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Arizona Corporation Commission
Steve Olea, Director, Utilities Division
Commission Chairwoman Mayes
Commissioner Newman
Commissioner Kennedy
Commissioner Pierce
Commissioner Stump
1200 W. Washington St.
Phoenix, AZ 85007

Externalities of Nuclear Energy

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Comments by Russell Lowes, www.SafeEnergyAnalyst.org
3339 E. Seneca St., Tucson, AZ 85716-3255, 520-321-3670

These are my comments on the proposed draft Integrated Resource Plan rules that would amend Title XIV of the Arizona Administrative Code (Public Service Corporations, Corporations and Associations, Securities Regulation, Chapter 2, Corporation Commission Fixed Utilities, Article 7, Resource Planning).

In February 1986 I presented as an expert witness to the Arizona Corporation Commission on the economics of the Palo Verde reactors. (Docket No. U-1345-85-156). My testimony was backed up by Terry Woodfield, Ph.D., a statistician and professor for Arizona State University that same year.

I request that the Arizona Corporation Commission include in the IRP externalities of each significant option for power production and savings.

This is a partial review of the externalities associated with commercial nuclear energy. While there are many externalities covered here, there are perhaps even more items not covered than covered. This is a very complex industry, with complexity on the scale of the defense industry. Much of the best work to-date on the externalities of nuclear energy was done around the end of the last round of construction of U.S. reactors, in the 1980s and 90s. Hence much of what I am presenting here is from that time period. Some newer research has been done, but still more new research should be done to update these works.

Government Subsidized Insurance; the Price-Anderson Act of 1957

In the 1940s and 1950s, the U.S. Government established a goal of promoting nuclear energy. However there was resistance to the Government promotion of commercial nuclear energy to start the building of commercial reactors, with the high dollar risk of a nuclear meltdown. Hence, the Price-Anderson Act was passed by Congress to limit the exposure to utilities, guaranteeing that the Government would step in after minimal utility-purchased insurance was disbursed and then pay remaining claims to a maximum $560 million. The NRC later admitted that a major meltdown accident could contaminate an area the size of Pennsylvania. In the 1982 Core Reactor Accident Report (CRAC-2), the NRC admitted that just the property costs for an accident at Indian Point in New York could be $314 billion, with 50,000 early deaths, 167,000 early injuries and 14,000 cancer deaths. The current limits of the renewed P/A Act have increased into the billions, but to nowhere near the potential damages.

In the CRAC-2 report, the estimate (in 1982 dollars) for one Palo Verde meltdown was 4,000 early deaths, 36,000 early injuries and 15,000 cancer deaths with $89.7 billion in property damage. This was estimated in 1982, before the population surge around the area of the Palo Verde nuclear plant.

COST OF EXTERNALITIES: Other than the costs listed above, there would be an additional insurance cost that would be very high if the nuclear industry had fully to insure itself, especially if health costs had to be covered. Public Citizen estimated in the 1990s that the insurance premiums would be $1-5 billion per year or perhaps even more. In a 1990 assessment, Dubin and Rothwell estimated that the cost of extra insurance would have run U.S. nuclear utilities $111 billion in 1985 dollars by 1988, growing to $131 billion by 2001. This estimate does not include health injury or death coverage.

Under Price-Anderson, medical claims are void; every person is considered responsible for themselves. Without the P/A Act, medical claims and injury and death suits could add over $1 trillion in external costs to one major accident. See "Other Environmental Costs" below.

Externalities of the Nuclear Fuel Cycle

While there are nine easily discernable steps to the fossil fuel life cycle, there are twenty steps to the nuclear "closed-loop" cycle. There would be far more steps to an "open-loop" nuclear cycle, that is, if commercial reprocessing in the U.S.A. were to become legal.

1. Mining 0.15% uranium ore, powered by oil

EXTERNALITIES: The externalities associated with oil-burning are inherent in nuclear fuel mining. Contamination from and rehabilitation of the disturbance and breakdown of ore bodies in mining is not currently completely included in the cost of electricity. Health costs from exposure to radiation from Uranium-238, U-235 and their by-products are not borne in internalized costs, but are passed onto miners and members of the public and to plant and animal life and destruction of natural water tables, etc.

2. Milling to 70-95% U_3O_8, powered by oil and a lesser amount of electricity, mostly derived from coal
EXTERNALITIES: The externalities associated with oil and coal-burning are inherent in nuclear fuel milling. Contamination from and rehabilitation of the disturbance and breakdown of ore in milling is not currently included in the cost of electricity. The associated health costs are also externalities.

