The G4-ECONS Economic Evaluation Tool for Generation IV Reactor Systems

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INTRODUCTION

The six Generation IV reactor systems will ultimately be evaluated on the basis of safety, sustainability, nonproliferation attributes, technical readiness, and projected economics. In 2004 the Generation IV Economic Modeling Working Group (EMWG) commissioned the development of a Microsoft Excel-based model capable of calculating the Levelized Unit Electricity Cost (LUEC) in mills/kWh or $/MWh for multiple types of reactor systems being developed under the Generation IV Program. This model is now called G4-ECONS (Generation IV-Excel Calculation of Nuclear Systems) and is being expanded to calculate costs of energy products in addition to electricity, such as hydrogen and desalinated water. The cost estimating methodology and algorithms are explained in detail in the *Generation IV Cost Estimating Guidelines* [1], for which the latest revision resides on the Website http://www.gen-4.org/Technology/horizontal/economics.htm and in the *G4_ECONS User's Manual* [2]. The model was constructed with relatively simple economic algorithms such that it could be used by most any nation without regard to country-specific taxation, depreciation, or capital cost recovery methodologies. It was also designed with transparency to the user in mind (i.e., all algorithms and cell contents are visible to the user).

MODEL STRUCTURE

Each section of the model computes a component of the LUEC, which can be divided into four components: (1) recovery of capital (including financing costs), (2) nonfuel operations and maintenance (O&M) costs, (3) fuel cycle costs, and (4) funding of decontamination and decommissioning (D&D) costs via an escrow fund. All costs are calculated on a constant-dollar levelized annual cost basis, and it is assumed that capital and financing costs are repaid over the operating life of the plant. Annual electrical production is also considered at a constant value over the life of the plant. Each component of the LUEC is calculated by dividing the annualized ($M/year) cost for that component by the annual production (kWh/year). An average capacity factor is also assumed over the life of the plant to relate electrical energy production (plant performance) to the net installed capacity of the plant.

The capital cost inputs can be entered at the subsystem level [i.e., separate cost (code-of-accounts) lines for the civil, nuclear island, electrical, heat management, and other subsystems]. If these subsystem costs can be linked to a separate reactor design/cost scaling model, G4-ECONS can be used in conjunction with an optimization tool to minimize the LUEC for a given reactor technology concept. It is the intent of the EMWG that this model be so used by the design teams for the six reactor systems as well as providing a "level playing field" means of comparing the six concepts. Nonfuel O&M costs are also assigned specific cost code-of-accounts categories, such as staffing, regulation, maintenance, overhead, etc., for data input. The fuel cycle cost calculation is a bit more complex and is described in a separate paper [3] by this author and D. Shropshire, also prepared for this meeting. The D&D cost is annualized by use of a sinking fund calculation, with the calculated annual payment based on the projected D&D funding requirement at end of life and the discount rate. Financing costs are dependent on the capital spending profile, which is assumed to be an S-curve for cumulative capital expenditure over some input number of years for design, construction, and startup. The S-curve algorithm calculates the overall interest during construction, which must be added to the "overnight" capital cost to obtain a total capitalized cost. Capital recovery/annualization is accomplished by use of a fixed charge rate, which depends on the discount rate and the plant operating life.

The G4-ECONS model has been tested on the following systems for which cost input was available—the System 80+ pressurized-water reactor (PWR), a Massachusetts Institute of Technology (MIT) design for a pebble-bed modular reactor (PBMR), and the Japanese Sodium-Cooled Fast Reactor (JSFR). It can also be used to evaluate small and medium reactor concepts. The G4-ECONS model will be demonstrated at the ANS June meeting session.

EXAMPLE RESULT

Table I shows actual output results for the PWR that was used to "benchmark" the model. [A light-water reactor (LWR) was used to benchmark the model because the most detailed cost information was available at the subsystem level for this technology.]

Table I. G4-ECONS Output Table for Typical PWR (Year 2001 Fuel Cycle Prices)[a]

Summary of Model Results		
Discount Rate = 10%		
	Annualized Cost in $M/Year	Mills/kWh or $/MWh
Capital (including first core and financing)	327.19	35.91
Operations cost	78.47	8.61
Fuel cycle—front end	29.07	3.19
Fuel cycle—back end	9.90	1.09
D&D sinking fund	0.68	0.07
TOTAL LUEC	**445.31**	**48.88**

[a]Constant 2001 dollars.

REFERENCES

1. "Cost Estimating Guidelines for Generation IV Nuclear Energy Systems–Rev. 3"; Generation IV Economic Modeling Working Group (November 30, 2006); http://www.gen-4.org/Technology/horizontal/economics.htm.
2. *A User's Manual for G4-ECONS*. Generation IV Economic Modeling Working Group (May 2006); (to be issued along with G4-ECONS software in 2007).
3. WILLIAMS, K. A. and SHROPSHIRE, D. E., "Fuel Cycle Economic Analysis Using an Excel Spreadsheet," ANS Summer Meeting, Boston, MA (June 24–28, 2007) to be published.