Generation Life Cycle Cost - IRP 2010 Input Parameter information sheet (Supply input) – provide a unique sheet per technology

This sheet is to be used as the primary stakeholder engagement tool. This document provides the information that will allow the stakeholders to make a meaningful contribution to the IRP Input parameters

<table>
<tr><td>Parameter</td><td>Generation Life Cycle Cost (GLCC)</td></tr>
<tr><td>Purpose</td><td>Is used to normalise the cost of various generating options so that their costs can be compared and evaluated for screening purposes.

Note: In the final modelling process actual costs are used.

Levelised energy cost (LEC, also called Levelised Cost Of Energy or LCOE) is a cost of generating electricity for a particular system. It is an economic assessment of the cost of the energy-generating system including all the costs over its lifetime: initial investment, operations and maintenance, cost of fuel, cost of capital. A net present value calculation is performed and solved in such a way that for the value of the LEC chosen, the project's net present value becomes zero.

This means that the LEC is the minimum price at which energy must be sold for an energy project to break even.

It can be defined in a single formula as:

$$\mathrm{LEC} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where

▪ LEC = Average lifetime levelised electricity generation cost
▪ It = Investment expenditures in the year t
▪ Mt = Operations and maintenance expenditures in the year t
▪ Ft = Fuel expenditures in the year t
▪ Et = Electricity generation in the year t
▪ r = Discount rate</td></tr>
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	▪ *n* = Life of the system Typically LECs are calculated over 20 to 40 year lifetimes, and are given in the units of currency per kilowatt-hour, for example USD/kWh or EUR/kWh or per megawatt-hour. When comparing LECs for alternative systems, it is very important to define the boundaries of the 'system' and the costs that are included in it. For example, should transmissions lines and distribution systems be included in the cost? Should R&D, tax, and environmental impact studies be included? Should the costs of impacts on public health and environmental damage be included? Should the costs of government subsidies be included in the calculated LEC? Another key issue is the decision about the value of the discount rate *r* (discussed in the Discount Rate fact sheet). The value that is chosen for *r* can often 'weight' the decision towards one option or another, so the basis for choosing the discount must clearly be carefully evaluated
Impact on the IRP	In this IRP this parameter reflects the real costs of generation plant and includes the following aspects: • Initial capital investment cost (including associated economic and financial parameters thereof); • Lead time; • Phasing of expenditure; • Economic life of the technology; • Long term operation and maintenance; • Long term cost of primary energy including such factors as escalation of costs and impact of plant aging on efficiency; • Availability and maintenance (covers the half life of plant) and its specific environmental performance; and • Transmission and (possibly) Distribution (excluding “backbone” costs). This parameter applies to all forms of generation considered in the IRP studies. The following are the types of generation technologies that could be considered for inclusion in IRP 2010:

- Coal - Pulverised Fuel, Fluidised Bed Combustion, Underground Coal Gasification Combined Cycle Gas Turbine, Coal Bed Methane.
- Gas -Open Cycle Gas Turbine, Open Cycle Gas Turbine conversion, Combined Cycle Gas Turbine
- Hydro - Pumped Storage and Pond Hydro
- Nuclear - Pressurised Water Reactor, Advanced Reactors (PBMR)
- Renewable Energy Technologies - Wind, Concentrated Solar Power tower/trough with and without storage, Solar PV thin film, Solar Concentrating PV, Biomass, Biogas, Landfill gas.

All these cost aspects are required to produce an optimal plan for the Country.

In this case optimal is defined as least total cost to the customer given the reliability, policy and strategic/scenario constraints.