Notes on 2&3: For both mining and milling, a significant issue arises with the subject of resource depletion. As uranium is depleted, the mining and milling of uranium increases. In the 1980s, the uranium ore grade average for the world was about 3000 parts of uranium per million parts of ore. That has gone down to 1500 ppm today and is projected to go down to about 400 by 2040. When that happens, the CO_2 released along with other pollutants in oil and coal energy production will increase. Nuclear may end up with over 420 grams of CO_2 per kilowatt-hour produced (not counting long-term waste management).

Associated with mining and milling cost is the issue of imports and trade imbalance. Only about 7% of the uranium fuel in the U.S. comes from the U.S. The remainder comes from Africa, Russia, Canada, Australia and other countries. What is the externalized cost of this trade imbalance and decreased position of energy security?

3. Conversion to UF_6, including several sub-steps of chemical processing, powered by mostly oil
EXTERNALITIES: The externalities associated with oil burning are inherent in nuclear conversion.

4. Enrichment: take milled uranium which is 0.7% U235 and 99.3% U238 to get the U235 up to 3.2-3.5%, powered by electricity, mostly coal
EXTERNALITIES: The externalities associated with oil and coal-burning are inherent in nuclear fuel enrichment. The U.S. Government heavily subsidizes and controls the enrichment process. The un-recovered enrichment costs from 1968-1990 in 1990 dollars equals $8.0 billion. Many more billions have been spent since 1990. Further subsidies are hidden in the enrichment step in the issue of coal-fired electricity for much of the enrichment in the U.S. This coal plant has been exempted by Congress from Clean Air Act regulation, thus causing more health effects and externalities associated with coal emissions.

5. Re-Conversion to UO_2 with 3.2-3.5% of that being U235, powered by oil, and electricity which is mostly from coal

EXTERNALITIES: The externalities associated with oil burning are inherent in nuclear fuel re-conversion, a process that is also largely controlled by the U.S. Government.

6. Fabrication, powered by oil to mine and manufacture the zircaloy fuel cladding
EXTERNALITIES: The externalities associated with oil burning are inherent in nuclear fuel fabrication.

7. Using the fuel in the reactor, powered by the nuclear fuel itself
EXTERNALITIES: Reactor meltdowns can occur while running nuclear reactors from operator errors, multiple equipment component malfunctions and design error. Reactor meltdowns can also occur from terrorist attacks with or without insider assistance, and from large aircraft strikes. Off-gassing is routine and can be accidental also. Water leaks can be accidental. Refueling and repair accidents are also possible.

8. Taking spent fuel out of the reactor and putting it into interim storage in spent fuel ponds, powered by energy from the nuclear plant and from electricity from the grid when the nuclear reactor is not providing electricity.
EXTERNALITIES: Here we have an issue of high risk. These spent fuel ponds are of fuel that has been removed from the reactor core. This spent fuel is still hot, and can melt down. It is cooled down for at least five years before processing it in the next step before long-term storage. The cooling ponds are not protected by a hardened dome, as the reactor is. These pools are in industrial buildings, and are even more susceptible to meltdown by mismanagement, or terrorist or accidental plane crashes.

9. Isolating and guarding waste of the long-term storage phase of spent fuel (perhaps two or more steps), powered by energy from the nuclear plant and off-site electricity mostly from coal and from oil in the creation of the matrix, it is projected, since the technology and policy is currently in place, yet still evolving.
EXTERNALITIES: Off-gassing of waste in different stages of processing (for example dehydrating and pulverizing) will cause exposure increases. Risk of spills of liquid materials, migration and property change (from solid to liquid to gas, etc.) will cause environmental challenges. Unpredictability of the interaction with cladding materials, contamination of watersheds and air, earthquake resistance and many other issues will become apparent over time. Some of these problems are already known and projected to be costly. The costs of rehabilitating watersheds, perhaps waste migration toward encroaching civilization near the waste areas. Population encroachment around waste sites could be similar to the encroachment around the Palo Verde nuclear plant.

10. Isolating and guarding waste of uranium mining tailings, powered by oil
EXTERNALITIES: Current methods of guarding tailings from mining included moistening the dusty tailings via sprinklers or covering with linings or a layer of earth.

