in Bermuda? To begin with, despite the fact there has been no deliberate attempt to shelter the economy from rapidly escalating world energy prices, it probably remains true that in many cases the private cost of energy remains below the social cost. In this regard, considerable scope for savings remains, as was indicated in the 1977 report of the Energy Conservation Committee.

Moreover, foreign exchange is a scarce commodity; the existence of protective import duties and exchange controls is indicative of a foreign exchange premium over and above the exchange rate actually paid. The cost to the balance of payments of imported oil has risen ninefold since 1972. In 1980 oil imports for domestic consumption accounted for about 14% of the total import bill. Thus, a heavy balance of payments burden and the potential for more efficient consumption provide sufficient incentive for an active energy policy. As will be seen, this policy has been concentrated in two areas:

(A) Prices; and

(B) Information and education.

With regard to prices I have mentioned already that Bermuda is a price taker - it is in no position to dictate to suppliers. Government has long recognised that it makes little sense to make life difficult for local fuel importers by attempting to hold down their prices - in the event of shortages such as were threatened in early 1974 and in mid-1979 it pays to have suppliers on your side. (The oil companies' policy of "equal misery" employed in such circumstances can sometimes be twisted in your favour). Nevertheless, Government has always recognised its responsibility to the public to monitor prices carefully and to be satisfied that only justifiable increases in costs (at all stages of the wholesale and retail chain) are passed on. Government also recognises the value of an orderly market and the avoidance of long queues at petrol stations and panic buying that have been experienced in other countries. In this regard, since June 1979, prices for petroleum products have been set for a minimum period of a month with reference to Caribbean postings, and the public is fully notified of impending changes. A similar monitoring exercise is carried out, again on a monthly basis, by the Price Control Commission in respect to BELCo's fuel adjustment charge, with the public being given due notice of any change in the price of electricity arising from a variation in world fuel prices.

A second and more direct influence on prices is of course through taxation, specificially customs duties. Fuel products, like tobacco and alcohol, tend to be in inelastic demand, particularly over the longer term. (Much of the short term reaction of sales which sometimes follows increases in tax typically soon disappears). Thus governments are guaranteed revenue from this source which could easily be lost if goods for which there are close substitutes were taxed instead.

Prior to the last budget, Government reviewed the existing structure of fuel duties. It was apparent that the already low duties on diesel and fuel oil had fallen substantially in real terms since the early 70's and an upward adjustment was overdue. However, we were also conscious of the impact which a higher rate of fuel duty would have on the price of electricity, particularly given the substantial sums of duty that will be paid by BELCo over the next few years in connection with the development of their new power station. It was therefore decided to exclude fuel purchased by BELCo from the review. However, duties on fuel oil (principally consumed by the hotels) and diesel oil (excluding BELCo) were raised to 5 cents a litre and gasoline by 2 cents a litre to 17 cents a litre. In order to preserve the real value of the duty the Minister of Finance also indicated that he intended to place fuel duties, like duties on most of our imports, on an ad valorem basis.

These increases in duty can be regarded as an example of the "big stick" approach to conservation. They have an obvious attraction to Government in that the result is generally improved conservation combined with a higher tax revenue. The main constraint on this approach is its inflationary consequences. Alternatively, Government can offer carrots in the form of reduced duties on energy savings equipment. In this respect our actions have been modest, but deliberately so. In the 1980 budget the rate of duty on solar panels was reduced from 20% to 5%, a decision fully supported by the Energy Conservation Committee. Although the effect of this duty concession on the cost of a solar powered heating system is in fact quite small, we have always regarded the negative inducement given by higher electricity bills as a far more powerful method of encouraging the widespread use of solar energy than anything that can reasonably be conceded in terms of tariff reductions.

The second main element in the Government's energy policy is in the area of information and education. The establishment of the Energy Conservation Committee in June 1977, and the publication of its report in December of that year, alerted the public to the scope for energy savings while at the same time identifying those measures that were a practical proposition for Bermuda. These measures included the setting up of a body to promote energy conservation by education. The Committee was re-established on a permanent basis in March 1979 after the threat of further fuel shortages following the revolution in Iran. At the same time, Government announced steps to reduce its own energy consumption so as to provide a lead to the rest of the community.

Since mid-1979, Government has published on a regular monthly basis data showing the Island's gasoline consumption together with BELCo's output and fuel usage. These data, together with the monthly notification of fuel prices, provide a continuing reminder to the public of the importance of conservation. In addition, the Energy Conservation Committee, in conjunction with the Department of Community Affairs, has taken over the role of educating the public as to the optimum use of their electrical appliances. The Conservation Committee under the chairmanship of Mr. Hal Dale continues to act both as a sounding board for ideas from Government regarding further energy savings as well as putting forward its own proposals.

In comparison with other countries Bermuda's official energy policy is, understandably, on a modest scale. Nevertheless, we believe the measures we have taken to be fully consistent with the objective of diminishing Bermuda's dependence on imported oil. As John Carey's figures (Chapter 5) suggest we have made considerable progress particularly when account is taken of the growth in the economy (an average of 4% per annum over the last four

years). This is not to suggest that further reductions in our dependence cannot be achieved but we are confident that through taxation policy and education realistic conservation objectives can be met.

7 - ELECTRICITY GENERATION IN BERMUDA

Llewellyn Vorley

The generation of electricity in Bermuda for sale to the public commenced on May 1, 1908, when a 50 kw generator was put in service at our present site on Serpentine Road. Initially the unit had been installed at premises on East Broadway in Hamilton but this unit did nothing more than provide power for an illuminated sign.

A further unit of 100 kw capacity was put into operation in March 1909, and on December 1 of that year we advertised that, as from that date, electric service would be provided "all through the night until further notice."

It would be safe to say our maximum demand in 1910 was minimal. By 1920 it grew to 330 kw, by 1930 to 1,675, by 1940 to 3,860 and by 1980 to 59,000 kw.

In common with economic development in Bermuda we experienced considerable growth in the years between 1956 and 1973. Our maximum demand in 1956 was 12,720 kw, with annual generation of 62.3 million kilowatt hours. In 1973 the maximum demand had increased to 54,700 kw with annual generation of 300.5 million kilowatt hours. In the 17 years the maximum demand increased at an annual cumulative rate of 9% while output increased by an annual cumulative rate of 9.7%, reflecting a decided improvement in annual system load factor.

Then, in early 1974, came the sudden and punitive increase in fuel prices and, in common with electric utilities world wide, growth ceased. In fact, it was not until 1977 that our maximum demand exceeded that of 1973. A period of modest growth ensued but an even more dramatic increase in fuel prices in 1980 led to a further leveling off in demand and output.

Forecasting our future load growth is not easy as we have to assess not only the probable increase in residential and commercial building in the years that lie ahead but also the effect of conservation and the use of alternative sources of energy - primarily the use of solar panels for water heating and other uses. Our planning and new generating plant requirements are currently based on a projected cumulative growth of 2% per annum for the next ten years.

All electric power generated by the Bermuda Electric Light Company is produced at our plant in Pembroke and we supply the entire requirements of the community with the exception of the U.S. Naval Air Station at Kindley Field.

Our plant consists of diesel and gas turbine generating units ranging in size from 2,500 to 15,000 kw; our present capacity (using a summer rating and making due allowance for normal continuous running) is 92.3 MW. Our heaviest and most consistent loads are in the summer months.

The diesels, because of their higher thermal efficiency, are used as base load units and accounted for 84% of total generation during the year 1980. This was a marked improvement over previous years and was due to the fact that (1) we commissioned two 8 MW diesel generating units in November 1979 and February 1980 and (2) maintenance of other diesel units was kept at a high level as we had adequate plant - particularly with the addition of four small peaking gas turbines in June 1979.

As a direct result we were able to effect a dramatic reduction in fuel consumption and this, in turn, resulted in a considerable saving in foreign exchange to the community. Output at our plant in 1980 was 331.86 million kilowatt hours - a reduction of 0.41% from the previous year. However, we used 615,839 barrels of fuel in 1980 compared with 725,475 barrels in 1979 - a saving of some 109,636 barrels or 15.1%. Reduction in fuel used per kilowatt hour generated in 1980 was 14.76%.

Generation is at 2.4, 4.16 and 13.8 kv and individual generator transformers step it up to 22 kv which is our transmission voltage. Throughout the Island our transmission system is underground, and distribution from the various sub-stations, overhead and underground, is at 4.16 kv.

At the end of 1980 gross plant investment was approximately $65 million, stated at original cost. Replacement value today would be well in excess of that amount and, in fact, a revaluation done this year for insurance purposes gave a replacement cost of $162 million. This figure does not include overhead lines or underground cables. Despite the absence of any industrial load in Bermuda our consumption of electricity per capita is high and undoubtedly reflects the generally high standard of living. When considering the capabilities of alternative sources the requirements for firm electric power must be taken into consideration.

We have a service area of approximately 19 square miles, a resident population of 54,050 and some 23,200 customers. In 1979 our maximum demand was 59,700 kw and we sold 303 million kilowatt hours. By comparison, in the same year, in Barbados, which is certainly one of the most developed of the Caribbean island nations, the maximum demand was 51,000 kw and kilowatt hours sold were 273 million. Bermuda, with one-fifth the population and one-eighth the land area, had a higher overall demand and consumption of electricity. On a per customer basis the Bermuda figure is 13,076 kilowatt hours per annum; that of Barbados is 4,147.

The main concern of this conference is to review alternatives for the future. We are equally concerned. More than three years ago,

as a direct result of our concern about the availability of oil and its probable costs, BELCo retained consulting engineers to prepare a thorough report on the current situation of generating electric power in Bermuda by conventional means and also to investigate and report on development of renewable forms of energy such as solar power, wind power, tidal and wave power, ocean thermal gradients and other developments.

Because of Bermuda's geographical position, size, concentration of population and ecological requirements our choices are somewhat limited but you may be assured we will continue to follow all developments as closely as possible.

There are no hydro-electric or geothermal sites in Bermuda and there is relatively little rise and fall in tide. We have, as a matter of interest, calculated the potential of harnessing the tidal power at Flatts Bridge but the small amount of electricity that could be produced would hardly justify interference with a unique tourist attraction.

Wave power is, of course, a form of wind power and we are aware of the considerable attention and research being conducted, particularly in the United Kingdom.

We are following with interest the trial wind power installations being made by Southern California Edison in conjunction with the U.S. Department of Energy and others. The investment is tremendous even in today's inflationary economy and operational results will be made available in a year or two. They are installing a 3 MW Bendix horizontal and a 500 kw Darrieus vertical axis wind turbine generator. The 3 MW unit is 190 feet tall with a three blade rotor 165 feet in diameter and will produce full power when the wind blows at 40 m.p.h.

Southern California Edison is also involved with the U.S. Department of Energy in the construction of a 10 MW solar energy thermal plant projected to cost $120 million. The area required for the solar collectors is considerable and whether we could find a site for such a plant here in Bermuda, if it is successful, is doubtful. However, this is an alternative to electricity generation by photovoltaic or solar cells and we are sure that development of solar cells will make power generation a reality albeit on a small scale for some time to come.

Hamilton Standard is involved in a contract to build a windfarm on Oahu in the Hawaiian Islands, consisting of 20 four megawatt wind turbine generators. They are also working on a 3 MW unit with a Swedish firm to be installed as a prototype unit near Malmö on the Southern coast of Sweden, and building a 4 MW unit for installation near Medicine Bow, Wyoming. These are indeed tremendous machines with a two bladed fibreglass rotor totalling 255 feet in diameter. The blade will be mounted atop a tapered steel tower 262 feet tall, and the top of the blades' arc will be nearly 400 feet above the ground. I am told that each unit will require a minimum clearance of 3,000 feet from any residential area and full load is not reached until wind speed is approximately 35 m.p.h. At 20 m.p.h. output is less than 25% of capacity and cut-in is at 15 m.p.h. Fortunately, we possess detailed wind measurements for Bermuda for every hour of the day over a period of two years and the mean velocity indicated is 14.7 m.p.h. During the summer months (when electricity requirements are greatest) the mean is 10 m.p.h. or lower.

We have also followed with interest the Mini-OTEC unit off the coast of Hawaii. This unit of 50 kw capacity has demonstrated an ability to produce 10 kw of net power and a number of designs for a full scale plant are on the boards. The selection of a suitable site is a

problem particularly if a temperature differential of 40°F is to be maintained and if the plant is to be located somewhere near the land. The Department of Energy produced a map showing areas with a temperature differential of at least 40°F at 500 meters and 1,000 meters; unfortunately, Bermuda is well outside the limit in both cases, but this does not preclude us from following developments as OTEC is becoming technically feasible and, hopefully in time, economically possible. As other fuels increase in price the cost of OTEC electricity will become more competitive - but only in areas where such plants are technologically viable.

BELCo has examined many uses for its waste heat and there is no question but that the most efficient use is for the conversion of sea water to potable water. Several proposals have been made but Government has decided that ground water, suitably treated, is the more economical solution and a sizeable reverse osmosis plant is under construction at the present time. We are, therefore, turning our attention to the recovery of waste heat for electric power generation. There is a possibility this may be co-joined with the use of waste heat from incineration of refuse at some time in the future.

Our resources are definitely limited and we must benefit from the experience of others when it comes to electric power generation by other than conventional means. Actual field experience will provide essential information on reliability, performance, operating and maintenance costs, operating constraints, economics and system interface requirements.

Some of the alternatives for generating electric power may well have potential in Bermuda at some time in the future but BELCo must also continue to supply electric power to all of its customers on a firm basis and must rely on fuel oil to provide the Island's basic needs for electricity for many years to come.

To this end, our efforts are being directed to the installation of a generating plant which, though more costly initially, will have the ability to operate successfully on the lowest grades of oil fuel which, we are now advised, will be more plentiful in the future than the more refined products.

The Company has recently obtained approval from the Department of Planning to construct a new generating station in successive phases, which is the formalisation of a long term plan by the Company. This concept was agreed to in principle over ten years ago.

Since 1955, the Company, concerned about the long term development facilities for electricity generation, has conducted continuous studies with consultants from the United States and England and, after careful evaluation of the economic, engineering and logistical factors, has concluded that the most favourable location for the construction of a new generating plant would be in the general area of our existing plant.

We will construct a generating station specially designed to house slow speed diesel units operating on a much heavier grade of fuel oil which will be relatively less expensive. Similar slow speed diesel units are now being installed in new power stations in Barbados, Bahamas, Jamaica, Guernsey and Corsica.

In order to meet the Company's estimated load growth projections, we consider it essential that the first of the two generating units should be in service by 1983, the second in 1985. It is estimated that the commissioning of a third unit would be timed for 1988, with further units to be installed as dictated by load growth and replacement of existing plant that reaches the end of its economic life. It is probable that on retirement grounds alone the completion of the new station would be necessary by the turn of the century.

The initial phase, in addition to the installation of the first two units themselves, will require the erection of new switchgear and control rooms and a maintenance bay. The relocation of other Company facilities including two existing fuel oil tanks will be necessary as well as the installation of a new fuel oil tank to hold the heavy fuel oil, which must be stored separately from the distillate fuels being used by the Company's existing plant.

It is vital that we all do what we can, now and in the future, to reduce our dependence on imported energy; however, our isolated position, a very high density of population, lack of available sites for generating plants and ecological requirements all serve to limit our choices.

8 - HOTEL ENERGY REQUIREMENTS

Don Jolliffe

Twenty years as a hotel engineer operating three hotels in Bermuda, and many years as a Consulting Engineer to hotels in Nassau, Barbados, Bahamas and Guyana have permitted me to accumulate experience on energy savings that may be of interest to this conference. The following suggestions have been tested in real-life situations; the results, therefore, should be reproducible under comparable conditions.

WATER

Water supply for Bermuda hotels has always been a big and expensive problem. Over the years we have had several serious droughts to the extent that we had to ship water in from the United States. Recently the Bermuda Government installed their own flasher-evaporator for distilling water, one of the most expensive methods of making water. With energy costs so high, it is costing some hotels $25-$30 per thousand gallons to produce, excluding preventive maintenance charges. Other hotels, and Government, are now changing to Reverse Osmosis. The cost of water from this process is between $9 and $10 per thousand gallons. Some hotels are operating with Government-supplied ground water, a system which is working quite well except that groundwater contains calcium chloride and can be very damaging to equipment if it is not treated. The most effective methods of saving water in a hotel operation are to 1. flush with either brackish or salt water; 2. keep constant checks on tank levels, and 3. re-cycle laundry water.

SOLAR ENERGY

Of the few solar systems presently working in Bermuda, most are in private homes and a few in cottage colonies. There is no large hotel

or commercial building presently heated by solar energy.

When my company considered a solar hot water system we received two price quotations. A careful appraisal, however, showed that the payback period would have been at least 18 years, and that it would have been necessary to replace the panels after about the same time period under Bermuda's climate conditions. On the other hand, I recommend them for household use where the payback would be within one to three years.

ELECTRICITY SAVINGS

Electrical Demand Control and Energy Management Systems have become important contributions to hotels and other commercial installations. I have large computer systems in two hotels which are doing an excellent job in keeping down our kilowatt-hours without a noticeable amount of discomfort to our guests.

The computer can schedule loads to be on only when required, such as exterior and interior lighting, and by turning off one or more loads for short periods at times. Ventilation and air conditioning systems can be shut down for a few minutes at a time and the areas involved will remain at a comfortable level.

In a 300 room hotel this system can save from 300,000 to 500,000 kwh per year. At the January, 1981 rate of 0.13 cents per kwh, this translates into a total saving of $65,000 per year, or 16% of the hotel's total electricity bill. Based on the assumption that a hotel room uses 29 kwh per day, and 100% hotel occupancy, Bermuda's 5,000 hotel rooms are estimated to consume a total of 52,925,000 kwh per year, equivalent to about 16% of BELCo's total output in 1980. Energy Management Systems such as the one described, if applied to all hotels, could thus result in savings to the industry of 8,468,000 kwh, or $1.1 million annually.

OIL SAVINGS

Most hotels in Bermuda, the United State and Europe with over 100 rooms use steam which is generated by oil or natural gas. Steam is used in Bermuda for laundries, hot water, kitchens, air conditioning and water distillation.

The following practical measures can result in appreciable savings:

1. Running efficiency tests on boilers.

2. Taking stack temperature and CO_2 tests.

3. If stack temperature is running 600°F most of the heat is lost to the atmosphere. A successful and inexpensive way to reduce stack temperature is to install turbulators in the tubes of the boilers. This lowers stack temperature to 300°F and puts more heat into the consumption chamber, resulting in an approximate saving of 12%.

4. If boilers are over twenty years old it has been my experience that they need to be replaced. In old boilers the maximum fuel-to-steam efficiency is 60% whereas it is 85% in a new boiler. At a fuel cost of $1.4423 per gallon and 4,000 hours of operation this means a difference of $63,461 per boiler per year.

Bermuda's oil requirements, computed on the basis of 3.5 gallons of oil per room per day including laundry for 5,000 rooms at 100% occupancy, are about 6,387,500 gallons per year. (Note that average actual occupancy is generally 60-65%).

RECYCLED OIL

The original idea of burning waste oil to generate steam came from Mr. Eugene Cox, Production Engineer at BELCo. I subsequently developed a system which, after problems, is

now down to a fine art. Since we first started we have used 400,000 gallons of waste oil from the local power company, garages etc. In addition to turning a waste product into energy this system has the benefit of withholding a potential contaminant from the environment. This technology has now sufficiently matured to be used in other hotels, with similar economic and environmental benefits.

9 - TRANSPORTATION AND ENRGY USAGE IN BERMUDA

Raoul Tyrrell

Prior to 1946 motor vehicles were not available in Bermuda or use by the general public. Great Britain and the United States both maintained large military bases in Bermuda at that time and a number of motor vehicles were available for their use. The public, however, with the exception of a few doctors, relied c horses, cycles and the railway.

The railway was smantled and sold to British Guyana (present Guyana) in 1947; from then on, although subject to stringent controls, motor vehicles were available all classes usage in Bermuda. Today Bermuda for general population of about 56,000, a has a resident population of 37,800 and a land motor vel square miles. Table I shows area of the data for Bermuda and five other compar count

TABLE 9.1

Country	Vehicles per thousand of Population	GNP Per Head of Population
United States	720	$8,660
Bermuda	680	9,820
France	520	7,100
West Germany	390	7,880
Great Britain	330	4,200
Jamaica	66	700

ENERGY USAGE FOR TRANSPORTATION

At this time energy consumption is not seen to be the primary problem associated with motor vehicles in Bermuda. Because preserving the Island's unique environment is of considerable importance to the economy, and because the changes resulting from automobile usage have occurred in such a relatively short period of time the major concern is the impact of motor vehicles on the environment rather than energy use per se.

Approximately 160,000 barrels of petroleum are used each year for transportation purposes excluding international airlines or military vehicles. This figure represents about 14 percent of the total energy consumed in Bermuda and is consistent with the figures reported for other countries. The annual cost of fuel used for transportation is about $5 million or 1 percent of the Gross National Product.

REDUCING ENERGY CONSUMPTION

The most obvious method for reducing the amount of energy used in transportation is to reduce the numbers and/or usage of motor vehicles on the roads. Towards this end, a number of proposals are under consideration within the Ministry of Transport, and specific recommendations will be made to the Minister in due course. In addition to energy savings, very substantial environmental benefits would be obtained from a successful program.

More efficient use of the present mix of transportation facilities could be achieved through the vigorous promotion of car pools, and a determined effort to promote and upgrade all forms of public transport. Bus and ferry schedules can be fully coordinated and expanded where necessary.

Motor cars in Bermuda are already limited to the smallest and usually most efficient models on the market. Energy savings are, therefore, not possible through a shift to smaller vehicles, as is now being done in North America.

ALTERNATIVE ENERGY SOURCES

Bermuda has no indigenous supplies of energy other than the wind and the sun; at this time neither is suitable for use with motor vehicles. However, solar cells are under development in several parts of the world and may be available in the forseeable future for use in automobiles by converting solar energy directly into electricity.

Various synthetic fuels are presently being tested, including 'gasohol', a blend of gasoline and ethyl alcohol obtained from vegetable sources. The finite supply and increasing cost of oil will make synthetic fuels viable, even inevitable, in the near future.

Liquified petroleum gas (LPG) is a by-product of the petroleum refining process. LPG is available in very large quantities in Europe and North America, and in both areas is used as a fuel for motor vehicles. In Bermuda LPG has long been used for cooking and heating, and in 1980 was approved for the conversion of two trucks on an experimental basis. LPG has several advantages, including its cost which in Europe is about 60% of the cost of gasoline; combustion is almost total, resulting in virtually no atmospheric pollution; and engine maintenance is considerably reduced.

Electric vehicles are also under active development in several countries, and their range, speed, low noise levels and lack of exhaust emissions make them ideally suited to Bermuda. Their present cost is very high ($15,000 to $20,000) and they are not available in quantity. There would be few

economic advantages, or opportunities for energy savings, in using electric vehicles in Bermuda, as petroleum would still have to be imported for BELCo's generators to recharge the vehicle's batteries. Nevertheless electric vehicles offer many advantages over internal combustion vehicles for our sensitive environment.

CONCLUSION

Bermuda, like every other country in the world, will sooner or later have to address and resolve the problem of declining supplies of petroleum, coupled with ever increasing prices. Since both ecology and economics may prevent the development of nuclear powered generating stations in Bermuda it would seem that solar energy, synthetic fuels, and conservation offer the most attractive alternatives.

10 - SOLID WASTE DISPOSAL AND RECYCLING IN BERMUDA

E.N. Thomas and G.M. Melotti

Over the last few years, all of our lives have been changed by a world-wide concern for the protection of the environment, the substantial increase in the costs of basic raw materials and energy, and the realisation that supplies of a number of these resources are finite and will be exhausted in the near future at present rates of use. These factors have also brought about a change in the way the world regards waste, and its diposal. Never before has so much time, energy and money been devoted to the science of waste disposal and to the development of a new technology.

Prior to 1970, the general approach to waste disposal was how to get rid of "x" tons of waste per annum as cheaply as possible and without causing a nuisance or a health hazard. Only very limited salvaging or recyling of selected constituents of the waste stream was practised and, except for ferrous metals, these were normally hand separated. Further, the low price of fuel offered no great incentive to regard waste as a possible fuel alternative. This was the position in 1969 when the Public Works Department was asked to investigate and recommend an alternative method of waste disposal, because the existing land fill operation was unsatisfactory due to a chronic shortage of suitable cover material. At that time the costs for the disposal of solid waste were $4.00 per ton for sanitary land fill, $6.00 per ton for pulverisation and $12.00 per ton for incineration. Consequently, pulversation was recommended and a twin stream swing hammer pulveriser was installed and commissioned in 1974.

After 1970, the emphasis changed. Waste today is regarded as a valuable source of raw material and, as a consequence of the escalating price of oil, as a viable fuel alternative.

Over the last decade, the technology to mechanically salvage selected constituents of solid waste or convert it to a source of energy, directly or indirectly, has emerged. Traditional incinerator plants with heat recovery and much improved reliability have been developed. The decade has also seen the introduction of modular incinerators, which offer advantages to the smaller communities. These changes prompted the Public Works Department in 1976 to investigate how best it might utilise the solid waste generated by Bermuda.

