

COSTING IRELAND'S ENERGY OPTIONS

Dr R. J. Nichol*

The primary objective of this paper is:

1. To improve our understanding of the comparative costing of our national energy options;
2. To point the ways in which economic research can help to improve this understanding.

I would like to begin with a reference to what I have called the geophysical economics of energy. Of the solar energy which reaches the earth about 30 per cent, known as the earth's albedo, is directly reflected and scattered into outer space in the form of short wave length radiation. About 47 per cent is absorbed into the earth as heat and about 23 per cent in wind and wave motion and in the water cycle (1). The tiny portion remaining is used by plants in the process of photosynthesis of carbohydrates. This is the entire source for the biological requirements of the earth's humans, animals and plants. Mankind is also using up another minute fraction of this biological energy which has been converted into fossil fuels under the planet's surface over the last 600 million years.

This first overview of the earth's geophysical economics suggests that from mankind's point of view the system is most inefficient and wasteful — 30 per cent radiated, 47 per cent heating the ground every day to dissipate every night, over 20 per cent into the wind, waves and rainfall. Mankind captures only a small proportion of the last in hydropower and a minute portion in windpower.

OPTIONS

In my analysis of the options I must emphasise strongly that it is possible, in the rapidly changing circumstances of our times, to envisage many different scenarios. My scenario envisages an oil position of increasing price and scarcity and the consequent urgent need to diversify, as quickly as possible, to other sources of power (2). There are some strongly held views not in accord with this scenario and I accept that they do have some validity (3). Superimposed on these considerations are the economic ones as to which power sources will provide in national terms the best return on investment. The position here can also change rapidly with escalating costs of fuel and construction. I have attempted a fairly simplified approach to what is a very complex problem and I beg your forgiveness in advance for any lack of sophistication.

The three broad geophysical options are:

1. Exhaust the small store of fossil fuel;
2. Capture some of the direct and indirect solar energy via sunlight, wind or water;
3. Use some of the primary or elemental forces of the universe such as nuclear energy.

These three options are in turn transferred into practical options by technology. Our dependence on the first and third — fossil fuel and nuclear energy creates the fourth option which is conservation.

* Dr R.J. Nichol is Deputy Director General at the Institute for Industrial Research and Standards

The technology as it stands presently allows us to look seriously at the following options as practical courses of action to be subjected to a set of tests. The options are:

1. Oil
2. Natural gas
3. Coal as an adjunct to, or alternative to, oil and gas
4. Nuclear power
5. Conservation
6. Some aspects of solar energy

The tests are availability and practical power potential in the short or medium term, national security and tests of an environmental, social, and economic nature. These tests can all be classified into three broad categories as:

1. Availability
2. Practical power potential
3. Socio-economic criteria

In terms of these three tests, we find that only three options have certain future availability and practical power potential for virtually all of our needs in the short or medium term. These are:

Nuclear power,
Coal as an adjunct to, or alternative, to oil, and
Natural gas in addition to nuclear power or coal.

Although the other two options, conservation and solar energy, have a very valuable long term potential, only conservation can contribute much in the short term. However, investment in conservation measures and R & D in alternative energy sources should commence now if long term potential is to be achieved. There is another possible option: more Irish gas and oil. However as exploration for these is under way, there is no point in considering investing in them until their existence is assured.

One of the most important tools, if not the most important, used in this process is costing. But before we turn to costing to see how it helps us make the final choice, let us look at the other tests or criteria which we already mentioned under the category of socio-economic criteria. These were:

National security,
Environmental, and
Social and economic considerations.

Nuclear power reduces the threat to national security as it substitutes a new fuel source, uranium, and allows the stockpiling of several years of uranium in a small space. However, we must be clear that without oil, industry and large parts of agriculture would virtually stop. The stockpiling of coal on the other hand is not a practical possibility.

Moreover, in the event of a severe oil crisis, coal would come under pressure both in terms of price and availability. This leaves only two real options from the national security point of view – nuclear power and natural gas. Is it possible to use natural gas and coal to bridge the ten year lead time in building a nuclear plant? The answer is yes, as additional electricity from natural gas could come onstream within 3 years, while a 600 MW coal plant could be in operation at a push within, say, 5 years, with additional capacity in another two years. So from the national security point of view a possible set of options is as follows:

- 1) Start building a significant (600 MW) coal power plant now (this is planned by the ESB);
- 2) Decide to build a 600 MW nuclear power plant now. (This is under consideration nationally);
- 3) Be prepared to use more natural gas for electricity generation in case of an oil crisis.

To see how this would affect our energy situation, let us look at our dependency situation at the 1977 level.

TABLE 1: Dependency Situation (4)

Source	MW	Electrical MTOE	Other MTOE	Total MTOE
Oil	1,536	1.41	4.12	5.53
Coal	15	.02	.52	.54
Hydro	219	.20	—	.20
Peat	408	.60	.64	1.24
Total	2,178	2.23	5.28	7.51

We have already heard Mrs Scott give us a most revealing view of the fallacy of depending upon projections for growth in electricity demand based on apparent current trends (5). In the US at the moment, for example, there is a cutback not only in the construction of nuclear power stations, but a cutback in the building of all kinds of power stations on account of the re-assessment of growth in such demand. Our energy problem, of course, is first to maintain our way of life itself, and secondly, to sustain possible future economic growth.

In an oil crisis the only option we have in the short term is conservation. Let us assume conservation possibilities of 20 per cent of total energy both electrical and non-electrical before industry and agriculture begin to suffer.

The following table uses capacity as an indicator of fuel used, not as actual fuel usage. There is not necessarily a linear relationship between the two. However, from the point of view of seeing the value of options, potential MWs derived are a useful indicator.

TABLE 2: Options Available (6)

Source	Electrical			Non Electrical
	Option 1	Option 2	Option 3	Option 2
	MW	MW	MW	MTOE
Oil	1,092	492	0	2.80
Coal	15	15	615	.52
Hydro	219	219	219	—
Peat	408	408	408	.64
Conservation	444	444	540	1.32
Gas	—	600	600	
Total	2,178	2,178	2,382	5.28

In Option 1 we can see that even with a 20 per cent saving through conservation we would still need in theory in 1977 just over 1,000 MW of oil-supplied power. But the more serious position would be for the non-electrical power demands such as oil for transport, industry and home, factory and office heating. They would be as shown above in the right-hand non-electrical column where nearly 3 million tons of oil are needed annually even with a 20 per cent saving.

In Option 2 we add the next available option in a crisis, available to us by, say 1982; an increase in our use of natural gas to produce electricity. The new picture can be seen in Table 2 under Option 2.

Assuming a 3 per cent growth in electricity demand from 1977 onwards approximately 2,700 MW would be required in 1985. Now let us add the 600 MW Moneypoint coal station available in 1984 for Option 3 shown in Table 2.

Therefore, as far as electricity generation needs are concerned we have except for approximately 300 MW (or 11.8% of our requirements) eliminated our dependence upon oil by 1985.

