

**BASIC FACTS AND EQUATIONS TO BE CONSIDERED,
TO RE-EVALUATE THE RISK AND THE FEASIBILITY OF ACTUAL
NUCLEAR ENERGY PRODUCTION, IN THE WORLD, IN THE
REGION, AND IN TURKEY¹**

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REPUBLIC OF TURKEY OKAN UNIVERSITY

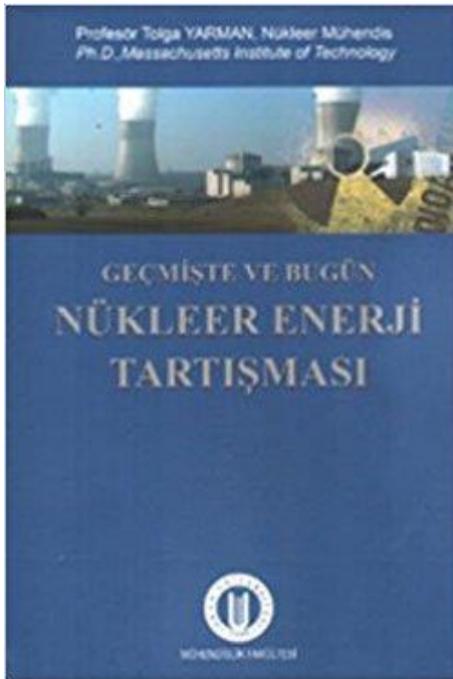
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*Special Panel on The International Disaster and Risk
Organized by Prof. Akihiko Morita, Shokei Gakuin University, Miyagi,
Conference on The Future of Nuclear Energy Policy:
Lessons from the Fukushima Nuclear Power Plant Accident,
Sendai, Japan, 27 November 2017*

¹ I am honored to have been invited by Prof. Akihiko Morita, to deliver this *special talk*. I had given a similar *special talk* at the *International Conference on Clean Energy, held in Istanbul*, at June 8 – 22, 2014. The present manuscript is prepared based on the latter talk's manuscript. The data used therein, yet, is updated as much as possible.

ABSTRACT

The author summarizes his life lasting experience, about nuclear energy production in the world, in the region and in Turkey, the way he condensed it, into his book entitled "*Nuclear Energy Debate in the Past and in the Present*" [in Turkish: *1st Edition 1995 (Esin Yayınevi, Second Edition 2010 (Okan University), Third Edition 2014 (Okan University), ISBN 9786055899127*]. Here is, its cover.



He shows that the relationships believed to be true in the past, specifically that of

[(Demand) - (Production Via Available Resources to Fulfill Demand) = (Gap in a Near Future)],

and that *pertaining to*

[The Only Resource To Satisfy The Gap]
= [Nuclear Energy] ,

came to be totally *erroneous*, throughout.

Further on, he shows that the originally *calculated nuclear power production risk*, with regards to working nuclear power plants, *also*, turned out to be, unfortunately, *severely erroneous*... He comments on the planned implementation of a nuclear power plant on the Turkey's Mediterranean Coast, chiefly in Akkuyu.

BASIC POINTS

- Nowadays, nuclear energy is not a *technical necessity*, but it rather points to a *political choice*.
- I respect the *political will*, provided that, *she respects* the will of those who dream of, and plan a different future for themselves, and their descendents.
- Now, from 1970's on, the *basic assumption* has been:

$$\begin{aligned} & [Demand] - [Resources That Are Ready To Satisfy The Demand] \\ & = [A Given Gap]. \end{aligned}$$

- The subsequent assumption, has been:

$$\begin{aligned} & [The Only Resource To Satisfy The Gap] \\ & = [Nuclear Energy]. \end{aligned}$$

- These assumptions along with, almost all of their *articulations*, turned out to be totally “*erroneous*”.
- First of all, the “*energy demand*”, all over the world, turned to be nearly *half* of what had been earlier predicted.
- The resources, such as *coal*, *oil* and *hydraulic energy*, turned out to be roughly *twice as rich*, as they were earlier thought to be.
- The *renewable energies*, in general, *unconventional energy resources*, furthermore, turned out to be much more important, than what they were earlier thought to be.
- Thus the “*gap*” in question, fell to be, *no more a gap*.

- Even if, there were a “*hypothetical gap*” , “*nuclear energy, has fell out to be the unique solution, to fulfill, such a gap*”.
- Indeed, for instance *Siberian natural gas*, which was never in the scopes in 1970’s, became, fully a *primary resource*, for the entire Europe, as well as for Turkey.
- In the same framework, “*energy efficiency*”, turned out to be a *full new resource of energy*, since, *the world realized that, she can achieve, all what she does, via only, consuming half of the energy, she used to consume*. We realized thus, we were like *bears* who, once they discover *honey*, nearby, would *paint* their entire bodies with it...
- Within the same context, solar energy and wind energy, became much more important than, what they were earlier thought to be.
- Henceforth, either in Europe, or in the broader sense, in the world, including Turkey, “*nuclear energy production*”, became *no more a technical necessity*, contrary to what was anticipated, in 1970’s.
- Under any circumstances; even by then (in 1970’s); *nuclear power deployment* based on just natural uranium, or enriched uranium, in other words, without production of Pu239 from natural uranium, or U233 from thorium, in “*nuclear breeders*”, and subsequent, technologically severe reprocessing of nuclear breeder fuel elements; was assessed to be a *dead end business*, for there is only about *6 million tons of natural uranium* on Earth, and that remained still too short for the *nuclear appetite* conjectured, by then...
- And *nucler breeder reactors*, with their compact power density production, thereby liquid metal cooling systems, turned out to be much more risky than what they were thought to be at the beginning.

