

**International Atomic Energy Agency**

# **NPP Costs (Capital, O&M and Fuel Costs) Calculation of LUEC**

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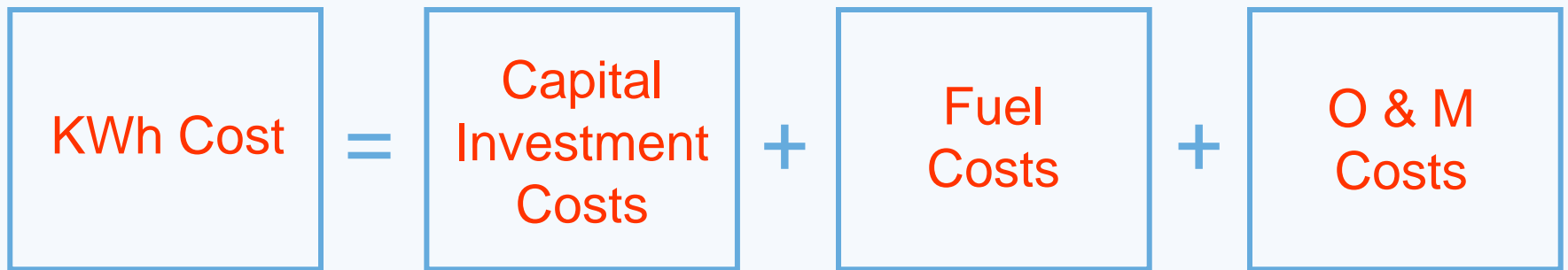


**EMPRESARIOS AGRUPADOS**

*Engineers and Consultants*

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Nuclear Power Plant Technology Assessment  
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## KWh Cost Components



# Capital Investment Costs (1 of 5)

• **Base Costs** = Direct Costs + Indirect Costs

• **Fore Costs** = Base Costs +  $\left\{ \begin{array}{c} \text{Supplementary Costs} \\ + \\ \text{Owner's Capital Investment and Services Costs} \end{array} \right\}$   
(or "Overnight Costs")

• **Total Capital Investment Costs (TCIC)** = Fore Costs +  $\left\{ \begin{array}{c} \text{Escalation Costs} \\ + \\ \text{IDC} \\ + \\ \text{Insurance and} \\ \text{Financial Fees} \end{array} \right\}$

## Capital Investment Costs (2 of 5)

### Total Capital Investment Costs (TCIC):

The total costs of engineering, equipment and materials, construction and commissioning for the complete plant

## Capital Investment Costs (3 of 5)

$$\text{Base Costs} = \text{Direct Costs} + \text{Indirect Costs}$$

◆ **Direct Costs:** Costs of all materials, equipment and labour directly associated with the fabrication, construction and installation of structures, systems and components that comprise the NPP

- Buildings and Structures
- Reactor Plant Equipment
- Turbine Generator Plant Equipment
- Electrical Equipment
- I&C Equipment
- Plant Cooling System Equipment
- Miscellaneous Plant Equipment
- Special Materials
- Simulator

◆ Items within these accounts include equipment, site labour and site materials costs



## Capital Investment Costs (4 of 5)

◆ **Indirect Costs:** Costs of engineering, construction and management services required to design and built structures and systems included in the direct costs accounts

- Engineering Services by Vendor and/or A/E
- Project Management Services by Vendor and/or A/E
- Construction Management by Vendor and/or A/E
- Construction Labour by Vendor, A/E and/or Construction Companies
- Commissioning Management by Vendor and/or A/E
- Auxiliary Construction facilities, tools and materials at site
- Owner's personnel training
- Housing and related infrastructure



## Capital Investment Costs (5 of 5)

### ◆ Supplementary Costs:

- Transportation and Transportation Insurance
- Contingencies
- Spare Parts
- Insurance
- Decommissioning Costs (if not included in O&M costs)

### ◆ Financial Costs:

- Escalations Costs
- Interest During Construction (IDC)
- ECA Insurance Premium,

### ◆ Owners Costs:

- Owner's Capital Investment Costs
- Owner's Services Costs
- Escalation of Owner's Costs
- Financing Costs of Owner's Cost