Possibilities in Bermuda for Recycling/Energy Production

In comparison with most other areas of the world, the disposal of waste in Bermuda has a number of peculiarities and complications. We have a densely populated yet limited land area and, because of our tourist industry, a need to maintain the very highest of environmental standards and to ensure the protection of the beauty and ecology of the Island and its waters. Because we are an importing nation, enjoy a high standard of living and have a tourist trade, the amount of refuse generated per capita is above average. Notwithstanding, the total amount of waste produced is small in comparison with other disposal centres in larger countries such the UK or the USA. The economies of scale that can be achieved at these larger centres are not possible here and some of the new technology available for waste treatment is not economically viable for Bermuda.

(a) Recycling and Reclamation of Materials

Household and trade refuse is a veritable "pot-pourri" of raw material - paper, textiles, metals, glass, vegetable and other food waste. In this era of changing values and shortages of raw material, many markets exist for the sale of these wastes. Remanufacture of these items using reclaimed material results in a saving both in the amounts of virgin material and energy required for manufacture. For instance, the production of stock aluminium from re-processed material requires only 4-5% of the energy required of producing the same material from virgin supplies. Similarly, iron and steel scrap can be re-processed at a quarter of the energy requirement of raw material.

The decision to proceed with recycling of materials is based primarily on cost versus benefits, taking due account of the anticipated technical feasibility. The cost factor is made up of the net income from sale of any reclaimed material, and the cost of disposing of this material if it were not reclaimed and re-sold. It is essentially a materials separation, handling, shipment and marketing process and relies eventually on a substantial and concrete market for the sale of any materials that are recovered.

Because Bermuda is an island all wastes that arise here have to be disposed of here or exported. The absence of any manufacturing and the complete lack of any entrepreneurial recycling chains (apart from a limited non-ferrous scrap operation) distinguishes Bermuda from most other developed countries. These would offer a means of both disposing of a portion of the waste stream, and obtaining some income.

This lack of access to a recycling chain presented a number of significant difficulties when considering the possibilities of materials reclamation from our waste stream, both from an operational and economic viewpoint. Shipping costs at that time were estimated at $60/ton (to U.S.) and we were well aware of the unreliability of the markets for salvaged material. Because the amount of materials we would be able to produce is small, we could expect to be on the "rough" end of the market most of the time, and possibly face the prospect of having to store

large quantities in the case of marketing or shipping problems. Therefore, we pursued the possibility of recycling and manufacturing in Bermuda and found that the quantities of selected waste available was insufficient to justify the capital expenditure on a plant. For example, Bermuda generates some 10,000 tons of waste paper per annum, a quarter of the tonnage required to consider recycling the waste and manufacturing paper in Bermuda.

On investigation we found that the likely costs of a full-scale recycling scheme, whether by means of a separated collection system or by án automated sorting facility, including shipment abroad, would range from $30-$50 per ton net (after allowance for income). This compared unfavourably with the cost of disposal under our present system of $21 per ton. It was fairly obvious that wholesale separation and reclamation from the waste stream would have no advantage, but it was also obvious that "selective" re-cycling to the more valuable materials - cardboard and aluminium - could be lucrative in conjunction with whatever method of refuse disposal we decided upon, and the separation could be done easily and at low cost.

(b) Solid Waste as a Fuel

At first sight, refuse does not appear to have many attractions as a fuel; it is bulky and heterogeneous; its content is variable and unreliable; and it cannot be stored for very long, particularly in summer. However, it does have some significant advantages: it has, on average, a calorific value of 4,500 Btu/lb, which is equivalent to a quarter of that of oil, and a third of coal; it is in steady supply; and it costs $21/ton to dispose of by other means.

It was with this backdrop that we began to consider the energy potential of the approximately 40,000 tons of garbage generated on the Island each year (estimated to rise to 50,000 tons by 1990).

In late 1979, after examining the alternative technologies available, including pyrolysis and the production of refuse derived fuel (for co-burning with conventional solid fuel), Government accepted a recommendation that a new direct incineration plant be built with waste heat recovery facilities. No recommendations were made for the use of this waste heat and although there appear to be a number of alternatives, we concluded that to maximise energy savings and justify the capital costs involved, the base load must be one where the demand exceeded the heat energy available 365 days in the year. The production and sale of "live" steam, chilled water, hot water and potable water were all investigated and none were found to meet this condition. Electricity was found to be the only product for which there was a year round market in excess of the quantity that could be produced from solid waste.

In consequence, shortly after acceptance of this recommendation, discussions were held with the Bermuda Electric Light Company to examine the possibility of combining waste heat from their generating operation with that from the proposed waste incinerator. As a result of these discussions BELCo commissioned its consultants to prepare a preliminary report on this suggestion.

The report recommended that such a scheme would be viable, and that the waste heat could produce approximately 50,000 lbs/hr of steam @ 145 lbs/sq. in. at 482°F (22.9 tons/hr @ 10 bar at 250°C) which could be used to drive a steam turbine, to produce an average of 2.8-3.3 megawatts of power, saving the consumption of some 1.2-1.4 million gallons of oil at a cost then of $1-1.2 million.

Having recognised that turbine bleed or exhaust steam could be used for other purposes - direct sales to local hotels, distillation of sea water, and possibly the production of chilled water for sale to local consumers for air-conditioning - it seemed appropriate to determine the best product mix to maximise energy savings and net income. This is currently under investigation. BELCo and the Public Works Department agreed to prepare a further report by the same consultants. The brief for this report is to establish whether the conversion of all waste heat to electrical power will fully exploit its potential and provide the maximum benefit to the Island or whether part use of this heat for piped steam and/or hot and chilled water production may provide enhanced savings in both dollar and oil terms. In addition, secondary use of turbine exhaust steam is to be considered.

It is anticipated that by 1985 Bermuda will be utilising its solid waste as an energy resource.

11 - THE CURRENT STATUS OF ALTERNATIVE ENERGY IN BERMUDA

Barrett Lightbourn and Jonathan Sands

"There seems to be little likelihood in the immediate future of superseding or replacing the existing (electrical) generating system and its attendant quality of service with an alternative major commercial system. Advances in technology will continue to be made in many areas of power generation and alternative energy sources (but) it remains to be seen when and how these developments will find practical, efficient and economical application for Bermuda."

[Excerpts from the 1977 Report of the Energy Conservation Committee]

While the existing generating system probably cannot be superseded or replaced, there are a number of alternatives readily available which can significantly reduce Bermuda's dependence on foreign oil imports (e.g. conservation and solar hot water). These alternatives are practical, efficient and economical now, while other energy sources (i.e. wind energy conversion systems, photovoltaics, solar cooling) are becoming competitive in the energy marketplace. But if we want any of these alternatives to have an impact on decreasing our dependence on foreign oil imports, there must be a social energy awareness as well as a national energy policy, both of which are lacking at the present time.

It is imperative that Bermuda tackle the energy issue if it intends to remain competitive within the tourist industry. The direct relation between inflation and energy price increases should be enough incentive to encourage consumers to conserve - whereas the trend has been to use more, not less. Through conservation and the implementation of more efficient energy technologies Bermuda should

be able to hold back the annual inflation rate, which would strengthen the economy as a whole. If a concerted effort to reduce energy consumption is not made in the near future there may be a time when Bermuda finds itself in a very difficult position - where it must change its energy patterns but does not have the time, nor the ability. Standards of living will change whether we take this challenge now or later, but the degree of change will be drastic if the present policy of wait-and-see continues. While the current status of alternative energy and conservation is very bleak it is hoped that energy standards and regulations, policy implementation, ongoing consumer education, and incentives to use energy alternatives will be supported and promoted by the government, businesses and consumers of Bermuda.

Conservation as an energy alternative

Conservation is an energy "source" which can be put to practical and economical use immediately, and which can also buy time needed to promote and initiate other alternatives. There is a potential for great energy savings at a very small cost. Very little capital investment is needed in most cases to substantially reduce the energy consumption of a residence, for example. What is needed more is education and incentive for the consumer. Information regarding building design in the 1977 Report of the Energy Conservation Committee unfortunately has not been made readily available to the consumer. Also at fault in this regard are the architects and engineers whose responsibility it is to inform themselves and the public about new building concepts. While there are a number of contractors offering assistance in energy conservation, through design services or equipment, government, architects/engineers, and contractors must all work in phase in order to see the concept through all facets of builing design.

Building design is not the only area where conservation can have a vast effect. Fuel imports for transportation are approximately 25% of the total energy use, but little effort has been made to promote car pools, to encourage conservation through less driving, or to expand the mass transportation system in the hope of reducing the number of automobiles on the road. Here again Government in conjunction with the auto dealers and the consumers must make an effort to improve efficiency and reduce the number of automobiles. Policies, standards and regulations will be necessary, but the results will justify the imposition.

Conservation as an energy alternative is the most effective method of decreasing energy consumption in the short term but, while methods of conserving are simple and generally inexpensive, there are numerous social and bureaucratic barriers to be overcome. For a conservation program to work a government must take the responsibility to educate the consumer, to support demonstration projects, and to provide incentives. Use of energy-efficient equipment (e.g. heat pumps, insulation, solar collectors) must be encouraged, and standards and regulations for new buildings must be mandated. In conjunction with the above, Government will have to work closely with the architects, engineers, auto dealers, contractors, and others to insure that the consumer has the knowledge and ability to conserve. Finally conservation will have to be viewed as a positive contribution, and not as an imposition, to society. Aside from buying time for implementation of other energy alternatives conservation can stimulate innovation, employment and economic growth.

Status of solar energy use

Present economically justifiable uses of solar energy include domestic water heating for residences, small and large guest houses,

hotels, laundries, and any other users of hot water (120-170°F). To date, there are approximately 8000ft^2 of installed flat plat collectors saving an estimated 800 barrels of oil per year (.13% of total consumption). The split is approximately 50% residential, 45% guest houses and hotels, and 5% others. There is potential for greater than 50,000ft^2 of solar collectors in the residential sector alone, which could reduce oil imports by as much as 8% below present levels. (A residential solar hot water system will provide between 70% and 80% of the annual hot water needs, and at current rates for electricity will show a return on investment of 12-15%). If all present consumers of electrically heated water added solar heating, yearly kilowatt hour consumption could be reduced as much as 15%.

With this potential available, one must wonder why the number of installed collector square feet is so small. There are many factors involved but the main reason is the apparently negative position taken by the government. Although the import on the solar collector has been reduced to 5% (from 20%) this incentive is outweighed by the increase in land tax combined with the difficulty of obtaining Planning Department permission to install a solar hot water system. This incongruence in policy does not encourage the use of solar heating. While there will be aesthetic drawbacks to numerous solar installations, the potential of solar as an energy alternative must be realised if Bermuda wishes to remain competitive within the tourist market. Government must take positive steps to encourage solar energy use, and at the same time regulate and minimise the environmental impact. Steps must also be taken to plan for the advent of photovoltaics (solar electricity), wind energy conversion systems (small scale) and solar space cooling systems, as these are the technologies that will be beneficial to Bermuda in the near future. Like a unified conservation program, use of solar energy can be expanded with little environmental and social impact while at the same time providing a boost to the economic growth of Bemuda.

<u>The lack of an energy policy</u>

At present there is no national energy policy: economics, conservative values and ignorance may be the main reasons for such a lack. Firstly, Bermuda has always been able to pass costs directly to the tourist, but as higher energy prices continue to dominate the overall inflation rate it may well be that the tourist will not accept this. In the past, energy prices were a small part of a business' operating budget but now they most likely make up the major portion; any cutback in energy consumption, therefore, should have a positive effect on operating expenses.

Secondly, Bermuda has always adopted a very conservative attitude when it comes to changes that will affect the social and environmental quality of the Island. There is no argument with this philosophy under many circumstances but where energy resources are concerned the biggest mistake would be to continue along the same conservative path. The sooner the move to a more energy efficient island is made, the better the chance that Bermuda remains competitive.

Thirdly, change towards a new energy balance will not be initiated until those with power to do so (i.e. the politicians) understand the complexities of the issue, and act accordingly. The 1977 Report of the Energy Conservation Committee provided a good base for further study (particularly in the area of building design). Unfortunately little has been done since then to carry out the recommendations of this committee. The report dealt primarily with concepts that were not immediately practical for Bermuda (e.g. solar power towers, large scale wind machines, OTEC plants). As a result those few who read

the report understood what is <u>not</u> practical, but were not made aware of the benefits to be gained from conservation (through consumer education) or other available energy alternatives.

As time passes the lack of a national energy policy will be increasingly detrimental to the economic growth of the Island. Increased energy costs will have to be absorbed by the general public, resulting in a steady decline of the standard of living. It is imperative that a national energy policy be initiated immediately. This policy should include ongoing education of the consumer and commercial sectors of the community, implementation of incentives for energy conservation and other energy alternatives, and legislation governing the energy efficiency of residential and commercial buildings.

<u>Energy Policy</u>

How is such a policy initiated? First of all the existing Energy Conservation Committee must by given more power to implement its decisions. The Committee should have on its permanent board representatives from the Departments of Planning, Transport, Public Works, Finance, Community Affairs, The Institute of Bermuda Architects and the Professional Engineers Society. The basic function of the Committee would then be to continually collect and digest information relevant to actually reducing the Island's dependence on fuel imports.

The permanent committee, or commission, could then present to Government proposals for:

- the accelerated development of alternative energy resources already proven economically attractive;
- the expansion of programs for the education of the general public regarding energy conservation;

- the implementation of energy efficiency standards for new buildings, as well as standards for retrofitting existing structures;
- the development of duty or land tax credits for the use of energy alternatives;
- the implementation of energy efficiency standards for appliances; and
- demonstration projects, consumer bulletins, information centers etc.

12 - ENERGY CONSERVATION AND ALTERNATIVE ENERGY EFFORTS AT NUSC TUDOR HILL LABORATORY

Michael D. Ricciuti

Tudor Hill Laboratory in Bermuda is a detachment of the U.S. Naval Underwater System Center (NUSC) with headquarters in Newport, Rhode Island. NUSC's interest in alternative energy dates back to the early seventies when the Center became involved in the M.A.P.S. (Military Application of Photovoltaic Systems) Program. In 1976, the Tudor Hill Laboratory was identified as the ideal candidate for the world's first hybrid solar system utilising both photovoltaic cells and wind turbines. However, no system was installed at Tudor Hill during the M.A.P.S. Program.

In 1978, the Center participated in the Jet Propulsion Laboratory's Low Cost Solar Array Program. The intent of this program was to test the environmental integrity of photovoltaic panels under a variety of conditions. Block Two solar modules were installed at the New London (Connecticut) Laboratory of NUSC and at the Tudor Hill Laboratory. The modules have been periodically monitored ever since. Despite the existence of a harsh environment, the panels installed in Bermuda have shown very little deterioration with time.

About four years of average daily insolation measurements are available for the Tudor Hill site. Daily insolation is being recorded using a Belford Instrument Company's pyroheliometer. The Center has purchased an Eppley Pyranometer with analog output and B.C.D. interface to allow direct and continuous computer evaluation of the insolation data. Data have been gathered using this instrument since September 1980.

The wind regime of Bermuda is well documented. Besides the ample historic records available, the Tudor Hill Laboratory currently has a cup-type anemometer on a sixty-foot tower continuously recording wind speed and direction. The base of the anemometer tower is 165 feet above sea level. Data are available for several years at this site. Tudor Hill Laboratory has purchased a new cup-type anemometer with digital interface for continuous monitoring of wind speed and direction in a manner similar to the insolation measurements. Automated data acquisition has not yet been accomplished.

There have been several proposals over the past few years for installing alternate energy systems at the Tudor Hill Laboratory. These proposals have generally been for feasibility demonstration systems subsidised in part by the U.S. Department of Energy and/or various other U.S. Government activities. Since the Tudor Hill Laboratory is not tasked with demonstrating the feasibility of alternate energy systems, any proposal for installation of such a system must impose a minimal impact on Laboratory assets and personnel. Furthermore, the system must not in any way create animosity with the government or population of Bermuda.

The primary energy requirement associated with the Tudor Hill operation is electricity for the Laboratory. The sole objective of our alternative energy program is to reduce the cost of energy required to sustain the Tudor Hill operation. Valid approaches to achieving that objective include conservation and collection and use of solar, wind or other natural energy. This proposal addresses both approaches.

To put the problem in perspective, the total electrical power consumption is presently about 500,000 KWh per year and, at current prices of $.135 per KWh, the energy bill is $69,500. Since our electric energy is directly dependent on the price of oil in a highly inflationary market, energy costs can

be expected to increase rapidly. At present rates of consumption, projected energy costs for 1980-1990 were computed for various assumed annual percentage increases in fuel costs. These computations indicate that Tudor Hill Laboratory energy costs in the 1985-1990 time frame are likely to be far from negligible. Even with optimistic estimates of the rate of annual increase in energy costs, the cumulative cost through 1990 will be several millions of dollars.

Proposed Conservation Measures

The most straightforward way to minimise energy cost is to use less energy. Conservation measures are therefore accorded highest priority in the Tudor Hill alternate energy plan (Fig. 12.1). Reduced demand not only yields immediate benefits in reduced cost, but also ensures more effective use of energy derived from solar and wind sources.

The electrical demand at the Tudor Hill Laboratory has three major components: the instrumention load, the air conditioning load and the housekeeping system. The housekeeping load is primarily the lighting systems used for day and night operations. The internal lighting system could be reconfigured to reduce that portion of the housekeeping load by 25% without reducing lighting to unacceptable levels. The instrumentation load can be minimised in two ways: old, high power instruments normally left on continuously can be manually or automatically turned off during periods when monitoring is not essential. As an example of potential savings, replacement of our time code generators with a low power solid state equivalent at $4,000 will save $12,000 in direct cumulative electric charges through 1990. We intend to study the use patterns and power consumption of other heavily used instrumentation to identify other opportunities for savings.

CONSERVATION MEASURES

I. NEW LOW POWER INSTRUMENTATION . . . . $ 20 K

II. AIR CONDITIONING . . . . 35 K

- ZONE CONTROL
- RECYCLE WASTE HEAT

III. BUILDING MODIFICATIONS . . . . 45 K

- DROPPED CEILING
- INSULATION

TOTAL COST: $ 100 K

ESTIMATED SAVINGS

ELECTRIC POWER REDUCTION: 63,400K WH/YR.

CUMULATIVE SAVINGS THROUGH 1990:

A. 10% RATE INCREASE/YEAR $ 158.6 K
B. 20% RATE INCREASE/YEAR $ 275.2 K
C. 30% RATE INCREASE/YEAR $ 482.8 K

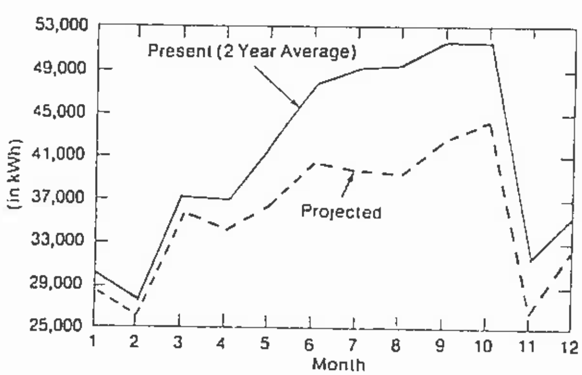


Figure 12.1 Tudor Hill proposed conservation measures.

The air conditioning system serves two essential purposes: it maintains the ambient temperatures within normal operating limits for the Laboratory instrumentation, and it controls the humidity to prolong instrumentation life and provide a suitable environment for storage of archival data tapes. The air conditioning system in its present configuration will consume over $1.2 million through 1990 assuming a 20% annual cost growth, and is therefore a priority target for conservation measures. This summer, NUSC will modify the present conditioning equipment to recycle waste heat from the compressors to maintain the building at a higher temperature while keeping the relative humidity within the required limits. This will reduce the amount of time the air conditioning system needs to operate and thus reduce electrical consumption. The cost of this project to NUSC will be about $35,000.

The present Laboratory building was constructed at a time when energy costs were of a secondary consideration. The building is minimally insulated and open to the gabled roofing surface over much of the floor area. This type construction is typical of that employed for buildings in Sunbelt Industrial Parks. Future plans call for a dropped ceiling throughout the Laboratory and insulation of air conditioning ductwork and the space above the dropped ceiling. The anticipated cost to NUSC of this additional work is approximately $45,000.

Figure 12.1 summarizes conservation measures and their costs, and shows the present energy use profile - based on an average of the last two years, and the projected yearly electrical consumption at the Laboratory when the modifications discussed above are implemented. The projected consumption profile will be the one used through the remainder of this paper when reference is made to electrical needs at the Laboratory.

In summary, it is believed that the Tudor Hill Laboratory electrical requirements can be reduced by 13% through the following low-cost measures:

1. Minimise the instrumentation and lighting loads;
2. Insulate the building against high outside temperatures;
3. Minimise the climate controlled volume;
4. Provide some degree of air conditioner zone control, and
5. Recycle air conditioner waste heat.

Proposed Energy Alternatives

The most practical means of reducing energy costs through the exploitation of natural sources of energy is to take advantage of solar and wind energy, both of which are abundant in Bermuda. Those two energy sources tend to be complementary in the sense that the seasonal minimum wind energy availability occurs during the season of maximum insolation, and vice-versa. The optimum alternate energy system is therefore a hybrid capable of using both solar and wind energy. The system capacity, however, should be biased towards extraction of solar energy, because the peak demand at Tudor Hill coincides with the season of peak solar energy availability.

Solar energy can be converted to useful forms by thermal and photovoltaic devices. Thermal collection is a mature technology, and collectors are inexpensive and efficient. Photovoltaic technology, or the direct conversion of sunlight into electricity, is an emerging technology, and collectors are presently expensive and inefficient. Although the efficiency of photovoltaic collectors is not expected to improve significantly, the cost is declining rapidly.

Extraction of wind energy is a mature technology. Improvements in wind turbines will continue to be made, but large increases in efficiency are not expected. The cost of wind energy extraction systems will continue to increase because the collectors are large, complex mechanical assemblies that will directly reflect increases in labor and material cost.

Site and Construction Considerations

Tudor Hill Laboratory is located on 25.1 acres of land leased in 1940 from Great Britain for 99 years. This hilltop, which is one of the highest topological features on the Bermuda Islands, permits an almost unobstructed view of the horizon in all directions. The Laboratory faces the ocean to the West, with the 200 foot length of the building approximately on a north-south axis. Behind the Laboratory, the land mass rises rapidly and then levels off at a height approximately 25 feet above the ground floor level of the Laboratory building.

The existing wind vane and 60 foot tower used for recording wind information as part of the Laboratory's ambient noise program are 185 feet behind the Laboratory building. Concern has been raised that the location of the Laboratory building will create turbulence on the hill for winds originating from a westerly direction, the predominant wind direction in winter. However, the primary site for the location of the closest wind turbine is 350 feet behind the Laboratory building.

Proposed Photovoltaic Subsystem

It is proposed to install a 60 KWp photovoltaic array consisting of flat plate silicon cells at Tudor Hill Laboratory. The system size is not fixed and depends on silicon cell cost at time of purchase; however, 60 KWp is a reasonable size estimate. The primary site for the installation of the array is on the grass field area to the southeast of the Laboratory. Some modification of this area is anticipated since an RF communications antenna is located approximately in the center. An estimate of 200 feet squared of ground area per peak kilowatt indicates that 12,000 square feet of surface area is required for the array. The proposed primary site has a usable area of 112,500 feet squared - giving more than adequate expansion possibilities.

Proposed Wind Turbine Subsystem

The wind turbine subsystem has caused considerable concern both in terms of safety and aesthetics. It is proposed to install two 15 kilowatt horizontal axis wind turbines at separated locations along the 160 foot topographic contour. The wind turbines are of a conventional design with three blades, a forty foot diameter, with blades and generator mounted on a free standing column. Exact specifications of the wind turbines are indeterminate at this time since their consideration is a recent development in this proposal. While a larger size wind turbine would offer significantly more output, it was felt that the wind turbines selected offered the best compromise in demonstrating system feasibility without unnecessary hazards or becoming too conspicuous.

A recent survey of Civil Engineering Lab personnel identified two locations as the primary sites for the wind machines. Anemometers, towers and data acquisition equipment are enroute to Tudor Hill Laboratory to enable a detailed wind profile measurement at these locations.