A REALISTIC RISK ASSESSMENT, AS OF TODAY

The risk assessment output, we learned when I was a student at Massachusetts Institute of Technology (MIT) (by around 1970), was about 10^{-5} , per reactor through a period of 30 years (*nearly the life time of a reactor*).

Yet, there occurred *three major accidents*, through causes *totally unforeseen*, that is, which lie entirely, outside of the former complicated risk analysis calculations:

1. Three Mile Island Accident (1979). The reactor power was 906 MWe.



Dead Unit of TMI on the Right

2. Chernobil Accident (1986). The Reactor Power was 1000 MWe.



Chernobyl Destroyed Unit

3. Fukushima Accident (2011)

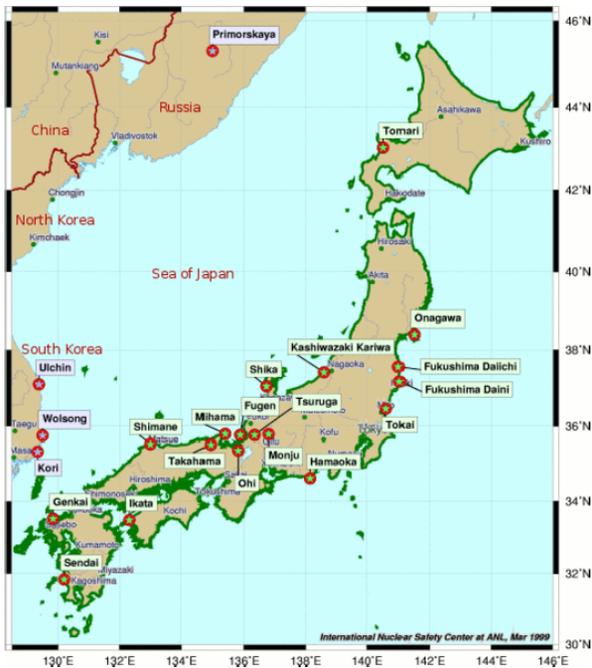
Three reactors underwent accident. Powers of concerned reactors were as follows:

1 x 460 [MWe](#) (Unit 1 damaged)

3 x 784 [MWe](#) (Units 2, 3, and 4 damaged)

1 x 784 [MWe](#) (Unit 5 experiencing cooling problems)

1 x 1100 [MWe](#) (Unit 6 experiencing cooling problems)



Japan Nuclear Reactors



Fukushima Accident

I bear the honor of having stated right after the accident to the press that, *this accident, despite the understandable optimism of Japanese leaders, should be classified in between TMI and Chernobyl Accidents, and even further will unfortunately climb to catch the Chernobyl level, if not anything beyond.*

The entire site, is now closed down. But let us take into account only *reactors badly damaged* which are units 1, 2 and 3 (*units 4, 5 and 6 were being luckily, shut down, for maintenance, before the accident*):

$$460 \text{ MWe} + 2 \times 784 \text{ MWe} = 2028 \text{ MWe}.$$

The *three major accidents*, thus, all together, account to a total, completely killed nuclear power of

$$906 \text{ MWe} + 1000 \text{ MWe} + 2028 \text{ MWe} = 3934 \text{ MWe}.$$

The total installed power in the world, is about 400.000 MWe. Most of the units of concern are quite old.

Therefore we come out, with a *life time risk factor*, of, approximately,

$$4000 \text{ MWe} / 400.000 \text{ MWe} = \%1.$$

This is huge!..

And, this is about 1000 times greater than the *classically, established risk factor* of 10^{-5} , which was at the beginning considered a rather conservative factor; in other words experts by the time thought that the risk, would even be smaller.

Some would criticize the above simple calculation, saying

- *Is it that easy to achieve a risk analysis?*

My answer is “Yes, indeed”!..

It is not any more complicated than to state that

- *When we aim for a big number, say, 1000 unbiased coin tosses, we would record nearly 500 heads, and similarly 500 tails. The probability of getting any of the two options, is, by definition 50%.*

What I did above is not any different, yet as soon as we have, thusly, a posteriori, enough statistics.

As to the nuclear accident risk analyses, the thing is the risk factor, was calculated on the worse possible scenarios. And what happened was, the accidents coming into play, delineated scenarios even worse than the “worse possible scenarios” framed by the risk analysts. No expert could ever think, what happened in TMI, or in Chernobly could happen. No expert could think that an earthquake so savage could take underneath the pacific ocean, and would cause, what it caused, in Fukushima.

Otherwise Japanese *nuclear engineering, safety and accident engineering, construction and earthquake engineering*, as well as *oceanography engineering*, turned out to be extremely successful, since, only 3 reactors went out of hand, out of some 50 operational reactors.

Therefore, one may easily grade Japanese nuclear technology as successful as 94%, while having taken measures to fight against *an earthquake and a tsunami disaster*, such as the last one.

The same, holds for *American and Russian nuclear technology engineerings*.

Yet *relatively* speaking, as slim as the failure may be on the whole, the *final damage* is obvious, and is very much hurting.

The same holds for *Chernobil Accident*.

The same, furthermore holds for the *TMI Accident*, where the damage, within the *great design capacity* of this particular type of reactor, was contained in the *secondary safety container*.

