6-12-1995 BB

A l'attention de Mr Bertrand Barré

Vous dites :

"J'espère que personne ne déterrera ce papier dans dix ou 15 ans ..."

Espoir déçu

Lallement

c.e.a.

I.R.D.I.
Etablissement: SACLAY
DIVISION D'ETUDE ET DE
DEVELOPPEMENT DES REACTEURS

N°: DEDR /DIR 86-829 DB/BV
Date: 3 Novembre 1986

NOTE

Le Directeur à Monsieur le Directeur de l'IRDI

Ref :
Objet: **Comité Technique AIEA du 24-25 Novembre 1986**

1031

Je vous adresse ci-joint un projet d'une communication préparé par Mr BARRE pour le Comité Technique AIEA du 24-25 Novembre 1986.

Compte-tenu de son contenu , qui sort du contexte technique habituel, je vous demande votre accord pour sa publication.

Jean RASTOIN

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RL	RL	X	
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JD			
PB			
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Rapin :

C'est un excellent pamphlet humoristique et très plaisant, et juste. Il faut donner accord

RL

Copie pour avis : IRDI-N

Copie Rastoin

October 86

I A E A TECHNICAL MEETING ON
"ADVANCES IN LWR TECHNOLOGY"
WASHINGTON.DC. Nov. 24/25 1986

FUTURE LWRs : THE TWO MARKETS

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I. Introduction

In France, we have a saying that goes : "Forecasting is a difficult exercise, especially when the Future is concerned ..." I do hope that nobody will, ten or fifteen years from now, dig out this paper and confront me with it, because I am going to venture some forecasts, about the world market for nuclear power plants in the near future. I had volunteered for the task before april 26, and I must confess that the Tchernobyl accident did nothing to dispell the haziness in my cristal ball ! At least, I am unlikely to be proven much wronger than the official forecasters were in the late 70s, as shown on fig. 1.

It seems to me, however, that, besides being uncertain, this market has at least a strong characteristic : it is double ; or rather, that there are two separate markets to address. On the one hand, countries like Western Europe and Japan are considering large sophisticated units to deliver cheap power, closely fitting the demand curve all along the year, while "emerging" nuclear customers want smaller, sturdier units to generate baseload power, be it somewhat more expensive. One of the paradox of this situation, indeed, is that the USA seem to fall in the second category.

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Most nuclear vendors are, actually, offering (on paper) two different kinds of designs, to address separately both markets. This, however, raises some important issues like : is there need for demonstration plants? how to take advantage of the return of experience? which R et D is needed for? and, most important of all, what will be the timing of development of each market?

II. The past markets (1950-1985)

From the Electric Data bank of CEA/DPg I have extracted, and shown on Table 1, the list of all nuclear plants, of a size exceeding or equal to 100 MWe, ordered in the world from 1950 to 1985. These data have been classified according to 4 criteria :

- date of order (by batches of 5 years)
- Unit size in MWe (<600, 600 <P < 850, 850 <P < 1100, >1100)
- Nature of the plant : LWRs or any other type (GCRs, HWRs, FBRs, RBMKs, etc...)
- Country

For the last criterion, countries have been assembled into 4 "regions" as follows :

- United States (U)
- Western Europe, Canada and Japan (E)
- Soviet Union and Eastern Europe (C)
- Rest of the world (O)

The total number of plants quoted here, 745, might seem very high, but it covers all the plants once ordered, included quite a few which have been canceled or discontinued. For the USA alone, the canceled plants number above 120, but we have chosen to include them anyway since their order was an expression of the prefered choice of the utility at the time it was passed. The data concerning all types of reactors have been schematized graphically on figure 2. Several features emerge from this picture :

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. The US behaviour is very specific, with its huge peak in 70/74 followed by nothing at all.

. Regions "E" and "C" exhibit somewhat similar patterns, with much smoother transitions, but orders are still growing in the eastern countries in the latest period (it remains to be seen whether the Tchernobyl accident alters this trend in the late eighties)

. It is dramatically clear that, despite the number of individual countries involved, the nuclear market is not yet significant in region "O" . If only "surviving" orders had been drawn, this remark would remain true.