Power Conditioning Equipment

The power output of both the photovoltaic array and wind turbines will be variable voltage direct current, and power conditioning equipment will obviously be required. The

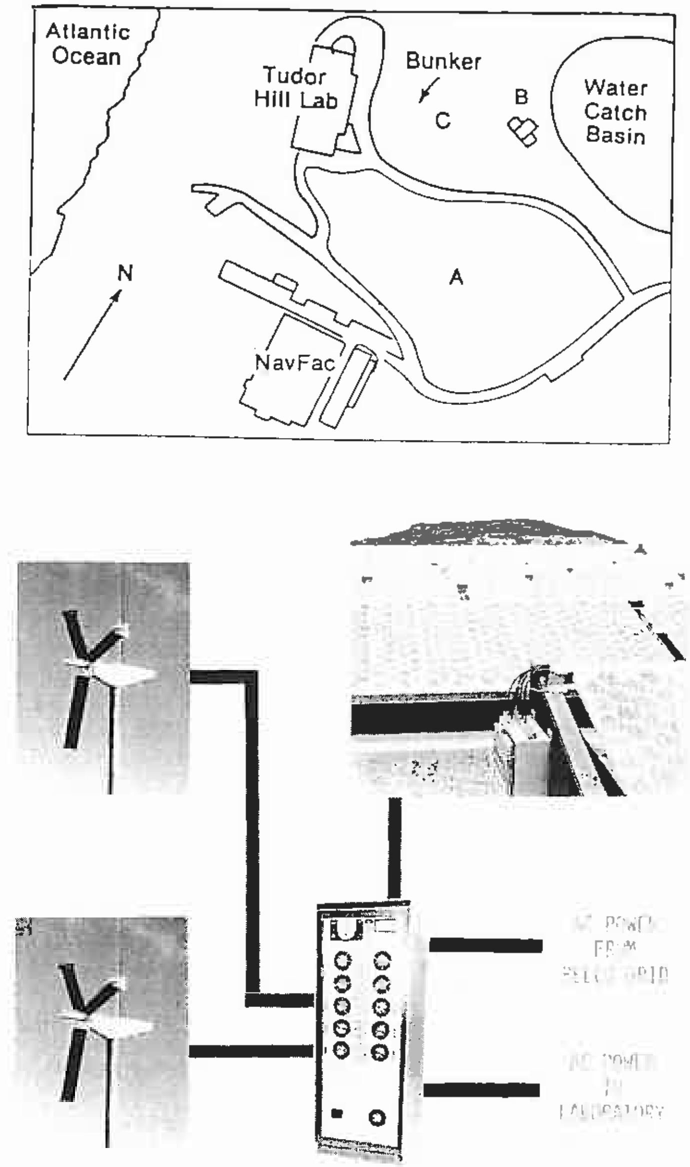


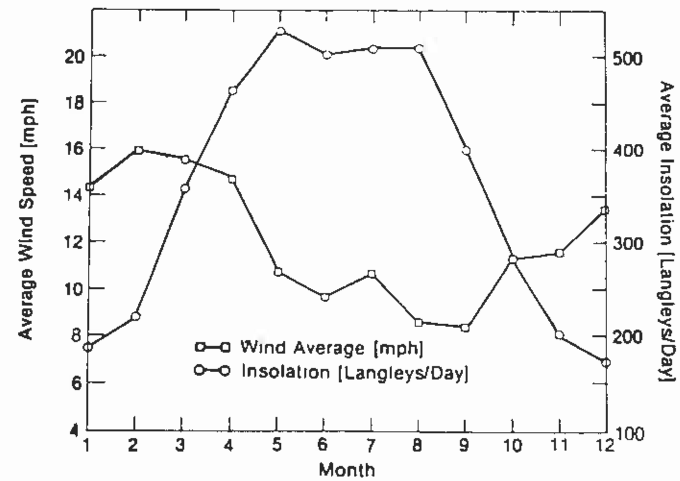
Figure 12.2. Tudor Hill plot plan and system configuration.

output power will be conducted to a peak power tracking invertor unit which will convert the direct current power to synchronous 110 Volt 60 Hertz alternating current compatible with the BELCo grid. The peak power tracking future of the power conditioning unit assures that maximum power is extracted from the photovoltaic array and wind turbines. This power conditioning unit is transparent to the user and incorporates safety features which do not allow locally generated power to be fed into the BELCo grid in the event of a BELCo power failure. Overall conversion efficiency is high, about 90%, and depends on system generating and loading conditions.

No energy storage devices are proposed since the expected output is a small fraction of Tudor Hill Laboratory demand. In the unlikely event that excess power is produced, the power conversion unit will feed it into the BELCo grid. Figure 12.2 shows a Tudor Hill area plot plan and the system configuration. Photovoltaic cells will be located in the vicinity of Point A. The wind turbines will be located at Point B and on the right edge of the plot plan along the rim of the catch basin. The power conversion unit will be housed within the Laboratory space.

Expected Wind Turbine/Photovoltaic Savings

A detailed analysis of both the insolation and wind speed data, and the Laboratory's daily and yearly load profiles is required in order to determine the yearly contribution of the wind turbines and photovoltaic array. The yearly profile was generated from an average of two years of energy use and was modified to reflect the anticipated energy improvements noted previously. The daily variation in electrical load clearly indicates the dominant role that lighting an air conditioning play in the Laboratory load profile.



AVERAGE WIND/INSOLATION PROFILES
Tudor Hill Laboratory, Bermuda

Figure 12.3. Average wind/insolation profiles, Tudor Hill Laboratory, Bermuda.

Figure 12.3 shows the average wind and insolation profiles recorded at Tudor Hill Laboratory. The complementary nature of the wind and insolation profiles makes the hybrid system of wind turbines and a photovoltaic array an extremely attractive power generating scheme. The insolation data are a three year monthly average measured on the Tudor Hill Laboratory Belford pyroheliometer. The wind speed data are also a three year monthly average measured on the Tudor Hill Laboratory propeller anemometer.

CONTRIBUTION OF HYBRID SYSTEM CONFIGURATIONS TO PROJECTED ELECTRICAL DEMAND

Month	Photovoltaic Contribution (kWh) 60 kWh	Combined Wind Contribution (kWh) 2-15 kWh	Percentage of Demand From Hybrid System
January	4092	7590	41.2
February	4368	5645	38.5
March	7812	7290	42.3
April	9900	6335	47.6
May	11346	3275	39.9
June	10620	2450	32.4
July	10974	3275	36.1
August	10974	1635	32.0
September	8460	1440	23.2
October	6138	3720	22.2
November	4140	3890	30.2
December	3720	5505	28.2
Totals:	92544	52050	33.9

Figure 12.4. Contribution of hybrid system configurations to projected electrical demand.

Figure 12.4 shows the anticipated output from a 60 kilowatt peak photovoltaic array. It is apparent from these tabulated data that the greatest contribution from the photovoltaic array occurs during the summer when demand is the highest, and that the percentage output peaks at 31% for the month of May.

The estimated output from the wind turbines is more difficult to compute than that from the photovoltaic array. Wind turbine generation

parameters, average wind speed and wind speed variations all have an effect on the computed output. For the purposes of analysis, the wind turbines are assumed to generate full output at 20 miles per hour wind speed. The expected output, negating wind gustiness and assuming a cubic power output versus wind speed, is also shown in Figure 12.4. The tabulated output shows the expected maximum power output during the month of January. A comparison of these data with those for the photovoltaic array again illustrates the complementary nature of the wind and insolation in the Bermuda environment.

Total System Contribution

The total contribution of the hybrid solar wind system toward the electrical load requirements of Tudor Hill Laboratory is also shown in Figure 12.4 and is tabulated for both a monthly and yearly basis. The data indicate that the hybrid system should produce approximately 34% of the Laboratory's yearly power demand.

System Monitoring

Because of the complexity of the proposed solar energy system, a fully automated data acquisition and signal processing system is mandatory for system monitoring. It has been proposed that the necessary software could be developed with the expertise resident in the Tudor Hill Laboratory staff. The long-term evaluation of the proposed system is extremely dependent on a proper data base.

Economic Analysis

The low cost of the Tudor Hill Laboratory conservation program and the resulting energy savings clearly require no further economic justification. By contrast, the estimates of potential savings from the hybrid energy system are not particularly encouraging. Total system costs including acquisition of all equipment required, installation and monitoring are approximately $2 million. Assuming a 25 year lifetime, a 10% return on investment, an 8% fuel escalation rate and cumulative uniform series factor of 20.05, the total system return is $477,506. This dollar savings is less than 1/4 total acquisition cost, making such a system economically unjustifiable based on the aforementioned assumptions.

However, several factors must be kept in mind before passing judgement on the proposed hybrid energy system:

1. There is a serious worldwide low cost energy generation problem and all alternative solutions must be encouraged.

2. Photovoltaic, wind turbine and solar water heating systems offer an immediate partial solution to the problem.

3. While fusion power may be the ultimate energy source, it may be totally impractical for Bermuda.

4. Technology, if sponsored by the proposed project, and others, will drive the real system cost down, particularly for photovoltaics.

5. The cost of oil derived energy is volatile and the accuracy of all cost projections is subject to considerable error.

In conclusion, I would like to acknowledge and thank Gerry Mayer and Robert MacDonald, both Engineers at Naval Underwater Systems Center who prepared most of the material I have presented today.

13 – DEVELOPING NATIONAL ENERGY POLICY: A CASE STUDY

Gary C. Barbour

Petroleum price increases which took place in the 1970's gave rise to many problems which have led to increased inflation rates, lower growth rates, and increased balance of payment deficits. Particularly for a country like Bermuda, these problems are magnified as the economic woes of the United States and Europe directly impact trade, commerce and tourism which are this nation's life-blood.

In addition to the "petroleum-related" problems, the energy scarcities of the 1970's brought with them an entirely new set of problems. These are chiefly the technological, economic and political problems related to diversifying an energy base to include nonconventional and preferably indigenous energy resources. With a need to accelerate market penetration of alternative energy supplies these stumbling blocks have become major impediments. Technological uncertainties of solar energy, environmental problems related to the use of coal, and health and safety issues associated with nuclear power, are all examples. In addition, integrated resource planning for the extraction, transportation, processing and utilization of new energy sources has created enormous managerial problems between federal, state and local jurisdictions.

While the purpose of the "Bermuda's Energy Future" conference is to discuss this second set of problems related to new technologies, it goes without saying that a diversified energy base can, in the long-run, mitigate most if not all of the "petroleum-related" problems many nations now face as a result of over-dependence on foreign energy supplies.

In the development of national energy policy there exist three fundamental policy determinants which are particularly important to Bermuda's energy future. A case study, that of the State of Hawaii, can best be used to identify these three policy determinants and illustrate their importance to energy policy development. In Hawaii a comprehensive energy self-sufficiency program is being implemented which would, over the next 25 years, reduce Hawaii's oil dependence from 90 percent to less than 10 percent and would save the State between $7 billion and $22 billion.

While Hawaii shares with Bermuda a number of common physical characteristics, because of significant differences in these three so-called "human elements" of policy development, Bermuda is likely to take a quite different course in terms of alternative energy resource production.

The most basic of the "human elements" is the need to discuss energy policy in the context of other national policy objectives. The search for energy self-sufficiency is not without its trade-offs, or premiums. At every stage in the process - from the laboratory to the rooftop - scientists, economists and politicians will be faced with decisions about pitting higher short-term prices against lower long-term prices; and pitting technological uncertainty against uncertainties of future prices and supplies. If the energy needs of the nation's people are great enough the trade-offs will be made. But unless the "premiums" associated with alternative energy supplies are discussed in the context of other national objectives, energy policy will be made in a void leading to an erosion of support for alternative supplies and eventual backlash against the technologies.

The second of the so-called "human elements" is closely related to the first. That is, the need to develop a clear understanding of the public's own perception of their energy problems. How Bermudians perceive their own energy problem is likely to be the single most

influential factor in the evolution of an alternative energy program. Are Bermudians concerned about oil cut-offs? Or is energy solely an economic concern? How do Bermudians respond to higher prices? Do they curtail energy use? Or do they find capital elsewhere to pay for higher energy costs?

It must be mentioned that while it is important to develop an understanding of the public's own perception of the problem, that perception can be somewhat of a moving target. The public's perception can change according to various "signals" by industry and government, and it can be manipulated intentionally or unintentionally through the media, information campaigns or general public discourse. Discerning the "elasticity" or "range" of public sentiment is an important factor in developing this understanding of the public's own perception of their energy problems.

The final "human element" in developing public policy is the need for effective leadership. Regardless of the technological certainty or economic benefits, a well informed, well organized and committed network of community leaders must be identified to catalyse further public participation. Whether this leadership be public or private, centralised or decentralised, the general citizenry, short of another world crisis, will need to be made aware and later educated as to the importance and benefits of programs to diversify the energy supply.

Development of effective energy policy, then, is highly dependent on three so-called "human elements". First, the need to discuss energy policy in the context of other national objectives. Second, the need to develop an understanding of the public's own perception of their energy problems. And third, the need to identify a committed and effective leadership network.

In the case of Hawaii, its people learned of their vulnerability quite early when, during World War II, the Japanese destroyed nearly all the civilian and military fuel depots. Had two remaining storage tanks also been lost, many feel, the outcome of the war and Hawaii's future would have been quite different.

After the Arab oil embargo of 1973-74, the U.S. too learned of its energy vulnerability and sought out Hawaii, with its generous endowment of indigenous renewable energy resources, to test the commercial viability of various alternative energy technologies. Hawaii had already displayed great potential for technologies using solar, wind, geothermal and biomass from sugar cane residues, and was anxious to use these resources to become energy sufficient.

By 1975, however, Hawaii became concerned that their state was being used by the U.S. as a testing ground and was receiving few tangible benefits from the renewable research and development being sponsored by the federal government on the islands. In addition, energy demands in Hawaii at this time were beginning to escalate after the shock of the '73 boycott had subsided. A third factor was that the islands' oil contract with Indonesia was due to expire in 1980. The uncertainties of availability and price, set to this exact deadline, provided Hawaii with an important impetus in developing an integrated plan to develop indigenous sources of energy.

Through their historical experiences with energy vulnerability, a frustration with federal dominance in Hawaii's energy future, and a contract deadline, the issue of energy not only became an important state priority but was solidified in the minds of all Hawaiians as being critical to the future of the State, thereby fulfilling two of the essential elements in the development of an alternative energy policy.

The third policy determinant, that of effective leadership, was anything but lacking in Hawaii. Governor George Ariyoshi and the Hawaii State Legislature enacted into law a State Energy Plan in 1978, the first such comprehensive plan of its kind. In 1979 U.S. Senator Spark Matsunaga introduced and had passed federal legislation to authorise a $1.5 million solar photovoltaic program with Hawaii being the primary beneficiary. And in 1980 the entire Hawaii Congressional delegation was able to have appropriated $500,000 to fund a joint U.S. Department of Energy and Hawaii Department of Planning and Economic Development "Integrated Energy Assessment."

This HIEA is now complete, all seven volumes. It provides two basic tools for decision makers to plan for Hawaii's energy demands within the context of the State's other important needs. First, the HIEA formulates three "futures" models projecting energy demand, supply and price for the next 25 years. And second the HIEA provides a detailed assessment of the renewable energy resource potential which exists within the State. Under ideal circumstances, the HIEA projects that Hawaii, over the next 25 years, could reduce its oil dependence from 92% to less than 10%, saving the State between $7 and $22 billion.

How then does the Hawaii energy experience compare to Bermuda's future for reducing dependence in imported petroleum? As highly educated and sophisticated people, Bermudians are very much aware of the tenuous energy outlook. But several factors lead me to believe that Bermudians do no yet rank energy as high a priority as do Hawaiians.

First, Bermuda has not yet experienced a severe supply disruption to solidify the concept of vulnerability. Perhaps Esso Bermuda and BELCo are correct in assuming that they will, in a crisis, be able to locate the 600,000 barrels of refined product Bermuda would need, but because of this assumption, Bermudians are sheltered from that sense of vulnerability which would lead them to develop indigenous energy sources. Hawaii's experience has been quite different, with regard both to the potential impact of an energy crisis and the priority of the energy problem within the minds of its residents.

Second, because the per capita energy consumption in Bermuda is rising at an annual rate of 7.4% in spite of 10-30% annual price increases, energy prices in this country appear to be extremely inelastic. This exemplifies Bermudians' rather modest concern about energy problems as they appear willing to make the economic trade-offs necessary to pay for ever increasing energy prices. Hawaii on the other hand has maintained a per capita energy rate less than that of Bermuda and the U.S. and has reduced their demand growth rate from 5% per annum in 1975 to 2.5% in 1979.

The absence of a perceived vulnerability and the inelasticity of petroleum prices do not entirely preclude the development of alternative energy sources in Bermuda, rather these conditions should only reduce the pace or scope of those alternative energy programs to be implemented. It should also be observed that when the threat does occur and Bermudians begin to respond to higher energy prices, this educated, sophisticated electorate is not likely to tolerate the type of bureaucratic ineptitude and institutional paralysis which has plagued U.S. energy policy. This government would be wise to have programs in place to respond to events before or soon after they occur.

Bermudians have a lot at stake: a beautiful island and a wonderful lifestyle. Efforts should be accelerated to update existing data on energy supply and demand in Bermuda and the effects of prices on inflation and GNP. Such a data base will prove invaluable for responding to a crisis situation or planning for stockpiling of emergency reserves.

In addition to updating Bermuda's data base, efforts should be made to assess the potential for small-scale alternatives for residential and commercial energy supply options. BELCo's evaluation of alternative energy applications seems to concentrate heavily on large-scale projects, shedding little light on the potential for conservation, heat pumps and various small-scale solar technologies. Such a resource assessment will be important once Bermudians begin to respond to market signals which will, over time, lead them to oil alternatives.

In summary, Bermuda's historical energy experience and inelastic response to prices seem to indicate that the present situation does not warrant a high profile program such as Hawaii's. Socio-economic conditions do exist, however, which demand public and private attention to pre-implementation planning activities such as data collection, small-scale resource assessment and contingency planning. Such measures will be critical to preserving the quality of life and standard of living this country has come to know and expect.

CURRENT ENERGY TECHNOLOGY

14 - POWER AND FRESH WATER FROM OCEAN THERMAL ENERGY CONVERSION (OTEC)

John H. Anderson

Bermuda is normally thought of as a small group of islands with few if any natural resources. I prefer to think of it as the centre of a vast ocean with 130,000 square miles of ocean surface that can be considered its greatest resource. Ocean Thermal Energy Conversion, commonly called OTEC, provides a means for utilising the ocean as a resource to supply power, fresh water, food, and chemicals. If taken advantage of, this can become Bermuda's largest and most important natural resource.

How does OTEC work? Since the ocean comprises 70% of the earth's surface the greatest part of the sun's radiant, or thermal, energy is received by the ocean. The sun heats the surface of the ocean somewhat more at the equator than it does at the poles. This warming causes the surface waters to expand slightly and raises the surface level of the ocean near the equator. The surface water then being at a higher level tends to flow toward the poles where it is cooled and returns to the equator along the bottom of the ocean as very cold water. This basic circulation is what causes the Gulf Stream to flow north, and permits Bermuda to have a mild climate tempered by its warm waters. This phenomenon also creates much warmer surface water than the water deep in the ocean. Typically in the tropics the surface water temperature is approximately $80^{o}F$, whereas it is close to the freezing point in the deep ocean.

In any heat engine, whether it be a nuclear power plant, or a diesel engine, power is generated by means of heat flowing from a warm body to a cold body. This principle can be used to generate power using warm water as a heat source at the surface of the ocean and

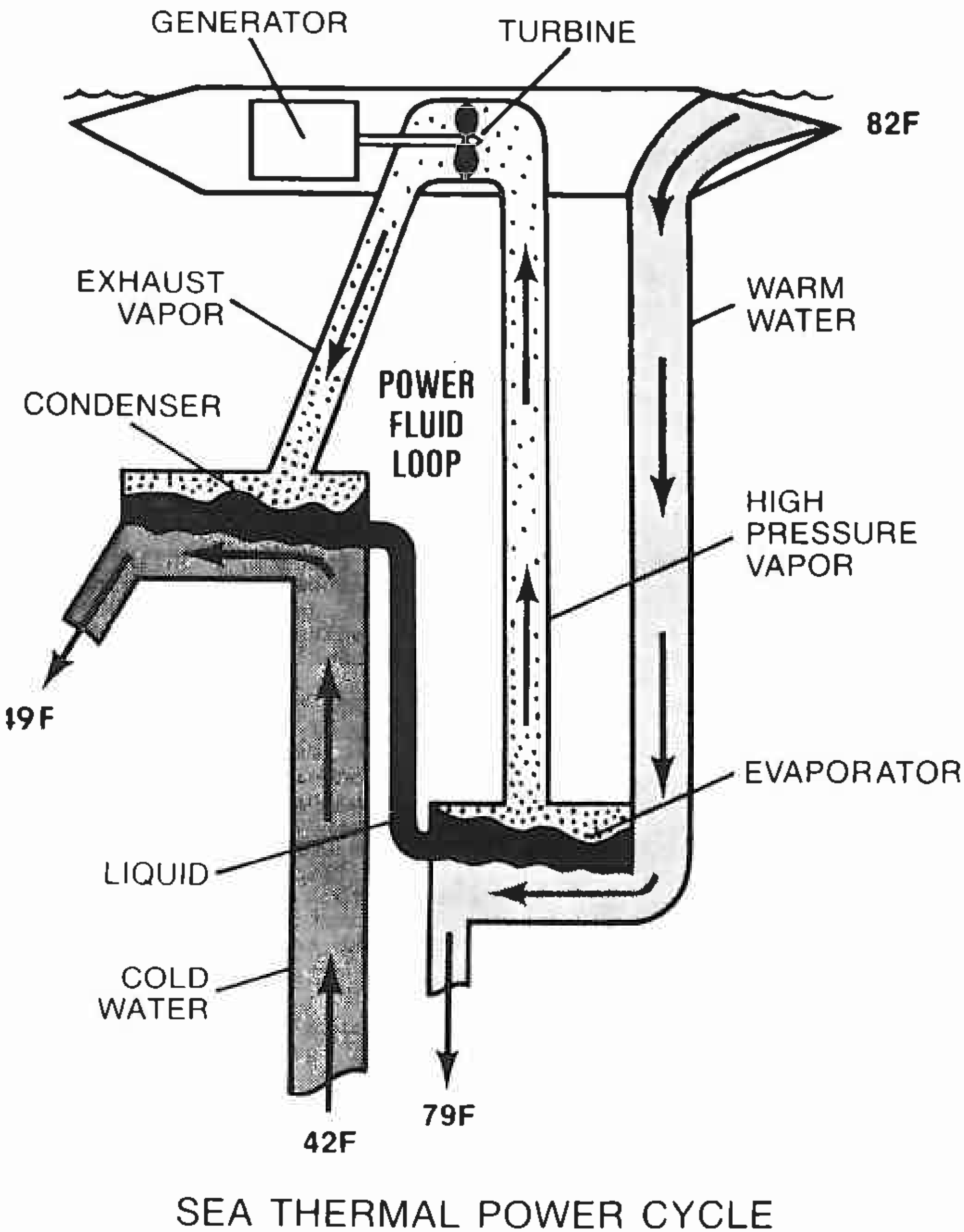


Figure 14.1 Operating principles of a typical OTEC plant.

cold water several thousand feet below as a cooling sink. If we could convert this flow of heat from the warm surface water to the cold deep water into power, then we would have an almost infinitely large source of power provided by the sun shining on the oceans of the world.

The principles of operation can be described as shown in Fig. 14.1. Warm water at approximately 80°F is pumped through a boiler where the heat from the water is used to boil a working fluid, typically R-22, the same fluid that is used in a household refrigerator. The R-22 working fluid boils at high pressure and the vapor then flows through a turbine which drives a generator. In order to create the flow to drive the turbine there must be a lower pressure area to which the vapor flows from the high pressure area. The low pressure area is created by a condenser which condenses the vapor back to a liquid because vapor pressure at lower temperatures is less than at higher temperatures. The vapor would be condensed by cold water being pumped through a pipe from several thousand feet depth in the ocean. Since the condenser is at a level above the boiler, the liquid from the condenser falls by gravity back to the higher pressure boiler. This completes the cycle. The working fluid then merely circulates around from the boiler to the turbine to the condenser and back to the boiler.

The typical OTEC plant floats with the warm water inlet screen close to the surface of the ocean where it takes in warm water, pumps it down to the boilers at the bottom of the plant from whence the water is ejected into sea. The water discharged from the boilers and condensers is directed as jets so that this provides a means of propulsion to maintain the platform at a constant position in the ocean. The electricity is transmitted to shore by means of an electrical cable which is suspended from the platform to the bottom, feeding from there to a shore-based installation. The weight of a 40 MW plant is expected to be approximately, 18,000 tons. The semisubmersible construction is well adapted to survive violent storms. The construction would be ordinary steel and aluminum for the main structure. In many respects, including the dynamic positioning system, the structure is very similar to semi-submersible oil drilling rigs that are in use in the ocean in many parts of the world today.

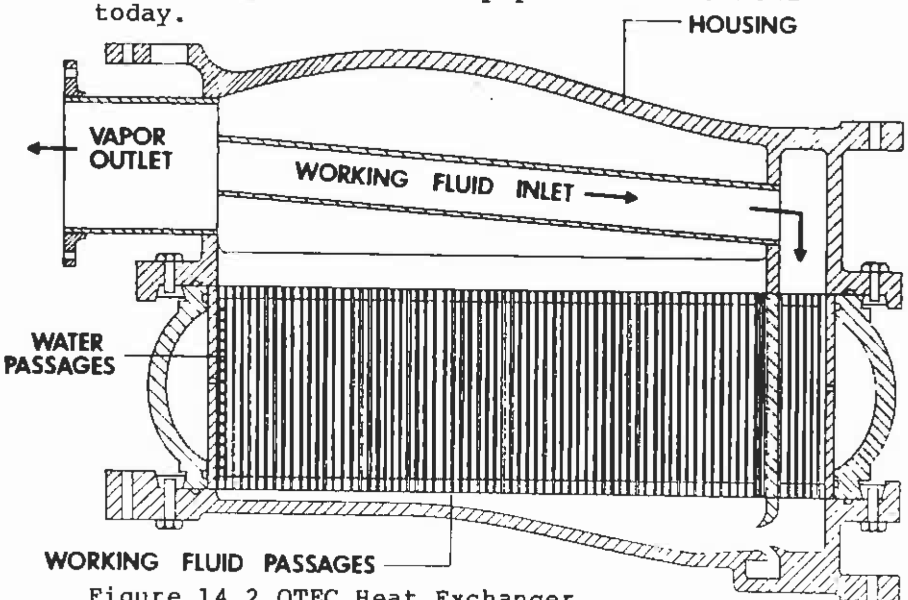


Figure 14.2 OTEC Heat Exchanger.