The *Japanese Prime Minister Yoshihiko Noda (in September 13th, 2011)* summarized the situation as follows:

- *In the long and medium term, we must aim toward a direction of reducing our reliance on nuclear power, as much as possible.*

Japan's trade minister Yoshio Hachiro, had, by then, said :

- *All of the country's nuclear reactors will be shut down, following the recent nuclear crisis at Fukushima. The country would have "zero" nuclear reactors in the future, public opinion, is generally united in reducing [nuclear power production means], instead of increasing them.*

It would be equally correct to state that Japanese Government, no doubt for various reasons, stepped back from her earlier decisions, and reconsiders the nuclear power deployment in Japan.

PROBLEMS

At any rate, we have to recall the following problems that were grown up, on the way:

- o The necessity of the achievement of *redundant safety measures*.
- o The related, prolangation of construction and licensing procedures.
- o The *increased cost of dismantling, also, waste disposal*.



Reactor Dismantling



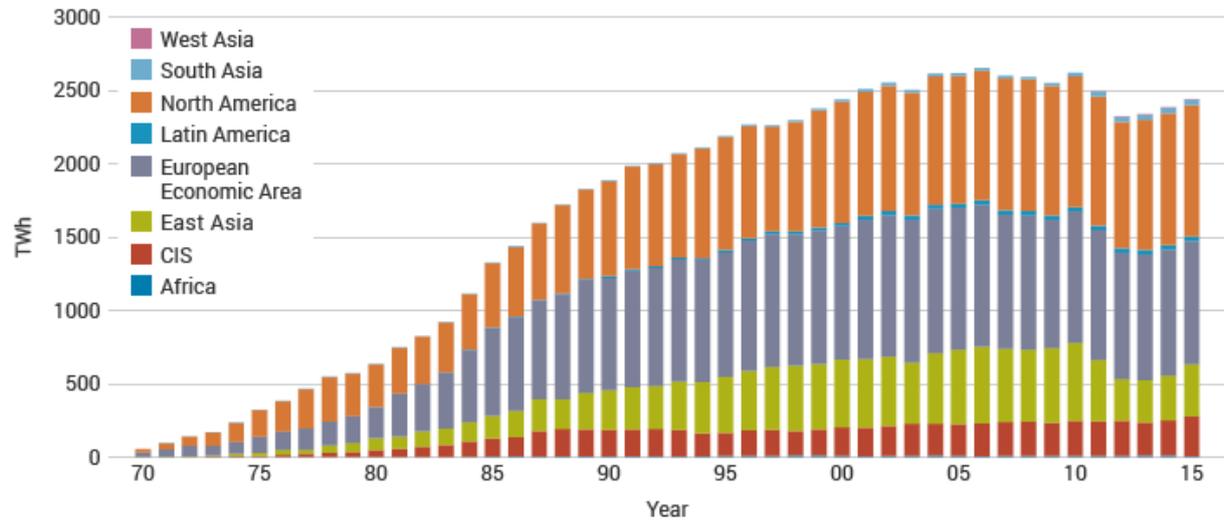
Waste Transportation

- o In any case, public reaction, against nuclear power production has considerably increased.
- o Let me stress that, *fast breeder reactors*, breeding *plutonium*, turned out to be very risky, and *plutonium reprocessing*, had to be given up.
- o This reduced by a factor of a 100, the *nuclear energy production life time* on Earth, estimated previously, given that natural uranium contains about 1% of fissile uranium U^{235} , and 99% of it consists in the fertile U^{238} . (“Fissile”, means, “able to give rise to fission”, i.e. production of nuclear energy. “Fertile”, means, “able to breed fissile material such as Pu^{239} ”.)
- o In effect, *uranium reserves of the world (6 million tons)*, can feed no more, classical (*i.e. not plutonium breeding*) reactors; than, a further set equal to a little more than the present set of reactors. (*Otherwise, as explained, this would have been a 100 times more.*)

All that, definitely, and badly, *decelerated the nuclear power deployment* in the entire world.