## NPP Cost Account Systems

- ◆ Comprehensive **Code of Accounts** addressing the full spectrum of NPP costs, **including:**
  - **Capital Investment Costs**
  - **Fuel Cycle Costs**
  - **O & M Costs**
- ◆ Cover all NPP cost items down to individual structures, systems, components and services.
- ◆ Facilitate cost categorization and can be used as a check list for cost calculations
- ◆ Two widely used Cost Account Systems are:
  - **IAEA Account System**
  - **US DOE Energy Economic Data Base (EEDB) Code of Accounts**



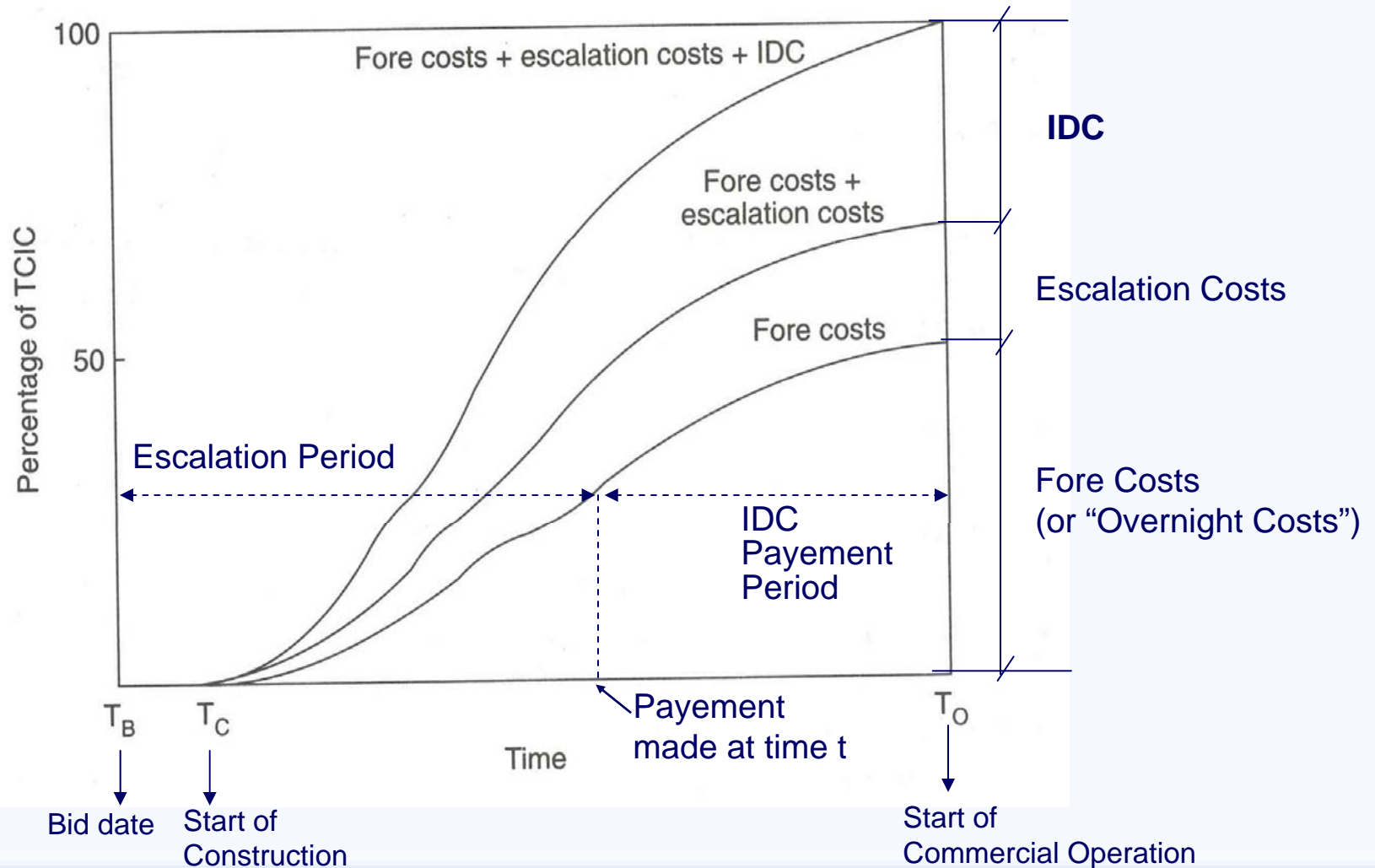
## Levelized Unit Energy Costs (LUEC) (1 of 2)