. All patterns show, to various degrees, slippages to the right i.e. a trend to increase units sizes. Regions "U" and "E" go all the way to sizes >1100 MWe, while "C" center on the 850-1100 range. To date (October 1986), no sign appears yet towards reverting this trend. Obviously, expressing those data in GWe rather than in number of units would only enhance the pattern.

. Progessively th LWR (and more precisely the PWR/VVER) dominates the market.

We can summarize these observations as follows :

USA	Market temporarily closed. Last orders were for big sizes ...
Eur/Can/ Jap.	Low growth due to near saturation, Big unit sizes
Comerion	Was fast growing, before april 26, but self contained. Outside Soviet Union, only VVERs.
Rest of the World	Not yet really started. Covers all the range of sizes

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III. The Ideal "eurojapanese" LWR

Even inside Western europe, there are as many situations on the nuclear front as there are individual countries : Denmark, Luxemburg, Greece, Ireland, Norway and Austria have no plan to enter the market, Sweden is obligated under law to terminate its program by 2010, the United Kingdom is still waiting for the results of the Sizewell enquiry, etc... By and large France, Belgium, the FRG, Finland, constitute, together with Japan, the bulk of the nuclear market in western industrialized countries for the next few years, and they have all decided in favor of LWRs (apart from a few advanced prototypes FBRs), in the 900 to 1400 MWe range.

For those countries, LWRs are already a significant component of their power mix, and their experience with nuclear electricity dates back to the sixties.

What utilities in those countries require are :

a) - Increased availability

b) - Improved manoeuvrability, as nuclear plants have already, in many occurences, exceeded baseload production

c) - Reduced total generation costs (capital, fuel and O & M)

d) - Increased safety (especially expressed as reduced risk to the investment, because risks to general public and personnel are already suitably low)

e) - capability to recycle nuclear materials

This last requirement is valid in those countries which, having decided that the best way to manage the nuclear wastes is to reprocess the spent fuel elements, are building up stockpile of Pu and reprocessed U above the needs of their fast breeder reactors.

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All these requirements point to large sophisticated plants to be operated as a global "park", by highly trained personnel. A better knowledge of the operating margins will be used to optimize economic performances of the park.

Convoy plants in Germany and N_4 plants in France are already well along that way, with the more futuristic Westinghouse/Mitsubishi APWR, GE ABWR and Framatome RCVS still further away.

Focussing on PWRs, which constitute the bulk of the plants presently under construction or in order, trends which lead to increased safety are :

- increase in the cooling water available inside the containment building, or already inside the primary circuit (higher vessels, bigger pressurizers, etc..)
- double containments with filtered venting
- complete redesign of the control room, with use of a few multi-function CRT displays instead of scores of panels full of lights and needles
- systematic use of simulator to train, and periodically retrain, the operators
- increased sophistication of the in-and ex-core instrumentation to gain a better on-line knowledge of the power and temperature distribution in the reactor cores
- separation of the functions in the control room : the operators, in charge of "normal" operation and transients give way to a specialized engineer when a given "abnormal state" in reached. The latter has for <u>only task</u> to keep the core cooled down et prevent radioactivity release, and has been trained solely for that purpose
- better protection against loss of off-site power and station blackout, etc...

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But, paramount among those features, is the extensive use of the return of experience from the operating plant, return which, obviously, requires a **minimum of continuity in the technology to be of any use.** We shall come back later to this very important point.

It is fair to say that the TChernobyl accident will probably have no significant impact on advanced LWR technology : RMMK and LWR designs are too far apart, an there does not seem to be any "lesson" to be learned, contrary to what happened after TMI. I am afraid that TChernobyl is only impact in the West will be on public opinion, and a very negative one !

IV. In search of the ideal plant for "nuclear newcomers"

Any country willing to buy today its first nuclear plant, will not need exactly the sophisticated "eurojapanese" product :

- the plant will most likely be operated in baseload mode
- the grid might not easily accomodate a unit rated over 600 MW
- Plutonium recycle will not be a problem - or a possibility before roughly two decades
- optimizing the cost of the kwh may not be as important as keeping the total capital investment below a "reasonable" level. (In many occurences, competitivity with fossil fuels may not be too difficult to achieve anyway if long transportations are involved)
- previous experience being non-existant, a bonus can be attached to designs able to "forgive" beginers' errors in the control room...

All this boils down to the **small, sturdy, forgiving plant** which, unfortunately, exists only on paper.