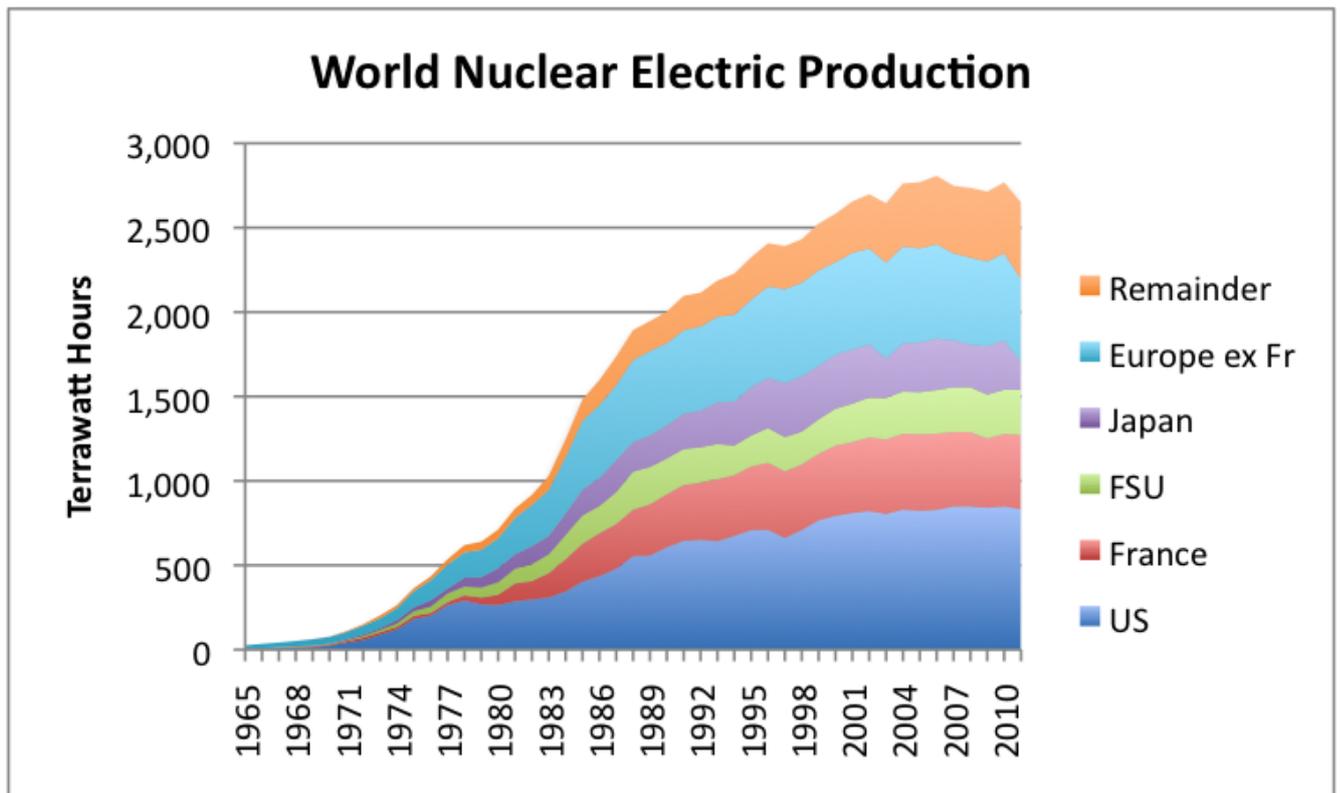
ACTUAL OUTLOOK

Nuclear Electricity Production

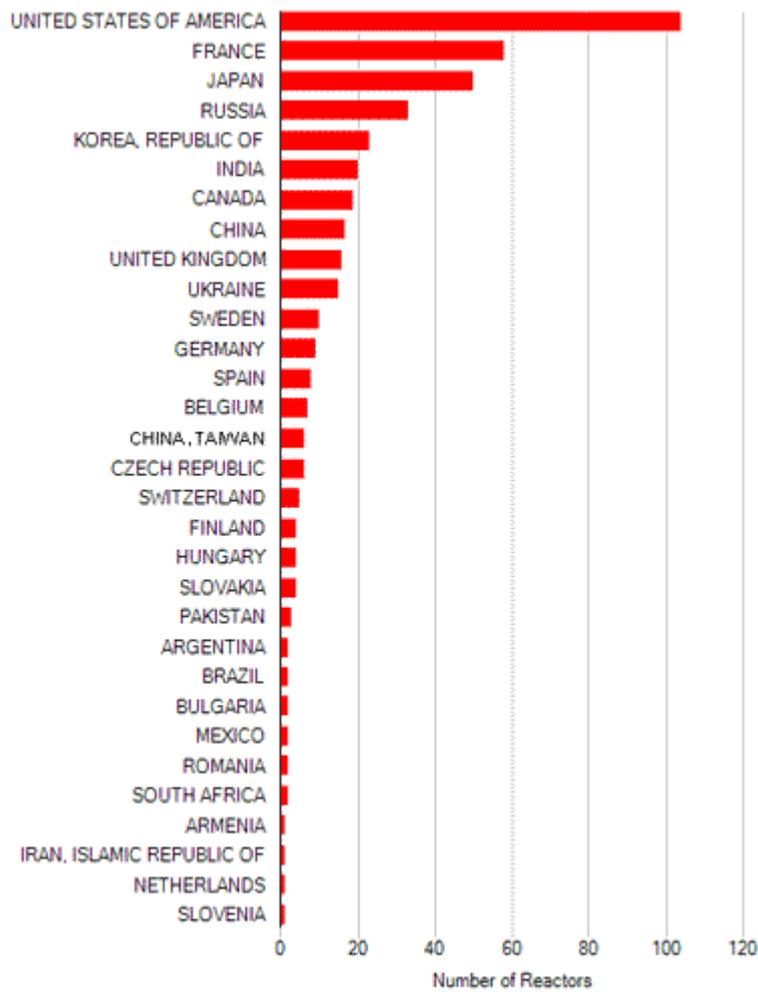


Source: IAEA PRIS

The share, in the total production, has thus fallen from 18% to 14%.



Number of Reactors In Operation World Wide
 (Source: World Nuclear Association)