We could also in theory double our output of Moneypoint to 1,200 MW by 1987 and increase further the consumption of natural gas for electricity to 1,000 MW, in a crisis situation, to provide electricity for public transport and for the domestic heating market, leaving whatever available oil we can obtain for agriculture, industry and transport.

From this analysis it becomes perfectly clear that in the next 5 to 6 years we will be still dependent on oil to a very large extent for electricity generation and consequently we have no alternative but to suffer the consequences of scarcity and price increases. It is also clear that the only policy open to us is to diversify, as quickly as possible, away from oil as an energy source for electricity generation.

We will, however, also be vulnerable to the vagaries of coal supply until a nuclear power plant could be built about ten years from now. Let us however accept that vulnerability for the remainder of the costing exercise since we do not have so many options that we can afford to deal only in those which are absolutely secure.

COMPARATIVE SOCIAL COSTS

Up to the time of the Pennsylvania incident last week it was generally assumed that the only realistic bridge to the safer and cleaner power from fusion and hydrogen, which it is hoped will be available in about fifteen years, was nuclear fission. Even the annual insult to the environment which would be caused by the disposal in the deep earth of nuclear waste would be very small compared with the devastating effects of, for example, the global mining, transport and usage of coal.

Up to last week there were many available tables of statistics showing the probability of a serious or potentially serious accident at a nuclear reactor. Unfortunately these are now all outdated by the reality of the Pennsylvania incident.

It is easy to say it in retrospect but the problem of projecting statistics for nuclear and the other options is that only nuclear has the potential for sudden local disaster with long term consequences, however remote or unlikely that potential may be. Before we rush to embrace other safe systems, however, let us consider some of the harsh realities about the costs of energy.

It may come as a rude shock to many of the advocates of alternative fuel systems, or the so-called 'soft' options, to learn that a thorough costing of the social consequences of all energy systems shows that the bigger the costs of the construction and materials used,

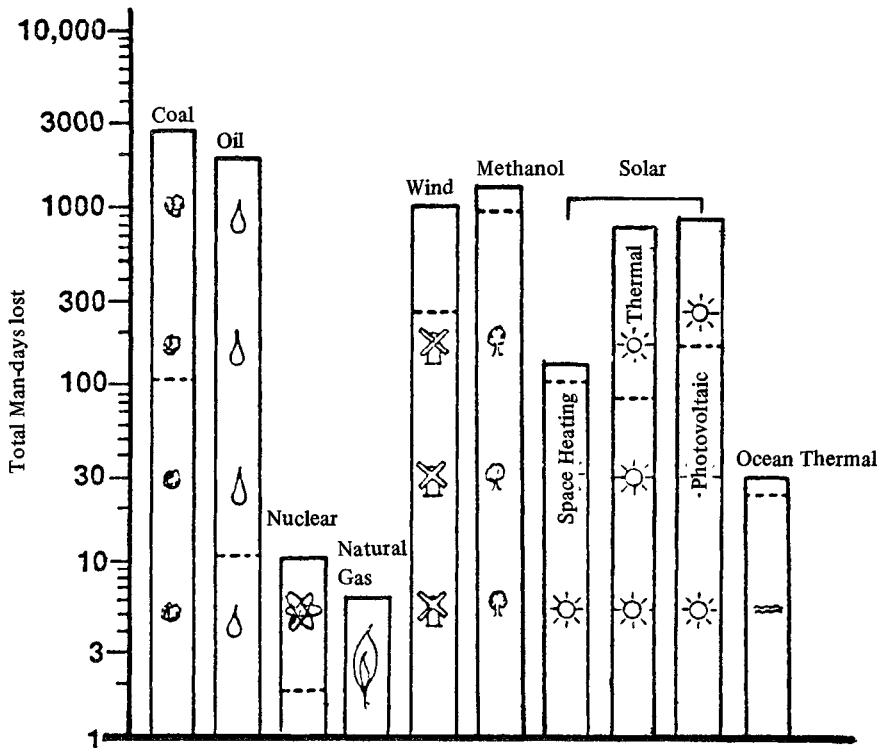
the greater the social consequences. And if you think that such "Capital Costs" are merely a once-off price, this is not so as their costs must be apportioned over the useful life of the installation.

Using this realistic approach we arrive at two sets of social costs: costs to workers during the construction and costs to the public at large. The non-conventional or 'soft' or alternative energy systems are most dangerous to workers because of the large construction times and large amounts of materials used in terms of megawatts obtained over system life. The worst is the one we tend to desire most of all, solar power via photovoltaic cells, next is methanol and next wind.

A coal or a nuclear power plant for example, would have only 1/30th of the construction demands of a windpower station of similar capacity. So the safest to build by far are the conventional systems: coal, oil, natural gas and nuclear.

In deciding which are the safest to run, we compare two only: coal and nuclear. The environmental and social consequences of using coal are significant but as most of the social consequences, such as mining deaths, take place elsewhere, the national consequences

Figure 1: Risk Assessments (8) (This is also a pre-Pennsylvania table)



for us are not great. However one can safely say that, barring a nuclear disaster, coal is many times more disruptive in its mining phase, produces many times more pollutant release and causes many times the deaths than those caused by the extraction and use of nuclear fuel (7). If we are to diversify from oil to coal to some degree it will be necessary for us to participate in the global devastation caused by the mining and use of coal.

As far as workers are concerned, taking both construction and operation into account, the order in terms of increasing risk to life and health is natural gas, nuclear power, oil, wave power, coal and other solar energy options. As far as the public at large is concerned, the order is natural gas, nuclear power, the solar options, wind, methanol, oil and coal. The position is illustrated beautifully in Figure 1 taken from the report by the Atomic Energy Control Board of Canada entitled "Risk of Energy Production". It gives the total man-days lost per megawatt year net output over the lifetime of the system. This total figure includes both the public man-days and the occupational man-days.

To summarise the social cost situation, all energy systems exact social costs. Barring nuclear disasters, nuclear is the second safest. The probability of a nuclear disaster has increased greatly since the Pennsylvania incident, so excluding nuclear, until new statistics can be generated, the most dangerous fuel to us is coal, the safest, natural gas.

The Pennsylvania incident is likely to strike a blow against the nuclear programme worldwide. This will bring more attention to the alternative systems.

COMPARATIVE CAPITAL AND OPERATIONAL COSTS

Before getting to the detail of costings the financial criteria associated with the different options can be examined. Let us briefly review the options which would seem to be realistic given what I have said. They are:

1. Nuclear power (over the next fifteen years)
2. Coal
3. A mixture of both coal and nuclear power
4. Natural gas in addition to the first three
5. Conservation
6. Solar

The elements to be considered in a national costing exercise are:

- i) Capital investment
- ii) Energy price
- iii) Economic impact
- iv) Environmental and health impacts
- v) National need.

From what I have already said, national need and the environmental and health impacts seem to allow the nuclear, coal and natural gas choice. Nuclear, however, may not be socially acceptable.

As we can accept that the economic impact is wholly beneficial, i.e. much needed energy to keep our economy going, we are left with

Capital investment, and
Energy price

These are in fact the same as the building and running costs. But as we shall see what is cheaper to build is not always cheaper to run.

