SCENARIO AND POLICY EVALUATION IN ELECTRICAL SUPPLY DECISIONS. THE ARGENTINE CASE

Dr. R.G. Coyle
Management Centre
University of Bradford
Emm Lane, Bradford
West Yorkshire, ENGLAND

Dr. J.C. Rego
Consejo Nacional de Investigaciones
Científicas y Tecnológicas
Casilla de Correo 131
5500 - Mendoza, ARGENTINA

ABSTRACT

The Argentine energy authorities elaborated a Plan for the Electricity National Sector, made known in 1979, where the policies to be followed for the period 1979-2000, were established. The Plan proposed basically a dramatic change in the structure of the present generating capacity configuration at the national level, toward a scheme predominantly hydro based. Apparently, the idea of an Electricity Sector less oil dependent, together with the utilization of a huge hydro-potential, which had been neglected until that moment, appeared promising. However, the study of the robustness of such plan, that is, its capability to perform well under different scenarios, became indispensable. The System Dynamics technique provided the possibility of analysing such robustness, by means of a continous-time simulation model of the Argentine Electricity Sector. This paper presents the results of experimenting with that model, in order to determine the soundness of the policies proposed.

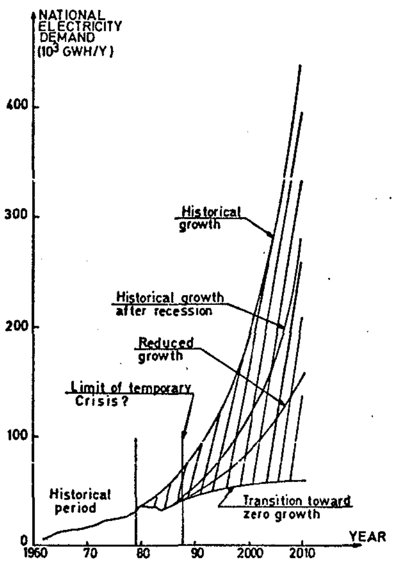
1. The "One Scenario" versus the "Multi-scenario" Approaches

The Argentine official energy Plan is based upon one scenario, wich is the projection to the future of the historical trend, where the electricity demand is expected to have an 8 per cent annual rate of growth. The report (SEE, 1979a) explains the consequences of this selected scenario, and the Plan is only tested against minor deviations from it. Broadly speaking this Plan depends heavily upon a steady high rate of national economic growth, which should be able to sustain a process implying 9 years doubling time.

Only the consequences of, or responses to, the selected scenario appear in the report, without examining alternative scenarios. Furthermore, the implications of unexpected behaviour in critical inputs to the system, such as fuel prices or capacity costs, are not considered, let alone construction delays, disruptions of international negotiation about shared rivers, etc.

This research examines several scenarios as exogenous inputs of the model, rather than the one-scenario test. The historical projection method, adequate perhaps for more quiet times and short-term analyses, looks naive in turbulent times, particularly in the volatile energy sector. Some alternative scenarios are shown in Figure 1. The historical growth scenario is increasing

Figure 1: ALTERNATIVE ELECTRICITY DEMAND GROWTH SCENARIOS.



at 8.3 per cent annual rate. An alternative, with an identical 8.3 per cent, starts after a possible temporary crisis of the national economy. There is good evidence for such a crisis in Argentina, whose annual rate of economic growth was about one per cent for the last years (apart from recent events). The curve called "reduced growth" indicates a less agressive growth after

a recession, and finally, we depict a transition towards a society without any growth at all. Similar scenarios to these described above have been used recently in energy simulation studies (Meyer, Mosekilde, 1980; p.28).

2. The Modelling approach

In the Argentine Power System planners work at middle range, over a 10-15 year time span, using different computer models, namely, load, generation, transmission and financial models (SEE, 1979a; p.321). The models are used for finding a minimum cost solution to the capacity problem, under very narrow variations of a given future scenario. We propose the use of a single model for exploring the behaviour of the Power System under strong deviations from the officially accepted future scenario.

There are some features in the Electricity Generating Sector, which make attractive the idea of modelling it as a controllable system already noted by Moody (Naill, 1977; pp.XV-XVI). Firstly the system as a whole has a big "inertia" to policy changes, mainly due to the long construction delays involved in capacity expansion.

Secondly, there is the existence of short-term versus long-term trade offs. The current management in Argentina found the Electricity System to be in a very critical situation. The system had become old and overloaded, based mainly on fossil-fuels. This has happened because the pressure for more generating capacity, particularly in the Pampean area, from cities overpopulated and industrialised, were answered with more additions to the conventional thermal capacity, rather than a careful development of hydro-electric sources. Regrettably, these handy short-term policies were feeding a vicious circle. Urgent problems were tackled by quick replacing and increased thermal capacity, because these involved the shortest construction delays, and were available in a wider power range.

Thirdly, it is expected that the Electricity Sector will meet turbulent times.

"The generic problem facing all consuming nations is to make an orderly transition -with a minimum of economic, political and social dislocation- from past characterised by relatively few constraints on energy utilization, to an inmediate future of increasing economic, environmental and political constraints. This transition period is one of adjustment in demand, supply and price and will persist well past the turn of the century until alternative sources of energy become commercially viable". (Choucri, 1976; p.99).

3. The Overall Structure of the Model

A simplified version of the Model structure appears in Figure 2 where, as in the previous Figures, every arrow indicates the direction of influence and the sign, plus or minus, the positive or negative kind of influence between the couple of variable linked by the arrow. The overall closed loop structure of the mode, typical of System Dynamics modelling, appears clearly, even when secondary links are not shown, for legibility's sake.