Several such designs have been promoted, but I known of nobody yet commited to building or buying one. All these designs do, indeed, exhibit features which would increase significantly the "passive" or "inherent" character of their safety, but the **added cost**[1] of these features is rarely recognized, and even more rarely aknowledged. The only "ultrasafe walkaway" designs seriously considered are aimed at applications where money is no real concern, like military bases in the far North, or satellites in deep space. But for down to earth power generation, nuclear plants must compete with fossil-fueled alternatives, and cannot ignore the economics laws.

ORNL has just completed its report on Nuclear Options Viability Study, mostly devoted to innovative, safer reactor concepts which could be commercialized between 2000 and 2010. Let me quote from its executive summary :

"Most advanced reactor concepts are smaller than present LWRs; therefore, they suffer the economic disadvantage, whether real or perceived, associated with economy of scale. This disadvantage is claimed to be offset or compensated for in varying degrees through an improved match with load growth, reduction in capital risk, increased shop fabrication, shorter construction time, increased standardization, design simplification, and less demanding construction management requirements. Licensing may also be simplified if credit can be taken for passive safety features such that other traditional safety systems, required by the defense-in-depht philosophy, can be eliminated. A substantial problem in achieving these compensations derives from the need for a large front end investment for certain of these features. Automated shop fabrication, in particular, will require a substantial backlog of orders to be economically feasible. Nuclear plant standardization is widely viewed as an important goal for viability"

I, personnaly, do not believe that those "innovative designs" are likely to replace modern LWRs in that time frame, and precisely for the reasons quoted above : overall economics, capability of taking enough credit for added safety, and, above all, need for full scale demonstration and proof of market.

I have some reasons for this pessimism :

Following the 1975 IAEA study of the potentiel market for small reactors, a number of reactor vendors have designed plants in the 125-300 MW range, to no avail. The only successful "small" reactor has been the 440 MW VVER sold to communist countries and Finland. But it was a replication of the domestic russian plant, as the Westinghouse 900 MW PWR sold to Spain or Korea were replications of domestic american plants.

I see no sign implying that would -be buyers are more willing today to buy untried designs - even from "proven" vendors - than they were in the late 70s. And, as we have seen above, small, study ... and expensive plants are not what the vendor countries need for themselves : I do not see any of them readier today than they were yesteryear to build at home a demonstration plant for the frail hope to sell abroad an unknown number of copies, may be none at all.

Up to now, it has not been possible to break the vicious circle_ "show me the market and I design the reactor/Show me the Demo and I show your the market". In the beginnings of the nuclear era, the "deus ex machina" which allowed this circle to be broken was the USAEC, with its policy of subsidizing demos in the US and abroad. It is technically possible that a third party, like the World Bank, play this role, but this does not seem very likely today. I must admit that for the W.B., deciding to subsidize a demo by KWU rather than Combustion Engineering, to take an example, would be a perilous political exercise ... I do not think either that IAEA has such a role in its Charter.

The very fact of designing a reactor "for exports only" will also do much to diminish the value attached to added safety : it may prove rather akward to use as a sales pitch arguments like : "you have to buy from us plants which are intrinsically safer than the ones we use for ourselves, because ..."

As a matter of fact, if a Demo is a necessary condition, it may not be sufficient. Its main virtue would be to substantiate the vendors claims about the cost of the product, the feasibility being not in doubt. But it still won't be the preferred product of the vendor itself. For a newcomer, it is quite different to buy a carbon copy of a Demo plant, or to buy a carbon copy of the plant actually selected by the utilities of the vendor country ! There is the matter of confidence, but there is also the transfer of operating experience, which does so much for the actual safety; and ultimately, there is the certainty that, were a serious problem to develop, the vendor country would be totally involved in solving it, as it could affect its own generating park. On could even reasonnably expect that, by reason of age, problems will appear first in the vendor country !

At this point my analysis would be : Though there are objective reasons to believe that there **should be** a class of plants best suited for newcomers, they won't leave the "paper" stage in the near future, and newcomers will have the choice between :

a) - settle for plants existing in buyers country, be they bigger than their liking. With today's buyers market, they will see vendors rushing to them with golden deals (wittness China)

b) - wait till their grid has grown to the point where they can accomodate such plants. There is still a lot to do in the meantine, in terms of formation, training, and technology transfer.

