The STP Expansion: Cost and Environmental Effects

by Robert C. Duncan, PhD[1]
duncan@astro.as.utexas.edu

CPS Energy, San Antonio's electric utility, has recommended that the city participate in the planned expansion of the South Texas Project. Nuclear plants like STP generate electricity without significant greenhouse gas emissions, so they help to avert global warming.

Nuclear versus solar costs

The lifetime-average cost for electricity from the planned STP expansion is just the total amount of money put into the project, divided by total electricity generated. CPS Energy's official estimate is *8.5 cents per kilowatt-hour.*[2] However, I think that this prediction should be reconsidered.

CPS Energy's estimate is actually the average cost during the first 40 years of operation.[3] But the new reactor units are expected to run for 60 years or more.[4] After 40 years, all capital (or building) costs are paid off, so subsequent electricity is much cheaper. This will be a valuable asset for San Antonians, which should be taken into account. A simple estimate shows that the true lifetime-average cost is about *6.6 cents per kw-hr.*[5]

This cost should be compared with the price of *16.5 to 19.0 cents per kw-hr* that Austin Energy, our neighbor-utility to the north, is committed to pay for solar electricity for the

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[1] The author is a research scientist at the University of Texas at Austin, now on leave to write a book, with a PhD in physics. He lives in Fentress, Texas, a small town about halfway between San Antonio and Austin. He has no connection of any kind to any energy company, or to any lobbying/advocacy group. (*Scientific website*: http://solomon.as.utexas.edu/~duncan/magnetar.html
Educational background: B.S. Dartmouth 1977; C.P.G.S. Cambridge University 1979 [Reynolds Scholar]; M.S. Cornell 1983; Ph.D. Cornell 1986; Post-doctoral Fellow Princeton 1986-88. Recipient of the Bruno Rossi Prize from the American Astronomical Society for contributions to high-energy astrophysics http://mcdonaldobservatory.org/news/releases/2004/0102.html .)

[2] http://www.cpsenergy.com/files/neighbors_night_presentation.pdf (p. 11)
[3] http://www.cpsenergy.com/files/STP_Assumptions_Overview.pdf (p. 22)
[4] The Advanced Boiling Water Reactor is designed to run for 60 years or more: http://www.cpsenergy.com/Developers_Builders/New_Infrastructure/Proposed_STP_Expansion/STP_FAQ/STP_FAQ_environmental.asp , http://www.world-nuclear.org/info/inf08.html . This is a quite reasonable lifetime for a nuclear plant. Even old-technology nuclear plants run this long. The Oyster Creek generating station recently had its 40-year license renewed for 20 more years. http://www.oystercreeklr.com/
[5] Since the plant runs for 40 years at 8.5 cents per kw-hr, followed by 20 years at 2.8 cents (the production cost projected by CPS Energy), the average cost over 60 years is $[(40 \times 8.5) + (20 \times 2.8)]/60 = 6.6$.

whole lifetime of its large solar array.[6] Nuclear electricity is *much* cheaper -- by a factor of 2.5 or more.

This means that, for the same financial commitment, San Antonians will avert the emission of at least *2.5 times more* tons of climate-threatening carbon dioxide than will Austin's ratepayers.

In this case, what is best for the economy is also best for the environment. And low cost isn't the only advantage. There is no solar power at night, when most plug-in cars will need to charge, or on cloudy days; but STP will run around the clock.

Of course, rate increases will be necessary for San Antonio electric customers during the first few years, in order to pay down the capital quickly and thus to keep financing costs low. But in the long run, San Antonians will pay lower electricity bills, and combat global warming much more cost-effectively than they could with any other energy source now available.

Nuclear safety and "waste"

The competent, professional engineers at CPS Energy understand these facts very well. Still, vocal, anti-nuclear activists object. These citizens warn that nuclear plants are too dangerous. In reality, nuclear energy now provides 20% of America's electricity,[7] but not a single person has ever been killed in a U.S. commercial nuclear power plant accident, not in 52 years of service.[8] This is a record of safety unequalled in heavy industry.