4. Alternative Scenarios for Policy Testing

The electricity demand is the basis from which the scenarios for the National Electricity Corporation are structured. Figure 3 exhibits the historical growth of the electricity demand. That demand splits in two, around 1979, the initial year of the simulated life of the model, to show both high and low electricity demand scenarios. The former follows the historical 8 per cent annual rate of growth, and the latter grows at 4 per cent.

The other component in scenarios is the behaviour of the international oil price, as distinct from the 1979 level assumed in the official scenario, as shown in Figure 4. In the present research, only the two higher oil price alternatives are considered. The fact that most of the producing countries have the exhaustion of their supplies in sight will probably lead to rising prices than depressing them.

Both rapidly and moderately increasing oil prices are combined one to one with the two electricity demand scenarios described in Figure 3 to define the alternative scenarios I, II, III and IV,

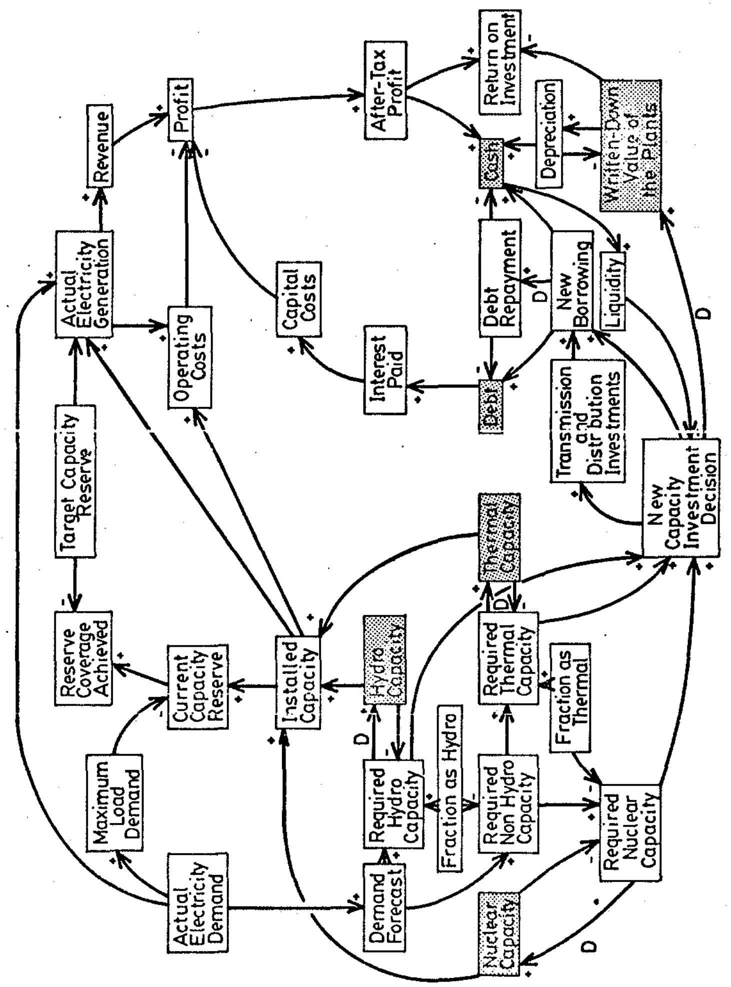


Figure 2: INFLUENCE DIAGRAM OF THE ARGENTINE CORPORATION OF ELECTRICITY (Simplified)

Figure 3: ALTERNATIVE ELECTRICITY DEMAND PROJECTIONS.

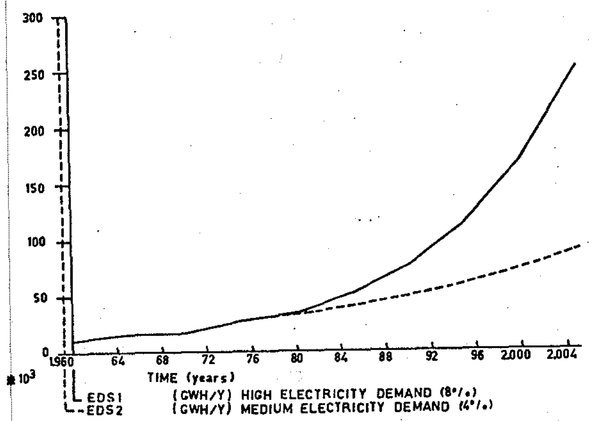
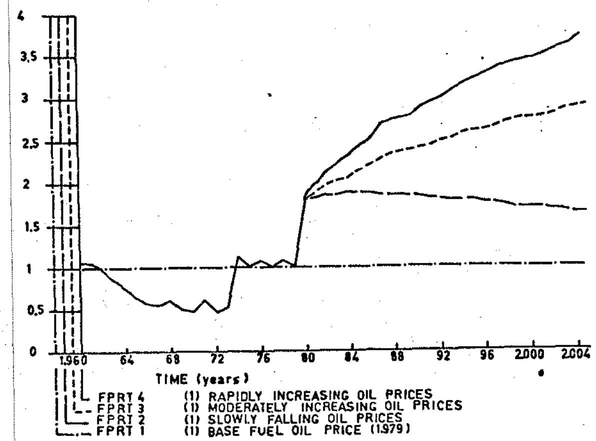


Figure 4: HISTORICAL (before 1980) AND ALTERNATIVE OIL PRICES PROJECTIONS.



Source: Adapted from Mosekilde and Meyer, 1981; p.III

as shown in Table 1, Scenario I envisages moderately increasing oil prices with high economic growth and consequently high electricity demand. This is the nearest to the official scenario.

