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CoG Analysis of New Nuclear needs a Major Overhaul

Additional submitted attachment is included below.

CoG Analysis of New Nuclear needs a Major Overhaul

In the 2009 IEPR, the Cost of General (CoG) model, prepared by Energy Commission staff, found that new nuclear power plants – specifically Westinghouse's AP 1000 design – would not be economically competitive. Since then, updates and revisions to the CoG model have omitted an analysis of the AP 1000 or any other new nuclear power plant design, presumably on the grounds that the 2009 results were sufficiently conclusive that new nuclear is uneconomic. Unfortunately, the 2009 edition of CoG was rife with unrealistic and demonstrably false input assumptions relating to nuclear power, including an outright transcription error from an otherwise reliable source. In addition, certain errors in CoG's methodology skew the results against plants with longer construction schedules and longer asset lives.

In determining the scope of the 2015 IEPR, the Energy Commission should not exclude consideration of new nuclear power plants. If an update to CoG is to be conducted as part of the 2015 IEPR, an analysis new nuclear should not be omitted. Instead, the 2009 analysis should be corrected and revised with the latest available information.

Net and Gross Capacity

CoG assumes a gross electrical capacity of 960 MW for a single AP 1000 reactor. The source of this number is not apparent. The name of the AP1000 is deliberately intended to advertise that the net electrical capacity of the reactor is at least 1000 MW (which will vary with the choice of cooling technology). A more accurate capacity rating should have been readily available to CEC staff and their consultants in 2009. In the "Final Safety Evaluation Report Related to Certification of the AP1000 Standard Design" (NUREG-1793), dated September 2004, the staff of the US NRC note in the introduction: "The AP1000 nuclear reactor design is a pressurized water reactor with a power rating of 3415 megawatts thermal (MWt) and an electrical output **of at least 1000 megawatts electric (MWe)**."

An error is also evident in the item for "plant-side uses & losses" (also known as "house loads" or "parasitic loads"). CoG assigns 2.2% of gross capacity to handle house loads. This turns out to be perhaps the only overly generous assumptions that CoG makes about the AP1000. IAEA's online Power Reactor Information System (PRIS) shows that the four AP1000 reactors currently under construction in the United States all are rated at 1250 MW gross and 1117 MW net. This implies a plant-side use factor of 8.9%.

The difference between a plant's net and gross capacity is important, because most cost estimates in other sources will typically be denominated by net capacity or net generation, whereas the calculations in CoG rely upon inputs that are denominated in gross capacity or gross generation.

Overnight Capital Cost

For an AP1000 entering service in 2018, CoG estimates an overnight capital cost of $6,387 per kW of gross electrical capacity in 2009 dollars, with an ever-rising cost trend for later plants. This estimate bears little resemblance to the overnight cost of the four actual AP1000s currently under construction in the United States. In the latest regulatory disclosures made by Georgia

Power to the Georgia Public Service Commission on the progress of constructing Vogtle units 3 & 4, the overnight capital cost of the two reactors was estimated at $4,310 per kW. South Carolina Electric and Gas has most recently reported an overnight cost of $3,400 per kW for V.C. Summer Units 2 and & 3. Of course, there is the objection that the cost of power plant construction varies by state. The adjustment factors used by the U.S. Army Corp of Engineers suggests that factor of 1.33 should be used to extrapolate costs from South Carolina and Georgia to California, giving overnight costs of $5,750 and $4,533 per kW, respectively, still both substantially lower than the CoG input assumption made in 2009.

The 2009 version of CoG applied sales tax to 100% of the construction cost of every technology. However, future versions of CoG were updated with technology-specific factors reflecting differing levels of sale tax applicability to power plant construction. This should be updated for nuclear power plants, as well.

Interest During Construction

The construction spending profile assumed in CoG 2009 is sourced from the Nuclear Energy Agency (NEA) of the OECD. It is reproduced faithfully in the consultant report upon which CEC staff relied, but it appears that CEC staff introduced an inadvertent transcription error when entering it into CoG. Below is the original schedule:

Table 30. Nuclear plant construction spending profile (% of total instant cost per year)

Year	1	2	3	4	5	6	7	8	9
% total instant cost	2.5	2	7	15.5	22	21	18	10	2

Source: OECD Nuclear Energy Agency, International Energy Agency, Organisation for Economic Co-operation and Development. Projected Costs of Generating Electricity: 2005 Update. OECD Publishing, 2005

The notes in CoG clearly show that the order has deliberately reversed. The apparent reason is that it was a mistake arising from the descending numeration of construction years in CoG.