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[6] The price that Austin Energy (AE) has contracted to pay for solar power from the planned plant in Webberville (eastern Travis County) has long been an open secret in Austin. Citizen testimony before the Austin City Council quoted a price of 16.5 cents per kilowatt-hour. This was corroborated on the public record in the Austin Chronicle: http://www.austinchronicle.com/gyrobase/Issue/story?oid=oid%3A751802. AE General Manager Roger Duncan (no relation to the author of this article) said that AE estimates a capacity factor of 0.23 for the solar plant, which together with its 30 MW peak capacity and $10 million annual expenditure (e.g., http://www.austinsmartenergy.com/downloads/Solar_RFP_Presentation.pdf) implies a purchase price of 16.5 cents per kw-hr. (Mathematical details: the 30 MW plant is designed to yield 30 Megawatts when full sunlight shines directly on its cells. Most of the time, it produces less. AE predicts that it will produce a fraction 0.23 of its peak capacity on average, or 0.23 x 30 = 6.9 Megawatt-years per year. But there are 24 x 365 =8760 hours in a year, and 1000 kilowatts in a Megawatt, so this is 60.4 million kw-hrs. The annual cost is 1000 million cents, so the price is (1000/60.4) = 16.5 cents per kw-hr.) Note that AE's purchase power contract involves a fixed price, so even if AE has overestimated the solar array's capacity factor, as I think it has (by 15%), the price would still be 16.5 cents per kw-hr. AE will simply end up buying 15% less solar electricity than it expects. If, however, AE actually used a capacity factor of 0.20 in its planning (a number that I think is accurate), and has misled the public about this—which seems unlikely-- then the price that AE will pay is even higher: 19.0 cents per kw-hr.

[7] Electrical power consumption from various sources are given in Table ES1 of the "*Electric Power Annual*" published by the U.S. Energy Information Agency http://www.eia.doe.gov/cneaf/electricity/epa/epa_sum.html

[8] Note that some radioactive steam was released during the 1979 Three Mile Island incident, but so little that there is only a small chance that this caused even a single case of cancer in the public. (The causes and effects of the TMI accident are now well-understood and not controversial. Information is available from many sources, e.g., http://www.nrc.gov/reading-rm/doc-collections/fact-sheets/3mile-isle.html) The first

(The *Express-News* noted that a lethal accident occurred at an Idaho military test facility in 1961.[9] But this was no commercial power plant. In fact, the equipment was very crude, with ill-fated technicians mistakenly pulling out control-rods by hand while standing on top of an operating reactor.[10] This bizarre incident is not relevant to modern, machine-operated power plants.)

Anti-nuclear advocates also claim that nuclear waste poses an unmanageable threat. In reality, the amount of nuclear waste produced in supplying electricity to an average American for a full year is only 33 grams: less than the weight of seven Jefferson nickels,[11] and 400,000 times less massive than the noxious, climate-threatening wastes produced in generating the same amount of electricity from coal.[12] This tiny, fully-

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commercial nuclear plant began to produce electricity in 1957, in Shippingport, Pennsylvania, 52 years ago.

[9] http://www.mysanantonio.com/livinggreensa/Nuke_safety_claim_is_wrong.html

[10] "At the time of the accident, a three-man crew was on top of the reactor... The nuclear excursion, which resulted in an explosion, was caused by manual withdrawal, by one or more of the maintenance crew, of the central control rod blade from the core considerably beyond the limit specified in the maintenance procedures." This quotation comes from http://www.cddc.vt.edu/host/atomic/accident/critical.html