Costs have escalated for both building and running over the past ten years. Various sources show costs of nuclear per 1,000 MW constructed giving from around \$150 million in 1968 estimates to \$1,000 million for actual capital costs of plants going into service in 1981, and for 1968 coal capital estimates of \$120 million for 1,000 MW constructed to \$680 million for actual capital costs constructed in 1981.

The correct capital cost however very much depends upon what stage of completion the plant is now at. The more work still to be done, the greater the cost. Here are a few examples:

TABLE 3: Nuclear Power Station Costs (9)

Location	Owner	Capacity MW	Estimated cost \$ million	Percentage completion	Estimated completion date
Louisiana	Louisiana Power & Light Co.	1,165	1,200	53	1981
Michigan	Detroit Edison Co.	1,100	894	76	1980
Michigan	Consumers Power Co.	1,382	1,600	55	1982
New York	Niagra Mohawk	1,080	1,350	25	1984
Ohio	Toledo Edison	906	2,400	0	1989

The last one is interesting. A similar plant in Ireland at US assumed escalation prices by 1989 starting now would cost us £1,200 million. The last public estimate (end 1978) given for Moneypoint was £350 million by 1985. The signs are now that this could be £450 million. If projected on to 1989 (including escalation of 10% per annum) this could be £600 million. If a nuclear-coal cost factor of 1.6 to 1.0 is used then a nuclear plant of similar capacity would cost £960 million. Increasing this in turn to 900 MW and taking account of the non-linear cost relationships for size would give us £1,300 million. This is reasonably close to the 906 MW Ohio plant seen in the last table which will cost \$2,400 million or £1,200 million by 1989.

TABLE 4: Fossil Power Station Costs (10)

Location	Owner	Capacity MW	Estimated cost \$ million	Percentage completion	Estimated completion date
Florida	Florida Power & Light	1,550	515	50	1981
Nebraska	Nebraska Public Power	1,300	676	50	1981
N. Dakota	Otter Fuel Power	410	390	25	1981
Oregon	Portland General Elec.	530	525	65	1980
Colorado	Colorado-Ute Elec. Assn.	400	429	0	1983

Some examples of US coal-fired plants are given in Table 4. The last is probably the closest fix we can get to our Irish Moneypoint plant where 650 MW will cost £450 million to build by 1985. The Colorado plant is costing \$429 million or £214 million for 400 MW. If we add an extra 200 MW and 10 per cent per annum US escalation to 1985, we get about £325 million. But comparing a US 1985 £325 million to an Irish 1985 £450 million is not easy as we must take into account not only different materials and labour costs but possible different escalation rates.

If capital costs are greater for nuclear plant compared with coal plant by a factor of 1.6 or more there is a different picture at the generating or operational phase.

TABLE 5: Running Costs in Mills/KWh for 1,000 MW LWR's (11)

Year of order	1967	1971	1974	1976
Expected year of operation	1972-73	1977-78	1982	1985
Fixed charges	2.8	7.7	15.5	30.7
Fuel costs	1.7	1.7	5.6	18.4
O & M	0.3	0.5	1.5	2.5
Total	4.8	9.9	22.6	51.6

TABLE 6: Nuclear Coal Comparison (12)

	Nuclear	Coal
Year of order	1974	1974
Expected year of operation	1982	1982
Fixed charges	15.5	13.0
Fuel costs	5.6	12.2
O & M	1.5	3.1
Total	22.6	28.3

Some past US estimates for running costs for 1,000 MW Lightwater Reactors are given in Table 5.

Fixed charges include interest, taxation, depreciation. These were over half of the total and increased steadily until 1974 when fuel replaced them as the fastest growing cost element.

Now let us compare in Table 6 coal based generating costs with the 1974-1982 figures above.

We can see that coal station generating costs were already almost 33.3 per cent higher than nuclear for the 1974-1982 estimates. The reasons are a trebling of coal prices caused by increases in miners' wages, improved safety measures, land restoration, SO₂ abatement and improved plant controls between 1969 and 1974.

Now let us try to make some rather difficult comparisons with Irish costs per KWh. First let us take the busbar* costs shown in Table 7 from the US Ryan Report. For coal generation these were 21 Mills per KW for 1976. This is 2.1 cents or at 10 per cent escalation up to 1977, 2.3 or in sterling 1.05 pence. Now a UK figure from the CEBG of 1.27 pence for 1976/77 for an oil-fired system (13), and finally the actual 1977 average price per unit sold for 1977 from the ESB's latest Annual Report is 2.557 (14). If we assume 100 per cent post busbar costs for transmission and other costs, we get 1.28 pence. So to summarise we have a 1.28 pence Irish price, a 1.27 pence UK price and a 1.05 pence US price per kilowatt hour.

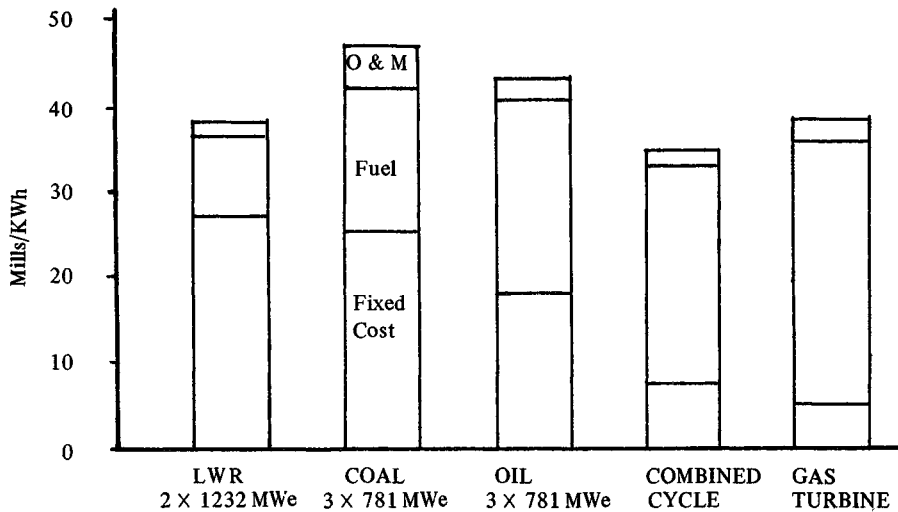
Let us now look at some general reasons for the gross escalation of generating costs of both nuclear and coal based plants.

First, the general increases brought about by:

- A. Increases in the rate of inflation;
- B. Above average increases in the cost of construction; and
- C. Increases in the cost of money.

* Busbar is the cost before transmission cost at a power station

Figure 2: Typical Total Generating Cost of Power Plants in 1985 (15)



These in turn raise *generating costs* by raising the fixed charges such as depreciation and interest. Second, the cost of changes in design and specifications. Third, delays and long lead times. Fourth, political, social and environmental considerations and obstacles. And here is a look at some typical American total generating costs as predicted for plants operating in 1985 as given in Figure 2.

We can see that nuclear costs are now around 38.0 Mills/KWh while coal costs are 46.0 or almost 20 per cent higher than nuclear. In sterling these are 1.90 pence for nuclear and 2.30 pence for coal per kilowatt, 1985 predictions. The coal price predicted is a 120 per cent increase over the US 1977 figures.