V. The US unknown

There is a missing unknown in the previous equation : there is a market with a huge potential for absorbing nuclear plants, and I obviously mean the USA. Be it not for the incredible fragmentation of the utility system in this country, the prefered plants, there, should be our "eurojapanese" ideal, which is a daughter of US technology anyway.

We are, however, being told that US utilities want smaller simpler plants, even at a higher cost on a per kwh basis.

It is easy to understand the trauma that US utilities have suffered, when you consider the list of nuclear projects canceled after huge amounts of dollars were sunk into them. The reasons for these failures have been multiple : overestimation of he load growth, high interest rates, incredible delays in construction time, some of them due to successful legal obstructions by intervenors, etc... Most of those reasons are not technical, if one excepts the specific impact of TMI, and the regulatory complexity induced by two features :

- no standardization to speak of, meaning that each individual design had to be assessed by itself - and that return of experience in very fragmented.
- obtention of construction permits for incomplete designs, which causes the infamous "two-steps licensing" process, where completed plants can be prevented for years to go on-line.

I fail to see why, or how, "passive" designs could overcome those difficulties, but it is not uncommon to try to alleviate non technical problems through technical solutions ...

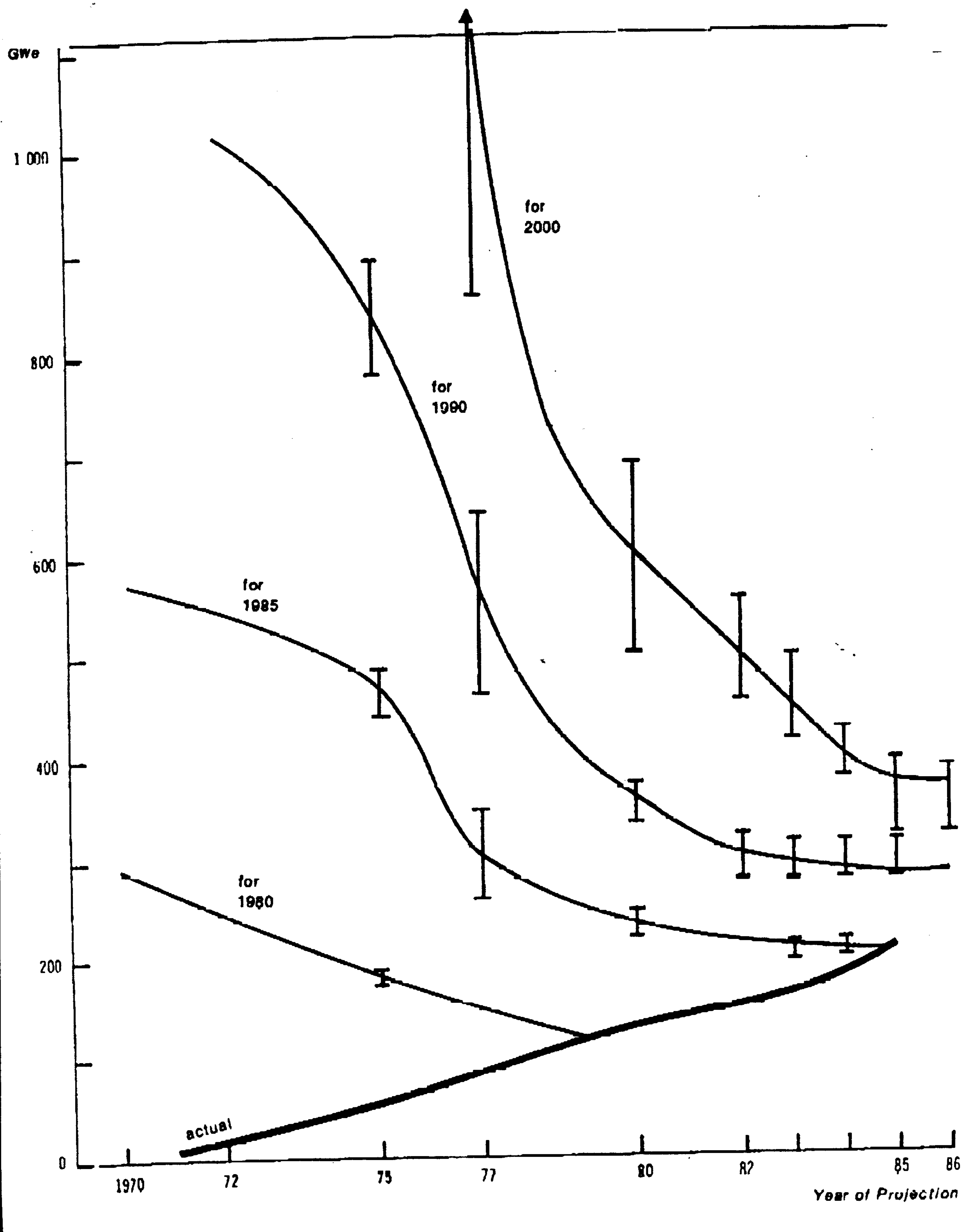
It remains that, year by year, the generation reserve margin of the US utilities is eroding, and some day - nobody knows when - orders of power plants will resume. Among the coal plants, a few nuclear units will certainly find their way, and the "second nuclear era" will open. My own bet is that those plants will be **quasi-classical LWRs**, and not those "innovative designs" described in the NPOV study.