Possibly the most costly and critical factor in ocean thermal power plants are the boilers and the condensers. Very large amounts of heat must be transferred from large quantities of water at very low temperature differences. Fortunately, we have made great advances in heat exchanger design and performance, so that this is no longer considered to be a major difficulty in the design of ocean thermal plants. The type of heat exchanger developed by Sea Solar Power is shown in Fig. 14.2. It

is a plate type exchanger with stacks of plates bolted together in a mechanical assembly. The plates have water flowing on one side and R-22, the working fluid, on the other side. Both sides of the plates have enhanced heat exchange surfaces that improve the efficiency of heat transfer. Table 14.1 shows a comparison of the heat exchanger performance of the SSP exchangers with others that have been tested by the U.S. Department of Energy at Argonne National Laboratories. Since the heat exchanger is the most important factor in plant performance, information such as is shown in Table 14.1 is important in evaluating the technical and economic viability of a plant.

TABLE 14.1

HEAT EXCHANGER PERFORMANCE COMPARISON

	U_o	h_{wf}	hw	Core Vol.	P
	(Btu/Hr-Ft^2 - oF)			(FT^3)	(i)
C-MU Condenser* (Vertical Single-Pass)	1045	3590	2470	140	3.3
SSP Condenser*	1940	4580	4500	10.2	1.15
Trane Compact Plate-Fin Evaporator	1230	4540	1720	N/A	3.1
SSP Boiler	2210	6440	4500	10.2	1.15

*All results at nominal heat duty of 3.2 million Btu/Hr, nominal water flow rate of 3200 GPM, and water velocity of 6.5 Ft/Sec.

U_o - Overall Heat Transfer Coefficient

h_{wf} - Working Fluid Side Heat Transfer Coefficient

h_w - Water Side Heat Transfer Coefficient

P - Water Side Pressure Drop

Table 14.2 illustrates design characteristics of various types of plants that are now on the drawing board.

TABLE 14.2
SSP VS. OTHER DESIGNS

Based on 100 MW Net Output

Items	SSP	Others
. Tons Displacement	33,000	215,000-385,000
. Cold Water Pipe Dia.	30'	50-100'
. Cold Water Flow	4790	14,500
. Warm Water Flow	8770	14,100
. First Plant Cost/KW	$2000-2500	$3200-5000
. Future Plants/KW	$800-1600	$1750-3000

To give an idea of how OTEC plants might compare in cost with other plants, Table 14.3 shows typical costs for coal and nuclear power plants compared to projected costs of the Sea Solar Power design. The capacity factor is the ratio of actual energy output of the plant per year compared to theoretical output at 100% of rated capacity for 100% of the time. The equivalent cost per kw is the cost per kw divided by the capacity factor. Not only do the coal-fired and nuclear plants cost much more than the mature Sea Solar Power Plants, but they also have a smaller capacity factor, and the cost of fuel must be added to the cost of the plant to determine the cost of the power. Based on these estimated costs, it is understandable why ocean thermal energy can eventually be a much lower cost source of power than present day coal or nuclear plants.

TABLE 14.3

TYPICAL PLANT COSTS

Type Plant	Per KW	Capacity Factor	Equivalent
. Coal Fired (1)	$2200	.70	3143
. Nuclear (1)	$2385	.60	3975
. First SSP plant	$2000-2500	.80	2500-3125
. Mature SSP plant	$800-1600	.90	889-1778

(1) From 1980 Wall Street Journal

Once power has been generated from the ocean water, then other products may be extracted, e.g. fresh water, ammonia, carbon dioxide, aluminium, hydrogen, methanol, oxygen; and the nutrient-rich water can be used for fish production.

An immediate and much needed by-product of OTEC is fresh water; Figure 14.3 illustrates how fresh water can be produced from an ocean thermal plant. Warm water from the surface is first deaerated so that a vacuum can be applied to the water, causing it to flash into steam at 80°F and lower. The steam is flashed in a successive series of chambers where the water temperature is reduced as the heat goes into vaporizing steam. The steam is then condensed as fresh water on condensers which are cooled by the effluent from the power plant condensers. The cycle is efficient and can produce fresh water at a power cost of less than 6 kilowatt hours per thousand gallons of water produced. This system has the potential to produce almost limitless quantities of fresh water, and could supply the entire needs of Bermuda. While the cycle is actually more complex than that shown on Fig. 14.3, it does illustrate the general

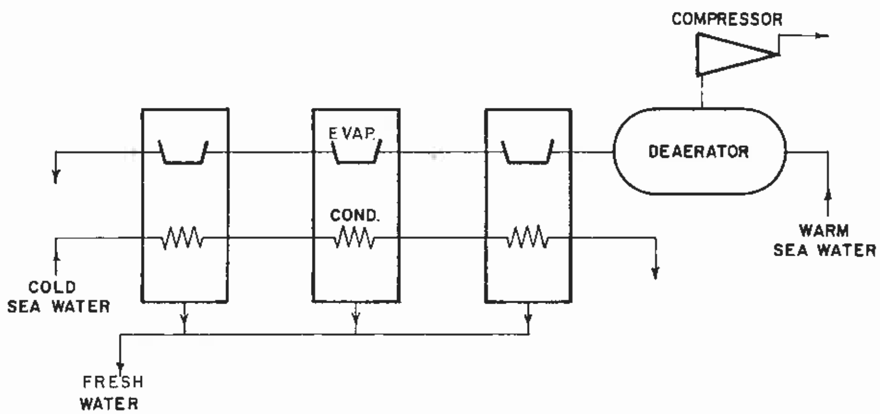


Figure 14.3 Proposed Desalting Plant Design.

principles, and that the process can be made more efficient by using the condensers developed for ocean thermal plants.

Once fresh water is produced, it can be separated into hydrogen and oxygen by the process known as electrolysis. Hydrogen can be combined in a catalytic process with carbon dioxide removed from the seawater in the deaeration process. The combination of hydrogen and carbon dioxide produces methanol directly, which can be used for automobile fuel.

The power requirements of Bermuda are such that a 40 MW plant as described could supply the average baseload for the entire community. A 40 MW plant is presently in the planning stage for Puerto Rico in a U.S. Department of Energy program. While it may be premature to consider Bermuda as the site for a first plant, once one plant is in operation it would be easy to construct similar plants of improved design that would be appropriate for Bermuda's energy needs. It should be noted

that while the temperature conditions around Bermuda are not as favourable as those in the Caribbean, future improvements in heat exchangers may well mean that Bermuda could be the site for a viable second generation OTEC facility.

Bermuda is now dependent on outside help for its entire economic welfare, whether it be food, oil, or tourism. OTEC can help turn this around. Instead of facing higher costs of energy and lower living standards, Bermudians can have greater independence and higher living standards by using OTEC to tap the tremendous resources of the ocean at the Island's doorstep.

15 - WAVE ENERGY

Finn-Erik Dahl and Nils Nordenström

Man has for a long time tried to figure out how to exploit the energy in ocean waves. Hundreds of approaches have been suggested during the last century. In the United States 32 patents had been registered by 1882, and in France alone the number had risen to 600 in 1957.

Figure 15.1 shows relative wave energy as a function of wave period. There are two dominant areas of extremes. The main tidal waves have periods at approximately 12 hours and 24 hours and are well defined. The tidal wave is deterministic; it can be safely predicted for hundreds of years ahead, because it is caused by the movement of the sun and the moon. Tidal energy plants exist today or are planned to be built in a number of places along the English Channel, in the Irish Sea, and in the Soviet Union. The dominant part of the wave energy, however, is in the wind waves and swells, and it is this energy that wave projects are trying to exploit.

As early as 1921 a wave power installation was built in Guyoteville in Algeria by Fusenot (Figure 15.2). An inlet was separated from the sea by a pier leaving only a small opening. Waves coming through the opening from the Mediterranean were the power input and the small inlet which acted as a resonator amplified the wave height. A float was attached to two arms which activated a pump. The whole installation broke down after a very short time because it could not withstand the forces acting sideways.

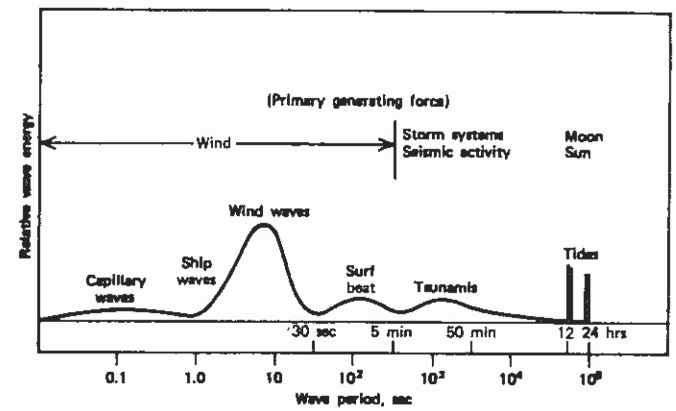


Figure 15.1 Estimated relative ocean wave energy and primary generating forces (adapted from Munh, 1950) after Sorensen 1972.

Although this piece of machinery was very simple and did not last long, Fusenot must be regarded as a pioneer because he attacked all the basic problems which we still try to solve.

Before we proceed to a description of some of the wave power concepts, let us briefly look upon wave energy from a global basis and compare this kind of energy with energy from other sources.

Wave energy at some locations

As a first estimate, it has been calculated that the energy stored in the waves created by the wind is approximately 2.7 TW (terawatt = 10^{12} watt), or nearly 1/3 of the present world energy consumption. However, only a minor fraction of this huge reservoir is easily accessible for exploitation.

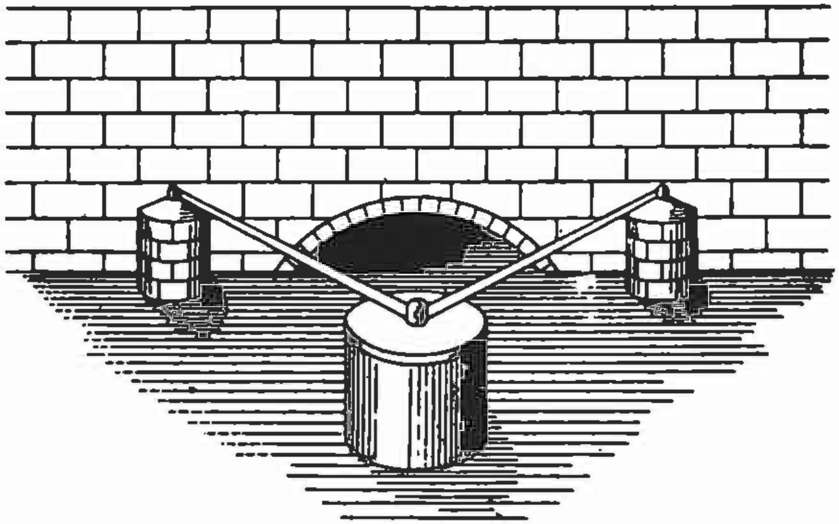


Schéma du dispositif de Fusenot à Guyotevills (Algérie)

Figure 15.2 Fusenot's wave power plant.

The energy in a wave system is

$P = 1/2\ H^2_S . T\ (KWm^{-1})$, or

$P = 0.8 H^2_S \cdot L$

where H_S is significant wave height in metres, L is the wave length in metres and T is the wave period in seconds. A typical ocean sea state with significant wave height 8m and period 10 seconds will thus contain 320 KW per meter wave front. However, such waves are not common in most places. For example, the annual average for the northern part of United Kingdom has been found to be about 50 KWm^{-1}.

Based on readily available wave data from the eastern Atlantic region, where Bermuda is situated, we have tried to calculate the wave power energy available in the Bermuda region. The results are shown in Table 15.1.

TABLE 15.1

WAVE POWER ENERGY AVAILABLE IN WESTERN CENTRAL ATLANTIC.
Water depths assumed greater than 100m.

Period	H_S m	Period s	P KW/m
Dec.-Febr.	4.0	10.1	80.8
March-May	3.5	9.6	58.8
June-Aug.	3.1	9.0	43.2
Sept.-Nov.	3.6	9.7	62.9

These numbers should be treated with the utmost care because they are representative as a mean for the whole sea area between the U.S. east coast and the mid-Atlantic ridge. However, the rough calculations indicate that there is energy in the sea area around Bermuda to be utilised. If we assume a wave power device with efficiency of 50%, utilising all the wave energy along 5 km wave front, the total energy output would be approximately 2.5TWh per year.

For the Norwegian Coast, Det norske Veritas has calculated the annual mean at certain locations 20 nautical miles off the coast. The results are shown in Figure 15.3. These calculations are based upon observations during 25 to 30 years and show that the average power has a maximum at Krakenes with 38 KWm^{-1} and minimum at Vadso with 12 KWm^{-1}. The overall average power for the Norwegian coast is 23.66 KWm^{-1}, which gives a theoretically available 598 TWh per year. This is a very large amount of energy amount compared with the electricity production (and consumption) in Norway, which during the last two years has been approximately 85 TWh per year. So the present demand for electric energy in Norway could be met by wave power energy alone if only one sixth of the theoretical amount could be transformed to electricity.

Norwegian wave power research

Because of this huge potential the current wave power research programme was launched in 1976. In a whitebook for energy supplies the Norwegian Government states that although the present technology has not developed so far that wave energy can be economically utilised today, wave energy should be a part of the energy system in Norway before the end of this century.

Table 15.2 shows the budget for this program as per today.

TABLE 15.2

BUDGET FOR NORWEGIAN WAVE POWER RESEARCH PROGRAM (In 1000 U.S.$)

Prog. area	1976	'77	'78	'79	'80	'81	Total
Wave power Technology	70	18	1116	2710	2916	2760	9590
Wave basin				430	430		860
Wave data etc.				120	100	44	264
	70	18	1116	3260	3446	2804	10714

Compared with the research funds for wave power in the rest of the world, Norway's

contribution is probably in the range of 10-25% of the total. The question arises whether all this money could have been spent in a more profitable way developing other energy sources? We do not think so. If we compare wave power research with research programmes for other energy sources, we will see that the money spent on wave power is just a small fraction. For example, probably more than $4 billion U.S. has been spent on nuclear energy programs, more than $300 million on solar energy and more than $100 million on geothermal energy.

If we compare how much can be harnessed from the different energy sources (Table 15.3) we can see that wave power may only be a minor contributor to the total world energy supplies.

TABLE 15.3

WORLD ENERGY SUPPLIES

(Given as order of magnitude 10^X KWh per year)

Source	Total	Available	Produced 1980	Produced 2020*
Petroleum	17	16	14	14
Gas	16	16	13	14
Coal	17	16	14	14
Geothermal	-	18	11	13
Atomic energy	17	16	12	13
Wave power	14	12	0(?)	11

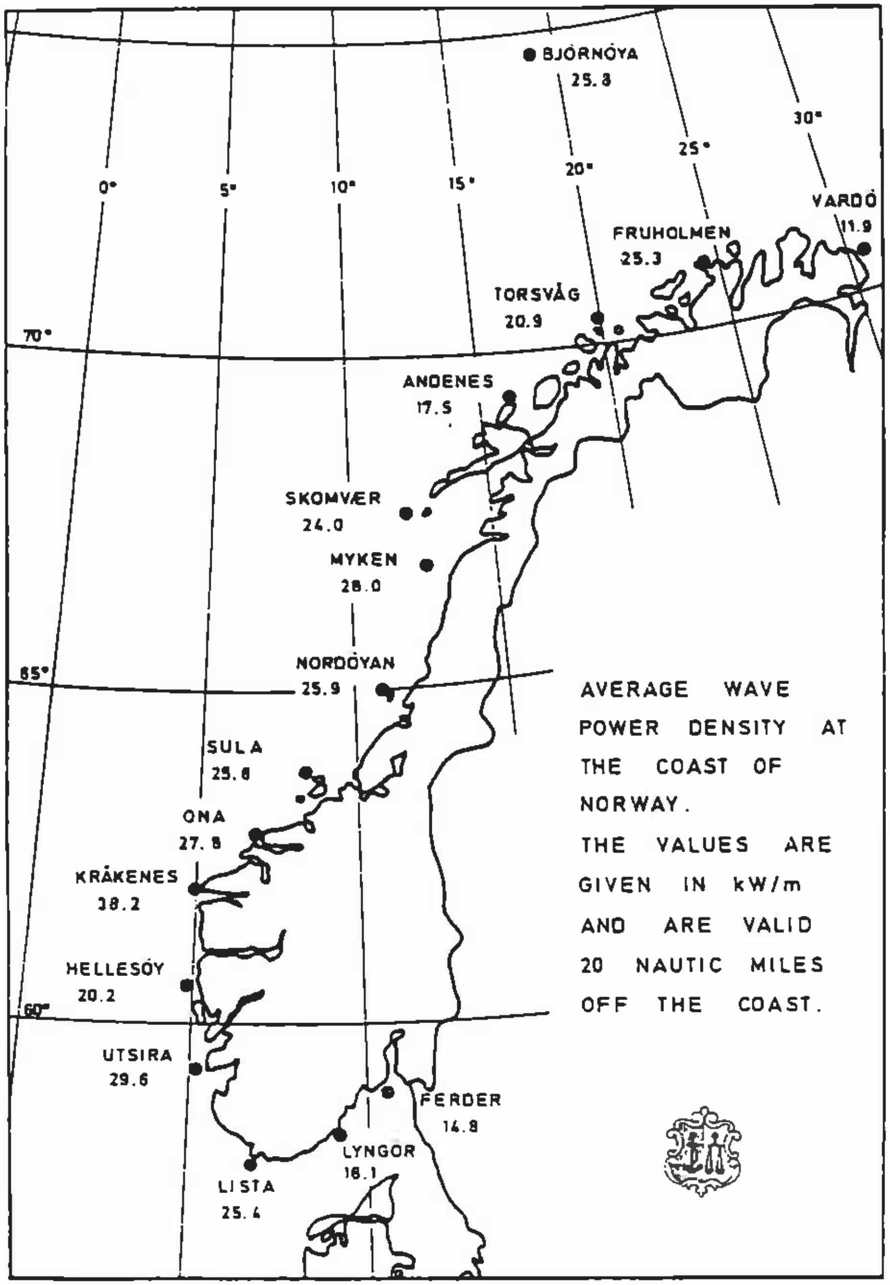


Figure 15.3 Average wave power density.

*Estimated by World Energy Conference. If we compare some renewable energy sources (Table 15.4), wave power is among the largest and of the same order of magnitude as hydroelectric power. However, such comparisons should be looked upon with suspicion. For example, for hydroelectric power it is assumed that not a single drop of rain avoids a hydroelectric plant. For solar energy it is assumed that all the sun's beams are captured, or that the whole earth's surface is covered with sun panels.

TABLE 15.4

WORLD ENERGY SUPPLIES FROM RENEWABLE SOURCES

(Given as order of magnitude 10^x KWh)

Source	Per Year		Produced	
	Total	Available	1980	2020*
Solar	18	?	10	12
Biomass	16	14	8	11
Wind	15	13	9	12
Waves	14	12	0	11
OTEC	15	13	6	10

* Estimated by World Energy Conference

The crucial question is what part of the total energy can be utilised. Based on the lessons we have learned from the U.K. Wave Energy Programme and Norway's own, we believe that less than 25% to 30% of the total wave energy may be utilised. Although some inventors claim that their devices have an overall efficiency of 80-90%, 50-65% seems to be a better estimate according to present knowledge.

Costs and efficiency will vary considerably depending upon which concept is used. So let us examine in some detail three Norwegian ideas which are presently receiving funds from the Norwegian Government for further development.

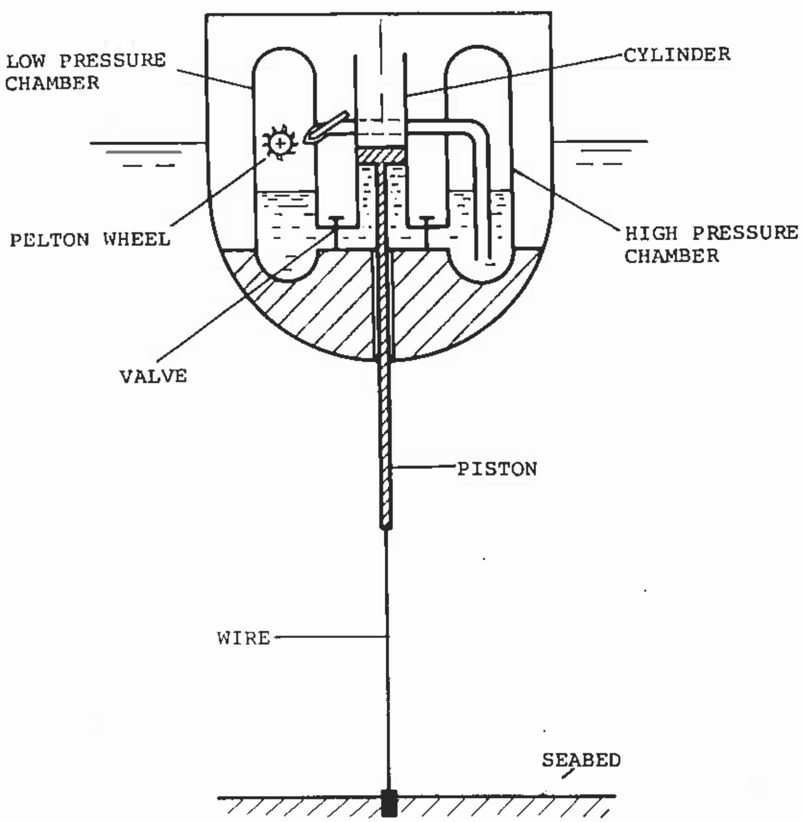


Figure 15.4 Budal-Falnes Heaving Buoy.

The first is called the Heaving Buoy (Fig. 15.4) and was presented in 1974 by two Norwegian physicists, Budal and Falnes. Their idea was to tune a surface buoy to the

frequency of the waves. The anchor holds a piston in a fixed or nearly fixed position, while the cylinder and piston due to wave motions compresses and decompresses the fluid below the piston and a flow of energised fluid is allowed to enter a high pressure chamber. The fluid returns to the low pressure chamber through a conventional Pelton wheel producing electricity in a generator. There are two parameters which can be varied in order to optimise the buoy. These are the buoy diameter and the pressure in the chambers. The most promising version is a small diameter, low pressure buoy. This version has an air turbine. Its calculated overall conversion efficiency is 57%, yielding GWh/year. However, cost analysis shows that the mooring system is the dominating cost item. This must be over-dimensioned so that the buoy can survive during extreme conditions, which along a greater part of the Norwegian coast means wave heights larger than 30m.

Another approach is the Oscillating Water Column (Fig. 15.5) tuned to the peak frequency of the waves within a bottom-mounted structure. The tuning can easily be changed if there is a significant change in the wave frequency. Its modus of operation is quite simple: wave energy is converted into pressure energy by overflow into a central reservoir. Conventional hydroelectric power equipment produces electricity. Model tests show, however, that this unit has a very bad performance in irregular seas so it should mainly be used in areas where swell is dominating.

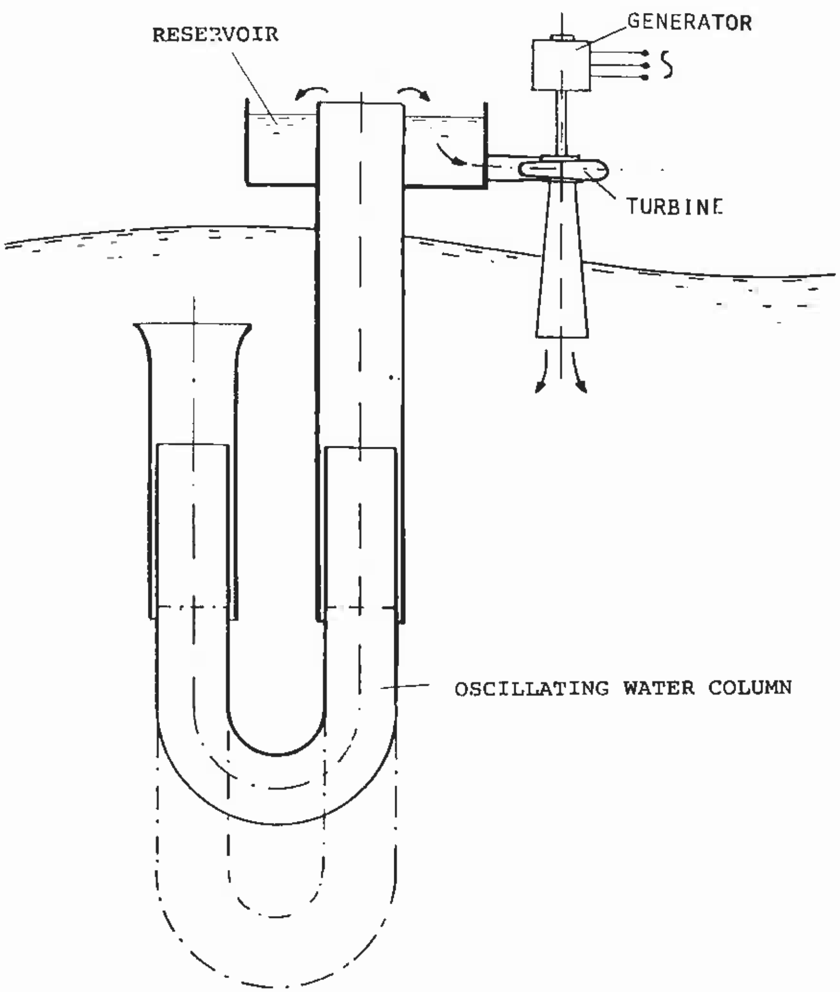


Figure 15.5 Oscillating water column.