[11] The total annual electrical power consumption of the U.S. is 4.16 billion megawatt-hours, according to the U.S. Energy Information Agency. (See reference in footnote 7.) Since the U.S. population is 304 million, according to http://factfinder.census.gov/servlet/SAFFPopulation, this is 13.6 megawatt-hours per person. The quantity of nuclear waste generated by this much electricity (33 grams) can be found, e.g., from formula [3] in Appendix 4 of "The *Future of Nuclear Power*"(http://web.mit.edu/nuclearpower/), adopting parameters which are typical for American nuclear plants in 2008: a "burn-up" of 50 GW-days/MTIHM (where "MTIHM" means "metric tons initial heavy metal"), a capacity factor of 90%, and a thermal efficiency of 33%. A Jefferson nickel weighs 5 grams. [*Parenthetical Note*: 33 grams is the weight of spent radioactive fuel: uranium and what uranium gets transformed into. The fuel rods consist of uranium oxide fuel pellets stacked inside 1.5 mm-thick zirconium-alloy ("zircalloy") tubes. Including the weight of oxygen as "waste" increases the tally by a factor of 1.13, and the tubes, or "cladding" contribute a similar amount of weight. Together, these components could be said to increase the amount of "waste" per person by about 10 grams, or two additional nickels. But the oxygen is not radioactive, and the cladding becomes only slightly radioactive inside the reactors. In French recycling plants, the cladding is chopped up and mixed into concrete for disposal.]

[12] The most voluminous waste product from coal burning is carbon dioxide, which is also the principle greenhouse gas that threatens our global climate. Table 9 on page 16 of the Energy Information Administration's "*Emissions of Greenhouse Gasses in the U.S.*" http://www.eia.doe.gov/oiaf/1605/ggrpt/index.html says that U.S. electrical power generation in coal-fired plants released 1.94 billion metric tons of carbon dioxide in 2007. Since a metric ton is 1.1 tons (North American unit) this is 2.1 billion tons. Coal-burning supplied nearly 50% of the electricity (footnote 7) for our nation of about 300 million people, so the amount CO_2 released in supplying a full year's electrical needs of an average American from coal-burning is about (2.1 billion tons)/(150 million people) or 14 tons per person. That is 400,000 times more mass than the 33 grams of nuclear waste produced in making the same amount of electricity (footnote 11). In addition to this carbon dioxide, coal burning releases into the environment noxious and toxic wastes that are also many thousands of times more massive than the (fully contained) nuclear waste produced in making the same amount of electricity. These including sulfur dioxide (which causes acid rain), nitrogen oxides (300 times more potent than carbon dioxide for global warming, and a source of acid rain plus low-lying ozone), hydrochloric acid aerosol, sulfuric acid aerosol, hydrogen fluoride, ammonia, and toxic/radioactive heavy metals -- arsenic, barium, mercury, selenium, thorium, uranium etc.-- in particles of smoke and "fly ash" waste. These heavy metals leach out of fly ash when it gets wet. See http://blog.cleveland.com/pdopinion/2009/02/nuclear_power_vs_clean_coals_d.html

contained waste stream has never hurt anyone, and there's no good reason to think that it ever will. If we resolve to dispose of it (which I don't favor doing, for reasons explained below), then it can be safely buried in a stable, dry desert location. Nevada would not be optimal; a better site would be southwestern Australia, which is more geologically stable and arid.[13] Of course the buried material would be radioactive for a long time, but this presents no special problem; what is buried, stays buried. Claims to the contrary are more political than scientific.

But burial may ultimately prove unnecessary and unwise, since 95% of "nuclear waste" is potentially valuable reactor fuel. Fast-neutron reactors can burn it for power – a *lot* of power[14] -- using processes that have already been demonstrated in pilot reactors and labs, but which require development work for industrial-scale application.[15] All of the end-

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The E.P.A. has documented more than 70 cases in 23 states where coal power waste has contaminated groundwater, surface water and drinking supplies, e.g. http://www.ens-newswire.com/ens/feb2004/2004-02-10-10.asp ; http://www.earthjustice.org/news/press/007/new-study-reports-pennsylvania-groundwater-contamination-from-coal-ash.html .