Similar predicted escalation on the Irish price would bring the kilowatt busbar price to 2.81 pence or the price to customers to 5.62 pence, more than double the present figure. Last year the British Department of Energy prepared a comparison of coal-fired and nuclear power station costs for the Energy Commission. Coal costs were projected under four profiles between two extremes.

Profile 1: Assumptions that coal cost would relate to oil.

Profile 4: Coal costs stay at present levels.

For nuclear, significant increases in cost including a doubling in price of uranium were included. The discount rate was very large at 10 per cent. Here are the findings.

It can be seen that if Profile Number 1 is the true one – coal prices following oil price coal costs will be prohibitive compared with nuclear. These findings suggest that the key cost of electricity generation from coal is the price of coal itself, and that the key cost for nuclear is construction not fuel cycle costs.

To summarise the financial situation total costs reveal that nuclear power is cheaper than all other current feasible options, because of the high fuel costs of the non-nuclear options. This, however, could change over the next fifteen years if uranium shortages caused uranium to be dearer per KW derived than coal.

TABLE 7: Coal Nuclear Fuel Cost Comparisons (16)

Year	Coal Costs (p therm)			
	Profile 1	Profile 2	Profile 3	Profile 4
1985	15.2	13.8	11.1	9.6
1995	20.2	18.0	13.1	10.3
2010	40.0	26.9	17.6	11.8

Note: Fossil fuel costs are conventionally shown in p therm nuclear in p KWh. The conversion is 1 therm 29.3 KWh. Translating these to KWh with a conversion efficiency factor of 0.38, we get

	Coal Costs (p KWh)			
	Profile 1	Profile 2	Profile 3	Profile 4
1985	1.37	1.24	.997	.862
1995	1.81	1.62	1.18	.925
2010	3.59	2.42	1.58	1.06

	Nuclear Fuel Costs (p KWh)		
	SCHWR	AGR	PWR
1985	.426	.400	.360
1995	.470	.441	.400
2010	.538	.530	.461

In terms of social costs including occupational and public accidents, illness and deaths, coal is the most expensive and natural gas and nuclear the least expensive barring nuclear disaster. In terms of occupational deaths and accidents, the solar or alternative options are the most costly.

Generating costs are greatly dependent upon capital or building costs because of the fixed charges which must be carried over the useful life of the plant. Existing power plants allow cheap electricity because the capital is already spent at past prices. The cost of generating power in the future will be greatly dependent upon the extent of price escalation in the years up to completion of the building phase of plants.

BACK-END COSTS

Before leaving the subject of real financial costs, I must briefly mention back-end or waste costs. On this subject few documents can be more interesting than last year's "Ryan Report" to the US Congress. Briefly, the report was a product of the Environment, Energy and Natural Resources Sub-Committee operating under the auspices of the Committee on Government Operations. The first 75 pages of the report contain the main report and its recommendations, the next 65 pages objections to the report and dissenting views. Twenty-four of the dissenters were from the 42 person main committee but 7 out of the 11 persons on the sub-committee also objected to it. The only working non-dissenters were the Chairman — Ryan and three other members. These

four were anti-nuclear and pro-solar. Two of these were from California and two from Texas.

The objections to the report, however, were so intense that much data and some consensus emerged. Of greatest interest is a table of power plant costs that both the perpetuators of the Report and objectors seem to agree with. Here it is:

TABLE 8: Powerplant Economics (1976 busbar costs, mills per kilowatt hour¹)

	Nuclear	Coal	Oil (Northeast)	Oil and gas (California)
Actual reported costs²				
Fuel	2.7	8.2	19.7	21.7
Capital costs	9.6	5.9	8.8	4.5
Operating and maintenance	2.3	1.8	2.4	0.9
Total	14.6	15.9	30.9	26.6
Additional responsibility³				
Stabilize tailings (at 8c/lb)	.05			
Transportation of spent fuel (at \$ 40/kg)	.16			
Geologic disposal (at \$ 150/kg)	.64			
Decommissioning (at \$ 400,000,000)	.04			
Reclamation of strip mining (at 30c/ton)		0.15		
Scrubber waste disposal (at \$16/ton)		1.6		
Scrubber capital cost (at \$94/kW)		1.7		
Scrubber operations (at 12,000,000/year)		1.7		
Revised total	15.4	21.0		

- ¹ Busbar costs are the costs for electricity leaving the plant. Roughly 30 mills per kilowatt hour must be added to the totals shown to cover the transmission distribution and overhead charges to the consumer. The numbers shown are national averages and considerable regional differences exist. (Note that 1 mill equals 0.1 cent).
- ² From ERDA "Update", July 1977, using FPC supplied 1976 data for 40 nuclear plants (51 units) and 49 multiunit recently constructed higher than average thermal efficiency, suitable for base loading coal plants.
- ³ Assuming an 1,150 MW plant, 40-yr-life, 70-percent capacity factor. Data supplied by the American Nuclear Energy Council and the National Association of Electric Companies.

Thomas N. Kindness, MC, September 12, 1977

Essentially what these findings and further analysis of them show is that the cost components with the greatest uncertainties result in an increase of less than 6 per cent, even allowing a 100 per cent uncertainty for geological disposal and 1,000 per cent for decommissioning costs.

CONSERVATION AND SOLAR

I would now like to look briefly at the costing of the other options: conservation and solar. I must, however, confess that I can say very little about these subjects in the short space allowed by this paper. First, the option of conservation. To fill any gap between increasing demand and available supplies, as with our oil situation, market forces direct

us to the selection of the least costly options, where we have options from *either* supply or demand options (for example export or import of oil). A convenient trade-off measurement device in realising the decision is the cost of producing a barrel of oil (equivalent) versus saving a barrel.

For example we can cost the options of home insulation or reduced private motoring versus the costs of finding and paying for new oil supplies. We can cost the provision of rapid rail services versus oil imports saved as a result. What we must ask is if some supply options are cheaper. If they are not we should use the conservation or barrels saved option.

We have only to look back at the conservation figure of 20 per cent plus on previous charts to see what an enormous return the conservation option gives us. This figure is based on reductions in fuel usage through better industrial practices, better insulation, and better public transport leading to reducing private motoring. The great advantage of the conservation option is that cash savings begin as expenditure and effort on the option begin.

From the national security point of view, the fact that even with coal and nuclear we may not bridge a crisis period in the next ten years caused by oil shortages means that the conservation option is as necessary as the other two. The costs are very simple: every barrel saved is worth more than a barrel bought if the conservation measure costs match oil costs even one for one, as employment and added-value improve domestically.

Look for example at the cost/benefit of district heating.

1. Millions of barrels of oil are saved by urban dwellers switching from oil central heating.
2. Marginal or excess heat is used from local power stations which would otherwise be wasted.
3. Local employment results from the laying of steam pipes.

So, in a district heating conservation option, current national unemployment costs would go towards the capital for the project and domestic users could divert money from overseas oil supplies to the local power utility.