TABLE 1. Alternative Policy Testing Scenarios

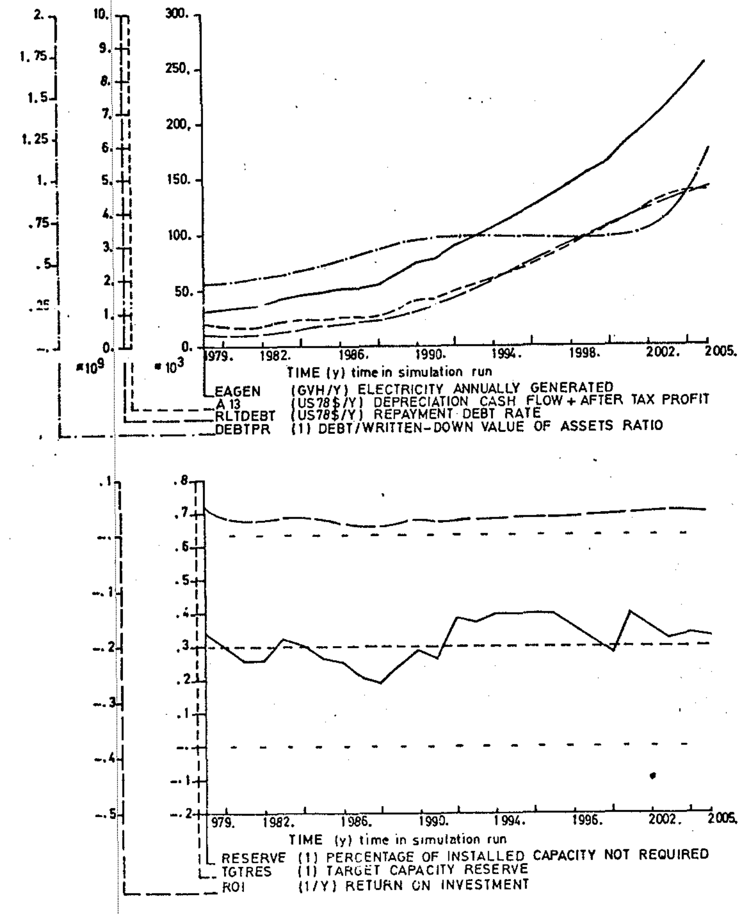
Annual Rate of Growth of Electricity Demand	International Oil Price	
	Moderately Increasing	Rapidly Increasing
8 per cent	I	II
4 per cent	III	IV

5. The Dynamics of the Argentine Electricity Corporation under Alternative Scenarios, when Pursuing the Official

To examine the dynamics of the system, guided by the policies of the official Plan (SEE, 1979a), the scenario assumed in those policies is allowed to change significantly. Some of the most important indicator of the system have been selected to summarise its behaviour. At this point of the analysis it is convenient to have a fixed reference yardstick, in order to compare behaviours when changing scenarios. For that purpose the electricity price remains the constant for the next experiments in this section. However unlikely this assumption may be, it helps in discovering extreme behaviour and in suggesting policies. The electricity price adopted is 10 per cent higher than the one fixed by the official planning, where a constant oil price was also assumed for all the 1979-2005 period. Even if the year 1979 is considered, for practical reasons, to be the initial year of the simulation, it is not possible to ignore oil price changes that happened later.

Figure 5 shows the dynamics of the Corporation under Scenario I, which is defined by an aggressive electricity demand and moderately increasing oil prices. The capacity reserve fluctuates around the target reserve, with the highest deviation being 12 per cent lower in the first half of the simulation and 10 per cent higher in the second half. The reserve stabilises around the target well past the year 2000. Until the year 1995, the price

Figure 5 : DINAMICS OF THE CORPORATION IN SCENARIO I: MODERATELY INCREASING OIL PRICES AND HIGH ELECTRICITY DEMAND.