I am quite ready, however, to believe than those new LWRs might be in the 600-800 MW range, rather than above 1100 : the very structure of the US utility system can induce this trend reversal. If such is the case, the picture will drastically change for the "newcomer" market : All surviving vendors will then have a strong motivation to design advanced middle sized plants for the USA, and to market them everywhere in the world : the vicious circle will be broken.

Until those blessed days, all serious improvement to LWR technology will continue to be aimed at the only, scant but alive, eurojapanese market, and profit only to those countries which can accomodate and afford relatively big plants.

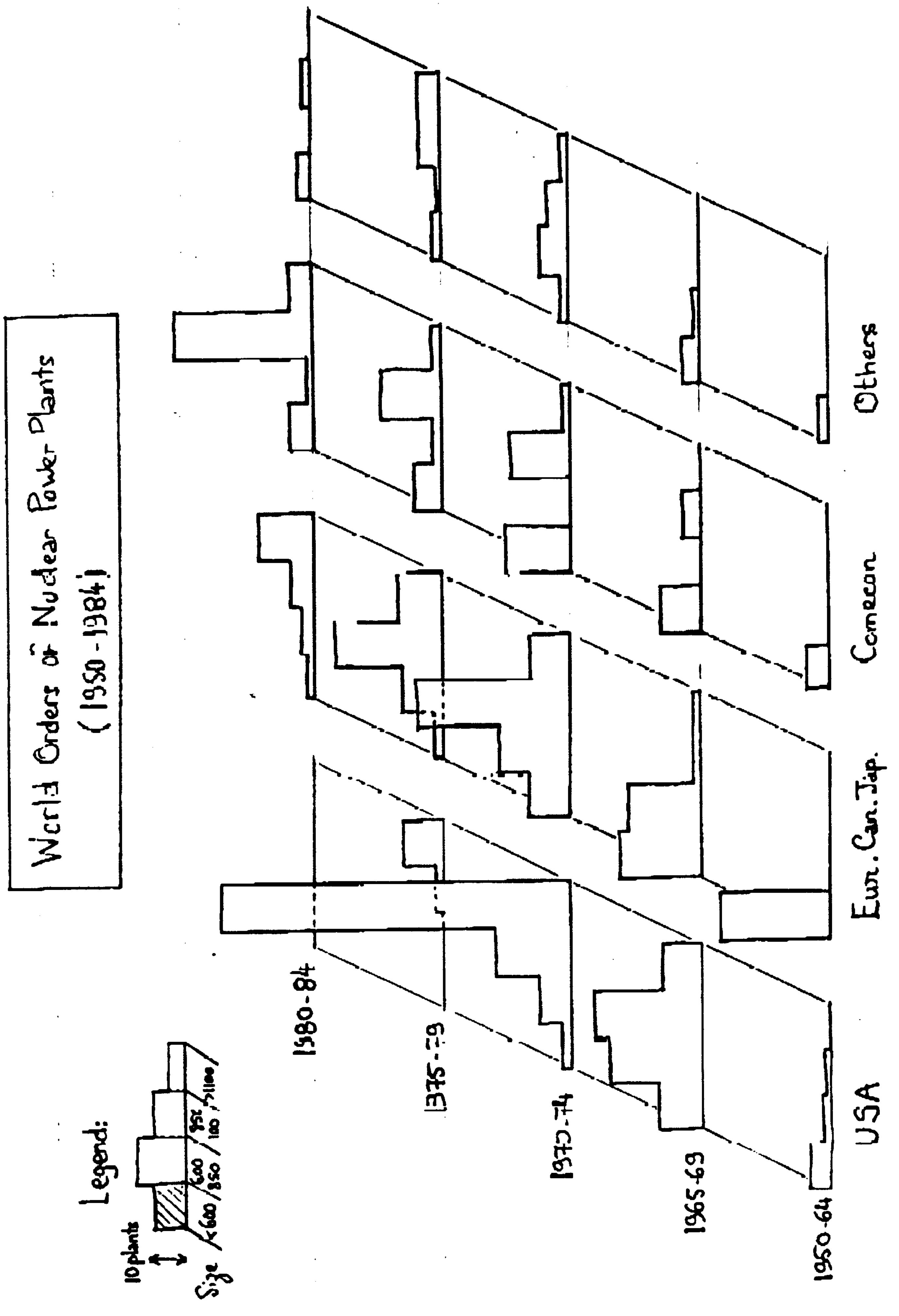
(1) to illustrate this point, let me refer to "Cheaper, Safer Plants or Wealth and Safety at Work" by T.A. Kletz (I.C.E. 1984), a very convincing pledge in favor of inherent safety in chemical plants :
"The most dangerous items in our houses are the stairs, more people are killed and injured on them than in any other way. Traditionally or extrinsically safe ways of controlling the hazard are to add hand-rails or make sure the carpet is not loose. The inherently safer solution is to buy a bungalow"
Not only are bungalows safer than flats they are also more pleasant to live in ... but where land is expensive, who can afford bungalows ?