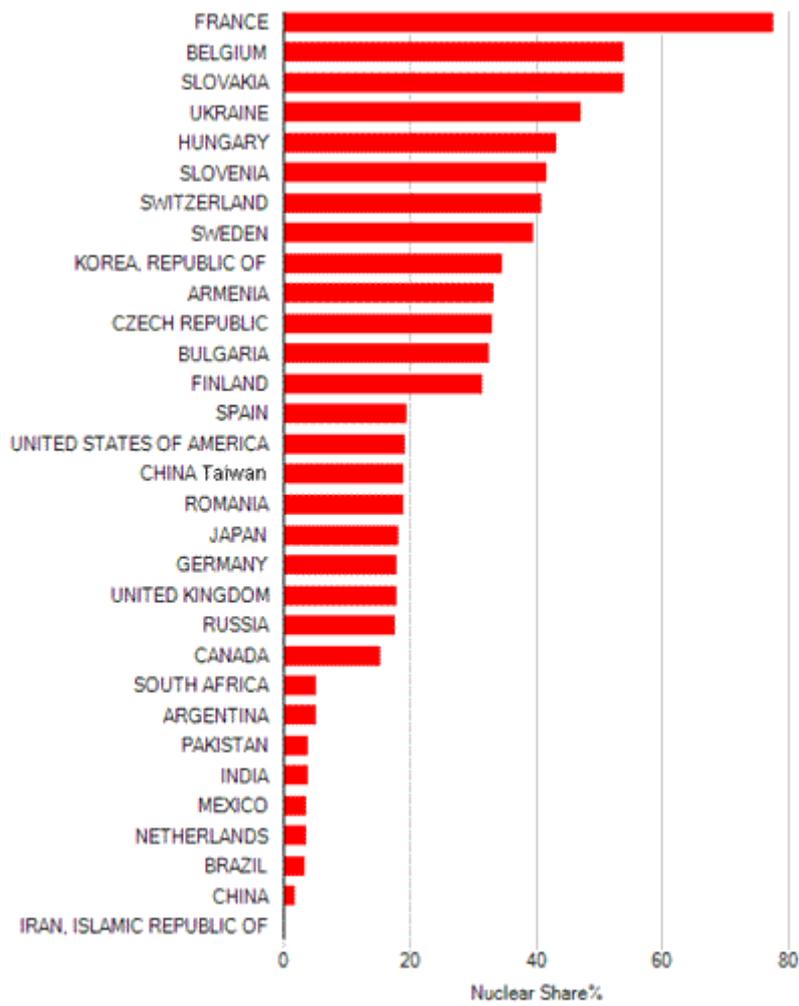


Total Number: 434 Units, Number of Countries: 31,

Total Power 372 GWe

Source: IAEA, 2013

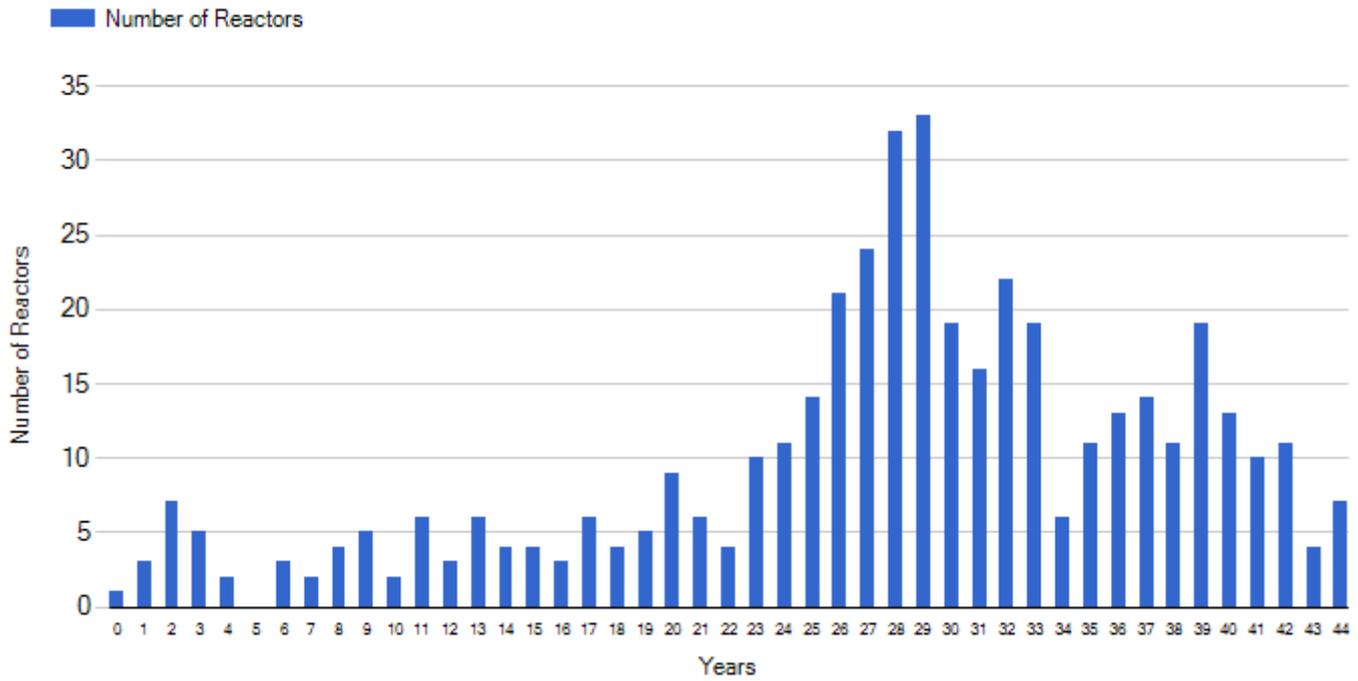
Nuclear Share in Electricity



Source: IAEA, 2013

Number of Operating Reactors by Age

Total Number of Reactors: 434



Source: IAEA, 2013

CASE OF TURKEY

AKKUYU SITE IN TURKEY



Earlier, it was believed that nuclear energy was very safe, cheap, and necessary, in order to fulfill the increasing energy needs. In fact, under the circumstances, it was believed that, nuclear was the only solution.

Akkuyu was then chosen as a nuclear site, by the Turkish Electricity Authority, by the beginning of 1970's.

The conditions, though, have been drastically changed, since then.

Already in 1999, I have told the following, to the Government at the *Energy Summit*, where I was invited by the *Prime Minister Ecevit*:

The erection of a Nuclear Power Plant, already by that time, in Akkuyu, would terribly damage *tourism, also the culture of fruits and vegetables*, in the region. there was no such criteria by the mid's of 1970's, we have accorded the "*site liscence*" to the place.