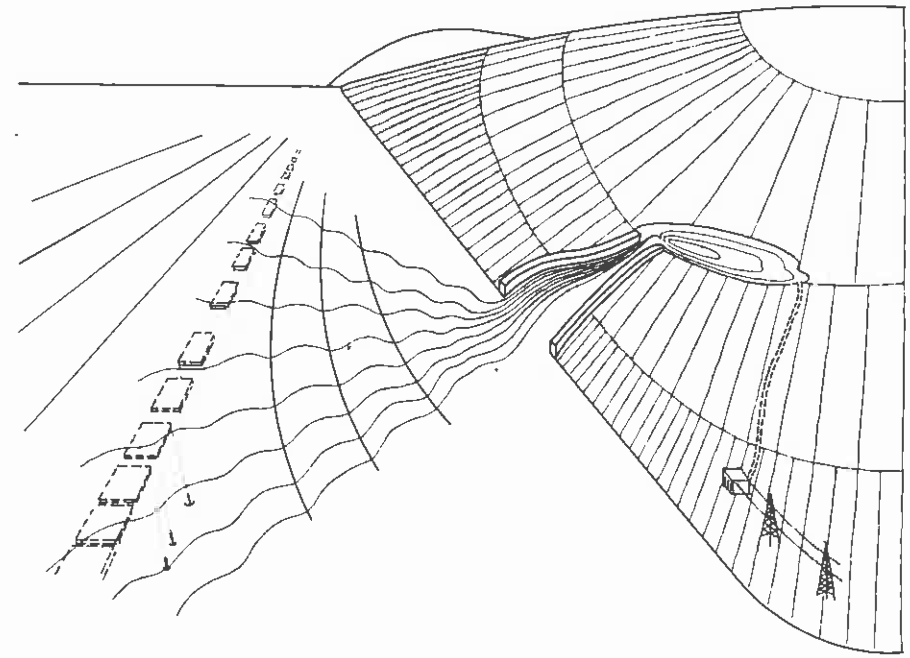


Figure 15.6 The Wave Lens

In 1977 a third approach was proposed by the Central Institute for Industrial Research in Oslo: the Wave Lens (Figure 15.6). The basic idea is simple. It is well known that the propagation velocity for waves is faster in deep water than in shallow water. Thus by using an artificial bottom with varying depth, a wave front can theoretically be made to converge at a single point, where a huge wave will form. It is further assumed that this huge wave will flow up to a reservoir from where it will feed a conventional hydroelectric plant. It should be mentioned that this approach is based on simple wave theory and that, for example, horizontal current gradients in the sea are not accounted for. Further, the subsea lenses are rather formidable structures of the same size as the wave length.

Concluding Remarks

If we exclude the tidal power plants, the only full-scale power plant based on wave energy which has been put to operation was the one constructed by Fusenot in Algeria in 1921, and that one broke down rather soon. Although there are many interesting concepts at present, probably many of them will not operate due to one reason or another which the inventor may have overlooked. However, in places were electricity is costly, wave power might one day be economical as part of an integrated supply system. We feel that given locations where regular swells are dominating, some of the buoy concepts might work and generate electricity within the next 10 to 15 years. To exploit the energy in irregular seas will probably need further technological developments and possible introduction of new concepts. As a last word, we want to emphasise that wave energy can only be one part of an overall energy system that also draws on other sources, such as wind, hydro and thermal electricity, nuclear energy, geothermal energy and others.

16 - WIND SYSTEMS

Paul Henton

No one source of alternate energy can solve all our energy problems, but used in combination, they can help to alleviate them. Wind energy is one power source that is applicable to Bermuda. The variabilities of wind prevent it being used for base load electric power generation. However, wind can be used as a supplementary source to save fuel. This is very important in Bermuda where electrical power is generated by diesel sets using high-cost oil.

In the past 500 years, wind energy has found economic applications three times and each time it became obsolete because a lower cost power source became available. A wind machine uses aerodynamically shaped blades to take the wind's kinetic energy and transform it into shaft power. This shaft power can be used directly for such mechanical applications as water pumping, or to drive a generator for the production of electrical power. The kinetic energy in the wind varies as the cube of the wind speed - that is to say that 20 mph winds contain eight times the energy of 10 mph winds. Any area where winds average 12 mph or more are suitable for wind systems.

Primitive windmills were first used about 1,000 years ago along the shorelines and on the islands of the Mediterranean Sea. About 500 years ago, more sophisticated windmills were developed for such uses as grinding corn and pumping water. The Dutch developed very efficient machines in the 17th and 18th century which drained and reclaimed large areas of coastal land. Then came the Industrial Revolution and steam power with its reliability replaced the variability of wind.

In the 19th century, wind energy made a come-back in the Great Plains of the United States where the farmers needed water for their cattle and for irrigation. And then came the internal combustion energy and windmills lost their popularity again.

But there was a demand for electrical energy for the farmhouses. Perhaps 200,000 small electrical generating windmills were installed in the 20's and 30's, but they in their turn were replaced by cheap, reliable energy from the Rural Electrical Authority.

In the 1930's, large scale wind generating systems were investigated in many countries. In the U.S., Palmer Putnam built a 1.25 megawatt machine on a mountain top in Vermont where it interfaced with the Vermont Power and Light Company. Putnam had many fine advisers on his staff, including Theodore Von Karman, who was responsible for the aerodynamics of the machine. Unfortunately, the blade roots were underdesigned and one failed shortly after the machine went on line. Putnam planned a newer and larger machine for which he performed an extensive economic analysis. Regretfully, he came up with the inescapable fact that wind energy could not compete with the 1/2 cent per kilowatt hour utility rates of the 1940's.

In Denmark, during World War II, diesel fuel for the utilities was scarce and a program was started to develop large wind systems for electrical power generation. This program was continued after the war when the South East Zealand Electrical Corporation installed a 200 KW induction generator machine which interfaced directly with the utility grid network. This machine ran successfully for many years until, eventually, low fuel costs made it obsolete.

The Electrical Research Association in Britain carried out extensive research on wind energy systems in the 1950's, installing several machines for evaluation at remote sites. One of these was in the Orkneys where, interestingly enough, a consortium of the

Figure 16.1 ERDA/NASA 100 Kw Experimental Wind Turbine - 1970's.

British Aerospace Corporation, General Electrical and Taylor Woodrow are currently installing a modern 200 KW wind system. This consortium is also evaluating the economics of large wind farms in the shallow waters off the east coast of England.

In the United States, wind systems development has been federally funded since 1973, with the major emphasis being on large systems. One example is the experimental 100 KW at Plumbrook, Ohio. Other larger machines up to

2 MW in size have been installed in windy areas of the U.S., Puerto Rico and Hawaii.

My company's efforts in the large wind systems area have been directed towards development of augmented devices such as the Tornado Wind System and the Diffuser Augmented Wind Turbine. These systems use static structures to direct large volumes of air through comparatively small rotors, thus eliminating many of the dynamics problems associated with very long blades. Other companies are developing various other wind system designs.

In 1978, the U.S. Department of Energy started a program to develop wind turbines for farm and rural use. Sizes of these machines ranged from 1.5 to 40.0 kw. One example of design developed under this program is the Grumman Windstream 25. This machine was designed to interface with the utility by means of a line commutated inverter. The WS-25 was installed at nine different sites, some with extremely harsh environments. One was installed at an Alaskan fishing village where - apart form the temperature difference - the environment was very similar to Bermuda because of the salt atmosphere and humidity.

The WS-33 is similar to the WS-25 in that use is made of a number of commercial components; a major difference is the use of an induction generator which interfaces directly with the grid rather than in our previous design where an invertor was required.

Erection of a wind system at a remote site is frequently a problem, because of the unavailability of heavy equipment. One solution, designed for the WS-33, is an erectable tower so that the machine may be mated to the tower on the ground and the whole system winched up to a vertical position.

A problem which must be considered in interfacing large capacities of wind systems with the grid is one of grid compatibility. Synchronous machines tend to generate their own voltage and frequency and may cause some grid instability if they represent a large portion of the grid capacity. Induction machines are less of a problem, although their need to draw a reactive power from the grid has to be considered.

To answer two questions before they are asked: noise is not a significant problem with small wind machines, neither is TV interference, particularly if fiberglass blades are used.

Let me close with an observation on incentives to the use of alternative energy systems. In the U.S., we have a number of Federal and state incentives as well as the Public Utilities Regulations Policy Act, which requires a utility to buy back excess power generated by the alternate source at the avoided cost. It was mentioned in an earlier presentation that the import duty on alternate energy systems was 5 percent, rather than the standard 20 percent. I feel that a more positive incentive for the use of such systems must be found than that of reducing the fine for owning one.

QUESTIONS & ANSWERS

Q. How many machines have been installed off-shore, and if so, what were corrosion problems?

A. I don't know of any off-shore, but you don't have to be off-shore to have corrosion problems. As I have mentioned, our Alaska site was particulary bad. However, the problem can be solved by correct material selection, etc.

Q. In the relief through property tax, was any weight given to the lower income rather than the affluent group? Is there any way in which we can get a spread of relief that will not be criticised by the public?

A. In answer to your first question, I believe that property tax relief is given at a flat rate.

* * *

Q. If we put a wind system on the reef, do we have much in the way of distribution losses?

A. That very much depends on the voltage. If you step it up, it should not be a problem.

* * *

Q. Is there a problem as regards size in interference between the wind systems which could be installed here?

A. I belive that the number of preferred sites would be limited so that machines would be spaced far apart anyway.

* * *

Q. Do you know of any hotels or anything like that in Puerto Rico or Hawaii that have installed windmills?

A. Not to my knowledge.

* * *

Q. Do you have any recommendations on what distance windmills should be from human habitation?

A. Some standards being developed by the American Wind Energy Association say 150 feet - but that still sounds small to me.

* * *

Q. My dream is that Bermuda has a fleet of electric vehicles that will come home at night and plug into an aesthetically pleasing wind generator on the roof. Is this feasible?

A. Perfectly feasible. Especially if you use one of our horizontal axis machines and one of the electric vehicles that Grumman just happens to build.

* * *

Q. Do you have problems with bearings?

A. We use sealed industrial type bearings. With the loads that are applied to them while the machine is running, they have infinite life.

* * *

Q. What is the maximum speed your machine will tolerate?

A. All machines developed for the U.S. DOE - of which ours was one - have a survival wind speed of 165 mph.

* * *

Q. If you were to use one of these machines for a small hotel, would interface with the utility be a problem?

A. No. Not with an induction generator which gets its reference from the grid.

Q. Could you give the cost per kilowatt range?

A. Depending on how you do your economic analysis, it can range from 3 to 25 cents per kilowatt-hour. My personal belief is that wind systems can be economically competitive - in other words, producing energy at somewhere between 6 and 12 cents per kilowatt-hour.

17 - SOLAR THERMAL APPICATIONS FOR BERMUDA

Drew A. Gillett

This paper presents the potential impact of solar thermal applications for heating domestic water on the importation of oil to Bermuda. Following a brief discussion of the technology, the history of solar water heating applications and the current pattern of energy use in Bermuda, the paper examines the performance and economics of an individual domestic water heating system. These results are then extrapolated to Bermuda as a whole to estimate the impact of substantial adoption of solar water heating techniques by the public.

INTRODUCTION

Solar water heating has been in use in various parts of the world for well over one hundred years. Notably, Japan, Israel, and the southern and western part of the United States have had significant solar energy industries in the past. Because of the rising cost and uncertain supplies of conventional forms of energy (particularly oil and electricity), these industries are currently undergoing a resurgence in popularity. Solar water heating is expected to continue this exponential growth throughout the remainder of this century, becoming a significant energy source well before then in many parts of the world.

The technology involved in solar water heating is often rather simple. Briefly, the sun shines onto a flat plate absorber positioned to face the sun. The absorber (which can be made out of copper, steel, aluminum or even various kinds of plastics) has been blackened to absorb the sun's rays and convert them to heat. The heat is conducted to a fluid (usually water or, in freezing climates, water/glycol) which is then pumped to a heat exchanger or storage tank where it gives up the absorbed heat to the domestic hot water. Various improvements to the system include transparent covers for the absorber to reduce heat loss, coatings to improve absorbence while reducing heat loss, and the addition of insulation throughout the system. Much of the research and engineering in the United States today focuses on freeze protection and complex control systems or high temperature systems which are not relevant to the heating of domestic hot water in Bermuda. The proven durable technology in use in similar climates throughout the world should result in cost-effective performance in Bermuda.

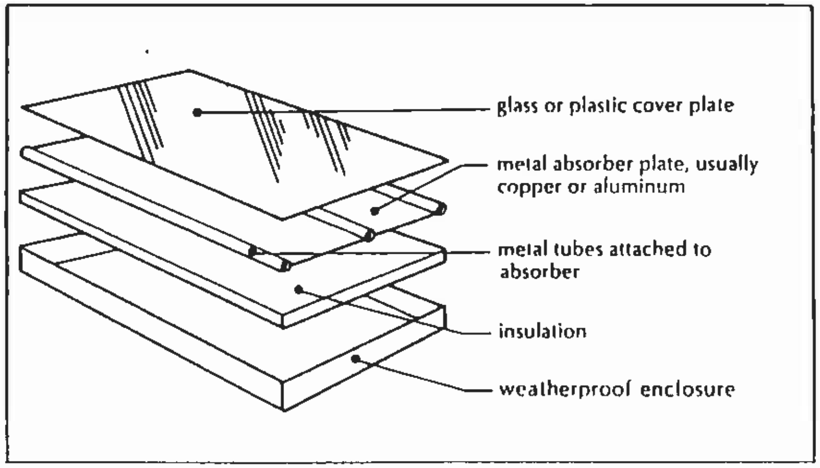


Figure 17.1 Flat Plate Collector. Source: Northeast Solar Energy Center.

HOT WATER USE IN BERMUDA

Typical hot water use in the United States is 20 gallons per day (gpd) per person. Recently, because of energy conservation, improved technology, and concern for water use this figure has been reduced to approximately 15 gpd for homes considering solar energy use. Based on a year round population of about 60,000 and an average tourist population of about 6,000, and the 20,000 residential

customers of the local electric utility, we can assume that hot water consumption per residence probably averages about 40 gpd. Heating this much water from a typical 65° F to 140° F requires 25,000 BTU's per day, or about 30,000 BTU's per day including standby losses. If this energy is provided by propane at 60% efficiency, approximately 180 gallons are required each year. If this energy is provided by electricity, about 3,600 KWH are required per year. At 1980 prices this consumption represents about $360 and $720 annually. It should be noted that the local utility must burn about two gallons of oil per day to supply this load which amounts to about eight barrels of oil per year per customer.

Given Bermuda's population and number of residential units and customers, it is reasonable to estimate that about 180,000 barrels of oil are burnt each year to heat hot water. This represents over 22% of all the oil the utility used in 1977. Since only 40,000 barrels of propane were imported in that year, and much of that was used for cooking rather than water heating, it is reasonable to assume that despite the more favourable economics of propane water heating it has not significantly reduced the use of electricity for this purpose.

PERFORMANCE OF SOLAR HOT WATER IN BERMUDA

Bermuda has an excellent climate for solar water heating. The same factors that make it a desirable tourist destination, warm temperatures and sunny climate, also indicate solar water heating will perform well. Further, the absence of freezing weather allows the simplification of the system resulting in lower cost, higher performance and improved durability. These factors should be included in designing or predicting the performance of a Bermudian solar water heating system.

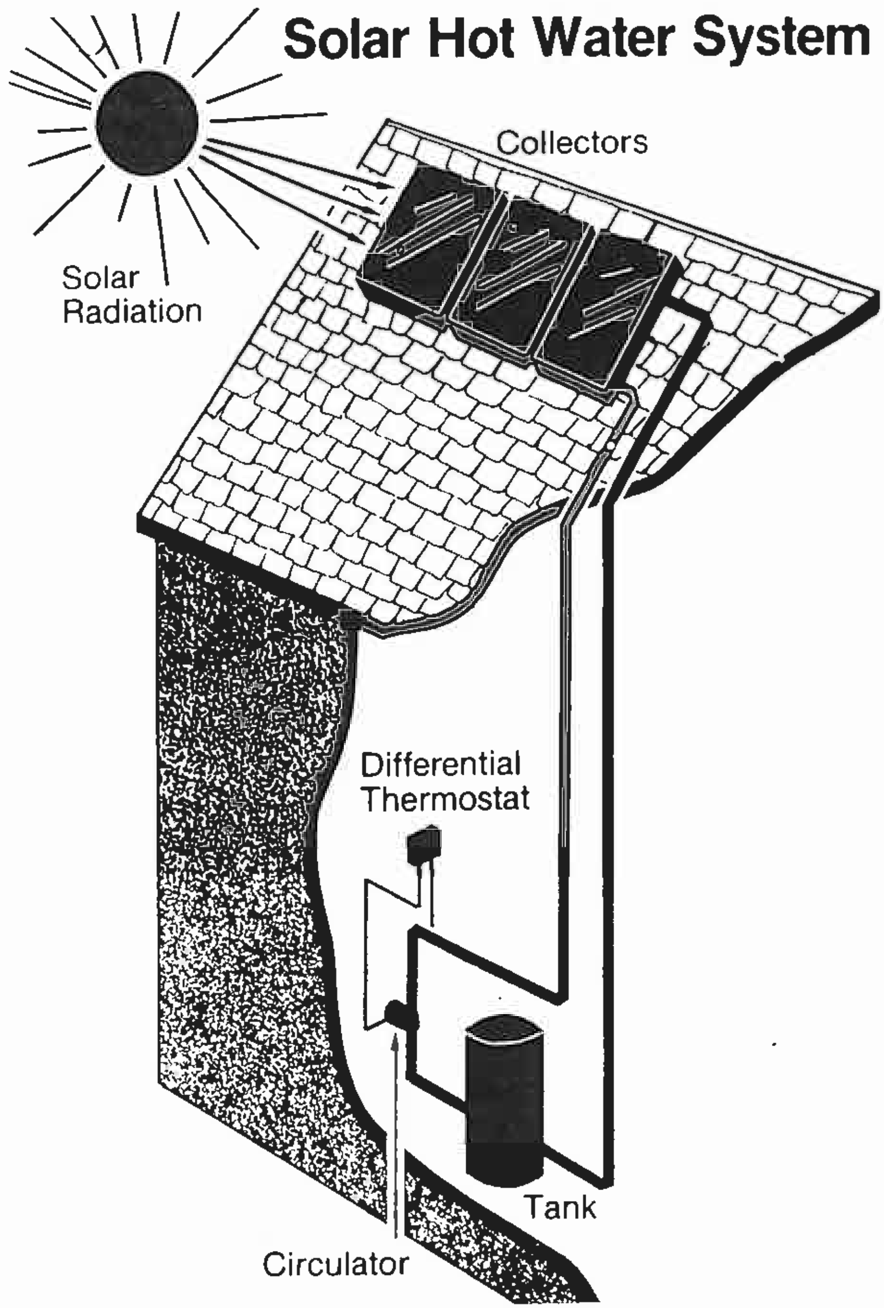


Figure 17.2. Source: Northeast Solar Energy Center.

Several computer programs have been developed for predicting the performance of solar heating systems of a variety of types and in a variety of climates. One of the more reliable and accurate and one in common use by engineers in the United States is a program called FCHART developed and maintained by the University of Wisconsin. Given a variety of inputs (Table 17.1) regarding system type, hot water used, tilt angle, size and characteristics of the collector and storage, the program calculates the performance of the system by month for a typical year. Using characteristics for a system suitable for Bermuda and selecting Charleston, South Carolina as the U.S. city with latitude, sunshine and year-round average temperature closest to that of Bermuda, the program predicts that (17.2) 42 square feet of collector (or two standard U.S. panels) should provide about 75% of the typical Bermudian customer's annual hot water load.

Larger systems will result in higher solar fractions and greater savings although the initial economics may not be as good. Smaller systems which have a slightly smaller first cost may not have as good overall long term economics. The performance of the system is fairly sensitive to the amount of hot water used, its temperature, the collector design, the type and quality of installation and the pattern of hot water use. Therefore, a detailed system performance analysis should be carried out for each system, particularly for systems designed for commercial buildings such as hotels. Often residential systems can be designed and sized based on local experience once that is gained.

ECONOMICS OF SOLAR WATER IN BERMUDA

A typical cost for a system of the type described above might be $2,680 in 1980 installed. System cost varies greatly based on the particular installation involved, the quality of the construction work, and the durability of the the system. Installation costs for similar systems in the U.S. in 1982 are expected to be well over $4,000. Much of the savings expected by utilising the simpler systems envisioned in Bermuda are offset by the high cost of shipping and importation as well as the need for skilled construction labor and engineering. Despite these high installation costs, solar domestic hot water systems prove to be a good investment in Bermuda.

On the basis of input data such as the cash flow and rate of return for a customer purchasing a solar system from savings, paying property tax, maintenance and insurance on the system and using it to displace electricity the program predicts that the customer will make a 20% return on his investment. The economics for a customer borrowing to finance the system are only slightly less favorable since the long term fuel inflation rate is generally acknowledged to be several points higher than the general inflation rate or the real interest rate. Despite short term fluctuations in the price of oil or electricity, solar domestic water systems have proven an economical investment for property owners over most of the United States. The additional benefits of a secure energy source, reduced pollution, an improved local economy and reduced need for capital expenditure by the utility are side benefits considered important by many customers.

IMPACT OF WIDESPREAD SOLAR USE ON BERMUDA

If two thirds of the residential customers were to implement a solar system of the type studied above, over 80,000 barrels of oil would be saved each year by the utility company in Bermuda. This significant reduction in energy use would improve the long term balance of payments, allow the utility to more easily meet the electrical needs of lighting, motors, computers, etc. and to concentrate its planning on the long term

growth and improvements to service rather than paying rapidly increasing oil bills. Further, each customer would see a reduction in monthly energy payments making him a 20% return on his investment in the solar system.

In terms of environmental impact, reduced air and water pollution both on the Island and the surrounding ocean would be obtained. The visual impact of collector systems can be minimized through careful integration of the collectors with the building structure, or screening from view. The optimum collector tilt angle in Bermuda allows collectors to be mounted fairly close to typical rooftops. Ground mounting of the collectors is always possible. It should be remembered that the total size of the typical system is less than one average sliding glass door. This is less than 0.2% of the floor area of a typical house in Bermuda.

IMPLEMENTATION

A program to assist in implementing this partial solution to the energy problems of the Bermudian economy could be undertaken by existing Government departments jointly to minimise cost, or a separate post could be commissioned. Most of the program would consist of education and demonstration since adoption of solar hot water systems already appears to be in the individual's economic self interest. Additional programs providing minor economic incentives (exemption from property tax, for example) or reducing perceived barriers to implementation (reducing building or zoning code restrictions) would be helpful in accelerating the adoption of the technology.

It is very important to realize that the implementation of this type of technology begins slowly because of the large number of individual solutions and decisions required. It would therefore be in the best interest of the country to begin immediately to implement a program of this type regardless of short term fluctuations in the price of oil. As the world has seen, oil prices can be doubled every 5 years with little difficulty. Since the last doubling occurred in 1979, 1984 is only a few years away. Finally, by implementing solar water heating technology, Bermuda would be insulating itself from the adverse effects on the tourist economy of oil price increases and would better be able to sustain itself through crisis periods.

18 - PHOTOVOLTAIC CONVERSION

Ted Blumenstock and
Jonathan Sands

A phenomenon known as the "photovoltaic effect" allows the conversion of light energy into electrical energy without moving parts. The devices needed for such a conversion are called solar cells.

The most efficient and inexpensive solar cells today are made of silicon. Silicon is the second most abundant element on earth, but it appears in compounds. For example, sand is a good source of silicon. After reduction and purification, silicon is a poor conductor in its pure form (semiconductor) and therefore it is doped with other elements to make it conductive to the point required. When phosphorus is added during the growth of the crystal, the silicon develops negative charge carriers (electrons); when boron is added, positive charge carriers (holes) appear. In this fashion, we talk about n-type and p-type silicon, respectively (Fig. 18.1).

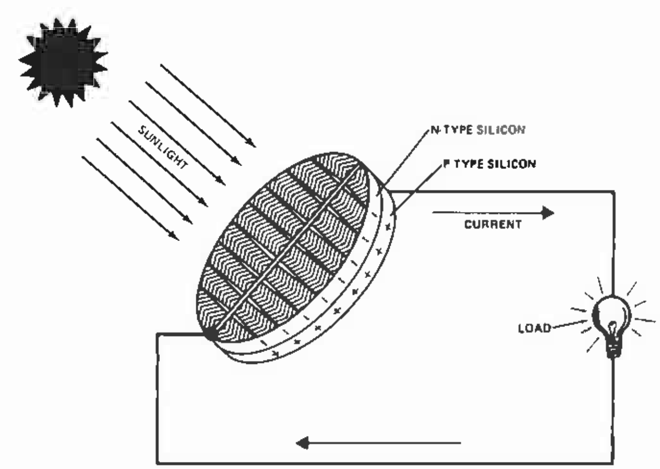


Figure 18.1 How solar cells make electricity.

