Allocating Costs for Non-Electricity Products from Generation IV Nuclear Energy Systems

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Economic Modeling Working Group (EMWG)
Generation IV International Forum (GIF)

GIF has two economic goals:

(1) **Minimize Levelized Unit Energy Costs (LUEC):** This favors large units with economies of scale.

(2) **Minimize Capital-at-Risk**, i.e., investment before commercial operation: This rewards smaller units that require less capital.

(EMWG-GIF) Cost Estimating Guidelines

is based on

Delene and Hudson, *Cost Estimating Guidelines for Advanced Nuclear Reactors*, Oak Ridge National Laboratory (1993) ORNL/TM-10071/R, and on

Engineering Economic Data Base (EEDB):

United Engineers and Constructors Inc, *Report for the Energy Economic Data Base Program*, Oak Ridge National Laboratory, July 1988: DOE/NE-0091

International Atomic Energy Agency's Code Of Accounts

The IAEA has developed its own account system: *Economic Evaluation of Bids for Nuclear Power Plants: 1999 Edition* (Technical Reports Series No. 396).

IAEA adopted the EEDB for capital costs and develops additional codes for O&M, fuel cycle services, and other parts of a nuclear energy system life cycle.

IAEA and EMWG-GIF Code Of Accounts

The EMWG-GIF COA is a slight modification of the IAEA's code of accounting system.

It is generally published in its "two-digit" format, where costs are rolled-up at the level of major subsystems.

It can be used to organize a cost estimate prepared using either a bottom-up or top-down approach.

EMWG-GIF ***Cost Estimating Guidelines*** Code of Accounts for Joint Production

The *Cost Estimating Guidelines* addressed the cost allocation of joint costs for nuclear, non-electric products in Chapter 10, “Unit Cost Calculations for Non-Electricity Products”

Cost Allocation Only Required for Non-Competitive Market Products

Electricity: The opportunity cost of electricity is the price on the grid in a competitive electricity market.

Hydrogen: Hydrogen could have a market price if there is a transmission pipeline.

Water, Process Heat, and Actinide Management: These are not usually traded in markets, so cost allocation guidelines should be followed.

Allocating Joint Costs in the ***Cost Estimating Guidelines***

EMWG-GIF *Cost Estimating Guidelines* on joint production follow "Power Credit" method in IAEA's DEEP (Desalination Economic Evaluation Program) as in IAEA, *Introduction of Nuclear Desalination: A Guidebook* (2000).

IAEA DEEP Application

- Here, we provide an example following DEEP's the "Power Credit" method
- We compare a PWR (System 80+) with an MHR (a General Atomics' Gas Reactor)
- We compare Reverse Osmosis (RO) with Multi-Effect Distillation (MED)
- Desalination plant uses only 2% of nuclear plant's electricity capacity (MED uses more heat than RO)

Comparing MHR with PWR in DEEP: Inputs see Rothwell (2007)

DEEP energy plant production and cost data		**MHR**	**PWR**
Net Electric Power	MW	1,145	1,256
Gross Thermal Power	MW	2,400	3,817
Specific construction cost	$/kW	$1,087	$1,669
Energy plant contingency factor	%	15%	10%
Construction lead time	months	60	72
Total specific construction cost	$/kW	$1,250	$1,836
Total construction cost	M$	$1,431	$2,306
Interest during construction (IDC) at 10%	M$	$385	$763
Total plant investment	M$	$1,775	$3,069
Specific investment cost	**$/kW**	**$1,550**	**$2,444**
Specific O&M cost	$/MWh	$3.34	$7.50
Annual levelized decommissioning cost	M$/a	$54	$94

Comparing MHR with PWR in DEEP: Outputs (values calculated by DEEP)

Cost of Capital	**10%**				
Specific Water Costs		**MHR RO**	**MHR MED**	**PWR RO**	**PWR MED**
Fixed charge cost	**$/m3**	0.537	0.533	0.537	0.533
Heat cost	**$/m3**				0.248
Plant electricity cost	**$/m3**	0.111	0.106	0.162	0.155
O&M cost	**$/m3**	0.170	0.129	0.170	0.129
Total Specific Water Cost (COW)	**$/m3**	**$0.818**	**$0.769**	**$0.869**	**$1.066**
Levelized Electricity Cost	**$/MWh**	**$36.88**	**$36.88**	**$53.70**	**$53.70**

Comments on MHR vs. PWR in DEEP

- The fixed charge for the cost of water is for desalination equipment only (because it is the same across reactor type)
- PWR+MED much more expensive than MHR+MED because of the lack of "free" waste heat from the PWR for multi-effect distillation.