When sprinklers break down, or when high winds occur, or when erosion or lining breaches occur with coverings, tailings dust emits into the air and water, creating health hazards. The associated health care costs are externalized. Further, future generations of men and women will need to stabilize these tailings for theoretically approximately 45 billion years, if you assume a 4.5 billion year half-life of U-238 over 10 half-lives for radioactive neutralization. The energy and dollar cost from that alone will reduce the energy output from nuclear energy to net negative and increase the cost by multiples, assuming a population of our descendants will be here to protect themselves. U.S. courts have ruled that high-level spent fuel waste must be managed for 1 million years, even though it is scientifically known that management must be for much longer.

11. Isolating and guarding waste of mill tailings, powered by oil
EXTERNALITIES: Current methods of guarding mill tailings include capping with various substances such as forms of cement and asphalt. Some capping has been designed to last 1000 years, but in some cases has already been breached within decades. Like uranium tailings, only with higher levels of uranium content, mill tailings contain U-238 with a half life of 4.5 billion years, essentially causing care to last for the rest of the planet's projected remaining 5 billion year lifespan.

12. Isolating and guarding waste of conversion machinery contamination, powered by oil
EXTERNALITIES: Apparently, very little has been done by the U.S. Government to take care of this step of the fuel waste cycle. I know of no assessment of this step.

13. Isolating and guarding waste of enrichment machinery contamination, powered by oil
EXTERNALITIES: Apparently, very little has been done by the U.S. Government to take care of this step of the fuel waste cycle. I know of no assessment of this step.

14. Isolating waste of re-conversion machinery contamination and the associated depleted uranium, powered by oil
EXTERNALITIES: Apparently, very little has been done by the U.S. Government to take care of this step of the fuel waste cycle. I know of no assessment of this step.

15. Isolating and guarding waste from the fabrication process, powered by oil
EXTERNALITIES: Apparently, very little has been done by the U.S. Government to take care of this step of the fuel waste cycle. I know of no assessment of this step.

16. Transportation of waste, powered by oil
EXTERNALITIES: First off, the U.S. Government has not set up a final destination for waste from conversion, enrichment, reconversion, fabrication or spent fuel, so we do not know how much will be transported and where it will be transported to. We do know that high-level waste will be mobile weapons of mass destruction, should they be breached by terrorists, or by accident.

17. Concurrently with the waste steps, setting up coordination of the nuclear waste plan, including policing, maintenance and repair of containment, criminal investigation and prosecution, cleanup from terrorist or accidental contamination (these systems do have their energy inputs, though difficult to quantify), powered by oil for transportation and construction of structures and electricity
EXTERNALITIES: To assess the possibility of the waste stream being as poorly managed as the wastes at Hanford, Rocky Flats, the Apollo nuclear plant, the Savanah site, etc., over many millennia, the costs of environmental remediation, including the rebuilding of natural bio-systems, residential, industrial and commercial facilities in cities, and the associate health costs will need to be taken into account.

-- There are the additional 3 steps of the nuclear plant cycle:

18. Construction of the plant, powered by oil
EXTERNALITIES: The externalities associated with oil-burning are inherent in nuclear plant construction.

19. Operation of the plant, including energy for pumps cooling towers, control room, etc., powered by the nuclear fuel
EXTERNALITIES: When nuclear reactors are not at a stable power output level, the associated energy required at the nuclear plant is taken from the grid or in emergencies from diesel generators, with the associated externalities of what is running the grid or the diesel fuel from generators.

Electricity from the grid or diesel generators is used for continued cooling of the reactor and the cooling ponds in the auxiliary building, the electricity for the control room, etc. Many nuclear reactors have been down for repairs for more than a year, all the while using energy from the grid.

20. Decommissioning/dismantlement of the plant and isolation from the environment, powered by oil
EXTERNALITIES: To cover the cost of decommissioning of reactors, only one tenth of one cent is currently required by the U.S. Government to be put aside by utilities into a self-regulated investment fund. The shortfall in relation to the real cost of decommissioning was estimated to be $2.4 billion though 1990 in 1990 dollars. Major economic decline could contribute to de-funding these funds.

In addition to these twenty steps of the nuclear lifecycle, there is a sizeable energy input into making the specialized industrial equipment that will make the nuclear plant components.

It may be very evident to some people, but if these waste steps are carried out over a million years, the energy inputs will be astronomical. One million years equals 14,286 human generations of 70 years per generation. One million years equals 25,000 reactor lifetimes of 40 years each.