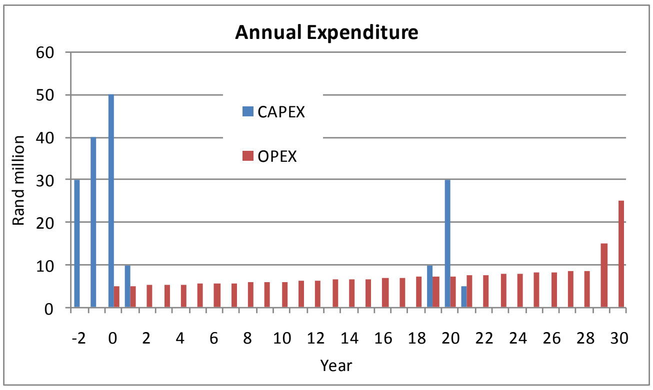
The GLCC is used to establish what is known as the screening curves, which determine the Levelised Cycle Costs of any generator as a function of generating plant characteristics (GLCC, plant efficiency, plant maintenance and fuel) and utilization level (capacity factors).

In addition to direct cost parameters, aspects such as lead-time and environmental performance could impact on the selection and timing of options to be included in the IRP plan.

Screening Curves

Firstly the actual cash flow patterns are transformed into an even (levelised) cash-flow pattern. Which enable different technology curves.

From



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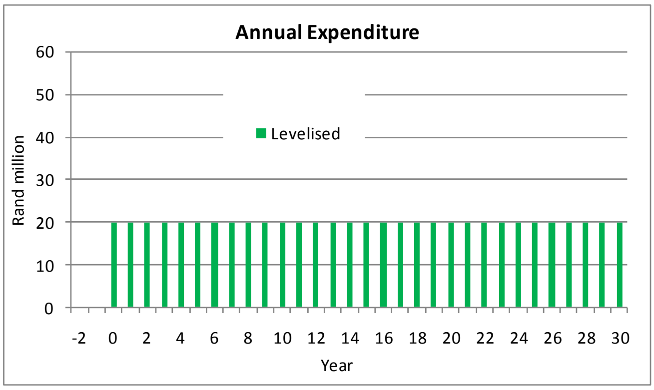
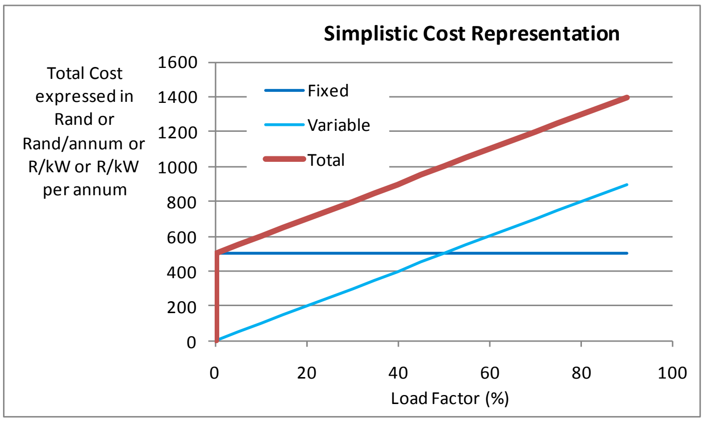


The above transformation from uneven annual expenditures to even amounts (in real terms) is done:

- Such that the Present Value of both cash flow streams are equal to zero
- Levelised cash flow stream always starts when the asset is taken into commercial service and ends when the asset is decommissioned
- To also accommodate uneven expected output/annum of production facility

After the above transformation, the GLCC of a generation facility can be expressed in Screening Curves.

From



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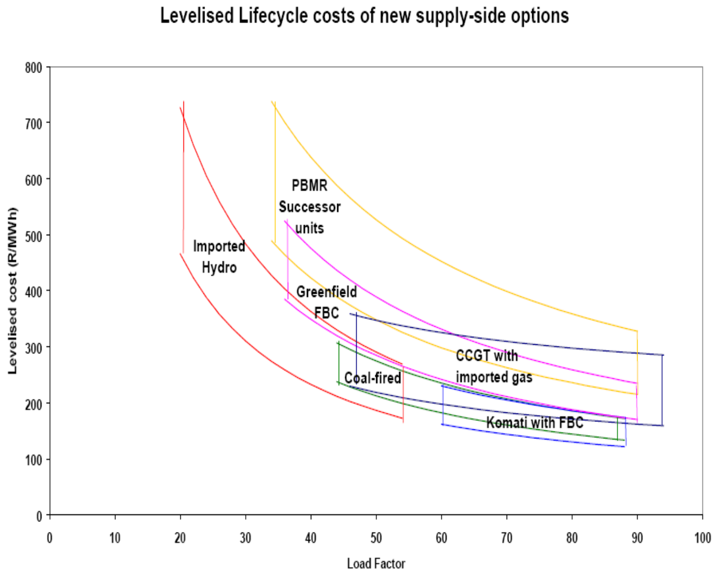


The Load Factor represents the extent to which the production facility is utilised.