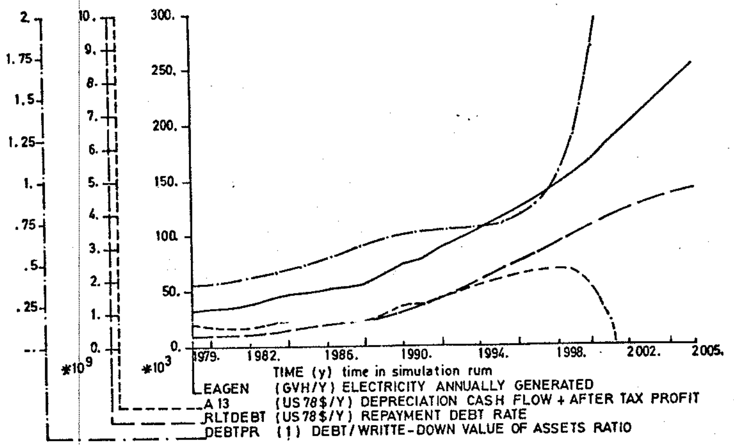


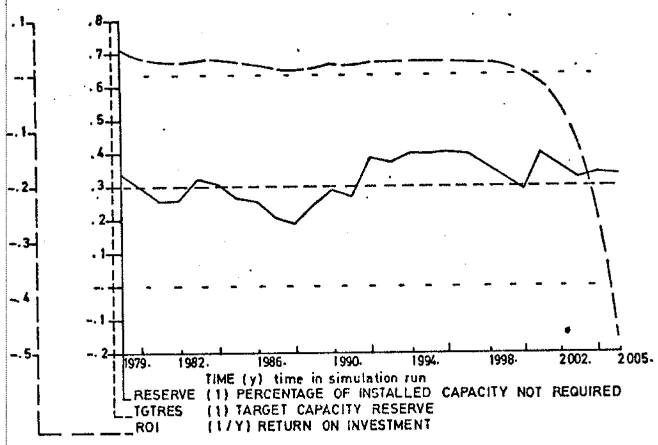
level selected is enough to cover long-term debt repayments of principal, the Corporation being in a good cash position. In the model, excesses or shortages in cash produce earlier repaying of the long-term debt, or more short-term borrowing, respectively. Because there is no limitation on borrowing, as it is convenient to assume in this analysis, positive feedback loops reinforce these cash positions. The good cash position manages to stop the long-term debt growth, which stabilises around 1990 until 2002, the debt to assets ratio being 64 per cent during this period. However, at the end of the period, cash shortages start to dominate, and the debt to assets value ratio starts increasing rapidly after the year 2000, crossing the 100 per cent mark in 2004. The return on investment which is around 5 per cent during the time the debt ratio is stable, and even higher later on, is also affected at the end of the period.

The next Scenario II, shown in Figure 6, has the same high electricity demand, but the oil price is now growing faster than in the previous Figure 5. The behaviour of the capacity reserve is exactly the same as in Scenario I, because at this stage the capacity ordering policy is decided by future capacity gaps and is not affected by financial constraints. The pattern of the general dynamics appearing in Figure 6 is similar to the previous one, with a difference: everything happens quicker. The debt ratio grows slightly higher than in the previous run, and remains briefly stable around 64 per cent in 1962, but it starts climbing up in 1996, reaching the 100 por cent mark in 1998. This is triggered off in 1993, when the cash available for long-term repayment is not enough. The return on investment, which was around 3 per cent during most of the first 20 years, become nil in the year 2000, and rapidly goes negative.

The remaining scenarios could be explained in the same way, using the graphs of the simulation, but that is too space consuming for a paper. A further discussion appears in Rego (1982), and we turn, instead, to a more compact representation based on the use of indices of performance. We feel system, as revealed in the

Figure 6: DINAMICS OF THE CORPORATION IN SCENARIO II: RAPIDLY INCREASING OIL PRICES AND HIGH ELECTRICITY DEMAND.





graphs, is the preferred method of fully understanding its behaviour.

6. Numerical Indices for Comparison of the Performance of the Corporation under Alternative Scenarios

The richness of the visual display of the behaviour of the system under different circumstances makes, paradoxically, their comparison difficult. Numerical indices facilitate the task. That entails having a clear idea of what target levels should be achieved by the model and what time series are generated by it.

The first series considered is capacity reserve. The ability of the system to keep as near as possible to the target 30 per cent is traced by an index, RESIX. This Index grows with the inability to control the generating capacity reserve.

The next two indices measure financial performance, are indicated by the Debt to Assets Value ratio, DEBTIX, and Return on Investment, ROI. Naturally the bigger the area under the debt proportion variable, the worse for the system, and the opposite is valid for the area under Return on Investment, with respect to zero level. For a fuller discussion of the construction of such indices for System Dynamics models see Coyle (1979).

These indices are accumulating levels, referring to the model's behaviour as a whole without any local meaning. The absolute values of the indices have been divided by those of Scenario I, which is the nearest to the official scenario.

TABLE 2. Reserve, Return on Investment and Debt Ratio. Indices Values achieved by Official Plan under Alternative Scenarios

Scenarios	Reserve Index RESIX *	Debt to Assets Ratio Index DEBTIX *	Return on Investment Index ROIIX
Scenario I	1.0	1.0	1.0
Scenario II	1.0	3.1	-0.2
Scenario III	1.6	0.7	0.8
Scenario IV	1.6	0.9	0.5

* The smaller the index values are, the better for the system.

Examination of Table 2, from the physical viewpoint, the firt four scenarios can cope with the capacity demand, though in Scenarios III and IV the system will have to live with capacity surpluses almost all the time.

From the financial viewpoint the sector's sensitivity to changes in scenarios, shown by the strong reactions of the indices to them. It is natural to expect that higher oil prices will make things worse for the corresponding scenarios, given the fixed electricity price assumption. The interesting thing is to know when it is worst. It is quite clear, comparing the financial indexes, that the effect of higher oil prices is smaller for low electricity demand scenarios than for the high ones. Scenarios III and IV are more alike than Scenarios I and II. Even Scenario I is nearer to III and IV than to Scenario II, the latter being under an unfavourable combination of high demand and high oil prices.

7. Long-Term versus Medium-Term Strategies

The experiments in sections 4 and 5 tested the officially desired 70 per cent Hydro-30 per cent Thermal/Nuclear mix by the end of the century. The experiments were based upon a long-term capacity ordering strategy. This means that planning is made over a 12 year planning horizon. Once the model works out which are the desired proportion of thermal, nuclear and hydro capacities, the buil-in control rules decide how much new capacity should be ready at that time, 12 years hence.

However, for the hydro sector, different construction delays must be taken into account, and the long-term policy is made in two steps.

The model selects the next long-term project from the list of candidates, if it can be fitted into the gap, but it also adds a medium term project if the original choice would leave too large a medium-term shortage of capacity. In principle this is the cheaper option, as the unit capacity cost is lower for the big long-term projects, located in the Plata and Patagonia basins. The model is discussed in more detail in Coyle and Rego (1982).

On the other hand, the medium-term strategy defines the gaps

to be filled with nuclear and thermal capacity over a 9 year planning horizon. For the hydro case, the 9 year or medium-term gap, is filled with medium-term hydro projects, and projected over the long-term horizon. If there is still room for long-term projects, they are ordered. The medium-term projects are typically smaller and more expensive, in terms of unit capacity cost than the long-term ones, but it should avoid supply shortages.