Other Environmental Costs – Routine Emissions and Accounting for Infrequent Meltdowns

Pace University Center for Environmental Studies conducted a study in the 1980s on two other environmental costs: that of routine emissions and the costs associated with a meltdown. This was based on the NRC prediction of a major accident 1in 3,333 reactor-years. The Pace University study estimates this externalized impact to cost about 2.4 cents per kilowatt-hour.

Ideological Support (or P.R.) for Nuclear Energy

The U.S. Government support for an energy system that relied on energy subsidies to survive had a high value in public relations dollars. So high is this advertising value, that some have put it at almost unbelievable levels.

Steve Cohn, professor of economics at Knox College in Illinois estimated that the promotional value to nuclear energy in 1987 dollars was 5.1 cents per kilowatt-hour. This is more than the direct cost of operating a plant, not including capital costs which are non-operating costs.

Job Loss

Generating 1000 gigawatt-hours of electricity per year requires 100 workers in a nuclear plant and 116 in a coal-fired plant, but 248 in a solar thermal facility and 542 on a wind farm.

EXTERNALITIES: What is the value of job reduction due to nuclear energy? What happens when you reduce job potential of 542 jobs at a wind farm to 100 at a nuclear plant – reducing the jobs by 82%?

Other Direct U.S. Government Subsidies

Capital Charges Avoided Via Tax Breaks: From 1968-1990, tax breaks for nuclear energy were $26.1 billion.

Research & Development and Regulation: From 1968-1990 R&D and regulation subsidy amounted to $46.8 billion

Proliferation of Nuclear Weapons

It takes less than 10 pounds of plutonium to make an atomic bomb. While this would require separation of spent nuclear fuel, an expensive and time-consuming process, with a renewed cry for reprocessing in the U.S., if we do resume reprocessing for commercial reactors, the opportunity for black market or terrorist diversions will be there.

Without a reprocessing system in place, the opportunity for "dirty" nuclear bombs is still there, via black market or terrorist diversions.
EXTERNALITIES: The cost of future contamination and destruction from atomic or "dirty" bombs is difficult to project, but the cost could be very high. Such repairs as rebuilding whole cities or portions of cities could completely outweigh the benefit from all the electrical generation from nuclear energy.

Water Consumption is Highest with Nuclear Energy

Water loss to the environment at Palo Verde is about 63,000 acre-feet per year. This about 45% of the water use of the City of Tucson. Water use is the highest for nuclear, compared to all other significant electrical power sources.
EXTERNALITIES: The loss of water to the environment is through evaporation. This causes two major sets of problems. First, water is displaced that could be used for natural purposes or for people. Second, the emitting of that much cloud-forming moisture into the air causes more heat capture, creating more global warming. The costs of these two factors are the subject of much study.

Destruction of Wildlife

At some reactors in the U.S., the fish kill is in the millions, even billions. Estuaries, lakes, rivers and oceans, all have been affected dramatically by the thermal discharges at commercial nuclear plants.

Three Periods of Subsidy

-- Establishing the Industry, 1950-1973, $10.6 billion plus 1950-1967 amounts unattained
EXTERNALITIES: The cost of direct federal assistance was 3 cents per kilowatt-hour, in 1990 dollars.

-- Post-Reorganization, 1974-1984, $39.2 billion
EXTERNALITIES: After the Energy Reorganization Act of 1974, 1.6 cents per kilowatt-hour was directly spent by the Federal Government.

-- Institutionalizing the Subsidy, 1985-1990, $33.5 billion
EXTERNALITIES: After 40 years of federal subsidy, the nuclear industry settled into an enjoyed 1.1 cent per kilowatt-hour direct federal support.

For this whole three-period era of 1950-1990, the average direct federal subsidy was 1.6 cents per kilowatt-hour. An update to this data is needed.

Conclusion

Nuclear reactors have a multitude of overt internalized costs and also an even higher number of covert, externalized costs. The externalized costs are so high that they really need to be counted when developing a plan for future action. I hope that the Commission respects the gravity of this vast array of externalities and includes a reasonable assessment of these costs for future Integrated Resource Plans.

References:

(1) "Fiscal Fission: The Economic Failure of Nuclear Power," Komanoff Energy Associates, 1992.
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Russell J. Lowes
www.SafeEnergyAnalyst.org
3339 E. Seneca St.
Tucson, AZ 85716