Parameter	AP 1000 PWR Nuclear	Biomass - Co-gasification IGCC (2018)	Biomass - Direct Combustion W/ Fluidized Bed	Biomass - I Combust W/Stoker E
Construction Costs by Year				
Years Out from On-Line Date				
Cost %/Year 0	**2.3%**			
Cost %/Year - 1	**1.8%**			
Cost %/Year - 2	**6.4%**			
Cost %/Year - 3	**14.3%**			
Cost %/Year - 4	**20.2%**			
Cost %/Year - 5	**54.9%**			
Years Out from On-Line Date	100%			
Months under construction Yr 0	12	12	12	
Months under construction Yr -1	12	6	6	
Months under construction Yr -2	12	0	0	
Months under construction Yr -3	12	0	0	
Months under construction Yr -4	12	0	0	
Months under construction Yr -5	48	0	0	

% Year0 (Last Year of Contruction) 2.5%
% Year1 (Next to Last Year of Contruction) 2.0%
% Year2 (2 years Before Last Year) 7.0%
% Year3 (3rd years Before Last Year) 15.5%
% Year4 (4th Year before Last Year) 22.0%
% Year5 (5th Year before Last Year) 21.0%
% Year6 (6th Year before Last Year) 18.0%
% Year7 (7th Year before Last Year) 10.0%
% Year8 (8th Year before Last Year) 2.0%

The effect of this mistake is to substantially shift much of the construction cost towards earlier years of construction, causing more interest to accrue on the cumulative construction outlays than under the original construction schedule.

It should be noted that CoG—while assuming that a nuclear power plant requires nine years for construction—does not provide a sufficient number of Excel rows to tabulate interest during construction in each year. Instead, the first four years are merged into a single year consisting of 48 months. When the same calculation is performed on nine separate cells, each representing one year, the interest during construction is found to be slightly lower. This methodological oversimplification affects no other technology in CoG except nuclear power.

Because CoG operates on a nominal cash flow basis, the treatment of inflation is a sticky issue. CoG contains a major error in calculating the effect of inflation on nominal cash flow during the construction period that inadvertently accounts for inflation twice:

1. The construction expenses are paid out in 2009 dollars in every year.
2. As time progresses, past expenses accumulate nominal interest. By definition, the nominal interest rate includes a factor that compensates investors for the diminishing purchasing of the dollar that arises from inflation. Thus, a construction expense accrued in 2009 will be capitalized into the final value of the plant in 2018 with a nominal monetary value that reflects the inflation that occurred over those nine years.
3. However, in the final year of construction, CoG performs a calculation to adjust all cumulative expenses (which have carried nominal interest the entire time) up to 2018 dollars from 2009 dollars.

This procedure is not accurate. Step 1 should be revised so that construction outlays are inflation-adjusted to the years in which they are spent. Step 3 should be eliminated, as step 2 already compensates investors for inflation. This error applies to all power plants in the CoG, but it affects nuclear to the highest extent because of its lengthy construction duration.

Finally, it should be noted that interest rates have fallen in the intervening years since CoG 2009 and this is reflected in the latest version of CoG. As nuclear power is a capital-intensive technology, the effect of this market development should be significant.

Operations and Maintenance Costs

CoG 2009 relies upon the Keystone Center's "Nuclear Power Joint Fact-Finding Dialogue" for variable and fixed operations & maintenance (O&M) costs. The Keystone Center provides both low ($100/kW-year) and high values ($120/kW-year) for fixed O&M, which presumably would be useful for CoG's low and high cost cases. Instead, CoG 2009 adopts the high value as the basis for the mid-case. For CoG's high case, the Keystone values are increased by a factor of 1.3. For the low case, CoG uses the same values as the Keystone high case. There is no apparent justification for these choices.