These benefits however would also apply to most of the realistic solar options, in particular biomass and wind and if it proves practical, wavepower. Biomass in particular needs urgent scrutiny, as it may be possible to use some of the existing waste or unused outputs of our forests in addition to short-rotation crops as fuel for electricity.

The exercise of these solar options would not only save barrels of oil but would also provide local employment. They would begin to provide energy from new sources to release diminishing imported supplies.

This kind of conservation measure and capital spent on solar energy projects lead me to the last financial device used in evaluating power source projects – the discount rate used for evaluating the delayed benefits of such programmes. In recent years rates of as high as 7 per cent and 10 per cent have been used reflecting similar sums done by large corporations in evaluating business ventures. In the past rates as low as 2 per cent and 3 per cent borrowed from government bond rates were used. The use of the higher rate is in fact totally meaningless when it comes to power source or conservation options, as the future benefits appear negligible. Had we used such rates for our national re-afforestation or land drainage programmes or even the Shannon hydro projects, these projects would possibly have never taken place.

From the national security point of view our situation is frighteningly simple. We are dependent upon an unstable and diminishing imported material for 80 per cent of our energy. The two most realistic alternatives, coal and nuclear, suffer from severe

disadvantages. We are most fortunate that we have natural gas to burn for electricity should there be a crisis over the next ten years. The only option we can embark upon which will begin to reduce our vulnerability immediately is conservation. Even if we go for nuclear right away a supply of nuclear powered energy ten years from now will be too late to help us through a crisis which may take place in the next few years.

I would see the following as a reasonable scenario. First, diminishing oil supplies, at increasing prices, threaten our economy and society. Production and exports and jobs will be at risk. People will begin to learn to live with petrol and home heating shortages. Two forces will be put to work to fight these trends: more natural gas will be burned for electricity and extensive conservation measures will be employed. More coal-fired stations will be built and overseas coal sources sought. Work will begin on biomass, wind and possibly wavepower.

Two events could change this scene. First more gas or oil found off our coasts and second further breakthroughs overseas in fusion and hydrogen technology. The second however is most unlikely within the next ten years.

Our costing needs are very simple. We must have energy and we must conserve what is available to us. We must make rapid decisions and incur no delays, as delays and changes in specifications are most costly. We must cost decisions which are dictated by the needs of our society and our national security. These must be to acquire more coal-fired power sources as quickly as possible, far ranging conservation practices and as many viable solar resources, such as wind, small hydro and biomass as we can plan for.

I am happy to be able to tell you that only last week the government gave the national leadership role in energy conservation to the IIRS. We are now working towards the production of a national programme for energy conservation in this country, and we will be saying more about this in the near future.

And as far as new energy sources are concerned, our problem is whether or not we should have specific kinds of power stations. It is can we get any of them fast enough.

It is with a great deal of humility that I have presented this treatment of the costing of "Ireland's Energy Options". The subject is a very complex one and deserves much more time and effort than I have been able to spare it. I hope, however, that I have stimulated some thinking on the subject and pointed out some avenues for future work.

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DISCUSSION

Dr J. J. Kelly: The authors have highlighted some of the important questions which face those of us who work in the energy field and which must be answered if the country is to continue to have an adequate supply of energy for economic development.

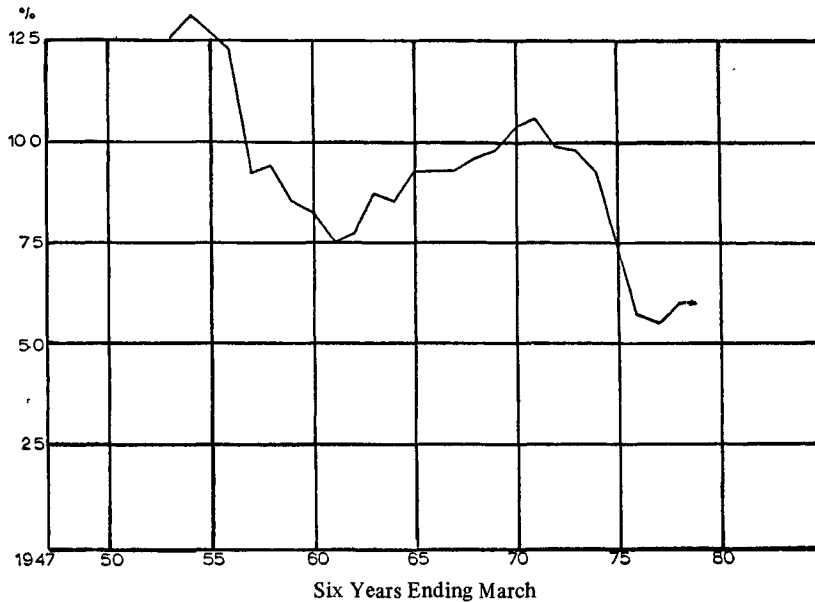
- i) How much primary energy will the country need through the next decade?
- ii) What types should we choose?
- iii) What contractual commitments should we enter into now? – and these cannot be delayed.

My comments are through the eyes of the utility which is responsible for future supplies of electrical energy, and I am making my comments in qualitative rather than in quantitative terms. I am also adding a word about the strategies we are using to try to cope with the many uncertainties which are involved.

Perhaps the most difficult decisions to be taken are those about electrical energy.

- i) It cannot be stored, and must be produced instantly on demand. The amount of plant is determined by the peak demand and it must therefore be installed in good time.
- ii) The time-scale on commitments is considerable.
 - Contractual commitments for base-load plant must be made some 6–10 years ahead. Base-load plant is the most difficult area because of its long lead-times for construction and the very high capital which is involved; individual new projects now cost upwards of £350 million.
 - Added to these lead-times, there is also the added commitment to the associated primary energy for some 20–25 years of operation.

Figure 1: Six Year Rolling Average Growth Rate.