Table 3 compares the normalised indices, for the long-term strategy with those for the medium-term one, in order to achieve the official Plan. The change to a medium-term strategy does not produce any differences in capacity reserve indices, for Scenarios I and II, but the financial indices are noticeably worse. This is logical, as the model is giving priority to the expensive projects having to order the big ones anyway, because of the aggressiveness of these scenarios. In the case of the lower demand Scenarios III and IV, the medium-term strategy produced capacity over-ordering, but affecting slightly the financial situation, confirming that the medium-term option is associated with more capacity reserve, and consequently, consumer protection, and higher costs.

TABLE 3. Reserve, Return on Investment and Debt Ratio. Indices Values achieved by Official Plan under Alternative Scenarios, considering both Long-Term (LT) and Medium-Term (MT) Options

Scenarios		Reserve Index RESIX *	Debt to Assets Ratio Index DEBTIX *	Return on Investment Index ROIIX
Scenario I	LT	1.0	1.0	1.0
	MT	1.0	1.7	0.9
Scenario II	LT	1.0	3.1	-0.2
	MT	1.0	19.3	-8.2
Scenario III	LT	1.6	0.7	0.8
	MT	2.3	0.8	0.8
Scenario IV	LT	1.6	0.9	0.5
	MT	2.3	1.0	0.5

* The smaller these index values are, the better this is for the system.

8. Testing a 50-50 per cent Hydro-Thermal Capacity Configuration Policy, under the Same Alternative Scenarios

Until now, what has been analysed is the robustness of the electricity Corporation, when it is trying to reverse its actual capacity configuration from being predominantly thermal to another where 70 per cent of the electricity is hydro-generated, in 25 years time. It is clear, from the previous analysis, that this policy is too sensitive to changes in scenarios. What could happen to another policy which tried to move to hydro more gently, say 50 per cent in 25 years, from the present 30 per cent?

Table 4 shows the index values achieved if the system changes from the present configuration to another 50 per cent hydro, 40 per cent thermal and 10 per cent nuclear. The figures obtained show that the system is nearer to target than the previous Table 3 in almost all scenarios, though is not a dramatic improvement relative to capacity. No doubt, the greater adaptability of the thermal equipment, given the wide available range of sizes which accepts continuous modelling, is what causes improvement.

From the financial viewpoint, the observed higher sensitivity to oil price of the sector in the high demand Scenarios I and II, is something to be expected, given the high oil dependence of this policy, compared with the official policy. And the difference is quite appreciable. On the other hand, for the lower demand Scenarios I and II, the financial performance of the 50-50 Hydro-Thermal policy is slightly better. This fact gives the system more room for manoeuvre, if there were, as is the case, any reason for expecting lower economic growth in Argentina than history has shown.

An intermediate objective like the 50-50 per cent Hydro-Thermal policy, might be followed, instead of investing in huge hydraulic projects, which have to be delayed because of financial difficulties; as in the case of Yaciretá Hydro Power Station and Paraná Medio Project, their construction is being postponed because of the excessive capital requirements for the present Argentine circumstances (La Nación, International Edition; 8 march 1982; p.8).

Finally, it can be added that the differences produced by the different medium or long-term strategies are smaller than in the official 70-30 per cent Hydro-Thermal policy, and even non-existent in Scenarios III and IV. This is also expected, given the smaller role played by the hydro sector.

TABLE 4. Reserve, Return on Investment and Debt Ratio. Indexes Values achieved by a 50-50 per cent Hydro-Thermal Capacity Configuration Policy under Alternative Scenarios, Considering both Long-Term (LT) and Medium-Term (MT) Options

Scenarios		Reserve Index RESIX *	Debt to Assets Ratio Index DEBTIX *	Return on Investment Index ROIIX
Scenario I	LT	0.8	6.5	-2.1
	IM	0.7	8.4	-3.1
Scenario II	LT	0.8	21.4	-9.8
	IM	0.7	34.3	-16.2
Scenario III	LT	1.7	0.7	0.8
	IM	1.7	0.7	0.8
Scenario IV	LT	1.7	0.8	0.5
	IM	1.7	0.8	0.5

* The smaller these index values are, the better it is for the system.

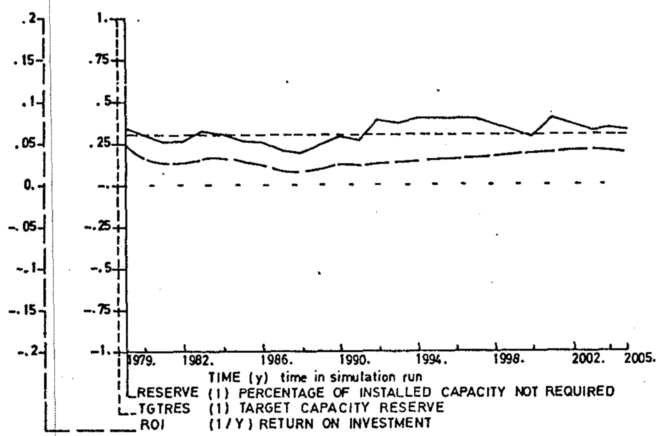
9. Policy Testing with Wrong Forecasting

The dynamics of the Argentine Corporation under alternative scenarios I to IV, described in the previous Sections 5 to 8 assumed that the driving variable of the model, the electricity demand, is perfectly forecast, by means of an exogenous input, without specifying how the forecast is made by external planning organizations. However, the perfect forecast situation is not the most likely to happen. Hence the interest in experimenting with wrong forecasting of the electricity demand. This section compares the effects of mild deviations from perfect forecasting situations, with those produced by very wrong forecasts.