- ◆ **LUEC:** Is the recommended and most widely used method of calculating the unit energy (KWh) costs of an electricity generating plant.
- ◆ **LUEC:** The rate at which each KWh produced must be sold in order to recover exactly the total plant lifetime costs
- ◆  $LUEC \times PW (\text{Energy Generated}) = PW (\text{TCIC}) + PW (\text{O\&M costs}) + PW (\text{Fuel Costs})$

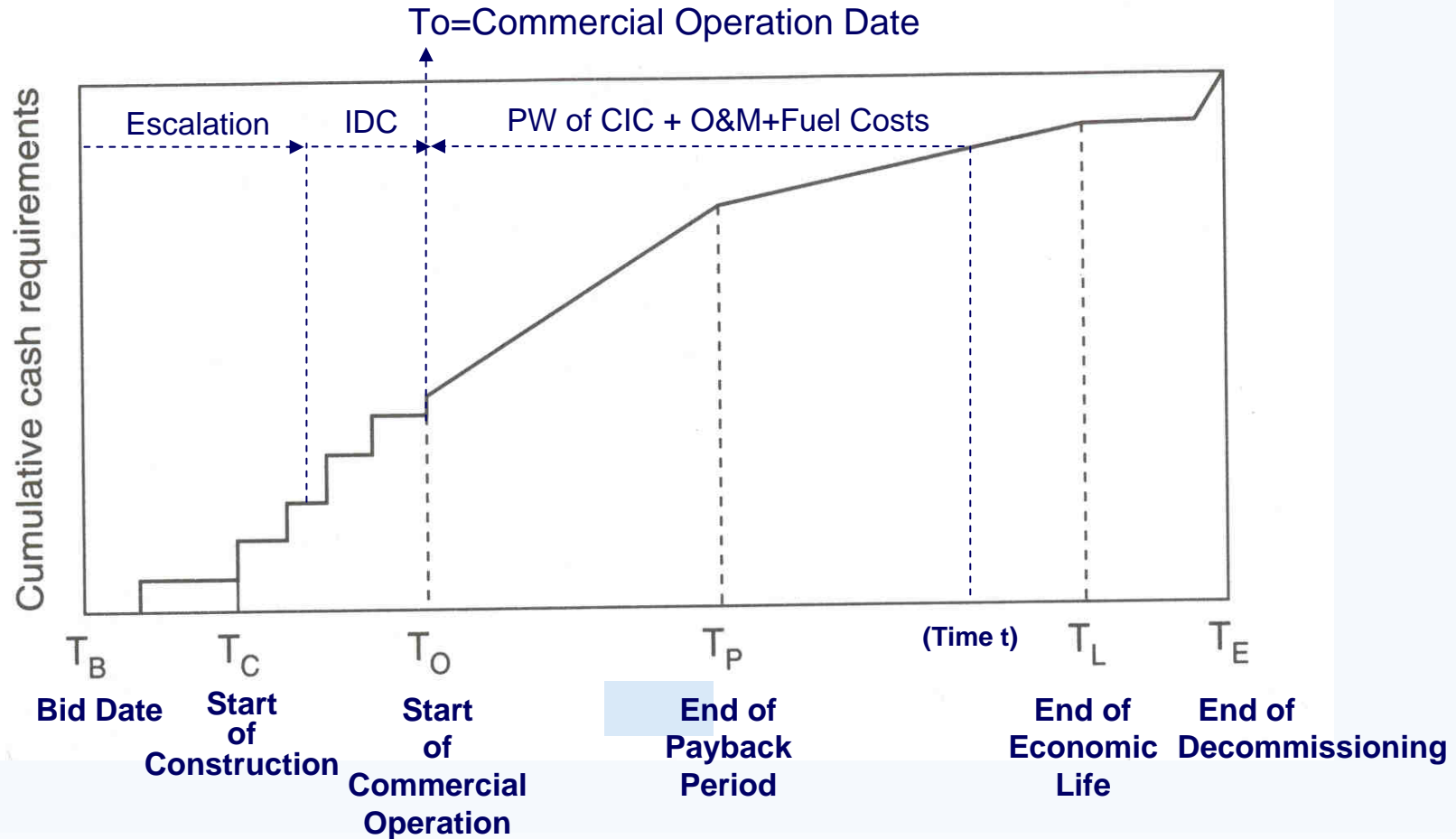
$$LUEC = \frac{PW (\text{TCIC}) + PW (\text{O\&M costs}) + PW (\text{Fuel Costs})}{PW (\text{Energy Generated})}$$