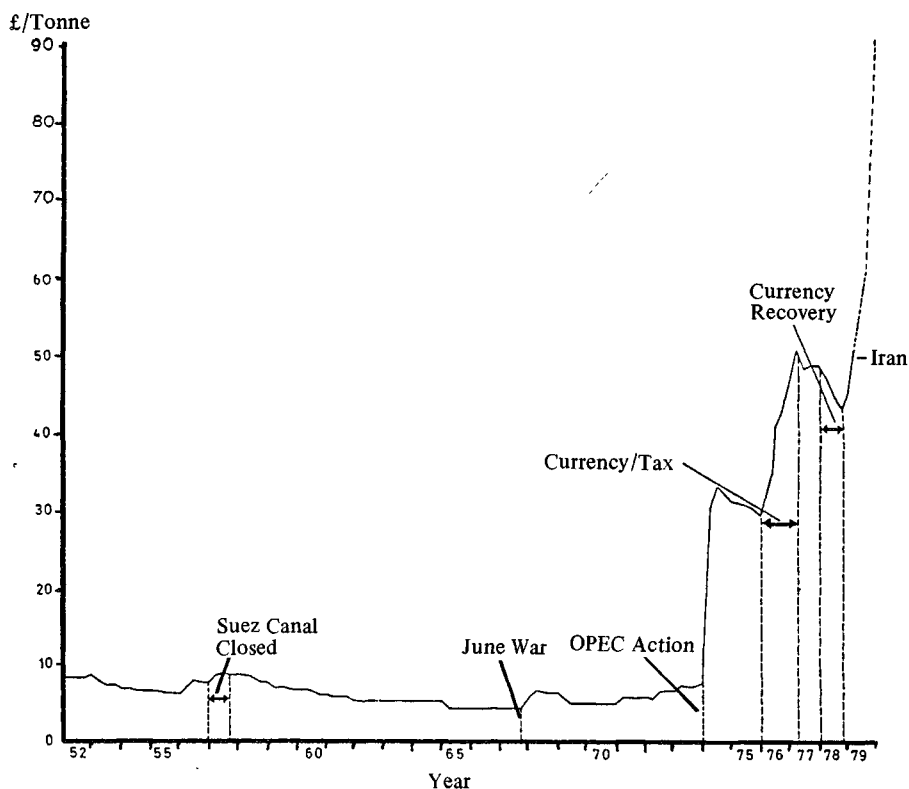


The authors have also highlighted the limitations of statistical analyses and projections, whether these are about growth or economics. These analyses provide necessary inputs to decision-making, but it will be obvious that in the final analysis there must be a large element of intuitive judgement. This is particularly relevant for a country with a comparatively small amount of indigenous energy. There are neither clear-cut nor easy options. We lived for too long with the false hopes of continuing supplies of cheap oil and of cheap and long-term finance.

Let me add a couple of comments about some of the statistics presented to you this evening. Mrs Scott's paper deals with energy projections for Ireland through the next decade or so, adding that she considers that the official forecasters are on the high side. She rightly comments that forecasters feel they are on shifting ground. A useful indicator which we use in the ESB is the 6-year rolling average for growth (corresponding to average lead-time for new plant — see Figure 1). This shows in a general way the relationships between energy demand and growth in GNP which she has mentioned, but the historical evidence over the last 30 years or so provides little comfort for those of us who depend on energy projections. We have seen the post-war boom in demand for electricity, followed quickly by the recession of the late 1950s, then the industrial boom that began in the late 1960s and carried through into the early 1970s, to be followed again by one of the most severe recessions the world has known in recent times.

Mrs Scott also deals with the possible effects of pricing on demand in the long term. I still need convincing that the abnormal increases in, say, petrol prices have had any real effect on the density of motoring. I would add that it is often difficult to disentangle the effects of price from other factors such as temporary shortages of energy sources. We are experiencing buoyancy in electricity demand just now, due to the shortage of heating fuels.

Figure 2: Oil Costs (Residual).



Economics, too, as dealt with by Dr Nichol, are also on shifting ground. It is world politics and the international market-place which decide the availability and cost of primary energy supply. This is a real crunch in arriving at our own decisions. Let me illustrate by looking at residual fuel oil and coal.

- i) Figure 2 shows the prices we have paid for residual fuel oil over the past 25 years or so and clearly indicates the vagaries of prices and their sensitivity to world events. Ireland has had little or no say in the prices that have had to be paid. Added to this, we are now threatened with world shortages through the next decade or so, but at least we know what oil has done and have been given a real foretaste of what it may do in the future.
- ii) We have yet to experience what may happen to the coal markets, despite the comparative abundance of resources. Market forces have not yet established the real prices which will have to be paid for coal.
 - There is no real international market as such in coal at the moment. A tentative estimate is that only about 10 per cent of the world's coal production crosses national borders.
 - Prevailing prices are largely for marginal extra coal from existing mines. This certainly applies to countries such as Australia, Poland and India. Forward contracts for substantive quantities will have to relate to new developments, taking account of a new infrastructure for world trade and tougher environmental regulations for production.

– If, as is threatened, oil supplies decline, there will be added pressure on the price to be paid for coal as the world resorts to the production of synthetic fuels. It is significant that the major oil companies have already diversified into coal production.

iii) Thus, we are in a rather artificial situation as far as coal prices are concerned, and it is a reasonable assumption that the eventual price to be paid will be tied in some way or other to the going rate for world energy. Availability of supplies (and this applies equally to oil and nuclear fuels) must still be a dominant factor for us.

Dr Nichol has also referred to some of the social factors that have to be taken into account in forward decisions. He has touched on some of the health hazards in fuel production and transport, and in its conversion to electrical energy. He might also have added the considerations of tougher environmental regulations and the problems of community acceptance. These considerations apply particularly in the case of thermal conversion – whether it be coal, oil or nuclear.

How, then, do we plan long term for electricity supply in a situation where we cannot make firm projections about demand, nor can we determine on economic and availability bases what types of plant and associated primary energy should be chosen.

Nevertheless, planning must continue within two main parameters –

- i) There must be adequate plant and associated primary energy for economic development, and
- ii) There must not be too much generating plant because of the very high cost penalty.

There are three strategic elements in the ESB forward programmes –

A. Conservation must be the primary strategy

- i) In a country which has only a small amount of indigenous resources, prudence alone demands that we try to conserve our energy needs. Oil at prevailing price levels contributes substantially to our import bill.
- ii) New increments of demand for electrical energy can only be met at increasing costs for capital equipment and finance, thus putting pressures on the real costs of electricity supply.

ESB marketing policy had already changed before the Arab action in 1973, ceasing the promotion of electricity *per se* and having as its main objective the shaping of the daily load demand and the improvement of the economic performance of the business.

B. Diversification of primary energy types and sources

- i) In the interests of the security of supplies, the objective is to try to have as good a spread as practicable. In line with this objective, the new Moneypoint generating station is being designed as a fossil-fuelled station capable of burning coal, oil or gas.
- ii) The soft options mentioned by Dr Nichol can only play a supplementary role. The scale of the generation programme that is currently being planned by the ESB is of the order of 30 Shannon Schemes. If the combined contributions from these options could produce the equivalent of one Shannon Scheme by the end of the next decade, it would be an achievement beyond the present state of development. Even at this level of contribution, these soft options could not materially affect the basic decisions that have to be taken.

C. *Flexibility* in the programme for plant and primary energy

- i) The pace of growth in the demand for electrical energy will be determined by the pace of growth in GNP, and not by ESB. We are not planning on a single discrete projection for growth, but consider it prudent to maintain a readiness to meet an average growth rate of 8.5 per cent per annum over the next decade, as an upper figure.
- ii) As much flexibility as is practicable has been built into the programme to enable the ESB to react to variations in GNP, to world events in energy, and to the possible finding of indigenous gas/oil reserves.