When light falls on silicon, we find that red light penetrates deeply, while blue light is absorbed immediately below the surface. Light arrives in photon units, each photon having a well defined energy. This energy is absorbed by an electron creating a negative-positive charge pair (electron-hole pair). The charge pair has a very short life, about one millionth of a second, after which they recombine. However, if a separating force could be provided in the form of a built-in electric field, the charges could be driven out of the silicon before they will recombine. The field is provided by the formation of a "junction". High temperature diffusion of phosphorus into a boron doped silicon creates an n-type to p-type junction and a built-in field. When the silicon slice is now illuminated, a photocurrent is flowing and a voltage is developing. We now have a power source, a photovoltaic generator or solar cell.

SOLAR CELLS AND PANELS

The current-voltage characteristics of a typical space type solar cell are given below. For over ten years most satellites employed 2 x 2 cm (4 cm^2) size solar cells, about 0.012 inches thick. These cells show a short circuit current of about 140 mA and the open circuit voltage of 0.55 V. The power of such a cell is about 0.055 watt in space, but on the ground only 0.048 watt in clear sunshine. These small rectangular cells appear blue in color, as they are coated with a thin oxide in order to reduce optical reflection.

It is only recently that commitments were made for the manufacture of terrestrial solar cells to be used on earth. These cells usually are not rectangular as most silicon slices are obtained from slicing round silicon ingots. The most typical characteristics of terrestrial solar cells are their size. It is important to produce solar cells with areas as large as possible since the power generated is

proportional to the area. The electric power delivered by the solar cells divided by the incoming light power defines the efficiency. Most conventional silicon solar cells are 10% efficient. However, in laboratory settings, 18% conversion efficiency was has been obtained. It is a constant goal to increase the efficiency as much as possible, and continuous improvements in this area are expected.

The larger the solar cell, the higher the current will be. However, the photovoltage is independent of the area. A typical silicon solar cell will deliver maximum power at approximately 0.45 V. Therefore, solar panels capable of charging batteries must contain numerous solar cells connected in series. For example, the charging of a 12 V lead-acid battery requires at least 30 cells connected in series. Such applications typically use 32 or 36 cells. This cell arrangement will provide maximum charging power in the 13-14 V region required for charging a 12 V lead-acid battery. The size of the individual cells in the panel determines the current. For example, the Solarex Type 4200 panel consisting of 36 round chevron design cells delivers a minimum of 20 W (peak), while the Type 1480, having individual cells half as large, delivers 10 W.

Of course, the characteristics of a solar panel (or array) reflect the characteristics of the individual solar cells and the amount of power delivered by a given solar panel depends somewhat on the ambient temperature. Most of the temperature dependence arises from the variation in the photovoltage, and it is an inherent behavior of solar electric systems. The power output will increase when the temperature is lowered at a rate of 0.3%/^{o}C. It is therefore necessary to compare data obtained at the same temperature. It is generally accepted to provide information on solar cells (or panels) at 25^{o}C (77^{o}F). As most users have no access to a "solar simulator", terrestrial solar cells or panels are tested either at "full sun" or illuminated with a photographic flood light (at least 2800°K temperature) of 100 mW/cm^2 intensity.

LIFE OF THE SOLAR PANELS

Silicon solar cells are made at very high temperatures; therefore, under normal operating conditions near room temperature their life is almost unlimited. The solar cells, however, must have electrodes which are made of metals. These metals are subject to corrosion. It is therefore necessary that solar cells be coated when built into the panel. The coating material should be highly transparent, weather resistant, resistant to ultraviolet light, etc. In practicality, the life of a solar panel is determined by these "packaging" materials. Solar panels can be produced utilising durable, weatherable materials with surfaces that remain clean and require no maintenance. In this fashion, long life is assured.

SOLAR CELLS

Solarex has developed several techniques for estimating the size of a solar-electric system needed to supply a specific application. These techniques quantify the inescapable variations in solar radiation, which are influenced by such factors as season, site latitude and weather.

The first, which provides an approximation of solar system size, utilises Solarex-developed Solar Radiation Maps (Fig. 18.2) which express daily insolation in terms of "equivalent sun hours". (An equivalent sun hour is one hour of sunlight at its typical maximum intensity, 1 kW/m^2; therefore, 12 hours of sunlight with an average intensity of 0.4 KW/m^2 equals 0.4 x 12 or 4.8 equivalent sun hours). To determine approximate system size, find your site's equivalent sun hours per day using the 4 Week Average map (if you must design for "worst-

case"- winter-operation) or the Yearly Average map (if reliable winter operation is not mandatory). Then determine the average daily current demand of your installation in ampere-hours, adding a 20% safety margin to compensate for conversion and line losses, extended unfavourable weather, etc. Apply the resulting figures to the following formula:

Formula 1.

$$\frac{\text{Average daily load in ampere-hours (Ah) at nominal operating voltage + 20 \% safety margin}}{\text{Equivalent sun hours at site}} = \text{Required System output in amperes (A)}$$

Then, referring to the Unipanel specifications choose a panel of the proper voltage - and divide its output into the required system output. As shown below, this indicates the approximate number of Unipanels required for the installation.

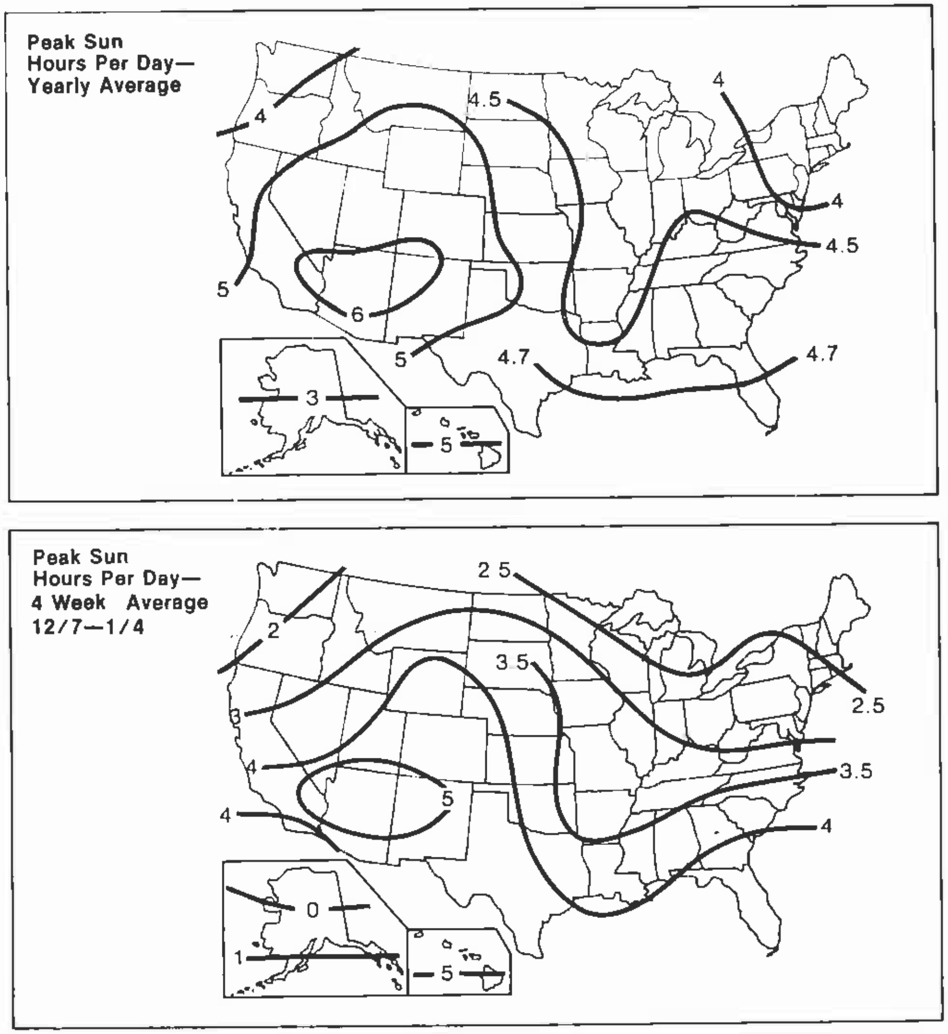


Figure 18.2. Solar radiation map shows variations in yearly average peak sun hours per day for locations throughout the U.S. (panel facing south; 45° tilt; no shade).

Formula 2.

$$\frac{\text{Required system output in amperes}}{\text{Output (amps @ nominal voltage) of panel selected}} = \text{Number of panels required}$$

For example, let's assume the installation to be powered is a radio repeater near Kansas City, Missouri requiring an average of 3A @ 12VDC 24 hours a day. Also assuming the system must be designed for worst-case (winter) reliability, we find winter insolation is approximately 3.5 sun hours per day (from 4-Week Average winter map). Substituting these figures into formula 1:

$$\frac{\text{(3A x 24 hours) + 20\% safety margin}}{\text{3.5 equivalent sun h}} = \frac{86.4\text{Ah}}{3.5} = 24.7\text{A required system out-put}$$

Selecting the HE60JG Unipanel(1) and substituting its output (2.56A @ 14V) and required system output into formula 2:

$$\frac{\text{24.7A (required system output}}{\text{2.56A (HE60JG output @ 14V)}} = \text{10 HE60JG panels in parallel}$$

(1) In systems using charge control circuitry and storage batteries, Solarex recommends that nominal panel voltage be slightly higher than nominal battery voltage, e.g., systems using 12V batteries should use 14V nominal panels.

The previous technique provides an approximation of system size, but gives no guidance as to required energy storage capacity. Most solar-electric systems incorporate a battery storage bank, providing the capability for continuous power supply regardless of weather conditions or time of day. Solarex has developed a highly accurate computer assisted system design procedure which delineates array/storage combinations capable of meeting application requirements and predicts year-round system performance at any terrestrial location. Provided with load parameters and accurate site insolation data, this program specifies the optimum panel tilt angle, computes array and battery capacity, and predicts total system performance over a 25-month period.

Solar electric systems are most effective in providing continuous power where commercial power is unavailable, too costly or unreliable. Solar cells are applied in many ways to furnish power, including:

- Radio and microwave repeaters
- Telemetry platforms
- Navigation aids
- Cathodic protection
- Lighting
- Irrigation
- Railroad signals
- Environmental sensors
- Remote buildings

19 - A BERMUDA ENERGY PLAN: THE CONSERVATION COMPONENT

Joan Habib

An overview of energy conservation may appropriately start with a definition of what it is or, more properly, what it isn't. For our purposes, conservation is not curtailment. I do not intend to discuss the out-and-out shut-off of energy supplies and the ensuing emergencies. Nor is energy conservation going to change our lifestyle dramatically or reduce our standard of living. Conservation does, more appropriately, mean using energy in the most efficient way - continuing to have the light, heat, and mechanical motion (those things which we expect energy to provide) at our current levels of use, or possibly even a little bit more.

People have spent a lot of time and effort trying to find a name for the relatively simple process by which we avoid wasting energy. Energy saving sounds trivial - a little too much like going without an ice cream cone in order to put a nickel in the bank. Curtailment is threatening. Conservation is the most often-used, but conservation and conservative have political connotations which are sometimes confusing. Energy productivity, a term associated with the work of Roger Sant of the Mellon Institute, comes closer to what we are looking for. But the problem of defining conservation remains unsolved. We seem like a bunch of frustrated ad men trying to come up with a new slogan guaranteed to sell more Crispy Crunchies for breakfast, but not without good reason. The public attitude which we must overcome with our advertising tactics is that this energy conservation stuff is not exciting. In fact, if you're not very careful, it is downright boring.

The truth of the matter is that in our modern world we find the "high tech fix" to our problems exciting and sexy. It also relieves us laymen of any responsibility. Things are in the hands of the technical experts. Watching the most recent U.S. space mission was thrilling, but few of us expect to take part in it. Nuclear power plants are awesome - both in the enormity of their exterior construction and in the powerful destruction that was their origin - but few understand what goes on inside. The U.S. is now embarking on the single greatest industrial undertaking the world has ever seen, the creation of an entirely new industry to produce synthetic fuels, so that we can burn coal, our most abundant energy resource, in our cars. Larry Lukin of the Synthetic Fuels Corporation has described this as "making the space program look like a Sunday afternoon picnic by comparison" - but few of us must consider how to do it. This is heady stuff. Conservation, on the other hand, is a multiplicity of decisions by people who don't view themselves as problem solvers for the nation, taking actions which are for the most part invisible and not high drama. Although new processes, new technologies and new applications continue to be discovered which will enhance our ability to conserve energy, the major obstacles are political, institutional, and social. We are not waiting for a technological breakthrough; we are waiting for people to decide to do something about it.

Price has traditionally been named the culprit. Because energy was so cheap, it was easier and less costly to waste it than to institute systems to save it. While this is no longer true, response to increased energy prices lags far behind the market. Long-held public attitudes about energy use are difficult to change. Faced with soaring costs for heating and cooling their homes, many homeowners wring their hands, rail at the oil companies, complain loudly and talk about having to dip into their savings or cut out their vacations in order to meet their bills,

rather than attacking the root of the problem by seeking ways to use less energy. In the past, the cost of replacing a cracked windowpane was greater than the cost of the energy used to heat or cool the air that was escaping through the crack. This is no longer true. Our habits of energy use, like all human habits, change with depressing slowness. But change we must.

We must begin to look at "conservation energy" as directly comparable to any other energy source - imagining that we can mine conservation energy or pump it from a multitiude of small wells. Viewed in the aggregate in this manner, we can understand the magnitude of the mother lode. Most estimates of potential conservation energy in the U.S. place it at 30 to 40% of current use or, conservatively, a resouce of 20 Quads. If we could discover a new field with a guaranteed annual production of 4 or 5 billion barrels of oil per year, there would be a lot of people anxious to invest. We'd have the equivalent of a new gold rush. To add further to the temptation, we can safely predict that the cost of this new find is in the neighborhood of 7 to 10 dollars a barrel, compared to the black gold we are currently importing for more than 30 dollars a barrel. This potential sounds almost too good to be true. Many people don't believe it is possible - another major barrier to the realisation of energy conservation goals. Where is this mythical field of 7 dollar oil? It's all around us. Gross energy distribution figures in the U.S. show that the residential sector accounts for 21.6%, commercial 15.9%, industrial 37.2%, and transportation 25.3% of total energy use in 1979. So industrial co-generation and more fuel-efficient cars and trucks are among our priorities. Our conservation energy is to be found in slightly different amounts and in differing places than yours here in Bermuda. Lacking heavy industry, and with severe restrictions on transportation already in place, the major sources of potential energy savings in Bermuda are most probably in the residential and commercial sectors with savings also possible by your electric utility. Because Bermuda's major undertaking is tourism, which implies hotels, restaurants, and other commercial establishments, let's take a look at an example or two.

New buildings are the most fascinating to contemplate in terms of energy efficiency because they come closer to our notion of the high technology fix and can incorporate the most novel of approaches more easily than older buildings. For example, a designer contemplating new construction on Bermuda should examine Ontario Hydro's newly built headquarters in Toronto. This is a pace-setting example of an energy conserving building and, in spite of its construction in a cold climate, has no conventional heating source. It is twenty stories high with a floor area of 1.3 million square feet. Five basic features set Ontario Hydro's new building apart from other well-designed buildings:

1. Efficient thermal design has been achieved through installation of double-glazed reflective glass and insulation to conserve heat in winter and to reduce energy use for cooling in the summer.

2. The lighting load has been reduced by about 33% by the integration of fluorescent fixtures with reflective V-shaped coffered ceiling panels. To provide illumination, this system uses only 2.7 watts to provide 100 footcandles as compared to 4 watts in most buildings.

3. An internal source heat pump system captures heat from lights, people, and equipment in the core area for perimeter heating in winter and for removal or redistribution in summer.

4. An immense underground reservoir stores up to 1.6 million gallons of heated or chilled water for use as required.

5. A centralised computer system monitors, controls, and optimises operation of all mechanical and electrical equipment.

As the result of these systems, savings on annual energy consumption is estimated at 20 million kilowatt hours. Given the cost of electricity in Bermuda, some simple math leads to a savings of about 3 million dollars a year over a conventional building. Given these figures, some life cycle cost estimating makes the construction costs of around 45 million dollars look good. The total energy use for this building is about one-third that of a new, well-designed building of similar size.

While it clearly makes sense to insist upon energy efficiency in new buildings both from the point of view of the investor and owner and as a matter of public policy, the fact is that building stock turns over very slowly so that new building designs have substantial impact only in the long term. Because the actions required are less visible and of a lower order of technology, promoting energy efficiency in existing buildings will require an extensive campaign of promotion. Initial large energy savings through retrofit of older buildings are available without capital investment, and the methods of achieving these savings are not technical or profound. They amount to turning down or up thermostats, lowering lights, fine-tuning of systems, shutting off unused equipment, reducing heating and cooling in unused rooms, and greater attention to systems maintenance. But truly substantial savings can be achieved in these ways.

Finding ingenious ways to reduce energy consumption for those services which support a tourist industry is an intriguing problem. Thinking about energy conservation in food services, for instance, raises some interesting corollaries to the notion of industrial cogeneration. There are several energy consuming systems that might be efficiently integrated. Take for instance food refrigeration. The process of keeping a refrigerator cold produces heat which is usually dispersed into a kitchen already overheated by ovens and dishwashers and which must be air-conditioned to maintain comfort. Relatively low-grade heat is needed to heat the water for dishwashers. This rejected heat from refrigeration compressors could be recaptured to heat water for dishwashers. The whole question of energy-efficient appliances becomes central to savings in this area. It might be a useful role of public policy to insist upon high energy efficiency ratings for all appliances imported to replace worn-out equipment, thus forcing a more rapid move toward the best available technology. Since the payback period for most of these appliances is less than 3 years, this would hardly place a hardship on the owner of the equipment.

Since the largest energy user in Bermuda is the electrical utility, BELCo, it makes sense to look closely at the potential for conservation in this area. In order to generate electricity, BELCo consumes 91% of all diesel oil imported to Bermuda and is the end user of 63% of all imports of petroleum. The efficiency of the utility is 30% indicating 70% energy waste in one form or another. This raises several questions. First, is continuing use of boilers designed to burn only diesel fuel a wise option? And second, is there any potential for waste heat recovery?

Energy lost in electricity production is always a problem. However, the magnitude of the loss in this case is so great a percentage of total import that every avenue for more efficient use should be explored. The cogeneration process which could be

implemented at BELCo is called "diesel topping" process - which means only that diesel fuel is burned in order to turn an electric power generator. The hot gases coming out of the engine are either used directly in a process that requires relatively low-level heat, or they are used to produce steam in a waste heat recovery boiler. The diesel topping cycle has the potential of saving more fuel than any other cogeneration cycle. Although BELCo generating facilities are apparently too distant from potential users (hotels, etc.) for this to be an option, it is likely that there is some other process that currently uses electricity but might relocate near the BELCo plant to use waste heat. A desalinisation plant to produce much-needed fresh water supplies or a large laundry facility shared by several major hotels are only two such possibilities. Another possibility to be investigated is that of district heating with steam, i.e. to tie those businesses and residences closest to the BELCo plant into a heating system. Yet another possible use of waste heat is the preheating of the diesel fuel itself which in some boilers allows for more efficient operation.

Since there appear to be no legal barriers to electrical generation by others than BELCo (provided that the electricity so produced is for in-house use) it might prove feasible for a consortium of commercial establishments (especially teamed-up, contiguous properties) to generate their own electricity. As part of this process, they may use the waste heat produced by such local electric generation to provide for many if not all heating and air-conditioning requirements for the consortium members.

Still another question is whether BELCo should modify existing boilers to accommodate other fuels, or at least commit to buying new boilers as needed, which have multi-fuel capacity. If fuel import costs continue to rise, it may ultimately be much more economical for BELCo to install boilers which can utilise solid waste, for instance.

The residential, commercial and industrial sectors, if examined thoroughly, will provide a fertile field for producing conservation energy. To apply the appropriate energy source to the work to be done is a concept that should be closely examined. Using oil generated electricity to heat domestic water, to cook, or even for space heating and cooling in Bermuda's relativley moderate temperature range, is like toasting marshmallows on a nuclear reactor.

Using too much energy has several effects upon our society. In the first place, it ties up capital which may be more profitably invested elsewhere. In the second, for those who must rely on foreign sources, it increases vulnerability and the potential disaster of a sudden cut-off of supply. If we view efficient energy use as a social good which the government should be interested in promoting, we can begin to look at the public policies which can be instituted to achieve more optimal energy conservation.

We have identified some of the barriers to conservation:

1. Lack of drama.

2. Lack of understanding of the magnitude of the potential.

3. Need to involve comparatively large numbers of decision-makers.

4. Lag time between rising market prices and consumer action.

What are the public policies which might be instituted to remove some of these barriers? There are several that come to mind at once.

Mandatory New Building Standards. This is a solution which is being hard fought in the States today. Builders feel that the proposed standards put too great a financial burden on them at a time when there is a general economic slow-down. They further feel that the suggested standards which set ceilings on energy use and allow the designer or builder flexibility as to how to achieve efficiency, are still stringent for the small construction company. The industry prefers the existing voluntary prescriptive standard which sets the R values for insulation, and indicates the nature of glazing, etc. It is a difficult problem but one which might well be resolved in Bermuda depending on the potential for new construction and the difficulties involved in implementation and acceptance.

Incentives and Disincentives. Bermuda's tax system does not allow for the granting of incentives such as the conservation and solar tax credits used in the U.S. since there is no tax against which to grant a credit. There remains the possibility to provide disincentives to wasteful practices in the form of penalties. On the other hand, one might want to consider a system of (non-financial) rewards to the most energy conserving building in each of a series of classes - residential, hotel of a certain size, restaurant, etc. - backed up by a media campaign-contest to focus attention on the problems and the possible solutions.

Import Restriction. In the same way that restrictions are in place on the importation of automobiles, it should be possible to consider restriction on the importation of energy-inefficient appliances. By allowing only those refrigerators, dishwashers, air-conditioners, and other major appliances which are proven to meet standards of appliance efficiency, it should be possible to upgrade the stock in use more quickly than will occur without restrictions.

<u>Information</u>. The policy that must underline all others, and probably the keystone of any effective energy conservation plan is information. Traditional market economics tend to underestimate the role that information dissemination plays in decision-making. These theories assume that people behave in "rational" ways and that decisions are made for price-related reasons. For example, if energy conserving improvement or solar systems are less costly than conventional fuels, the paradigm assumes that they will be installed. The supposition is that the information about the relative costs of both energy sources is readily available.

This model may explain the behaviour of large industrial firms. AT&T, Ontario Hydro, Dow, and others have made serious and successful efforts to implement energy efficiency regimes. These companies have corporate energy managers, large accounting staffs, and well-developed criteria for making "economically rational" decisions. Energy investments must yield the same rate of return or offer the same pay-back as other investments.

Aggregate energy use statistics reveal industry's advantage very clearly. Between 1973 and 1978, overall energy use increased by 0.9%/yr. Industrial energy actually declined by 1.2% in the same time period. By contrast, residential and commercial use increased 2.6%/year. Homeowners and small businesses are frequently unaware of the economic advantages of energy-saving investments. Most households have little experience with rate of return computations or pay-back calculations, much less life-cycle costing procedures. But useful economic data are only one type of information that needs to be available to homeowners and small business people. Energy users also need to know where to find knowledgable contractors, architects, and builders. If they do the work themselves, they need access to materials, equipment, and

suppliers. But most of all, they need to know that there is a community-wide commitment to conservation, that their efforts are part of a whole, and that they will make a difference.

Ultimately we have a limited number of available alternatives in our quest to feed our gluttony for fuel. The fossil fuels of our planet will some day run out, no matter how hard we try to delay that day. We have yet to solve the problems associated with nuclear fission, notably waste disposal. Fusion energy is not yet a commercially viable option. Renewable resources such as direct use of sunlight, wind energy, biomass, tides, or OTEC are all real possibilities. But no matter what our energy sources are, the question remains whether there is any sense in using too much of it. There must be a point at which a rational individual perceives that it is just plain foolish to waste a valuable resource. No matter which energy future is destined to become the reality, conservation will be a primary component.

20 - TRANSPORTATION ENERGY CONSERVATION STRATEGIES FOR BERMUDA

Frederick C. Dunbar

Bermuda is in the enviable position of having a relatively fuel efficient transportation system. This does not mean, however, that the Island should be overly complacent about its oil consumption. Bermuda's balance of payments suffers every time OPEC decides to raise the price of oil. Also, during a supply disruption, Bermuda does not have the luxury of switching oil from other uses just to keep the transportation system functioning; all the rest of Bermuda's energy also comes from oil.

It would appear that Bermuda is at least as vulnerable to an oil supply cutoff as any other developed nation. Reducing the transportation system's dependence on oil would make a cutoff less painful. Nonetheless, I would advise taking a cautious approach to transportation energy conservation. My reasons for this are as follows:

1. Bermuda's transportation system will, in all likelihood, become even more fuel efficient over the next two decades simply as a result of market forces;

2. Bermuda should avoid strategies that conserve oil but make the Island less attractive as a tourist resort, by far its most important source of income;

3. Bermuda's most immediate transportation problem is congestion around Hamilton and on some of its main arterials; in the short run, solving this problem will be more important than reducing transportation oil consumption;

4. Energy conservation is not costless, and some strategies involve investments having worse effects on the Island's balance of payments than reducing oil impacts.

In discussing transportation energy conservation, I assume that the government of Bermuda will continue to limit the size and number of automobiles to encourage tourism. This ensures a small, fuel efficient fleet. However, as gasoline prices rise, consumers will desire even more fuel efficient cars. Automobile manufacturers are accommodating this demand by making cars which sacrifice relatively few amenities for more miles per gallon.