A better source to consider for O&M costs are those reported by regulated utilities in FERC Form 1. The Nuclear Energy Institute has aggregated the data and hosts it at this link. This dataset implies that the Keystone Report's O&M estimates are out of sync with reality, unless one expects that the AP 1000 and other Gen III light water reactors will incur substantially highly O&M costs than Gen II reactors. There is no apparent justification for such a forecast.

Another peculiar feature of CoG's estimate of nuclear O&M costs is the inclusion of a "grid integration" term from the Keystone Report. Whether or not it is an accurate value is immaterial so long as the CoG continues to exclude integration costs for any other technology, particularly intermittent renewables. Until such time as the Energy Commission staff are prepared to make a comparable estimate of grid integration costs for all technologies represented in CoG, the inclusion of this term into the LCOE of the AP 1000 is inappropriate.

Fuel

The nuclear fuel price forecast used in CoG 2009 appears to be a simplistic exponential extrapolation of ever-increasing cost. This bears no resemblance to the historic price trends, which is of a stable and low except for brief spikes during periods of heightened market interest in new nuclear construction. Additionally, a long-term forecast of high and rising nuclear fuel prices does not account for potential long-term market responses such as increased uranium exploration, higher fuel burnups, spent fuel reprocessing, nuclear weapons stockpile elimination ("Megatons to Megawatts"), breeder reactors using U-238, and the development of the thorium fuel cycle. A new analysis of new nuclear in CoG should seek out a more reasonable nuclear fuel price forecast.

Operating Lifetime and Performance

The mid-case capacity factor for the AP 1000 assumed in CoG was 86.5%. Such a value is not defensible as a mid-case estimate, as the U.S. nuclear reactor fleet has consistently hovered around a capacity factor of 90% since the year 2000. In fact, in 2014, the industry set a historic record with an average of 91.8%.

For the equipment life, the CoG mid-case assumes a value of 40 years. It should be noted that the AP 1000 is designed for a 60 year operating life without need for major part replacement, such as the reactor vessel or steam generators. Regardless, in developing the high (30 years) and low (60 years) cost cases, CEC staff note that modifications to the equipment life appear to have no effect on the levelized cost.

Operational Info.		
Planned % of Year Operational	88.9%	81.5%
Reference Target Capacity Factor	*86.46%*	*75.0%*
Average Output During Operation	100%	100.0%
Equipment Life	40	
Overhaul Interval in Hrs	0	
eduled & Maintenance Outage Hours		
Maintenance Outage	**11.12%**	
Forced Outage Hours/Year	2.72%	

jklein 5-22-09
KEMA has average, high and low values but this valuehas no effect on levelized costs.

This is because “Equipment Life” is a redundant input not used by CoG for its calculations. Instead, the controlling input is “Economic/Book Life,” in Row 11 of the “Plant Type Assumptions” sheets. The high and low cases should be recalculated with modifications made to this value.

Cash Flow Accounting

A major flaw exists in CoG’s cash flow accounting that makes it inappropriate to compare between technologies. CoG levelizes the ***nominal*** cash flow necessary to meet O&M costs, fuel costs, debt service, taxes, etc. This has the effect that technologies with shorter economic lives, *ceteris paribus*, enjoy an artificial advantage over technologies with longer economic lives even when the real, inflation-adjusted net present value of their cash flows and generation are equivalent. Instead of levelizing nominal cash flows, CoG should levelize ***real*** cash flows. Southern California Edison noted this problem in a letter to the Energy Commission, date June 1, 2011. The next page reproduces a diagram provided by SCE to illustrate the error. It is disappointing that the most recent publicly available version of CoG has not been updated to reflect these comments, as this error contributed significantly to the overestimate of the cost of the AP 1000 in CoG 2009.