Thus, in the programme being planned, there is flexibility in the time-scale in the horizontal axis; the vertical scale represents discrete steps in addition to our programme and determines the sequence of these additions. The overriding factor, however, is that the relevant *decisions cannot be delayed beyond critical 'go' dates.*

Professor James A. Crutchfield: It is refreshing to see this debate on Irish energy alternatives cast in the general framework of economic forecasting (economy-wide and by sector); the implications of these forecasts for the level and composition of energy demand; and the incremental costs of providing primary energy from alternative sources. Hopefully, this implies recognition of the fact that energy is an input to productive and consumptive processes fully comparable to other inputs of labour, materials and managerial effort. We expect (and find in the increasing number of econometric studies in other countries) that households, industry, and government enterprises will adjust to changes in the relative prices of different sources of energy and in the relative costs of energy and other inputs that can substitute for it. I agree with Dr Nichol, however, that the range of social choices involved in evaluating energy alternatives encompasses but is broader than economic choice alone. Thus, Ireland and every other nation must look for the lowest cost energy mix over time, with full regard to security and environmental costs. Unfortunately, there is no single numeraire in which these often conflicting multiple objectives can be compared directly. To some extent, the choices with respect to future energy policy must be based on an intelligent presentation of alternatives, to be adjudicated finally in the political process.

There is some difference in the scenarios within which the two principal authors have considered the energy future of Ireland. Mrs Scott has looked at the adjustment process -- to higher energy costs and the interrelated growth in GNP -- over time. Her concern is not with catastrophic cutoff of energy supply, but of reaction to increasing scarcity and higher prices of energy and changes in the supply mix. Dr Nichol has emphasised the worst case situation (not entirely, of course) which is certainly a matter of legitimate concern but probably less useful in considering policy alternatives. Complete cutoff is really likely to occur only in the event of all out war -- in which case oil supply might indeed be the least of our worries. My comments on the two papers run largely in terms of Mrs Scott's framework; that is, only the normal number of small wars and disasters, but with a persistent, though intermittent, rise in the real marginal cost of oil, coal, gas, and nuclear energy and their impact on supply options for Ireland.

First, then, to Mrs Scott's paper. She presents a strong, well-supported argument that there are crucial deficiencies in forecasts of Irish energy demand that seem to be most influential in policy determination. As she points out, there are obvious inconsistencies in the forecasts of *per capita* energy use relative to GDP in Ireland as compared with other nations. If correct, these forecasts imply that Ireland would become

one of the heaviest users of energy among the western nations. Only Canada, the US, Sweden, and Norway would exceed Irish energy use *per capita*, and all of these (even including the US for the moment) are “cheap energy” countries.

Apart from some scepticism, which I share, about projected growth rates in GNP in Ireland, Mrs Scott’s principal criticism of these demand forecasts is their failure to include any response to higher real prices – an implicit assumption of zero elasticity of demand which is simply incompatible with economic rationality on the part of consumers or producers.

Mrs Scott’s empirical findings with respect to price elasticity seem to parallel those of a number of studies in other countries and rest on far more acceptable assumptions with respect to rational economic behaviour than the zero elasticity forecasts. It seems likely that the improvement in fit with the assumption of a declining responsiveness of energy demand to growth in GDP is to be expected, since the constant or increasing demand elasticity with respect to GDP leads to nonsense results after even an intermediate period of time.

It seems likely that the estimates of elasticity for energy demand with respect to price developed by Mrs Scott represent an understatement. Though she has recognised, properly, the lagged response of energy demand to changes in price (reflecting the necessarily slow process of changing factor combinations, particularly in industrial equipment and housing), there is no way in which her technique can include a factual estimate of *induced* research and development triggered by the increase in relative energy prices. There is every reason to believe that elasticities computed on the basis of adaptation using known technologies must be too low, since there are recognised areas in which improvements in energy use can be achieved, but which lie beyond present technical frontiers. The stimulus of rising energy prices could be expected, to reallocate R & D in both public and private sectors to realise these opportunities.

The obvious next steps are suggested by Mrs Scott. One is the need to disaggregate the data and analyse by sector. In this connection, it should be noted that while some sectoral responses to increasing prices of energy come about as an Irish response, much of it originates elsewhere and shows up in lower energy components in imported consumer durables and industrial equipment. It is also essential to develop forecasting techniques in which the reciprocal relationship between energy as an input to the productive process (and therefore to GNP) and the causal effects of changes in GNP on energy demand are recognised explicitly. This carries with it the need to incorporate input-output techniques to capture the impact of demand responses to price change on intermediate inputs as well as final products. Finally, it seems likely that even the preliminary data and conclusions in Mrs Scott’s paper can be used to assess the impact of active demand management, as opposed to passive reaction to price changes.

There are some obvious areas of agreement with Dr Nichol’s comprehensive paper which call for little additional comment. There can be no question of the need for diversification of energy supply sources and for continued monitoring of technical developments in other countries for possible adaptation to Irish conditions. The evaluation of all options must be undertaken not merely in economic terms, but in the broader social objectives of cost, national security, and environmental acceptability. Finally, there can be little disagreement with his insistence that there is no quick fix or easy solution. Ireland’s adaptation to the energy crisis must be one of minimising pain – either learning to live with less energy use or paying for it in higher cost supplies.

There are, however, some areas in which I find myself in considerable disagreement

with Dr Nichol's presentation. These are summarised below.

With respect to the options available, it seems curious that oil is left out entirely. While it is true that the supply of oil is finite and the real cost of obtaining it will increase over time, OPEC or no OPEC, it seems highly doubtful that the doleful predictions of zero oil availability within an intermediate time period should be taken seriously. Obviously, there is always the possibility of arbitrary interruption of substantial portions of the world's oil supply by the OPEC nations. But not all the oil is in OPEC countries and not all of the OPEC countries are in the Middle East. The political nature of oil supply and the position of Ireland as a small, relatively neutral nation, suggests that it is unlikely to be completely deprived of oil on little or no notice. Long term contractual relations with countries such as Mexico, Nigeria, Indonesia, etc., might involve such small portions of their total supplies as to be nearly inconsequential, but they could provide a partial answer to the crucial intermediate period supply problem which must be bridged to reach, hopefully, a secure plateau of endlessly renewable energy sources in the future.

Dr Nichol, despite his excellent statement of the overwhelming desirability of energy conservation in cost terms, treats it as a once for all adjustment, available only after a relatively long period. This seems questionable on both counts. There is considerable short term potential for conservation and, much more important, the real gains will come as a long run, *continuing* response to higher prices and scarcity. Energy-saving standards for new construction and retro-fitting of existing houses and commercial buildings with insulation could do much to reduce the large element of energy consumption required for space heating, and this will require a relatively long time period. Similarly, rationalisation of internal transportation can achieve very substantial reductions in oil consumption without serious impacts on GNP, but only if considerable time is allowed for adjustment and replacement investment.

I sympathise with Dr Nichol's difficulties in trying to develop estimates of comparative marginal costs for energy from different sources, since the data are remarkably poor on both a worldwide and local basis. Comparison is made more difficult by the absence of any detail about the scaling process through which the costs of a 600 megawatt plant can be derived from data on 1,000 megawatt plants and by his use of future cost estimates couched in nominal rather than real prices.

Data from other sources cast some doubt on the apparent advantage of nuclear over coal-fired plants as indicated in Dr Nichol's paper. Figures published by a major American energy consulting firm indicate that costs of nuclear power have risen much faster than for coal generation. Their 1969 estimates for 1976-78 operation show nuclear at 7.9 mills per kilowatt hour at the bar as compared to 10.7 for coal. But 1978 estimates for operation in 1988-1990 are 64 mills and 65 mills for the two sources. Expressed in constant 1977 prices, this would yield costs of about 49 mills per kilowatt hour - a figure that is consistent with present estimates of American nuclear plants now coming on line at costs ranging from 32 to 45 mills.