[13] A proposal for a waste repository in Australia was pursued during the 1990s by a company called Pangea Resources: http://www.youtube.com/watch?v=UjBSAlu0hjM Following campaigns by Greenpeace and others, nuclear waste depositories were outlawed by the Western and South Australian Parliaments in 1999 and 2000. However, a severe drought is occurring in remote, rural Australia. The area is very desolate. http://www.bom.gov.au/climate/index.shtml Some models of climate change suggest that the drought will be chronic. http://www.sciencedaily.com/releases/2007/10/071003130920.htm A for-profit, international waste repository, with a dedicated seaport and railroad, could be a wholly beneficial boon for this sparsely-inhabited region. (I say this because I believe that a properly engineered repository will never have any ill effects.) It is reasonable to suspect that the benefits of this proposal will eventually become clear to Australians, especially if future waste doesn't include long-lived transuranic components. The main advantage of Australia over Nevada is Australia's nearly-perfect geological and seismic stability. Nevada unfortunately lies in the "basin and range" area of continental stretching by plate tectonics; there is a chance that the fault near Yucca Mountain could become active before the waste decays. However, even if this happened, the result would be that a small area of desert would become more radioactive than the background. It would be no withering scourge on future generations.

[14] So-called "spent" fuel rods actually harbor about 19 times the fission energy that they have produced in becoming "spent," all of which can be released by fast-neutron reactors in an appropriate advanced fuel cycle, using technology which has already been demonstrated (see next footnote). Such rods have been used once, but are far from "spent." and are hardly "waste" at all!

[15] A used fuel rod contains about 93.5% uranium (U), 5% fission products (split atoms), and 1.5% "transuranics." The transuranics are mostly plutonium (Pu), with a smattering of other elements heavier than uranium. These transuranics are the components that require sequestering for many thousands of years. [Note: the precise proportions of various components in spent fuel rods depend upon how long the fuel is "burned" in a reactor. The proportions quoted here are typical for current U.S. power reactors. See, e.g., Table A-4.1 in Appendix A of "*The Future of Nuclear Power*" http://web.mit.edu/nuclearpower/] Now, all of this "nuclear waste" except fission products can be used as fuel in fast-neutron reactors like the EBR-II reactor that ran successfully at the Idaho National Labs for 30 years beginning in 1964. (In 1994, the program was terminated by badly-informed politicians for no sensible reason: http://www.skirsch.com/politics/ifr/O'Leary%20Problems.pdf .) To prepare the used fuel rod for fast-neutron burning, it must undergo "pyroprocessing," a procedure fully demonstrated in labs, but not yet done on industrial scale. The only waste from such an advanced nuclear fuel cycle is the fission products (split atoms), which remain radioactive only for a relatively short period of time. After 400 years, fission products decline in radioactivity to the level of the uranium ore from which the material originally came. For useful discussions, see http://www.huffingtonpost.com/steve-kirsch/climate-bill-ignores-our_b_221796.html, http://www.sustainablenuclear.org/PADs/pad0509till.html and

wastes from such advanced nuclear plants are no more radioactive than natural uranium ore after only 400 years. If America fails to develop this advanced nuclear technology, other countries like Japan or France eventually will.[16]

So "nuclear waste" is small in volume and not very difficult to manage. Far from being a threat to future generations, it may prove to be a valuable energy resource.

San Antonians should listen to qualified engineers and scientists who understand both the technology and the environmental imperatives, and not be scared by forecasts of doom from well-meaning but poorly-informed political advocates. These advocates are often guided by gut feelings of fear rather than rational cost/benefit and risk assessments.[17] It is easy to spread fear about powerful technologies, but this can ultimately cause more environmental harm than good.

In conclusion

We should not falter or hesitate in using the most powerful and effective technologies available for averting the threat of global warming. Future generations will be grateful if we overcome our spurious fears and misunderstandings, and make the right choice.

The STP expansion is vital for San Antonio's economy, as our city faces a future of electric cars, with burgeoning electricity demands. It is also a wise and necessary investment in our planet's future health.