Load Factor of a Production Facility (Generator)

= Expected Output (MWh) / (Maximum Continuous Rating (MW) x hours in period)

Assumptions included in establishing the parameter values in this sheet

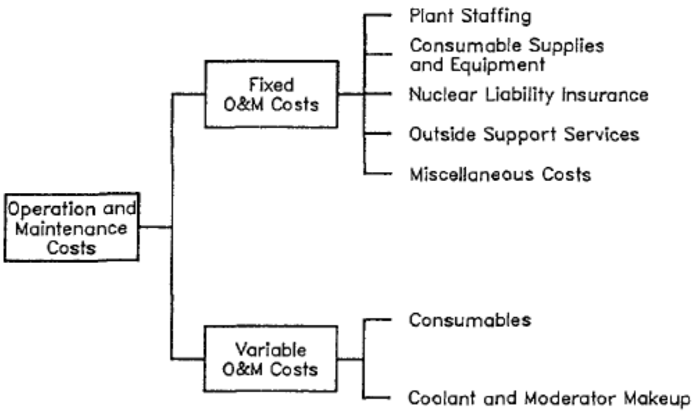
In general the assumptions for capital investment cost will be dependent on the following aspects:

- Source of supply, e.g. Asia, US, Europe;
- Length of construction schedule;
- Foreign versus local content;
- Site meteorological conditions;
- Funding packages;
- Proximity to load centres;
- Sophistication of technology;
- Procurement strategy; and
- Operating regime.

Operation and maintenance are generally divided in fixed and variable cost component and include all non-fuel costs that are not included in the fixed cost category. The key assumptions in establishing this parameter will depend on following:

- Size and type of plant;
- Direct and indirect cost of labour;

- Cost of all other material other than fuel consumed during the operation of the plant (e.g. cost of sorbent used in a sulphur removal system);
- Outside support services;
- Decommissioning costs;
- Diversity of primary energy sources;
- Proximity of the fuel source;
- Nature of the fuel purchase contract and the link to foreign currency; and
- Operating regime.



The illustrations above shows the O&M split for a nuclear plant.

Fuel costs and fuel cycle costs assumptions refer to the costs that must be recovered in order to meet all expenses associated with consuming and owning fuel in a power plant. There is however a difference between conventional (e.g. gas, oil, coal, etc) and nuclear fuel. Conventional fuel is essentially consumed in a single batch whilst a single batch of nuclear fuel maybe used in a reactor for several years and then recycled. There are also many nuclear fuel cycles and each of these maybe composed of a large number of time dependent steps such as mining, milling, conversion, enrichment, fabrication, irradiation, storage, shipping, reprocessing and waste disposal. The illustration below reflects the breakdown of nuclear fuel cycle cost.

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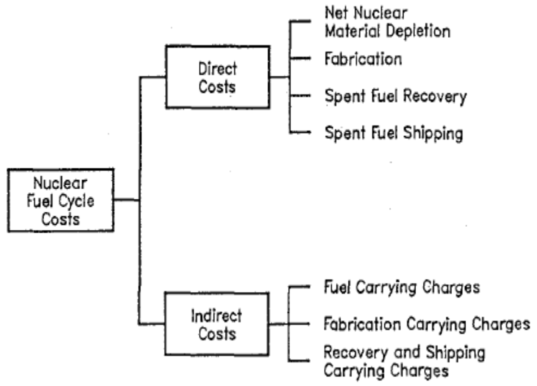

The direct cost in the illustration refers to expenses of materials, processes and services required to put the fuel into a form in which energy can be extracted. Indirect costs refer to interest/carrying charges on investments and they are the result of the time separation between expenditures for fuel and revenues from the energy generated from the fuel. As an example fuel used for in a light water reactor is typically irradiated for three years and is then stored for at the reactor site for another multi year period. The time-lags between fuel cycle operations are what lead to extensive carrying charges. For conventional fuels such as coal, oil, and gas stock piling may also lead to significant carrying charges.