There is no study on this, even as of today (*i.e. by then in 1999*) (*and, as of now, in 2017, as far as know, there still is no study on it.*)

Even if everythiig goes very fine, one can guess that, our *tourism*, will be affected negatively, vis-a-vis our neighbouring countries, and chiefly *Greece*.

The same goes for the *culture of fruits and vegetables*, if a nuclear power plant is erected in Akkuyu.

Even if, this is not true, people will blaim fruits and vegetables coming from our mediterranean region, claiming that, *they are contaminated*.

Even, a *terrorist claim* with regards to a *sabotage*, no matter how unserious it may be, will affect tourists.

I still assume a *perfect operation and maintenance*.

Furthermore, the Mediterreanean Sea water, is about *10 degrees* warmer than that of the black sea, and this in both, summer and winter.

This will yield a difference in the *thermodynamic efficiency* of the plant of roughly 10%, in the case of erecting it, in Akkuyu, instead of a site by the Black Sea Coast, which would then cause the loss of about, 500 million \$ out of 5 billion \$ (*coast of a nuclear plant of about 1000 MWe*).

This is what I have told Prime Minister Ecevit's Government in 1999, and the Government dropped the project.

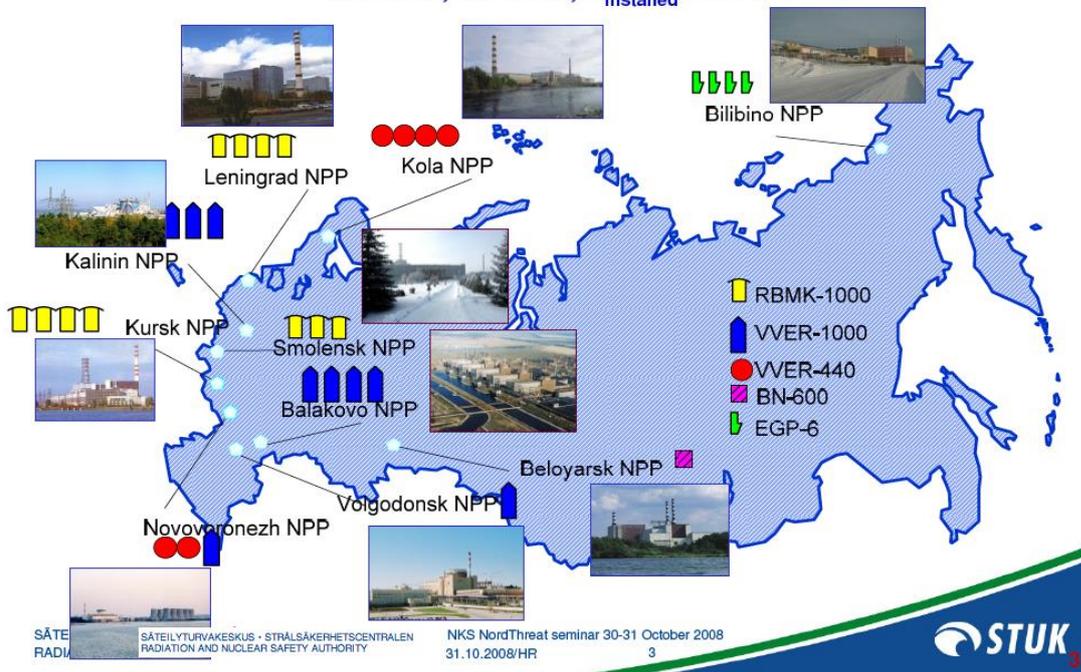
Yet, actually *we are, back to square, one*. An agreement between the *states of Russian Federation* and the *Republic of Turkey* has been signed up, and work, was (*to me, very unfortunately*), started out.

I have told Russian colleagues, (in 2011, the following, after I have summarized for them, what I told the Turkish Government under iMinister Ecevit, in 1999:

- o I have nothing against Russian nuclear technology. Although *Chernobyl was a scandalous disaster*, Russian engineers and technicians were, *real heros*, and did practically the impossible, to halt and overcome the nuclear nightmare.
- o Build, in your own south coast, on the *Black Sea*, nuclear power plants, and sell us *nuclear electricity*, just like you sell us natural gas, and we will be ready to pay you *twice* the price of the nuclear electricity you now propose.
- o This is to say, you cannot do that, for people living by your *Black Sea coast*, will not let you do it, fearing their tourism would accordingly be, badly hurt.
- o Indeed there is no Russian nuclear reactor, at all, on the Black Sea coast.