IAEA's "Power Credit" method for Allocating Costs in Joint Production

The IAEA DEEP Program calculates the cost of water and power for single (1), as well as dual (2)-purpose plants, using the "Power Credit" method.

It is based on the comparison between the 2-purpose plant and an imaginary reference 1-purpose power plant using an identical primary heat source, e.g., nuclear reactor.

Power Credit method (Step 1)

Step 1: Calculate total cost (COST1) and total energy output (ENERGY1) for a hypothetical 1-purpose plant.

Calculate average cost (**AC1**) for the energy product (or use market price):

AC1 = COST1 / ENERGY1

Power Credit Method (Step 1 Example)

Step 1: Comparing electricity and desalinated water from PWR and MHR (note Capacity Factor =90%):

AC1(MHR) = $36.88/MWh

COST1(MHR) = $38,000/hour

ENERGY1(MHR) = 1030 MW

AC1(PWR) = $53.70/MWh

COST1(PWR) = $60,700/hour

ENERGY1(PWR) = 1130 MW

Power Credit method (Step 2)

Step 2: Calculate for the 2-purpose plant

(1) **total costs (COST2)** and

(2) total multiple outputs:

(2.1) **energy outputs (ENERGY2)**

(2.2) **and quantity of other product (Q)**

Power Credit method (Step 2 Example)

Step 2: Calculate for the 2-purpose plant (MWh+RO)

(1) Total Costs (COST2)

COST2(MHR) = $43,700/hour

COST2(PWR) = $66,400/hour

(2) **Quantity of Water (Q) = 7,900 m^3/hour**

ENERGY2(MHR) = 98%ENERGY1(MHR)

ENERGY2(PWR) = 98%ENERGY1(PWR)

Power Credit method (Step 3)

Step 3: Calculate Power Credit (**PC**) equal to the value of the energy (**ENERGY2**) evaluated at average cost, **AC1**:

PC = ENERGY2 x AC1

Power Credit method (Step 3 Example)

Step 3: Calculate Power Credit (PC) for RO

PC = ENERGY2 x (COST1 / ENERGY1)

PC = (ENERGY2 / ENERGY1) x COST1

PC = 98% x COST1

(desalination only requires 2% of plant electricity capacity)

PC(MHR) = 98% x $38,000/hour = $37,250/hour

PC(PWR) = 98% x $60,700/hour = $59,500/hour

Power Credit method (Step 4)

Step 4: Calculate the average cost of the other product (e.g., water):

$$\mathbf{AC_Q = [COST2 - PC] / Q}$$

The cost of energy is AC1, as for the 1-purpose plant.

All savings in joint production are assigned to the "other product," e.g., desalted water.

So electricity customers could be subsidizing water customers.

Power Credit method (Step 4 Example)

Step 4: Calculate the average cost of the other product (e.g., the cost of water, COW):

AC_Q(MHR) = **($43,700/hour – $37,250/hour)/7,900m^3/h**
= **$0.818/m^3**

AC_Q(PWR) = ($66,365/hour – $59,500/hour)/7,900m^3/hour
= $0.869/m^3

COW(from MHR) ± 5% = COW(from PWR) ± 5%

Levelized Unit Energy Cost (LUEC)

So that AC = LUEC, substitute

(1) **total discounted cost** for the 1-purpose plant for COST1 and **total discounted cost** for the 2-purpose plant for COST2.

(2) **total discounted energy output** for the 1-purpose plant for E1 and **total discounted energy output** for the 2-purpose plant for ENERGY2.

(3) total **discounted non-energy output** for the 2-purpose plant for Q.

Levelized Unit Product Cost (LUPC)

LUPC (e.g. COW)

$$= \frac{[\text{COST2} - (\text{ENERGY2} \times \text{LUEC})]}{Q}$$

Alternative LUPC (e.g. COW)

$$= \frac{[\text{COST2} - (\text{ENERGY2} \times P)]}{Q}$$

where P is the market price of electricity

REFERENCES

Economic Modeling Working Group (EMWG). *Cost Estimating Guidelines for Energy Systems*. Generation IV International Forum (GIF) (Sept. 2003, updated Oct. 2006).

Rothwell, Geoffrey and Kent Williams, “Is Nuclear Power Competitive Producing Electricity or Hydrogen?” with Kent Williams. *International Journal of Nuclear Hydrogen Production and Applications* 1, 2 (2006).

Rothwell, Geoffrey, “IAEA’s DEEP in Carlsbad: Co-Producing Energy and Water in Southern California,” *International Journal of Nuclear Desalination* (2007).