a) <u>Mild Forecasting Errors</u>

The aggressive scenario I will be altered in such a way that simulates a failure in recognizing errors of the order ± 30 per cent in estimating the annual rate of growth of the electricity demand. This is done by means of an Error and Bias Factor, EBF, which multiplies the rate of growth used in the forecast equation The comparison between these three cases, Figures 7, 8 and 9, shows the high sensitivity of the system to these forecasting mistakes. The system starts ordering in the direction of the mis-

Figure 7: EVOLUTION OF THE CAPACITY RESERVE AND RETURN ON INVESTMENT, IN SCENARIO I, ASSUMING PERFECT FORECASTING (EBF=1).



take, so at the beginning of the second decade, when the effects of the wrong decisions come up from the pipeline construction, the system is well over capacity reserve target in case Figure 8 and under the target in the other, Figure 9. But inmediately after noticing the anomalies, the negative control loops start counteracting them, and keep trying all along the run.

Figure 8: EVOLUTION OF CAPACITY RESERVE AND RETURN ON INVESTMENT, IN SCENARIO I, ASSUMING OPTIMISTIC FORECASTING (EBF=1.3).

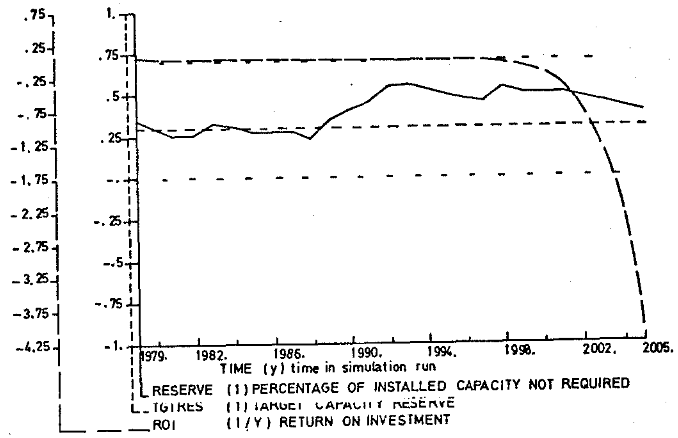
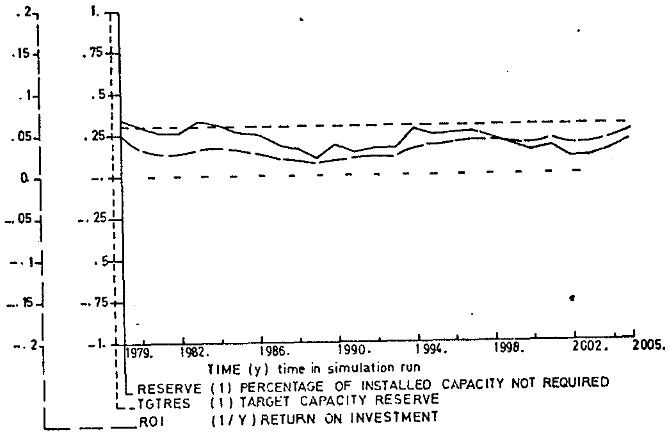


Figure 9: EVOLUTION OF CAPACITY RESERVE AND RETURN ON INVESTMENT, IN SCENARIO I, ASSUMING PESSIMISTIC FORECASTING (EBF=0.7).



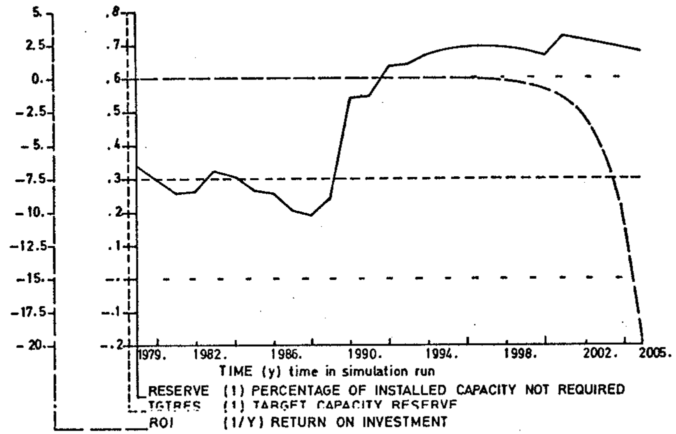
It can be observed that the financial situation is more dangerous in the case of overestimation of the demand, as shown in Figure 8, where the positive feedback loops penalizing cash shortages make the system collapse after the year 2000. It should be remembered, though, that this is valid from the point of view of the company, and the social costs implied in the capacity shortages appearing in Figure (9, have not been taken into account.

b) Very Wrong Forecasting

The next couple of experiments describe extreme cases of bad forecasting. In the first one the electricity demand, after having grown steadly for the first decade, suddenly, because of a crisis at the national level which shatters the whole economy, the annual rate of growth of the demand falls by half, after being quite high 8 per cent. It is assumed that this crisis is not foreseen by the forecasters, because of its unexpectedness, and it is only during the crisis that they will correct the forecast, adjusting it to the new situation. It is quite clear in this case that the belief in a bright future during the eighties, not altered until the country is actually inmersed in the crisis, produce catastrophic results, particularly for the company, which have to live with the results of a decade of very optimistic decisions, which leaves the system with a huge capacity surplus, as shown in Figure 10, the capacity reserve being 70 per cent almost all the second half of the simulated life of the system. Inmediately after the shift in demand, which happens in 1990, all the financial indicators show a dramatic change for the worse. Cash shortages become noticeable inmediately after, together with the rapidly increasing Debt to Assets value, not shown in Figure 10. The Return on Investment crosses the zero barrier soon after 1990 as well.