Aside from direct controls on the fuel efficiency of imported automobiles, there are basically three types of strategies that can be used to promote energy conservation. Each of these, and my preliminary conclusions regarding their effectiveness for Bermuda, are described below:

1. Public Transit: Encouraging mass transit is probably not going to help Bermuda conserve fuel. The energy efficiency of buses will not be much higher on a seat-mile basis than the energy efficiency of private automobiles. The costs of more fuel efficient rail transit far outweigh potential energy benefits.

2. New Technology: Electrified vehicles, in one form or another, are well suited to Bermuda. The major drawback of electric vehicles is that all of Bermuda's current electricity generation is by oil. However, it is still possible that these technologies could provide oil savings. They could also provide a hedge against oil disruption if some portion of the Island's future electricity generation comes from alternate fuels.

3. Non-Technological Strategies: There are a variety of low-capital strategies which are available to Bermuda such as using taxes, rationing and consumer awareness programs. These strategies vary in their effectiveness and no overall conclusion as to whether they should be implemented is possible. They may be of most importance for contingency planning, which is discussed elsewhere.

THE BUSINESS-AS-USUAL TRANSPORTATION ENERGY OUTLOOK

Bermuda does not consume large amounts of oil for transportation. The reasons for this are obvious: (1) the most common vehicle is a motorbike with a small (no greater than 100 cc) engine; (2) automobiles are limited to no more than one per household and now number 13,600 relative to a population of 55,000; (3) automobiles are also limited in size (approximately 1600 cc is the largest available) and the current fleet averages about 25 miles per gallon; (4) average annual miles travelled by a car is small (about 6,000) because trip distances are short.

All of these factors combine such that the average oil consumption for transportation in Bermuda is a modest 3.8 barrels per year per person. Less than one-third is for automobile energy alone - 1.2 barrels per year per capita. By comparison, automobile gasoline consumption in the U.S. is about 8.2 barrels per person annually - about half of all transportation energy consumption.

About 5 percent of Bermuda's total foreign trade bill goes to oil imports for transportation (250 thousand barrels of distilled product at about $50 per barrel). This is a significant but not overwhelming economic drain.

Future transportation energy consumption should be at about the same level or less. The reason for this is that growth in travel will probably be offset by the introduction of more fuel efficient vehicles. Indeed, if Bermuda's consumers are anything like those in the United States, automobiles should be about 40 percent more fuel efficient in 1990. We can also expect increased miles per gallon from buses and trucks though not as quickly as in cars.

Coping with oil cutoffs is more of a problem than increasing fuel efficiency per se. The Island is not so idyllic that it can function without motorised transport. Moreover, if there are fuel shortages, the transport sector will have to vie with every other use of energy for allocations because these also depend exclusively on oil.

PUBLIC TRANSIT OPTIONS

After the OPEC oil embargo in 1973, attention focused on using public transit to conserve oil in the United States. It was soon realised that such a strategy provided only marginal, if any, savings. Some of the problems with trying to use public transit as an energy conservation strategy can be seen with data from Bermuda.

Bermuda relies on buses for its transit service. By 1990 bus fuel efficiency should be no greater than automobile fuel efficiency. Bermuda's auto fleet should be achieving approximately 35 miles per gallon in 1990. At 1.4 persons per trip (the average vehicle occupancy obtained in the United States), this means that auto fuel efficiency will be approximately 2440 Btus per passenger mile. This is to be compared with the current Bermuda bus system which gets 3550 Btus per passenger mile or about 40 percent more than the average auto. (Bus fuel efficiency was computed by adjusting U.S. experience, approximately 2890 Btus per passenger mile, for the lower load factors which occur in Bermuda, 132 versus 162 passengers per day per bus).

It is somewhat surprising to note that a fully loaded bus achieves about the same as the future fully loaded auto (about 890 Btus per passenger mile). Thus improving the load factors of either buses or cars gives Bermuda the same energy payoff.

Currently, Bermuda's transit system pays for most of its operating expenses out of the farebox. To improve load factors without restricting auto use would require increasing operating deficits and public subsidies. I would advise against subsidising transit solely to conserve energy. Experience in the United States has shown that when there are transit operating deficits, public pressure rises to reduce transit costs by cutting service and the transit system deteriorates in quality. It is quite possible that attempts to improve transit through operating subsidies would be counter-productive.

Rail transit is more energy efficient than bus. However, even the most modest of conventional rail systems (called: Light Rail Transit) would be inordinately expensive for Bermuda. Each light rail vehicle (LRV) would replace approximately two buses if such a system were put in place. When amortised over 30 years the annualised cost of these vehicles is $37,000 greater than two buses. At current loads, Bermuda would achieve about 1760 Btus per passenger mile by using LRVs rather than buses. This means that each LRV would save about 160 barrels of oil per year, which is the equivalent of $7,000. But Bermuda would be losing approximately $30,000 a year simply to save this energy. This does not include the annualised cost of other capital items (right of way, track, stations, which could total $80,000 per year).

In sum, using conventional transit technology to conserve energy does not appear promising.

NEW TECHNOLOGIES

Over the long run, Bermuda need not be constrained by existing technology. There are a number of exciting developments occurring in the electrified transportation field. Two emerging technologies which Bermuda should watch carefully include electric vehicles and automated guideway transit. Each of these will be discussed below with a view to 1990 and beyond.

<u>Electric Vehicles</u>

Bermuda is almost an ideal environment for private electric vehicles. Many of the drawbacks of electric cars which are unacceptable to American consumers are not relevant in the Bermuda market. Range limitations are not a powerful deterrent in Bermuda because average trip lengths are small. Vehicle speeds are kept low by law. Bermuda's climate is so temperate as to make heating and air conditioning unimportant.

The major drawback of electric vehicles is that Bermuda's current electricity is all generated by oil. However, this is not as large a barrier as one would intuitively expect.

In order to see whether electric cars would have a market in Bermuda one should look at their total cost to the consumer as well as their potential for saving fuel. The typical 1990 small internal combustion engine vehicle should get about 36 miles per gallon and have a total cost of 30.5 cents per mile, both numbers computed for Bermuda's fuel market and driving conditions.

By comparison, U.S. electric vehicles which are expected to be on the market in 1990 will cost approximately 37.5 cents per mile and, assuming an oil-fired utility with 28 percent energy efficiency, would achieve the equivalent of 26 miles per gallon. Under these assumptions, the electric vehicle is not a bargain to the consumer nor does it conserve oil.

However, the story does not end here. U.S. electric vehicles are being designed to achieve ranges and highway speeds much greater than are needed for the Bermuda market. In addition, Bermuda's base-load electric utility efficiency should be closer to 40 percent by 1990. Designing an electric vehicle to meet Bermuda's diving conditions results in a total cost per mile of 32.9 cents and an equivalent miles per gallon of 43. In this scenario, there is less than a 10 percent price difference between electric and conventional vehicles and an actual gain in fuel efficiency of almost 20 percent.

Electric vehicles for Bermuda can be made even more attractive by adjusting two other factors. The first of these would be to allow off-peak pricing of energy in overnight recharging of electric vehicles; this would cut the cost of electricity by approximately 50 percent. The second adjustment involves the implicit discount rate used by consumers when they evaluate the higher cost of electric vehicles compared t~'o their lower operating cost. In the United States, this discount rate is usually considered to be about 10 percent. In Bermuda, the law prevents lenders from offering more than 7 percent interest. Given that the opportunities for savings by households cannot result in a rate of return higher than 7 percent, it might also be the case that this is the same discount rate they would apply in evaluating automobile purchases.

The net result of these adjustment is to make a Bermuda-designed electric vehicle cost 27.6 cents per mile (compared to 28.6 cent per mile for a small internal combustion engine vehicle

also assuming a 7 percent discount rate). Such a vehicle could achieve 43 miles per gallon of oil consumed compared to 36 miles per gallon for the conventional car. All things considered, electric vehicles may be both more energy efficient and lower-cost for Bermuda in the future.

Of course, there are several barriers which have to be overcome to ensure that there is a market for electric vehicles. For one, the "Bermuda design" would have to be produced in large enough quantities to get scale economies from its manufacturer. This means that the Bermuda market would have to amount to at least a few thousand vehicles. In addition, Bermuda would have to develop a network of dealers and repair facilities to support owners. Still, the numerical results presented above are quite provocative.

<u>Automated Guideway Transit</u>

Automated guideway transit is another emerging technology. This rubric includes a wide variety of alternatives; from high-speed moving walkways to vehicle systems which are almost as large as light rail.

Perhaps the most interesting feature of such an alternative is that it can enhance the Island's status as a tourist resort. In comparable circumstances, theme parks in the United States have a large amount of operating experience with alternative automated guideway transit systems.

The new systems can be much more energy efficient than conventional public transit systems. Those that are designed to be used only on demand can achieve higher load factors than traditional transit. Also, a number of technologies use passive vehicles (or moving guideways) which do not carry the engine or power source in the vehicle. Such systems can achieve energy efficiencies of 210 Btus per passenger mile at full load or about one-fourth that of conventional transit or auto.

The drawback of these new technologies is their cost. They cannot be justified on energy grounds alone: each $3,000 in annualised capital expenditure would save, at best, $1,000 in oil. Thus, they are not appealing solely as a means of conserving fuel. Rather, they should be evaluated in terms of Bermuda's overall transportation needs with energy considerations balanced against other factors.

Specially Designed Electric Vehicles May Be An Attractive Option

Representative 1990 Characteristics

	Miles Per Gallon (MPG)	Total Cost (c/Mile)
Small Conventional Car		
10% Discount Rate	36	30.5
7% Discount Rate	36	28.6

4-Passenger Electric Car	Equivalent MPG from Oil-Fired Utility with Efficiency of: 28 Percent	40 Percent	Total Cost (c/Mile)
Current Prices and 10% Discount Rate			
U.S.Prototype	26	37	37.5
Bermuda Design	30	43	32.9
Off-Peak Prices and 7% Discount Rate			
U.S. Prototype	-	37	31.4
Bermuda Design	-	43	27.6

Assumptions: Automobiles are driven 6,000 miles per year and have a seven year lifetime.

Gasoline costs $.60/litre. Electricity costs $.15/kilowatt-hour average and $.073/kilowatt-hour off-peak. Vehicle characteristics and other costs are from Carlere et al., (1980) and Shackson and Leach (1980).

NONTECHNOLOGICAL STRATEGIES

There are a variety of low-capital, market-oriented strategies, which can reduce oil consumption. Most of these are useful for crisis management and are discussed in the chapter on contingency planning. Below, I have confined the discussion to only two which are relevant for longer term energy conservation.

Driver Awareness Campaigns

The U.S has a number of government sponsored driver awareness programmes aimed at reducing gasoline use. They inform people about the fuel efficiency of alternative car models, and tell drivers how to squeeze more gallons out of the cars they now have. The campaign uses a variety of materials, including pamphlets, handbooks and films. Often, the message appears in the news, but is otherwise disseminated in mailings or workshops and seminars.

Though the campaign may have some impact, it is not well funded, nor does it have the appearance of a typical Madison Avenue effort. At the time of these federal activities. several automotive products (slippery oils, radial tires and small cars) were also promoting fuel efficiency. These privately funded ad campaigns were probably more effective, though possibly more costly.

I would conjecture that conservation should be marketed just like any other consumer product. The success of a driver awareness programme depends on the extent to which it causes consumers to reduce gasoline consumption of their own free will. This objective is similar to that of a private firm attempting to market a new product line or rejuvenate an existing product through advertising. Market research and established methods for product promotion would probably be more successful than the current approach.

Fuel Taxes

Politicians who propose increasing taxes on oil consumption have short careers. Despite the unpopularity of this strategy, it does make sense to economists. (This helps to explain why so few economists become elected officials.)

Bermuda currently funds much of its government out of import duties. These tariffs could be easily rescaled so as to increase the price of oil and decrease the price of all other imported goods. Similarly, Government could raise registration fees on low miles-per-gallon cars and lower the fees on high miles-per-gallon cars. If proposed in such a way that fuel taxes are viewed as being redistribution rather than new taxes, they might be more acceptable to the public.

CONCLUSION

Bermuda's transportation energy conservation choices are less painful than those in other developed countries. Simply extending the current policy of limiting the size and number of cars ensures a fuel efficient transport system. In the long run, the Island can choose among emerging electric technologies which may make the Island even more attractive while conserving oil.

21 - WASTE-TO-ENERGY OPTIONS FOR BERMUDA

Jay Campbell

An important consideration in comparing waste with other alternate energy sources is that a waste-to-energy program will often provide economic and environmental benefits in addition to solving the waste disposal problem. In many communities, waste disposal costs are increasing (presently $20/ton in Bermuda) as environmental and aesthetic issues make new landfills problematic. A waste-to-energy program may thus provide a partial solution to both problems and often, as seems the case in Bermuda, the timing and approach will be guided primarily, or even forced by, the disposal needs.

The following presentation discusses these issues and reviews options for recovery of compost, paper, metals and other materials. Such options are relevant to energy conservation in that they reduce imports and the associated costs of transportation and handling, save the energy utilised for materials production and, if marketable, improve the overall economics of a waste-to-energy operation.

Energy and Materials from Solid Wastes: Approaches and Technologies for Small Communities

For the past 10 years emphasis in waste-to-energy activities in the U.S. - both in federal program and privately marketed systems - has been on large-scale facilities. Their capacities of over 500 tons per day and their technological sophistication and costs, often $50 per ton per day, make such systems impracticable for smaller communities where the available waste is only between 50 and 200 tons per day. (Bermuda's current generation is about 100 tons per day of residential waste). Only recently has emphasis on small-scale, low-technology, low-cost energy recovery systems been evident in federal programs and commercially available technologies.

Options for energy and materials recovery for small communities are listed in Table 22.1. Those options that are not realistically applicable for small communities, and thus not discussed, are: mass burning waterwall or refractory-lined heat recovery incinerators; processed fuel plants with dedicated boilers; pyrolysis systems; and natural (landfill gas) or controlled anaerobic conversion facilities. Each of the smaller scale options in Table 22.1 is briefly described and their potential for application to small communities in general is discussed. The reasons why individual approaches may be more or less applicable for Bermuda are highlighted. Modular incineration systems which seem to be the logical and most favoured approach on the basis of thorough study by the Department of Public Works and their consultants are discussed last and in the greatest detail.

TABLE 22.1. LOW TECHNOLOGY SMALL-SCALE RECOVERY SYSTEMS OPTIONS FOR SMALL COMMUNITIES

- Source separation
- Refuse-derived fuel
- Co-disposal
- Composting
- Modular incineration
- Combinations

Source Separation: Nearly all of the materials presently recovered from municipal solid waste (MSW) in the U.S. are from source

separation programmes. Metals, glass and paper are separated from the waste prior to collection and either brought to a recycling center or collected separately. Contaminants must be removed in processing by the collector or buyer for the products to be reusable. The alternative to source separation of materials, mechanical centralised separation (usually done in conjunction with production of a refuse-derived fuel), is equipment intensive and operationally complex which makes it uneconomical for the small community systems and the limited quantity of recoverable materials available in the waste.

The key elements of a successful and economical source separation program are: committed and organised sponsors; high and continuing levels of householder participation; clear product specifications; firm, long-term markets for recovered materials; and adequate facilities and processing capability for product handling, cleanup, stockpiling and loading.

Source separation programmes can be combined with most other resource recovery approaches with minimal effect on the fuel value of the wastes. The impact of source separation programs - even paper recovery - on waste fuel properties, for example, would likely be negligible. The effect may indeed be positive if unburnable glass and metal are removed from the waste fuel.

In Bermuda, the main obstacles to a cost-effective source separation program (or even a centralised material recovery system) is the small quantity of materials, lack of a firm local market, and the high transportation costs to off-island markets. The availability or near-term development of a local market for any of the most plentiful recoverable materials is not likely.

Preparation of Refuse-Derived Fuels (RDF): The selection of one of a number of forms of refuse-derived fuels depends on the market for the fuel product. As compared to unprocessed waste with a heating value of 4000 to 5000 Btu/lb, RDF typically has a heating value of 6500 to 7500 Btu/lb or about half the fuel value of coal. Small communities generally have insufficient waste to interest large RDF users, or are not located near plants such as coal-burning utilities where a fluff form of RDF could be burned. Smaller industrial and institutional size boilers are more numerous and geographically dispersed and offer a potential market for RDF.

A dense form of RDF - such as pellets - is preferred for such applications because pellets have properties similar to the stoker coal used in these types of boilers. The densification technology and related combustion experience in the U.S. and Europe has developed only over the last 5 years and is currently being evaluated in several commercial installations. However, long-term operating experience and economic history are still lacking.

Any refuse-derived fuel system is equipment intensive and yields a significant fraction (usually 40 to 50%) of the waste as a residue from processing. These considerations and, in particular, the absence of a local solid fuel user eliminates the RDF system as an option for Bermuda.

Co-disposal: The combustion and disposal of dewatered sewage sludge in an incinerator or bolier burning unprocessed or processed solid waste (RDF) is termed co-disposal. Co-disposal can benefit a small community by solving both disposal problems with a single system. In the U.S. this technique is being evaluated in several larger mass burning incinerators and smaller-scale modular-type units.

Since Bermuda does not presently have secondary treatment of wastewater and thus does not generate a significant quantity of sewage sludge, co-disposal is not a relevant option.

Composting: Composting is the natural, aerobic decomposition of waste to form a humus product with potential value as a soil conditioner. While composting in the U.S. has been practical for many years, applications on a mixed municipal waste-type feedstock have been beset by a number of problems. These have been related to diminished demand, regulations governing toxic contaminants, and increased processing costs. For small communities, composting of mixed MSW has disadvantages of being equipment intensive, requiring large land areas and, like production of RDF, producing a significant quantity of residue. Composting of selected waste fractions such as agricultural waste or garbage might improve the product quality and reduce some production costs, but would have negligible impact on waste volume reduction or energy conservation.

TABLE 22.2 MODULAR INCINERATOR FACILITIES IN OPERATION OR CONSTRUCTION IN THE UNITED STATES (SPRING 1981)

Location	Energy/ Material Products	Capacity (Tpd)	Status
Auburn, ME	Steam	200	S
Batesville, AR	Steam	75	C
Burley, ID	Steam	Unknown	C
Crossbille, ID	Steam	60	O
Durham, NC	Steam	105	S
Dyersburg, TN	Steam	100	S
Genesse Township, MI	Steam	100	O
Groveton, NH	Steam	24	O
Jacksonville, FL	Steam/metals	75	O
Lewisburg, TN	Steam	60	S
Newport New, VA	Steam	40	C
N. Little Rock, AR	Steam	100	O
Osceola, AR	Steam	50	O
Palestine, TX	Steam	28	C
Pittsfield, MA	Steam	240	S
Salem, VA	Steam/metals	100	O
Windham, CT	Steam	108	C
Blytheville, AR	Steam	75	O
Siloam Springs, AR	Steam	16	O

S = Shakedown C = Construction O = Operational

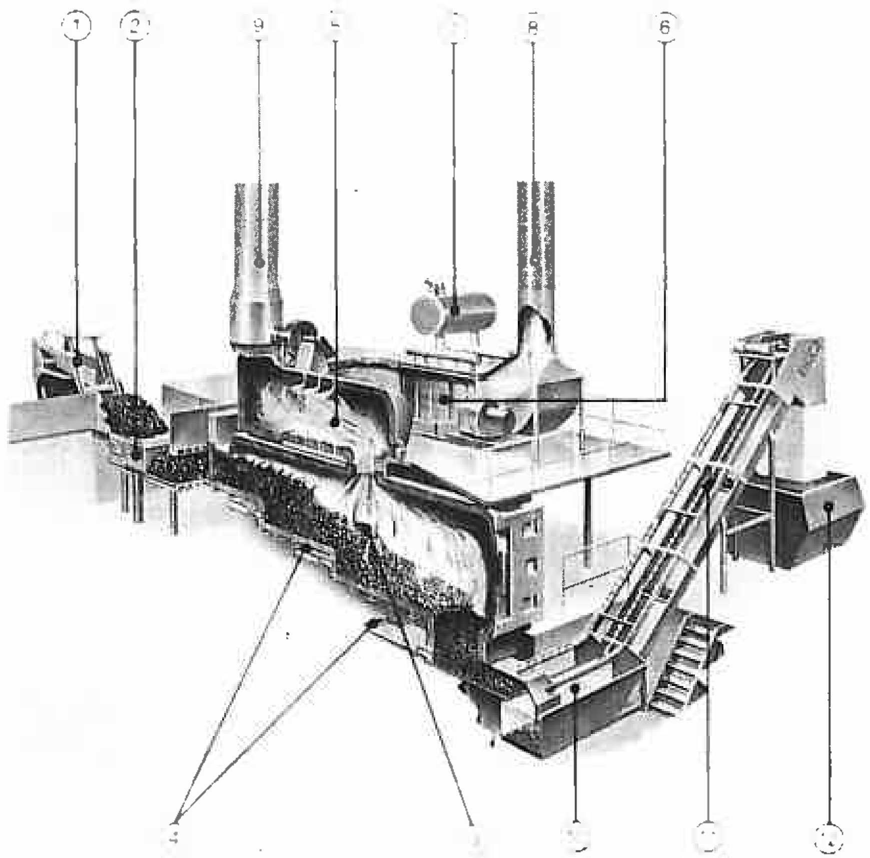
TABLE 22.3 MODULAR INCINERATOR - OPERATIONAL AND ECONOMIC PATH

	North Little Rock, AR	Salem, VA
Capacity - Design	100 tpd	100 tpd
Actual	65 tpd	89 tpd
Capital Cost	$1.6 million (1977)	$1.9 million (1979)
Operating, Maintenance and Dept Cost	$23.33/ton	$18.18/ton
Revenues (Steam @ $2.80/M Btu)	$11.80/ton	$ 8.58/ton
Net Operating Cost	$11.50/ton	$ 9.60/ton

tpd - short tons per day

Modular Incineration: Developed in the late 1960's mainly for commercial waste disposal, modular or "starved air" incinerators were first equipped with heat recovery equipment and applied to mixed municipal solid wastes in the mid-1970's. Table 22.2 lists 19 locations in the U.S. where modular incinerators with heat recovery are operating or under construction. The system capacities and energy or materials products are also shown. Table 22.3 provides operational and cost data on two sites. (Take note of the base years for the costs in any extrapolation).

Figure 22.1 illustrates a typical modular incineration unit. Unprocessed waste is passed by hydraulic rams through the primary combustion chamber. Here the waste is ignited and combusted with the air controlled to a minimum to limit particulate carryover. The solid residue drops into a water quench at the end of the chamber while the partially combusted gases and remaining particulates pass into the secondary chamber where additional air is added to complete



Key to Figure

1.	Loader	7.	Steam separator
2.	Hydraulic ram feeder	8.	Primary stack
3.	Primary combustion chamber	9.	By-pass stack
4.	Transfer rams	10.	Ash quench hopper
5.	Secondary combustion chamber	11.	Ash removal conveyor
6.	Heat exchanger	12.	Ash container

Figure 22.1 A typical modular incineration system (Courtesy Consumat Systems, Inc.)

combustion. An auxiliary burner (oil or gas) is available in the secondary chamber to insure sufficient heat to complete the combustion.

The hot gases pass on to an energy recovery system where, depending on the energy market, hot air, chilled or hot water or steam are produced. Typically, 6000 lb of steam are produced from combustion of 1 ton of mixed MSW.

Early modular units were not equipped with air pollution control equipment, primarily because particulate emission regulations did not apply to incinerators of the size involved. Recently, however, the federally recommended U.S. limit on particulate emissions of 0.08 gr/dscf has been adopted by local authorities and made applicable to modular sized units. Emission testing on MSW-fired modular systems in North Little Rock, AR and Salem, VA suggest that particulate cleanup equipment would be required to meet the 0.08 gr/dscf standard. For Bermuda this may or may not involve addition of bag filter-type collectors on new units, thus adding to the capital costs previously reported (Table 22.3).

The approach in systems installation and operations and reports on performance of operating modular facilities burning MSW reveal several characteristics that make them attractive for small communities like Bermuda. The use of modular construction allows for flexibility in selecting unit and plant size to meet capacity and redundancy requirements.

The modular construction also simplifies shipping and field erection, important in a location like Bermuda. Also, a relatively compact, low profile plant layout is possible. The energy product (steam, hot water) and characteristics (steam pressure and temperature) can be tailored to the specific energy market. The units have shown to reliably achieve significant waste volume reduction (90 to 95%), thus minimising the quantity of residue to landfill. The relatively simple operation requires minimum pre-treatment of wastes and uses an automated control system.

Experience to date in the U.S., however, reveals several areas in modular system installation and operation that should be more closely watched in planning, design, and procurement of this type of system for Bermuda. The sizing of the plant and plans for retaining landfill for residue disposal must take into account that not all wastes can be processed in modular units. Trade wastes are are often too large and would require size reduction; demolition and metallic wastes have no fuel value and could cause damage to the ash removal system; agricultural wastes are usually too large or wet to be effectively combusted without size reduction and/or mixing with drier material (use of the existing shredder might be considered in this regard). In any case, the current and projected quantity and composition of the various waste types should be assessed for use in system sizing and preparation of performance specifications.

The requirements for handling of the incinerator residue must also be considered. Although experience has shown the residue to be primarily inert and sterile, potential for leaching of heavy metals into the groundwater still exists and may affect planning for a residue disposal site.