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http://www.nationalcenter.org/NPA378.html, as well as "A Smarter Use of Nuclear Waste" by William H. Hannum, Gerald E. Marsh and George S. Stanford, *Scientific American*, December 2005, http://www.nationalcenter.org/NuclearFastReactorsSA1205.pdf.
See also http://skirsch.com/politics/globalwarming/ifr.htm and links therein.

[16] One form of nuclear fuel reprocessing is already done on an industrial scale in France and a few other places. This uses the PUREX process, a chemical separation procedure invented in the U.S. in 1943, to separate plutonium. The plutonium is then mixed with uranium to make mixed-oxide fuel ("MOX") fuel rods, which are used in ordinary (slow-neutron) nuclear reactors. As described in the previous footnote, pyroprocessing used in conjunction with fast neutron reactors (together called the "integral fast reactor" method, or IFR: http://www.sustainablenuclear.org/PADs/pad0509till.html) is a superior, many-times recycling method, which uses *all* of the fission energy in spent fuel rods, not just the plutonium, while never separating out any material from which bombs could be made at any stage in the process. There has been considerable progress on this of late, at many labs worldwide. For example, http://article.nuclear.or.kr/jknsfile/v40/JK0400183.pdf

[17] Daniel Gardner's book, *The Science of Fear: Why We Fear the Things We Shouldn't – and Put Ourselves in Greater Danger* (http://www.amazon.com/Science-Fear-Shouldnt-Ourselves-Greater/dp/B001U0OGAY/ref=sr_1_1?ie=UTF8&s=books&qid=1252279113&sr=8-1) discusses recent psychological research showing how many people justify (rationalize) their gut-level fears and biases through selective attention to facts, combined with a lack of balanced, quantitative perspective on the relative harms and dangers of human (industrial) activities. The book also describes how such errors in thinking are widely encouraged by political advocates, in order to inflame public fear for policy-influencing purposes, although these advocates invariably believe that they are acting in an unbiased and rational (or at least fully-justified) way. Chapter 4, "The Emotional Brain" gives a useful discussion of nuclear power politics.

APPENDIX: Capital Cost

Some citizens worry that the cost to build the new reactors (Units 3 & 4) will exceed CPS Energy's prediction. Back in the 1970's, before STP Units 1 & 2 were built, their costs were underestimated.

However, this historical fact is of little or no relevance to the new reactor units. None of the engineers or managers involved in planning Units 1 & 2 are now involved with STP. Moreover, the advanced technology of STP's planned new units has already been proven by long use. Four reactor units of the same design ("Advanced Boiling Water Reactor" or ABWR) have already been built on time and under budget in Japan, three under the direction of the same engineering team employed at STP.[18] The first such plant came on line in 1996. More are now under construction in Japan and Taiwan. These plants have all run successfully, with over 30 reactor-years of experience so far. They have a proven construction time (from first pouring of concrete to first power production) of 39 months.[19] The cost for building these plants in Japan was about $2000/kw,[20] so CPS Energy's 1080 MW share would cost only about $2.2 billion in Japan. It will cost more in the U.S., but the successful experience in Japan means that costs and construction times can be reliably estimated.

The U.S. Nuclear Regulatory Commission approved the ABWR design (being used in STP Units 3 & 4) way back in May 1997, saying that it exceeded "NRC safety goals by several orders of magnitude."[21] The STP expansion is one of only four new reactor projects nationwide on the short list to receive U.S. federal loan grant guarantees.[22]

For all of these reasons, CPS Energy's projected capital cost is a reliable estimate of the final cost.

This article is available online (with clickable links) at http://egpreston.com/STPexpansion.pdf

[18] http://www.stpnoc.com/New%20Units.htm
[19] http://www.ge-energy.com/prod_serv/products/nuclear_energy/en/new_reactors/abwr.htm
[20] The first two ABWRs were built for $2000/kw; see http://www.world-nuclear.org/info/inf08.html
[21] See reference in previous footnote.
[22] http://djysrv.blogspot.com/2009/05/four-projects-in-lead-for-nuclear-loan.html