- ◆ When each unit of electricity produced is sold at the LUEC monetary units, the summ of present worths (PW) value of lifetime electricity revenues will be equal to the summ of PW values of lifetime costs incurred in implementation and operation of the plant

# Cumulative Costs of TCIC cash flow streams



# Cumulative cash requirements



## Levelized Unit Energy Costs (LUEC) (2 of 2)

$$\sum PW(\text{Lifetime\_Electricity\_Sale\_revenues}) = \sum PW(\text{Lifetime\_Costs})$$

$$\sum_{t=T_0}^{T_L} \frac{(LUEC) * (kWh)_t}{(1+d)^{t-T_D}} = \sum_{t=T_D}^{T_E} \frac{(TCIC)_t}{(1+d)^{t-T_D}} + \frac{(O\&M\_Costs)_t}{(1+d)^{t-T_D}} + \frac{(Fuel\_Costs)_t}{(1+d)^{t-T_D}}$$

$$LUEC = \frac{\sum_{t=T_D}^{T_E} \frac{(TCIC)_t + (O\&M\_Costs)_t + (Fuel\_Costs)_t}{(1+d)^{t-T_D}}}{\sum_{t=T_0}^{T_L} \frac{(kWh)_t}{(1+d)^{t-T_D}}}$$

$(TCIC)_t$  = TCIC in year t

$(O\&M\ Costs)_t$  O&M cost in year t

$(Fuel\ Costs)_t$  Fuel Costs in year t

$(KWh)_t$ : KWh produced in year

d = Discount rate

$T_B$  = Bid date

$T_D$  = Date to which discount is performed

$T_O$  = Date of commercial operation

$T_L$  = Date of end of plant life

$T_E$  = Date of end of decommissioning



## Fuel Costs

Fuel costs include the costs of the front and back end of the fuel cycle

- Fuel Supply, first core
- Fuel Services, first core
- Fuel Supply, reloads
- Fuel Services, reloads
- Heavy Water supply
- Heavy Water replacements
- Reprocessing Costs
- Final Fuel Disposal (no reprocessing)
- Financial Costs of the fuel cycle



## O&M Costs

[ O&M costs include all non-fuel operation and maintenance costs ]

O&M costs are generally divided into:

- **O&M fixed costs:** invariant with plant electricity production
- **O&M variable costs:** incurred as a consequence of plant operation

### O&M Costs

- Wages
- Consumables
- Repairs & Replacements
- Purchased O&M services
- Insurance and taxes
- Fees and Inspection expenses
- Decommissioning allowances
- Radioactive Wasted Management

## Main factors influencing the KWh cost

- Bid prices
- + or - costs from bids equalization resulting from technical bid evaluation
- BOP cost estimates (items not included in the bid price)
- Commercial and contractual terms and conditions
- Economic parameters used for cost calculations
- Financing terms and conditions
- Construction schedule
- Plant power output
- Load factor, each year
- Number of operating hours and Plant load schedule, each year
- Fuel bid prices (initial core plus some reloads)
- O&M cost estimate
- Fuel back end cost estimate (spent fuel management & decommissioning)
- Owner's costs

## Main economic parameters to be defined for KWh cost evaluation

- Escalation and interest rates
- Inflation and discount rates
- Economic life (*Shorter than the plant design life*)
- Reference date prices (*Usually the bid date*)
- Date to which discounting is performed (*Usually commercial operation date*)
- Exchange rates of price currencies (*Single currency vs. Several currencies*)

## Plant Power Output and Load Factor

- Gross power output (MWe): at generator terminals
- Net power output (MWe): at main transformer HV terminals

$$\left[ \bullet \text{ Net power output} = \frac{\text{Gross power output} - \text{Auxiliary power consumption} - \text{Transformer losses}}{\text{Transformer losses}} \right]$$