Figure 1. PROJECTED NUCLEAR CAPACITIES FOR OECD



Source : OECD/NEA. April 86

Figure 2.


World Orders of Nuclear Power Plants
(1950-1984)
Legend:
10 plants
Size
1980-84
1975-79
1970-74
1965-69
1950-64
USA
Eur. Can. Jap.
Comecon
Others

World Nuclear Power Plant Orders

Year	Region	< 600 LWR	< 600 Oth.	600–850 LWR	600–850 Oth.	850–1100 LWR	850–1100 Oth.	> 1100 LWR	> 1100 Oth.	TOTAL
		Output MWe								
1950-1964	USA	6	0	2	0	0	1	0	0	
	EurCanJa	9	25	0	0	0	0	0	0	
	Comecon	2	4	0	0	0	0	0	0	
	Others	2	1	0	0	0	0	0	0	
	TOTAL	19	30	2	0	0	1	0	0	
			49		2		1		0	52
1965-1969	U	11	1	28	0	33	0	11	0	
	E	15	10	9	12	1	0	1	0	
	C	11	1	0	0	1	4	0	0	
	O	1	4	1	0	0	0	0	0	
	T	38	16	38	12	35	4	12	0	
			54		50		39		12	1[illegible]
1970-1974	U	1	1	6	4	29	0	105	4	
	E	7	7	14	8	48	0	12	0	
	C	20	0	0	0	9	10	0	7	
	A	0	3	6	2	6	0	2	0	
	T	28	11	26	14	92	10	119	6	
			39		40		102		125	306
1975-1979	U	0	0	0	0	2	0	12	0	
	E	2	0	2	11	30	4	13	1	
	C	9	0	0	3	17	2	0	3	
	A	2	0	0	1	6	0	6	0	
	T	13	0	2	15	55	6	31	4	
			13		17		61		35	126
1980-1984	U	0	0	0	0	0	0	0	0	
	E	1	0	3	0	6	0	21	0	
	C	7	0	0	1	37	5	0	6	
	A	1	2	0	0	2	0	0	0	
	T	9	2	3	1	45	5	21	6	
			11		4		50		27	92
1985	U	0	0	0	0	0	0	0	0	
	E	0	0	0	0	4	0	2	0	
	C	0	0	0	1	0	0	0	0	
	A	0	4	0	1	2	0	0	0	
	T	0	4	0	2	6	0	2	0	
			4		2		6		2	14
TOTAL		107	63	71	44	233	26	185	16	
			170		115		259		201	745