Map of Russian NPPs sites

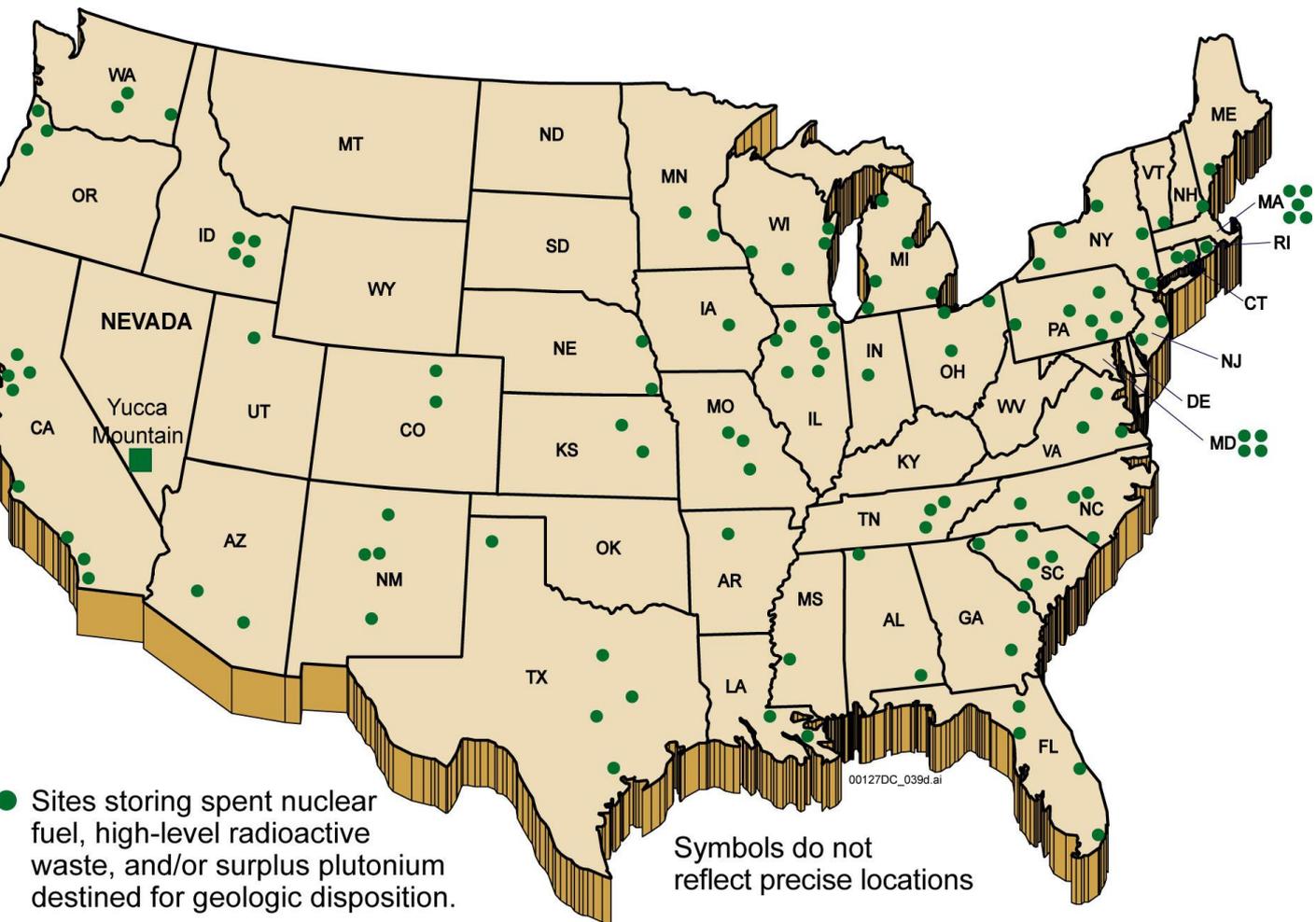
10 NPPs, 31 units, $N_{\text{installed}} = 23242$ MWt



- o More than anything else, over the years, the risk of a *nuclear accident* on the basis of the present technologies, due to totally unforeseen reasons have grown up, *1000 or even 10 000* times.
- o Thence, even if you build the nuclear station (*in Akkuyu*), you will not be able to get it operated... It will become the *most expensive nuclear museum* of the world!..

WASTE DISPOSAL PROBLEM

World Nuclear Unsolved Waste Disposal Problems





*The Waste Disposal Site,
Yucca Mountain, Nevada Desert*



Inside Yucca Mountain

Thus, the *nuclear waste disposal problem*, is yet unsolved, in the world. *Nuclear waste storage*, even if this were only *psychologically*, will harm even more, the region.

Therefore, I firmly believe we have to go out of Akkuyu.

The decision- makers, if they insist on nuclear power production in Turkey, should go to *Central Anatolia*, despite the need to cool the reactors by *air*, which shall certainly increase the cost of electricity, but then, save at least, relatively, *tourism, and the culture of fruits and vegetables, in our Mediterenean coast*.

If we insist in Akkuyu site; our neighbours, will benefit enormously, as far as our *competition in tourism, with them, is concerned!*..

I am not against nuclear power, *although, the risk assessment I have presented above, has to be reconsidered, seriously*.

I am in any case, against nuclear fallacies, claiming that one can acquire nuclear thechnology on a turn key basis, further, via reactors operated by guests foreigners.

AN ENGINEERING SCANDAL



*Gas Thermal Plant Erected in Bursa Plain, about a 100 km from Istanbul. This is what I call an **Engineering Catastrophy!** (The Picture is taken by Dr. Umur Gürsoy.)*

We should try to avoid such a scandal in Akkuyu, chiefly...

As a final Word, here is a Turkish saying:

- Do not damage your eye while curling your eyebrow!..

Questions by Prof Akihiko Morita and Answers by Prof. T. Yarman

Q: You insist that nuclear energy is not only option nowadays unlike 30 years ago.

A: *I insist that it is no more a "technical necessity" the way it had been considered in the past. It is just a political and optional choice matter, which only people can decide about, through votes, and not just experts. Experts have no right to choose a government, or decide about our future. They can only advise, one way or the other. But voters will decide about their own future and their children's future. Then our children when their time comes will decide about their future, and about our grand-children's future.*

What your experts do is in effect to impose their own political choice, if this were just a technical decision, that only they can make. No!..They are in this sense far beyond the area of their technical duties... They violate peoples' will of choice and decision right for themselves.

Q: In Japan, however, energy experts still hold that renewable energies are not yet cost effective compared with nuclear energy.