The other very wrong situation considered is the opposite to the previous one. The ecocomy of the country, after a decade of low growht, suddenly improves, doubling the annual rate of growth of the electricity demand. Again this situation has not been foreseen, and therefore only corrected when the crisis of growth actually happens. The systematic pessimistic forecast done during

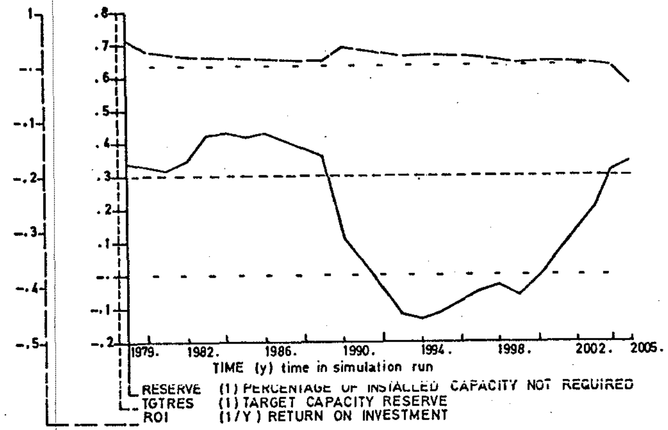
Figure 10: DINAMICS OF THE CAPACITY RESERVE AND RETURN ON INVESTMENT IN THE CASE OF AN UNFORESEEN COLLAPSE OF THE ELECTRICITY DEMAND.



the first decade condemns the system to a long period of under equipment after the crisis. The Capacity Reserve of the System, as shown in Figure 11, is not able to survive the shock, and until the year 2000 the system no only has no capacity reserve but even lacks the required capacity for the level of demand imposed on the system, However, it is possible to see the system's ability to recover its capacity reserve, achieving target after the year 2000.

From the financial viewpoint, however, the situation is not as bad as could be expected. The reason is that, because of high electricity demand, enough revenue keeps cash shortages away well past 1966. By then the Debt to Assets Value ratio is still 65 per cent, and its stampede does not happen before the year 2000, although this is not shown in Figure 11. The return on Investment, well over the 2 per cent level almost all the return, is still positive in 1998. Regrettably, if it is not too bad for the Corporation of Electricity, it is for the country as a whole, which does not get

Figure 11: DINAMICS OF THE CAPACITY RESERVE AND RETURN ON INVESTMENT IN THE CASE OF AN UNFORESEEN BOOM GROWTH IN THE ELECTRICITY DEMAND.



all the energy it requires.

The four wrong forecasting situation examined are compared in Table 5, where numerical indexes for Capacity Reserve, Debt to Assets Ratio and Return on Investment are compared on the perfect forecast Scenario I base

10. Improving the Robustness of the System to Wrong Forecast by means of Alternative Excess Capacity Aversion Risk Policies

This section is concerned with the protection of the system against what appears to be so sensitive at, that is, wrong forecasting. To defend the system against unexpected shocks, which have not emitted any signal before the crash actually happens is a hopeless ambition, as the extreme cases analysed in Figure 10 and 11 have shown. Unrealistic as it may appear, it is not so. There is no economic crisis which happens over a forenight, but in two or three years the whole spectrum of the economy of a country can change, like from the overoptimistic view of the Argentine

TABLE 5. Reserve, Return on Investment and Debt Ratio. Indexes Values achieved by Official Plan, under Mild Wrong Forecast of Scenario I situations, and Very Wrong Forecasts.

	Reserve Index RESIX *	Debt to Assets Ratio Index DEBTIX *	Return on Investment ROIIX
Scenario I with Perfect Forecast EBF=1	1	1	1
Underestimating the rate of growth in Scenario I in 30 per cent EBF=0.7	2.9	0.9	1.2
Overestimating the rate of growth in Scenario I in 30 per cent EBF=1.3	5.0	17.0	-7.4
Low Demand After a Decade of High Demand	19.5	73.5	-36.0
High Demand After a Decade of Low Demand	14.3	1.2	0.5

* The smaller these Index Values are, the better this is for the system.

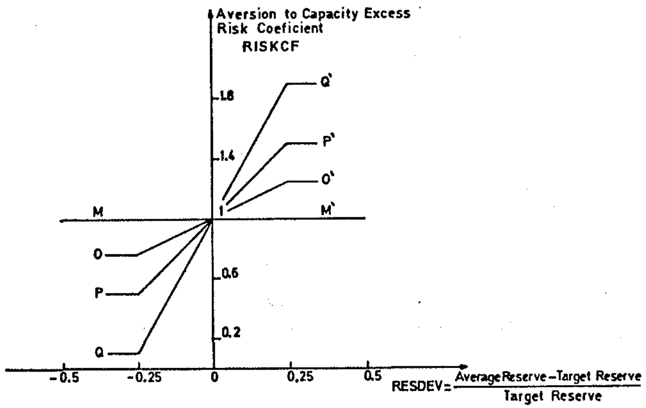
planners at the beginning of 1979, to the gloomy perspective foreseen around 1982. However, the decisions which affect the capacity growth for the next 10 years were already taken in the seventies, when the belief in constant growth were shared by many forecaster. Therefore, even if they know now that such growth is not going to happen, there is nothing the planners can do about it, except to stop or delay the process of construction of the power stations, which does not make much sense from the engineering viewpoint in most cases, once the process started. On the other hand, if what is going to happen is a growth boom, it simply will catch the system too late, without any possible course of action.

There is however more hope in the case of more monotonous type of processes where the signals are progressively putting the bad forecasting problem in evidence. It is suggested here to use the capacity reserve discrepancies over target as signals of bad behaviour of the system.