Note also that these estimates, like Dr Nichol's, assume an equal time lag between the decision to build a plant and the time it comes on line. Yet his own discussion makes it clear that coal plants can be built more quickly; and, very important, in smaller units that are still able to operate at minimum attainable costs.

The significance of this for a small but technically proficient country, given Mrs Scott's cautions about demand forecasts, lies in the wisdom of keeping options open as long as possible. The nuclear option may turn out to be essential and Ireland must continue to do the time-consuming homework that precedes the siting and construction of

nuclear plants. It must be kept closely abreast of developments in other countries with respect to the efficiency, reliability, and safety of the competing technologies now being pursued. But for the present, the evidence suggests that multipurpose plants, capable of burning any of the available fossil fuels, can be built more quickly and in units small enough to minimise the “eggs in one basket” problem without undue risk, while waiting for others to resolve the starkly real problems of safety and reliability which have been thrust before the world by a series of incidents culminating in the near disaster in Pennsylvania.

My main concern with Dr Nichol’s cost estimates is that some very important elements have been omitted or played down in his presentation.

1. A very early commitment to nuclear power imposes additional costs in lost opportunities to benefit from technological advance – and the experience of the past few years suggests strongly that the nuclear power industry is still far from the bottom of its learning curve.
2. Costs of waste disposal and obsolete plant disposition are completely unknown at this time. I was astonished that Dr Nichol would accept so casually cost estimates from a report which he himself regards so lightly. There is wide consensus among scientific and technical experts that there are no firm answers as yet on adequate storage techniques. In this sense, it is intriguing to look at the words of Dr Norman Rasmussen (certainly no opponent of nuclear energy): “The problem reduces to finding *very sure* storage (emphasis supplied) for several hundred years, then relatively safe storage for ten thousand to one hundred thousand years. This would require impermeable material, geologically stable for 10,000 years”. In the face of these requirements, the costs quoted in Dr Nichol’s paper – indeed, any costs – are a bit hard to take seriously. It is true, of course, that much of the nuclear waste from Irish plant operation would be disposed of elsewhere, but the cost would ultimately fall on the shoulders of user countries, Ireland included.
3. The combined effects of measures to ensure against accidental discharge of radioactive materials from an operating plant are high – but as the Three-Mile Island, near Harrisburgh, Pennsylvania experience demonstrates graphically, they are not high enough. It makes no sense to compare the impact of plant failure in a nuclear operation with failure in coal, oil, gas or turf plants. The nature of failure, the potential catastrophic results, and the enormous and still unresolved technical difficulties of undoing damage have been laid before us in the Three-Mile Island incident. Fortunately, the worst did not occur, but the margin was far too close for comfort; and even successful containment imposed very high costs (including a substantial loss of economic activity during the shutdown) that continue to this time. For example, disposition of the large amounts of now radioactive water required to reduce core heat to safe levels will be tremendously expensive, and to date no acceptable solution to disposition of this material has been found. All of this adds up to saying that a much higher level of technical training and maintenance standards must be required for nuclear plant operation – far above those of normal electricity generating plant. While some of these skills can be borrowed, ultimately they become a burden on the Irish power user and taxpayer. And the cost of even a near miss would represent a blow to the Irish economy.
4. The near disaster at the Three-Mile plant and the dozens of potentially serious accidents that have occurred in the US and other countries were due to mechanical failure or to unwitting human error. What of the prospect that the same or much worse threats to human health and life could be initiated deliberately by terrorist groups? Viewed

simply as a matter of economic costs, our experience with security at prisons, banks, and military establishments suggests that it is far from adequate at present levels. A nuclear plant would have to bear the cost of extraordinary protective measures. Moreover, the enrichment process and its logistic requirements open up the possibility of diversion of weapons, materials and sabotage at each stage of transportation and handling of waste materials and new fuel. The need for special plant locations, special transportation vehicles, special treatment of fuel materials to prevent use in weapons, all add up to distressing increases in total costs of nuclear energy.

5. Because of the safety and safeguard problems, it seems most unlikely that heat generated by the fission process can be used economically. Yet experience in several European countries has demonstrated dramatically the possible cost savings from integrated use of what otherwise must be painfully disposed of as waste heat.

The treatment of environmental costs of other possible sources of primary energy is surprisingly loose. It is difficult to attribute any real meaning to a graphic comparison of environmental costs, energy produced from nuclear and conventional fossil fuel with wind, solar, and ocean thermal conversion when the technologies of the latter three are still essentially unknown (at least at a commercial scale which would be meaningful). With respect to coal, the environmental damages associated with air pollution in many parts of Europe and the United States would be much less serious in the Irish setting, given the small size of the industrial sector, the possibility of locating coal plants away from other, limited concentrations of industrial activity, and the prevailing weather patterns and topography. A much larger degree of waste disposition in the atmosphere could be safely undertaken in Ireland.

Actually, the environmental costs even of conventional fossil fuels are very poorly defined at present. The whole matter of environmental impacts and their integration into a decision-making matrix with respect to energy alternatives calls urgently for much higher levels of research than are presently being undertaken. Obviously, Dr Nichol is as aware of this as any other expert in the energy field – but it does seem unrewarding to present comparisons of environmental costs which really have no acceptable technical or economic basis in fact.

Since it is not pleasant to pursue endlessly a negative theme, I should conclude by offering a few positive thoughts. With respect to national security, even the threat of complete cutoff can be minimised, though not inexpensively, by stockpiling (perhaps including locking-in, after development, some of Ireland's gas producing capacity). Admittedly, this is not a cheap alternative, but it may be much cheaper than investing in excess capacity in nuclear power plants that may be technologically outmoded or environmentally unacceptable by the time they come to full utilisation. Pressure for more effective conservation in energy use could be increased by making the cost of stockpiling a charge on present energy users.

Another alternative would be to offer attractive financial benefits for long term contracts for oil and coal from suppliers in areas that are reasonably secure politically, – this in addition to the protection offered by adherence to IEA. This might require institutional arrangements to reduce the present total reliance on major private oil companies (a requirement that may have other benefits well worth considering).

Diversification of energy sources might be expanded to include a gas link with Europe via the UK, with full knowledge that in present value terms this is not economically attractive. Security costs something regardless of the options chosen.

Over the long run, the two papers provide some clear guides to policy; a flexible, adaptive strategy to deal with uncertainty in energy supply and technical advances (don't get locked in); a selective, active set of policies to manage the level and composition of energy demand; and a publically announced, debated, and agreed upon plan to deal with really serious supply contingencies.

In summary, the change from a fossil fuel energy base to renewable sources must come to Ireland in time. But it need not come as a crisis and it need not be traumatic if the nation uses time and existing resources wisely. It does not appear to call for more than a limited commitment by Ireland to nuclear energy within the next decade.