The assumptions of plant performance parameters will depend on the following:

Location, e.g. inland vs. coastal;
Altitude;
Ambient temperature; and
Operating regime.

The range of environmental performance parameters will depend mainly on the extent to which environmental control measures will be applied, e.g. Flue Gas Desulphurisation and Carbon Capture and Storage facilities.

Normally only the transmission facilities established specifically for the generation resource is included in the cost of the facility. This excludes any “backbone” and other strengthening type transmission facilities.

Generation facilities embedded in the distribution system, e.g. small wind generators, may need specific distribution facilities to be established. In this case the same principles as for transmission facilities will apply.
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<td>Parameter Value</td>
<td>Actual values used are still be defined and will be complete by the end of May. Stakeholders are invited to submit costs curves to the modelling team in the interim. Examples are given below. For this IRP purposes the GLCC data used will be collected</td>
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	from international sources and will be adapted for RSA conditions.
Range of Parameter Value	The different sources of the GLCC data will lead to a wide range of possible values. *Note: The values recommended to be used for IRP 2010 will be distributed not later than mid May.* **Notwithstanding, stakeholders are invited to submit their recommendations with motivations.** A summarised statistical analysis of 11 reputable independent studies in the USA , see table below, illustrates the typical values that can be expected:

Technology	Range of Values			Median			Multiple of Ave Least Cost
	Min	Max	Max/Min	Low	High	Ave	
Natural Gas converted to electrical energy at site	3.3	11.0	3.3	4.2	6.2	5.2	1.00
Coal Integrated gasification combined cycle (IGCC)	3.5	9.7	2.8	5.5	5.5	5.5	1.06
Pulverised Coal (PF)	1.8	12.6	7.0	4.5	6.7	5.6	1.08
Geothermal	2.7	11.4	4.2	6.5	6.5	6.5	1.25
Wind (onshore)	3.6	14.5	4.0	6.6	6.6	6.6	1.27
Hydro (small)	3.9	11.7	3.0	7.2	8.1	7.7	1.47
Coal+Carbon Capture and Storage	3.1	12.6	4.1	6.7	9.4	8.1	1.55
Hydro (river)	4.6	17.5	3.8	4.6	11.6	8.1	1.56
Wind (offshore)	5.7	23.5	4.1	11.2	11.3	11.3	2.16
Biomass	8.0	14.6	1.8	11.0	11.0	11.0	2.12
Hydro (large)	2.7	17.2	6.4	5.2	17.2	11.2	2.15
Nuclear	2.7	30.2	11.2	6.3	30.2	18.3	3.51
Wave	9.8	63.1	6.4	18.0	29.0	23.5	4.52
Solar Thermal	15.9	29.4	1.8	18.5	29.4	23.9	4.60
Solar Photo Voltaic	13.9	103.2	7.4	25.0	33.5	29.3	5.63
Tidal	11.8	123.2	10.4	29.4	32.3	30.9	5.93
Concentrated Solar Photovoltaic	15.9	103.2	6.5	15.9	59.2	37.6	7.22

Real 2009 US dollars, inflation- and PPP- adjusted

The *Max/Min* values above illustrate the typical wide range of values. For example the max value for nuclear is 11.2 times the min value. The Multiple *of Ave Least Cost* is the relative cost of the various options from the lowest cost (1) to the most expensive (7.22). For example Concentrated Solar Photovoltaic is 7.22 times more expensive than Natural Gas converted to electrical energy at site.

Preconditions necessary to make possible for this parameter to be included in the IRP	Preconditions necessary to make possible for this parameter to be included in the IRP 2010 are: • Technology maturity • Developmental state of the project • Government policy • Government approval

Parameter Owner	DOE with input from the SO Planning function