A: *I find this ridiculous.*

Experts in the guise of expertise speak for the interests of their bosses. They are paid for that. They may not even realize that what they do is advertisement of the interests of their bosses. And I certainly believe this is a crime. And this should be told to them. The interests of the bosses is recycled in a small portion to the pockets of the experts. But what they do on the whole is i) scientific crime, for, they are not even capable to realize what they do is not science or engineering, but a low grade propaganda, ii) they violate peoples' right of making up their own future, so this is really a democracy crime, at the same time.

They do not behave as scientists (no matter how much they may be knowledged), they are, behind the guise of scientists, I am sorry, dangerous fascists...

The other point is the cost...

Here again I must say, they lie...

I can estimate that the damage Fukushima accidents did to Japan and to Earth, starting with the Pacific Ocean is about 1 trillion dollars. That of Chernobil was around 300 billion dollars...

Experts never take into account the cost of such a damage.

Even so, where is their error margins, in their costs? They never supply this...

I can on the other hand estimate that the 54 Japanese Nuclear Power Plants cost is about 200-250 billion dollars altogether. So you see this is still way to low as compared to the damage the 3 Fukushima reactors did to Japan and to the wider environment. A huge area in Japan is contaminated. Pacific Ocean is contaminated, even as far as Australia...

So your experts are either not honest, or conditioned by their formation, and cannot make cool analysis. They appear to be too much biased.

A nuclear scientist, cannot be a nuclear holigan. He has no right to act so. We are not talking about the nuclear-sport football team's fanatics, but nuclear experts... So they better realize their limits and stop steeling our children's future... People on the other hand, with consciousness yet, can of course take the risk and make a nuclear future choice...

I have to add that in Fukushima, for the first time in the history, a "nuclear sewage" occurred, due to the liberation of spent fuels under tsunami, otherwise imprisoned in nuclear spent fuel cooling pools, nearby the reactors...

I have the honor of sharing with you that, I am the first nuclear scientist, as far as I know, who predicted and pronouced this diabolic accident, and coined the denomination of "nuclear sewage". Miles from Fukushima, still display very unfortunately a "nuclear sewage" (and that has not happened before anywhere else in the word)...

Q: Our government submitted the attached estimates as of July 2015.

From the left, nuclear, coal, LNG, wind, geothermal, small hydro 1, small hydro 2, bio, oil, solar 1, solar 2, gas cogeneration, oil cogeneration.

In their estimates, nuclear is the cheapest, 10.1 Yen/kWh.

A: *Baloney...*

Ask them where they have taken into account the cost of the Fukushima accident, and possible future accidents... And what is their error margins... It is a pity that, they coin numbers, just like this, without any error margins on them...

Government means, interests of reigning people, and this does not always match with wider people's interests...

I can understand how deceived and damaged may be actually Japanese nuclear industry. I sympathize with this. They may feel indeed, they may be left out jobless... I can see on the other hand that they must be influencial on the governments.

But I am a scientist... I cannot act like they do.

I do not even find ethical what they do.

They may not know it, or they may not ralize it, but what they do lacks scientific sageness...

They are not talking truths, just the truths - nothing but the truths, and all of the truths...

Q: In this connection, however, our government admits that cost of solar generation decreased radically in the other countries to 9 YEN/kWh.
So, my question is if the cost of renewable energy is cheaper than nuclear in general.

A:

i) In the light of what I shared with you above, the answer is definitely yes... I must add that we are talking about the actual nuclear technology. New technology must be made inherently safe, and most likely, smaller, modular, so no accident could cause damage at the levels we have lived in Chernobyl and in Fukushima. It would be silly if I denied nuclear energy production, as a dedicated nuclear engineer. I am fascinated by nuclear energy production. So I am not a bit proposing that we should not go any further nuclear. No!. We should yet develop other nuclear technologies. We should also go nuclear fusion. Other details are provided in my presentation...

ii) But there is a whole other and very critical issue, also a great resource of energy. This is "energy efficiency". TMI accident (1979), and Chernobyl accident (1986) taught us a big lesson. While developing other technologies, to untie ourselves from expensive oil, we learned that, we were spending a double amount of energy to achieve all we needed to achieve. In other words, we can now do everything we used to do, but via spending only half of the energy we used to spend. The energy efficiency can be increased even further. Just an example: In our houses nowadays we have light bulbs of only 10 Watts, but have the same luminosity we used to tap with bulbs of 100 Watts. I can provide you with dozens of examples of this kind... If you go this way, you will easily see that nuclear energy production fell off to be a technical necessity, by far... Again, I love to see nuclear experts work on inherently safe nuclear reactors, modular, smaller reactors, and fusion reactors...

Q: I would appreciate if you could provide me with any most-updated statistics or article on this matter.

A: *I believe I already did... As an MIT Ph.D. in nuclear science and engineering, I love to make fast estimations on the magnitudes of occurrences...*

I believe not many experts could provide you rapidly with the Fukushima damage cost I spelled above, readily ... And it is so very much simple to handle when compared to cumbersome numbers embedded in many lies...

Here is another crucial estimation I made (it is in my presentation). The risk of a 1000 MWe nuclear power plant to undergo a fatally damaging accident throughout a life time span, is 1 % with the existing nuclear technology, whereas by the time I was a Ph.D. student back at MIT, it was believed to be, and this in the worse case, 100 times smaller. This means 1 of 100 nuclear power plants of the given size are to undergo a fatal damage, for totally unexpected reasons.

Now no expert can decide on adopting or declining nuclear power production. This should be decided on people's political will...