Since reliability is particularly important for a more remote installation like Bermuda but has yet to be fully demonstrated for modular incinerators (in refractory life and tube life, for instance), redundancy in the number of units and spare parts is essential. The degree of redundancy is also determined by the energy market, i.e., requirements for responsiveness, allowable interruptions, and seasonal demands.

Depending on the facility siting (an issue not addressed during the Conference) and the emission requirements, the need for and cost (capital and maintenance) of air pollution control systems will have to be determined. This will influence the operating leeway on feed mix and capacity, and the use and cost of auxiliary fuel. Although automatic control systems simplify the operation, the more successful modular plants in the U.S. appear to depend on committed and skilled operational and maintenance personnel.

Table 22.4 provides a representative list of vendors of modular incineration systems. Early and continuing contact with system vendors as well as other operating facilities (Table 22.2) is suggested to stay informed regarding problems, solutions and improvements that may develop.

Of particular interest would be the plants in North Little Rock, AR where the vendor has assumed responsibility in an attempt to resolve operational problems, and Salem, VA and Jacksonville, FL, where processing systems are being evaluated in part to assess the potential for reducing the impact of glass on incinerator operations.

<u>Other Observations and Conclusions</u>

There are several non-technical observations that may be made on the approach and selection of a waste-to-energy system in Bermuda. As noted earlier, these remarks do not benefit from access to the consultant's report to have been released in early May.

From the most recently available planning report and conversations with personnel in the Public Works Department, it appears that planning to date has been thorough and realistic; that the information on U.S. and foreign technologies is current and accurate; and that the government personnel and consultants are well informed and unbiased.

An additional less tangible factor which may have significant benefits in implementing a waste-to-energy system in Bermuda is the Government's previous experience with a solid waste shredding plant. The lessons learned in planning, design, procurement and operating of the shredder facility, i.e., the hands-on experience, has been shown by other operators to be a key factor in planning improved second generation facilities.

Present efforts to coordinate and possibly combine energy recovery with a heat recovery boiler at the utility diesel generation plant are well advised. Such an approach appears to offer economic and operational benefits in the sizing, siting and operating of the waste heat boiler and in maintaining energy production in spite of seasonal variations in demand or problems with fuels availability or equipment reliability.

The issues on the use or sale of the energy product and on siting of a plant are too detailed to be explored in this paper. I understand that a consultant has been appointed to provide a detailed review of all of these factors which influence a final decision. In addition to the selection of an appropriate technology, there are geographical, environmental, socio-economic and political factors, considerations in facility financing and ownership, and questions of pricing the energy product and disposition of the revenues.

In summary, it appears that two factors are coinciding that will force a decision on a waste-to-energy system in Bermuda. One is the pressure to develop a long-term solution to an acute disposal problem, and the second is the recognition by the Government and people of Bermuda of the need for energy conservation and alternate energy production to reduce the dependence and high cost of imported energy. For both reasons the timing is appropriate to implement a waste-to-energy system in Bermuda.

TABLE 22.4 PARTIAL LISTING OF MODULAR INCINERATOR MANUFACTURERS

Consumat Systems, Inc.
P.O. Box 9373
Richmond, VA 23277
804/746-4120

Kelly Co. , Incl (Industrial)
6770 N. Teutonia Avenue
Milwaukee, WI 53209
414/352-1000

Comtro Div., Sunbeam Equip. Corp.
18 Mercer Street
Meadville, PA 16335
814/734-1456

Environmental Control Products, Inc.
Department T
P.O. Box 240707
Charlotte, NC 28224
704/588-1620

U.S. Smelting Furnace Co.
Smokatrol
1202 E. "A" Street
P.O. Box 446
Belleville, IL 62222
618/233-0129

International Waste Industries
South Adams & Queen Streets
Pottstown, PA 19464
215/323-2200

Boeing Engineering & Construction Co.
P.O. Box 3707 M/S 9A-01
Seattle, WA 98124
206/575-5768

Enercon Systems, Inc.
16113 Puritas Avenue
Clevand, OH 44135
216/267-0555

22 - NUCLEAR ENERGY

B. L. Cohen

Burning fossil fuels makes use of chemical reactions, deriving energy from rearranging the electrons that orbit around the nucleus of atoms. Much more energy can be derived by reactions between the nuclei themselves, rearranging the neutrons and protons of which they are composed. The most practical way of doing this at present is with the fission reaction.

A reactor for utilising fission consists of uranium fuel rods surrounded with a fluid such as water. Under proper conditions, this leads to a steady evolution of heat which is transferred to the fluid. The heat is then used to produce steam which drives a turbine and ultimately a generator to produce electricity as in all other types of power plants. This type of fission reactor now generates about 13% of the electricity used in the U.S.

What can nuclear energy do for Bermuda?

A serious problem in applying nuclear energy to Bermuda's needs is that nuclear power plants lose their cost advantage rapidly when scaled down in size. A 1000 MW plant constructed and operated at 1980 prices would produce electricity for 5c/KW hour vs. 6.3c/KW hour for coal, but at 100 MW the costs for the two are equal at 6.8c/KW hour, and at 400 MW, coal has a cost advantage with 7.8c/KW hour vs. 9.5c for nuclear. Both still have a decided advantage over oil-fired plants which give costs of 13.5c/KW hour for a 600 MW plant.

It has long been recommended that if nuclear plants are to be competitive in small sizes, drastic new design approaches are needed, and the German company, KWU, has now produced such a design. It is a natural circulation (i.e.

no pumps) boiling water reactor rated at 200 MW. The cost is estimated at $400-$500 million at 1981 prices. The vendor is ready to accept an order now, and promises completion in 4 years. I roughly estimate that it will produce electricity for 12c/KW hour vs. 11c/KW hour for coal in a 200 MW plant and 16c/KW hour for oil, assuming 1981 prices for construction, operation and fuel.

Can Bermuda utilise 200 MW? Its present electrical usage averages about 60 MW, but other uses for the excess capacity might be appropriate. For example, steam from nuclear plants can be diverted to provide energy for water desalination. This, of course, reduces the electricity output by 1 MW for each million gallons/day of desalted water. The cost of this water at current prices would be about $5/1000 gallons, which is apparently half the cost of current desalination activities in Bermuda. But how much fresh water can Bermudians use? If they were to use 200 gallons/day/person, which corresponds roughly to U.S. residential use (it would cost $1/person/day), the total use would still be only 15 million gallons/day which would consume only 15 MW from our 200 MW power plant.

Another new use of electricity might be electric transport. The usual disadvantages with electric cars - limited daily total mileage, poor acceleration and poor high-speed performance - would cause little problem in Bermuda. Moreover, electric cars have some important advantages including less noise, less pollution, and fewer break-downs and repairs. It is expected that they will be cost competitive in the U.S. by 1990.

An electric car uses only about 0.8 KW/hr of electricity per mile of driving. Even if there were 50,000 cars in Bermuda, and each was driven an average of 30 miles per day, this would still only use an average electric power of (0.8 x 50,000 x 30/24 =) 50,000 KW = 50 MW.

The highest forseeable electric power load in Bermuda is then 60 MW from present uses - and this should be going down - plus 15 MW from water desalination, plus 50 MW for electric cars, or a total of 125 MW. It thus seems like a 200 MW plant would be too big for Bermuda. If it were used to produce an average of 125 MW, the cost/KW hour would go up to near or above the cost of electricity generated from oil at present prices.

This might still warrant some consideration. In one stroke it would make Bermuda energy independent for the 80% of the time the nuclear plant might be expected to operate. In most cases, shutdowns can be delayed for many weeks if the plant output is vitally needed.

Environmental problems

The news media have given the impression that there are important environmental problems with nuclear energy. However, if one relies only on information available in the scientific literature, any unbiased scientific analysis would conclude that nuclear energy is very much less harmful to health than coal burning, and is probably less harmful than any alternative. A recently completed paper of mine (available on request) gives the following table listing the number of fatalities per GWe-year among the public from various sources, integrating effects over the first 500 years, or over an infinite time span, effectively several million years. While this table is argumentative even within scientific circles, it serves to point out some common misconceptions in the public understanding of environmental hazards associated with all sources of energy.

Fatalities/GWe-year among the public from electricity production

Source	Time integration: 500 years	Time integration: Infinite
Nuclear:		
high level waste	.0001	.17
radon emissions	.06	-500
low level wastes	.0002	.002
gaseous (^{14}C, ^{3}H, ^{85}Kr) emissions	.12(.03)*	.3(1)*
reactor accidents	(.02-govt. studies) (U.S., FRG, Sweden) (2.4-anti-nuclear activists)	
Coal:		
air pollution	25	25
radon emissions	.01	30
solid wastes (Cd, As)	2.4	47
Photovoltaics:		
coal use (3% of coal burning to make steel, cement, glass, Al)	1	3
Cd S (if used)	4	400
Ga As (if used)	0.7	7
Wind, solar power tower		
coal use (as above)	1	3

* () is from new control technologies to be implemented in the near future. It is evident from the table that even if we ignore the large life saving effects of nuclear power due to removing uranium from the ground and hence averting future health effects from its radon emissions, the wastes from coal burning are hundreds of times more damaging to human health than nuclear power. Oil burning is usually considered to be at least 10% as damaging as coal burning.

Problems in public understanding

A significant problem confronting the use of nuclear power is public misunderstanding. First in this category is a grossly exaggerated fear of radiation. To a great extent, the U.S. media have exaggerated radiation stories. I did a study of the New York Times Information Bank over 5 years (before the Three Mile Island accident), and found the following average number of entries per year on accidents of various types:

Accident Type	Entries/Year	Average Deaths Per Year in U.S.
motor vehicle	120	50,000
industrial	50	12,000
asphyxiation	20	4,500
radiation	200	0

Note that for the first three times the coverage was roughly in proportion to the number of fatalities they cause, whereas with radiation, the proportion is several orders of magnitude higher.

The media constantly use inflammatory adjectives - "deadly" radiation, "lethal" radioactivity, etc. They do not use these adjectives when referring to electricity which electrocutes 1,200 Americans per year.

In covering radiation incidents, the media never make the obvious comparisons with natural radiation which is usually many times higher. For example, the radiation received by people (and animals) near the Three Miles Island accident is as much as they receive every 3 days from natural radiation. It is as much as the extra radiation they receive in one airplane flight, or in spending 4 days in

Colorado where the natural radiation is much higher. I have never heard the media make such comparisons.

In their treatment of radiation, the media have tried to give the impression that health effects are poorly understood. By comparison the health effects of radiation are better understood than those from air pollution, food additives, chemical releases, and many other environmental hazards.

The public has also been given misleading impressions about the genetic effects of radiation exposure. Many scientists believe that the long term effects are negligible, and that the short term effects, lasting for 5-10 generations, are those we should worry about. These short term effects are roughly equal to the cancer deaths, i.e. for every cancer predicted, we may expect one eventual genetic defect from nuclear power. Some perspective on this may be obtained from the fact that there were no excess genetic defects among the first generation of progeny born to the survivors of A-bomb attacks on Japan.

Another problem exaggerated by public misunderstanding is the idea of a reactor meltdown accident. The media frequently refer to it as "the ultimate disaster", and infer that it would render a whole state uninhabitable. The fact is that in most cases, a meltdown would kill no one and contaminate nothing. According to all analyses (Kemeny, Rogoom), this would very probably have been the case if there had been a meltdown at Three Mile Island, so in no sense was that accident close to a health disaster. According to government studies, the average number of fatalities expected in a meltdown is 400, so to equal the 10,000 fatalities per year from air pollution due to coal burning, there would have to be a meltdown every two weeks. Anti-nuclear activists claim that an average meltdown would cause 5,000 fatalities, so according to them, for nuclear power to be as dangerous as coal, there would have to be a meltdown every six months. Note also that there have been about 1000 reactor-years of commercial operation and over 2000 reactor-years of naval experience without any melt-downs. Best estimates indicate that in the worst meltdown situation, expected only once in 10,000 meltdowns, serious land contamination would cover an area of a 20 mile diameter.

Another important problem in public understanding is a failure to quantify risks. In my paper "A Catalog of Risks", I convert various risks to days of life expectancy lost by the average American. Some of these are:

Risk	Days Lost
All U.S. electricity nuclear	.04 (government studies)
	2 (anti-nuclear activists)
Coal burning air pollution	13
Oil air pollution, fires	4
Gas fires, asphyxiation, exploration	2.5
All energy generation-distribution	20
Each extra pound overweight	30
Small car vs standard	50
Standard size vs large	50
Being poor	700
Working as a coal miner	1100
Remaining unmarried	2000
Smoking cigarettes	2000
Having a smoke alarm in home	-10
Service by mobile intensive care unit	-100

In view of these comparisons, public fear of nuclear energy in highly irrational. As a result, government and industry are burdened with additional concerns which translate into costs not shared by other energy sources. A realistic appraisal of potential risks, however, is as important in planning a power plant as are considerations of demand and economy.

SUGGESTED READINGS

Conservation

Ford Foundation. Energy: The Next Twenty Years. Cambridge, Mass.: Ballinger Publishing Co., 1979.

Hirst, Eric and Janet Carney. Residential Energy Use to the Year 2000: Conservation and Economics. Oak Ridge, Tenn.: Oak Ridge Nat'l Laboratory, Sept., 1977.

Lovins, Amory B. Soft Energy Paths: Toward a Durable Peace. Cambridge, Mass.: Ballinger Publishing Co., 1977.

Ridgeway, James. Energy Efficient Community Planning. Erasmus, Penn.: J.G. Press, 1979.

Rothchild, John, and Frank Tenney. The Home Energy Guide: How to Cut Your Utilities Bill. New York: Ballantine, 1977.

Stobaugh, Robert, and Daniel Yergin (eds.). Energy Future. New York: Ballantine Books, 1979.

Thompson, Grant P. Building to Save Energy: Legal and Regulatory Approaches. Cambridge, Mass.: Ballinger Publishing Co., 1980.

Nuclear

General Electric Co. San Jose, Ca. General disruption of a boiling water reactor, 1975.

Martin, A. Pressurized water cooled reactors - Performance and product improvement, Kerntech, 14, 427-447, 1982.

Gough, W.C. and B.J. Eastlund. Prospects of fusion power. Sci. American 50-64, Feb 1971.

Otec

Dugger, G.L., H.C. Olson, W.B. Shippen, E.J. Francis, and W.H. Avery. Floating Ocean Thermal Power Plants and Potential Products. J. of Hydronautics 9, 129-141, Oct 1975.

Trimble L.C. and B. Messinger. Ocean Thermal Energy Conversion System Evaluation. AIAA paper 75-616, AIAA/AAS Solar Energy for Earth Conference, Los Angeles. Apr. 21-24, 1975.

Dugger. G.L. (ed.) Workshop on Ocean Thermal Energy Conversion. Applied Physics Laboratory, Johns Hopkins University, 1975.

Solar

Anderson, B. and M. McPhillips (eds.). The Solar Age Resource book. Everest House, NY, 1979.

Carter, J.R.. Jr. and H. Y. Tada. The Solar Cell Radiation Handbook. TRW Systems Groups Publication. 21945-600 1-Ru-00 June 28, 1973.

Häfele, W. Energy choices that Europe faces: a European view of Energy. Science 84 (4134), 364, 1979.

Solarex Corp. Making and using electricity from the Sun. Fab Books., PA. 1979.

Solid Waste

Lowe, R.A. Energy recovery from waste, solid waste as supplementary fuel in power plant boilers. U.S. Environmental Protection Agency, Pub. no. Sw - 36dii Wash. 1973.

Resource recovery, The state of Technology. Midwest Research Institute final report to the Council on Environmental Quality, Wash., Feb. 1983.

Evaluation of Small Modular Incinerators in Municipal Plants. Prepared by Ross Huffman Associates under U.S. EPA Contract No. 68-01-3171, Washington, D.C., 1976.

Campbell, J.A. Waste Fuel Densification: Review of the Technology and Applications. In: Proceedings of the International Conference on Prepared Fuels and Resource Recovery Technology. U.S. Department of Energy, Nashville, TN, February 1981.

Marshall, R.O., J. Smith and G. Melotti. A report on waste disposal in Bermuda and recommendations for future policy. Bermuda Ministry of Works, Agriculture and Fisheries, Hamilton, Bermuda, 1977.

Sheppard, K.R. Fuels in a Waste-to-Energy System: The Teledyne Experience. In: Proceedings of the International Conference on Prepared Fuels and Resource Recovery Technology. U.S. Department of Energy, Nashville, TN, February 1981.

Source Separation Collection and Processing Equipment: A Users Guide. U.S. Environmental Protection Agency, Report SW-842. 1980.

Small Modular Incinerator Systems with Heat Recovery. Prepared by Systems Technology Corporation for the U.S. Environmenal Protection Agency, Report No. SW-797, November 1979.

Transportation

Carlere, W.M., W.F. Hamilton, L.M. Morecraft. The Future Potential of Electric and Hybrid Vehicles. General Research Corporation, Santa Barbara, CA. 1981.

Difiglio, Carmen. The Urban Transportation Sector: A Preliminary Energy Conservation Strategy Assessment. U.S. Department of Energy, Washington, D.C. 1979.

Hamilton, William. Electric Automobiles. McGraw-Hill Book Company, New York, NY. 1980.

Kulp, G., D.B. Shonka, M.J. Collins, B.J. Murphy, K.J. Reed. Transportation Energy Conservation Data Book: Edition 4. Oak Ridge National Laboratory, Oak Ridge, TN. 1980.

Lave, Charles. Transportation and Energy: Some Current Myths. Policy Analysis. The Regents of the University of California, Berkeley, CA. 1978.

Shackson, Richard, H., H. James Leach. Maintaining Automotive Mobility: Using Fuel Economy and Synthetic Fuels to Compete with OPEC Oil. The Energy Productivity Center, Mellon Institute, Arlington, VA. 1980.

Wind

Wilson R.E. and P.B.S. Lissaman. Applied Aerodynamics of Wind Power Machines. Oregon State Univ., Corvallis, 1974.

Heronemus, W.E. Pollution-Free Energy From Offshore Winds. Preprints 8th Annual Conference and Exposition, Marine Technology Society, Sept. 11-13th, 1972, Wash. DC.

Spectrum - An Alternate Technology Equipment Directory. Alternate Sources of Energy, Inc., Route 2, Box 90A, Micaca, Minn. 1975.

V. Daniel Hunt. Windpower - A Handbook on Wind Energy Conversion Systems. Van Nostrand Reinhold Co, NY. 1981.

World Oil Market

Congressional Budget Office. The World Oil Market in the 1980: Implications for the United States, Washington, D.C. Government Printing Office.

Deese, David A., and Rye, Joseph S. (eds.). Energy and Security. Ballinger Publishing Company, Cambridge, Mass., 1981.

Energy Modeling Forum 6, World Oil, Summary Report (Draft 3), Stanford University, Stanford, Calif., 1981.

Exxon Corporation. World Energy Outlook, Exxon Background Series, Exxon, New York, 1981.

National Petroleum Council. Emergency Preparedness for Interruption of Petroleum Imports into the United States. Publications Department, National Petroleum Council, Washington, D.C., 1981.

U.S. Department of Energy, Energy Information Administration, Annual Report to Congress, 1980, U.S. Government Printing Office, 1980.

World Bank, Energy in Developing Countries, Washington, D.C. 1980.

ACKNOWLEDGEMENTS

The idea for this conference came from Richard M. Gorham who, most appropriately, also made the concluding remarks. We received further encouragement from Dr. the Hon. John Stubbs, then Minister of Planning, Housing and the Environment, who also formally opened the Conference; and from Harold I. Dale, Chairman of the Energy Conservation Committee, who provided guidance throughout.

The following sponsors, through their financial contributions and active interest, made the Conference possible: Energy Conservation Committee, Bermuda Electric Light Co., Bank of Bermuda, Bank of Butterfield, Mundogas SA, Princess Hotels, Bacardi International, Bermuda Airconditioning, Bermuda Telephone Co., Bermudiana Hotel, Esso Bermuda, Frank B. Hall (Bermuda), Mr. Erling Naess, P.M. Ltd., Shell Co. of Bermuda, Bermuda Gas & Utility, Trimingham Bros., Argus Insurance Group and Bermuda Jaycees.

Local arrangements were largely in the competent hands of Margaret Emmott, Jill Cadwallader and Harry Barnes of the Bermuda Biological Station, and Mary-Ellen Smith of Solar Engineering Technology. The hospitality of Per Lorentzen added significantly to the spirit of the Conference.

The cover for the Proceedings was designed by Christiane Sterrer and Michael Hutley. The manuscripts were typed and word-processed by Margaret Emmott and Zina Francis, with help from Jill Cadwallader.

We are very grateful to all who have contributed, in so many ways, to the success of this project.

AUTHORS AND PARTICIPANTS

Erwin P. Adderley	Director Department of Planning Hamilton, Bermuda
John H. Anderson	President Sea Solar Power, Inc. 2422 South Queen Street York PA 17402.
Gary C. Barbour	Professional Staff Member U.S. Senate Energy & Natural Resources Committee Washington DC 20510.
Ted Blumenstock	Managing Director Solarex Corporation 1335 Piccard Drive Rockville MD 20850.
Arthur Bowen, Ph.D.	Department of Architecture & Planning University of Miami Coral Gables FL 33124.
Lynda Brothers, Ph.D.	Former Deputy Assistant Secretary U.S. Department of Energy Washington DC.
Jay Campbell	Director of Test Operations The National Center for Resource Recovery, Inc. 1211 Connecticut Ave., NW Washington DC 20036.
Jan Card	Engineer Island Solar Ltd. Cobbs Hill Rd. Warwick, Bermuda.

John Carey	Manager Esso Bermuda Ferry Reach St. George's, Bermuda.
Bernard Cohen, Ph.D.	Director Nuclear Laboratory University of Pittsburgh Pittsburgh PA 15268.
Harold Dale	Energy Conservation Committee, Chairman c/o Anfossi, Dale & Co. Atlas House P.O. Box 279, Hamilton Bermuda.
Fred Dunbar	Senior Consultant National Economic Research Associates 5 World Trade Center New York NY 10048.
Drew A. Gillett	North East Solar Energy Center 470 Atlantic Ave. Boston MA 02110.
Richard M. Gorham	The Supermart Front Street Hamilton, Bermuda.
Joan Habib	Director of Energy & Research National Wildlife Federation 1412 16th Street, NW Washington DC 20036.
Archie C. Hollis Hallett, Ph.D.	Chief Executive Officer Bermuda College Prospect, Bermuda.
Paul Henton	Grumman Energy Systems 10 Orville Drive Bohemia NY 11716.

John Houghton, Ph.D.	Senior Policy Analyst Office of Science & Technology Policy Exec. Office of the President Washington DC.
Don Jolliffe	Group Engineer Bermudiana Hotel Hamilton, Bermuda.
Barrett Lightbourn	President Island Solar Ltd Cobbs Hill Road Warwick, Bermuda.
Geoff M. Melotti	Public Works Department Hamilton, Bermuda.
Colin Miles	Assistant Financial Secretary Ministry of Finance Hamilton, Bermuda.
Nils Nordenström	Det Norske Veritas P.O. Box 300 N-1322 Hovik Norway.
Miles Outerbridge	Woodbourne Associates Woodbourne Place Pembroke, Bermuda.
Michael D. Ricciuti, Ph.D.	U.S. Naval Laboratory Tudor Hill Southampton, Bermuda.
Jonathan Sands	President Solar Engineering & Technology Bda Ltd. P.O. Box 120 Warwick, Bermuda.
Wolfgang Sterrer, Ph.D.	Director Bermuda Biological Station Ferry Reach 1-15, Bermuda.

John Houghton, Ph.D.	Senior Policy Analyst Office of Science & Technology Policy Exec. Office of the President Washington DC.
Don Jolliffe	Group Engineer Bermudiana Hotel Hamilton, Bermuda.
Barrett Lightbourn	President Island Solar Ltd Cobbs Hill Road Warwick, Bermuda.
Geoff M. Melotti	Public Works Department Hamilton, Bermuda.
Colin Miles	Assistant Financial Secretary Ministry of Finance Hamilton, Bermuda.
Nils Nordenström	Det Norske Veritas P.O. Box 300 N-1322 Hovik Norway.
Miles Outerbridge	Woodbourne Associates Woodbourne Place Pembroke, Bermuda.
Michael D. Ricciuti, Ph.D.	U.S. Naval Laboratory Tudor Hill Southampton, Bermuda.
Jonathan Sands	President Solar Engineering & Technology Bda Ltd. P.O. Box 120 Warwick, Bermuda.
Wolfgang Sterrer, Ph.D.	Director Bermuda Biological Station Ferry Reach 1-15, Bermuda.

The Honourable John Stubbs, M.D.	Minister for Planning and the Environment Hamilton, Bermuda.
E. Norman Thomas	Deputy Director Dept. of Public Works, Hamilton, Bermuda
Raoul Tyrrell	Director Transport Control Dept. Hamilton, Bermuda.
Llewellyn Vorley	Managing Director Bermuda Electric Light Company Limited Hamilton, Bermuda
Frank Watlington	SOFAR Station St. David's, Bermuda

The Honourable John Stubbs, M.D.	Minister for Planning and the Environment Hamilton, Bermuda.
E. Norman Thomas	Deputy Director Dept. of Public Works, Hamilton, Bermuda
Raoul Tyrrell	Director Transport Control Dept. Hamilton, Bermuda.
Llewellyn Vorley	Managing Director Bermuda Electric Light Company Limited Hamilton, Bermuda
Frank Watlington	SOFAR Station St. David's, Bermuda