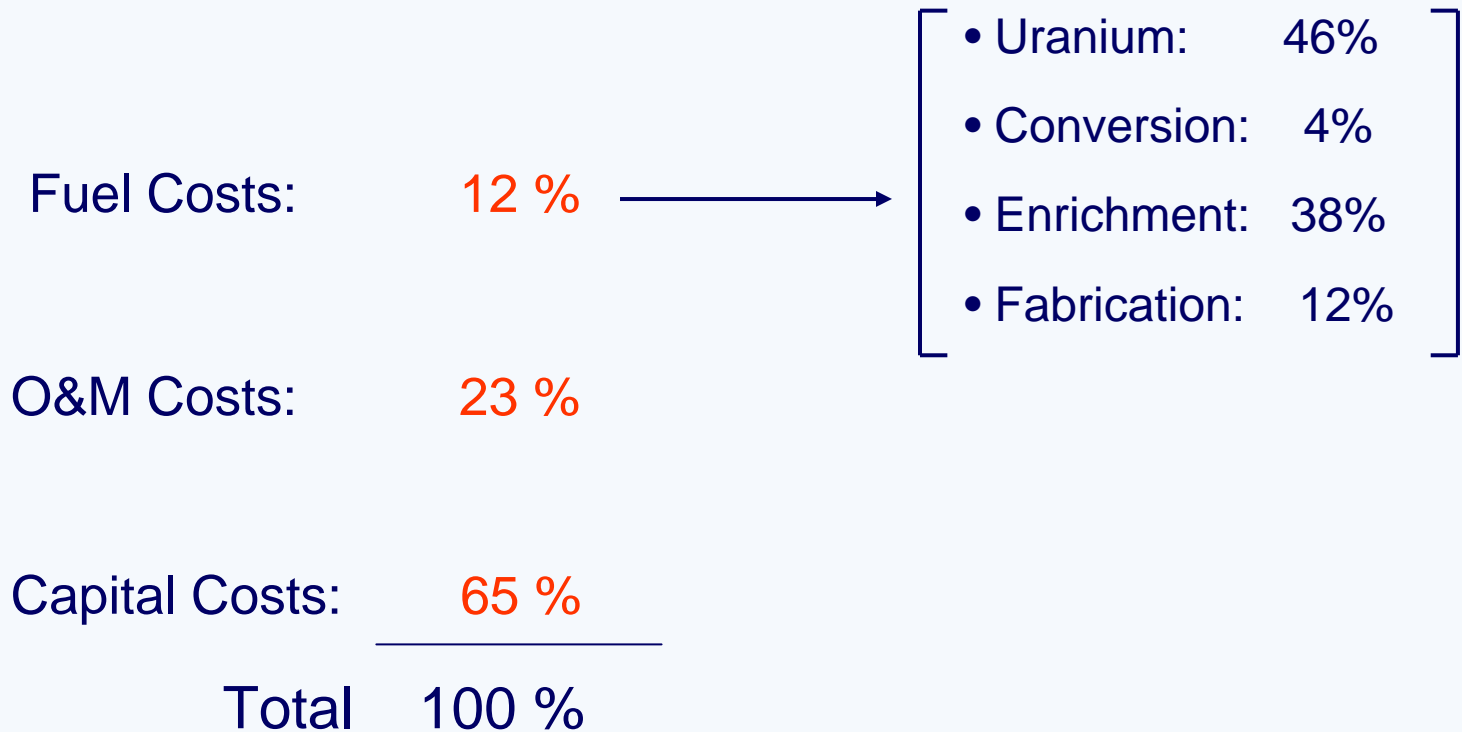
$$\left[ \bullet \text{ Load factor ( \% )} : \frac{\text{Net MWh produced in the reference period}}{\text{Net MWh that can be produced at 100\% net capacity}} \times 100 \right]$$

- KWh Cost calculation requires to define the load factor for each year during the plant economic lifetime

$$\left[ \bullet \text{ Net Plant Heat Rate} \left( \frac{\text{KJ}}{\text{KWh}} \right) = \frac{\text{Heat produced by fuel (KJ)}}{\text{Net KWh produced}} \right]$$



## Typical Nuclear KWh cost breakdown



(ALWR, 1200 : 1600 MWe)

## Reference NPP Costs

- Basis:

- Reactor type: ALWR, Generation III or III+
- Net power output: 1200 to 1600 Mwe range
- Good site without complicated site preparation
- Plant cooling system: natural draft cooling towers
- Vendor Standard Plant Design

- Approximate KW and KWh costs (year 2008) to be used just as a reference:

- Overnight Capital Costs (whitout Escalation and IDC) = **2600 to 3000 Euro/KW**
- Overnight Capital Cost for a 1500 MW unit = **4000 to 4500 Million Euros**
- Total KWh Costs (TCIC+O&M+Fuel) = **3.5-4.0 cents of Euro/KWh**
- Production Costs (O&M + Fuel costs only) = **1.2-1.4 cents of Euro/KWh**