Figure 1

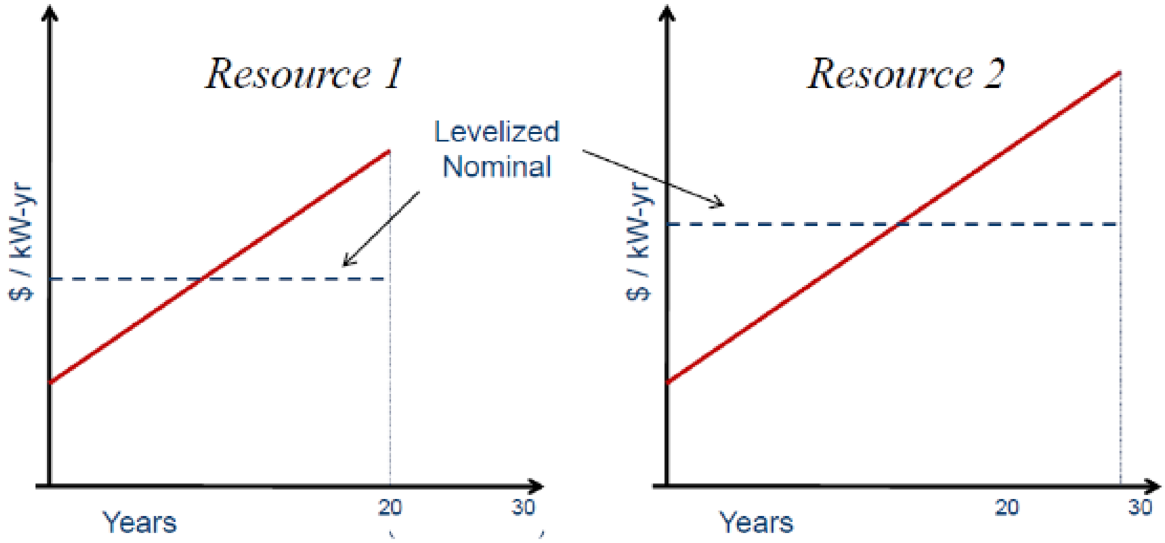
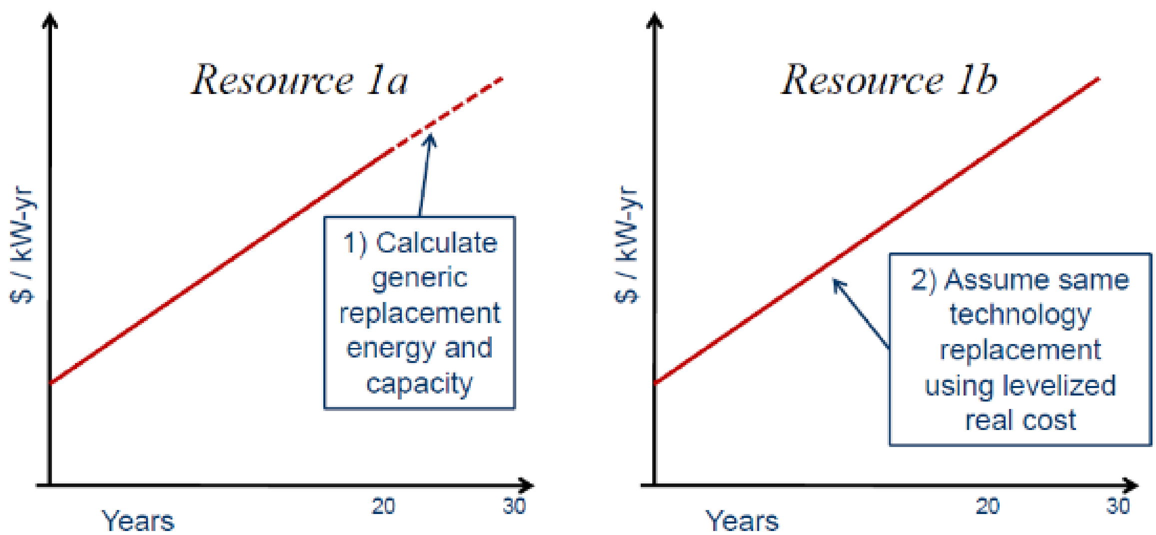


Figure 2



Source: Southern California Edison

Conclusion

The CoG 2009 analysis of the AP 1000 of new nuclear suffers from a number of deficiencies discussed above. It would be inappropriate for the Energy Commission to come to any conclusions about the future of nuclear power without first substantially revising the CoG analysis. The IEPR 2015 scope should call for public input on how to improve the analysis of the AP 1000 or other advanced reactors, as well as general methodology improvements.