The policy parameter considered, which affects the ordering of new capacity is the Aversion to Excess Capacity Risk Coefficient, RISKCF. It has been defined in such a way that modifying the capacity ordering equations, by RISKCF values bigger than one, indicate aversion to order more capacity than the one indicated by the future control capacity gap. On the other hand, values RISKCF smaller than one indicate willingness to order extra capacity.

It is reasonable to assume that the higher the capacity reserve is over capacity target and consequently its corresponding normalized deviation, the higher the aversion to over-ordering capacity would be. Figure 12 shows alternative proportional control rules, with increasing degrees of sensitivity to the capacity reserve deviations

Figure 12: ALTERNATIVE TABLE POLICY FUNCTIONS FOR EXCESS CAPACITY RISK AVERSION COEFFICIENT DEPENDING ON CAPACITY RESERVE DEVIATIONS FROM TARGET.



The alternative policies described in Figure 12, which are obtained by changing the Table TRISKCF correspondingly for every re-run of the model are going to be tested against alternative mild wrong forecast scenarios, defined in Table 6. It shows errors by excess and defect in estimating the actual rate of growth of electricity demand, for both low and high types of demand, so scenario A underestimates the actual 4 per cent of the demand and so on.

TABLE 6. Alternative Mild Wrong Forecast Scenarios for Testing Alternative Excess Capacity Risk Policies

Actual Value of Annual Rate of Growth of Electricity Demand	Wrong Value of Annual Rate of Growth of Forecast Electricity Demand			
	0.03	0.05	0.06	0.10
0.04	A	B	-	-
0.08	-	-	C	D

The results of experimenting with RISKCF appear in Table 7, where the consequences of changing the tables for RISKCF in the different wrong forecast scenarios A, B, C and D, are presented, regarding the Capacity Reserve Performance Index RESINX. Each scenario is represented by a column in Table 7, the first value of that column represents the base value for RESIX with perfect forecasting and constant RISKCF=1, and the second one, the RESIX value with wrong forecast and constant RISKCF=1. The third, fourth and fifth values in each column represent the eventual improvement of RESIX, using the alternative policies presented in Figure 12, when compared with the second value, corresponding to the situation where no counteracting action is taken.

Comparing the fifth row of Table 7, which contains the RESIX values obtained when the policy represented by curve QQ' of Figure 12 is applied, with the ones appearing in the second row, where RISKCF remains constant all the length of the run, it is clear that

TABLE 7. Performance of Capacity Reserve Index RESIX* for Alternative Excess Capacity Risk Policies, under different Wrong Forecast Scenarios

Alternative Policies for RISKCF	Alternative Wrong Forecast Scenarios A	B	C	D
RESIX Value with Perfect Forecasting and Constant RISKCF=1	1.00	1.00	1.00	1.00
RESIX Value with Wrong Forecasting and Constant RISKCF=1	0.85	1.81	1.97	4.12
TRISKCF Policy Table MM'				
TRISKCF Policy Table 00'	0.87	1.55	1.86	4.11
TRISKCF Policy Table PP'	0.88	1.44	1.62	4.05
TRISKCF Policy Table QQ'	0.90	1.34	1.42	3.80

* The smaller these Index Values are, the better this is for the system.

the most sensitive policy of Figure 12 has improved the RESIX Performance Index Values, except for Scenario A. In this Scenario A the wrong forecast actually improved the performance of RESIX, and the policies tested do not help. The explanation for this anomaly is that the initial conditions of the system are the results of an optimistic high scenario view during the sixties and seventies, and what actually happens in Scenario A is that the wrong pessimistic forecast writes off from the beginning that optimistic assumption, while the control policy will take some time in reacting to the reserve signals. Extensive simulation experimenting might find more efficient table functions representing excess capacity aversion risk policies, and the use of the optimiser version of DYSMAP would help indeed, but at least RISKCF proved to be worth trying, in getting nearer to the performance in the perfect forecast situations.

11. Conclusions

System Dynamics models have traditionally beeen associated with completely continuous models at a high level of aggregation. Such

an approach would have been completely inappropriate in this case and it was necessary to solve the modelling problems of mixing continous and discrete processes in the same model, and dealing with individual hydro projects whilst retaining the breadth of view needed to evaluate national scenarios. This proved to be remarkably easy with the DYSMAP simulation package (Cavana and Coyle, 1982) and represents, we feel, a useful extention of the methodological capability of System Dynamics.

a) The system controls the capacity reserve effectively against exponential demand growth, but it copes badly with changes in electricity demand trends due to its heavy inertia.
b) The officially proposed Plan, does badly in some plausible scenarios. Nonethless, its sensitivity is more dependent on the level of investment required than on changes in fuel prices. Also, the higher the level of investment, the more sensitive the sector is to changes in oil prices. Therefore, it is more costly to err in the demand forecast than in the oil price forecast. Indicentally, the degree of detail achieved in that official Plan. like the timetable for operating individual hydroturbines, looks overdone, in view of the unpredictability of the sector.
c) Favouring a medium-term or consumer orientated strategy for capacity ordering is effective in the lower demand scenarios, in the sense that more capacity is available and consequently more consumer protection, without increasing the costs significantly, but its benefits are lost in the higher or combined low with high electricity demand scenarios, where more money is spent without achieving any capacity reserve improvement.
d) The fact that lower electricity demand scenarios are more resilient to high oil price futures, due to the smaller overall capacity investment required, means that more oil dependent capacity configurations might be absorbed in economic depression situations, although there is the risk of being caught without the required capacity if the crisis is overcome. A fifty-fifty hydro-thermal capacity mix by the end of the century does well even in the higher oil price scenario.

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