ECONOMICS OF NUCLEAR REACTOR

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Points of Presentation:

- Government Commitment to NZE Target
- Structure of Electricity Generation Cost From Nuclear Power Plant (NPP)
- Levelized of Electricity Cost (LCOE) of NPP
- Funding of NPP Project

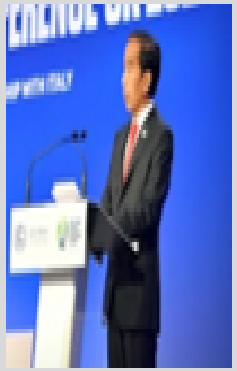
INDONESIA'S COMMITMENT TO REDUCE GHG

Energy Transition towards Renewables to reduce GHG and reach Net Zero Emissions

PRESIDENT'S DIRECTIVE

UNFCCC - COP21, DECEMBER 2015

Reducing GHG emission for 29% or **41%** (by international assistance) by **2030** based on NDC.



COP 26, 2 NOVEMBER 2021

Indonesia will be able to **contribute faster to the global Net-Zero Emissions. 2060 NZE Target**

G20 Presidency

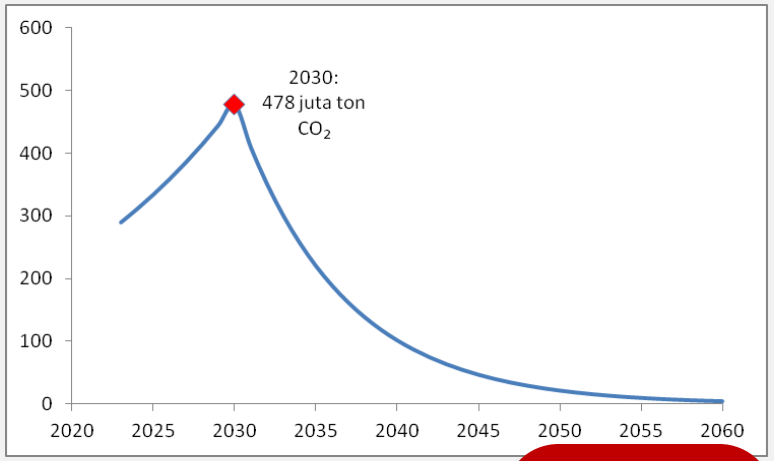
"Recover Together, Recover Stronger"

The focus of Indonesia's G20 Presidency lies on 3 main issues:

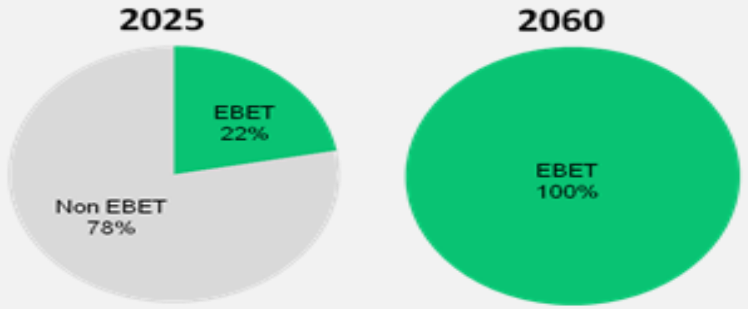
1. Inclusive Global Health,
2. Digital-Based Economic Transformation,
3. **Transition Towards Sustainable Energy.**

Government outlook: stated in the draft RUKN 2023–2060

Economic growth
6% p.a



2060
NZE

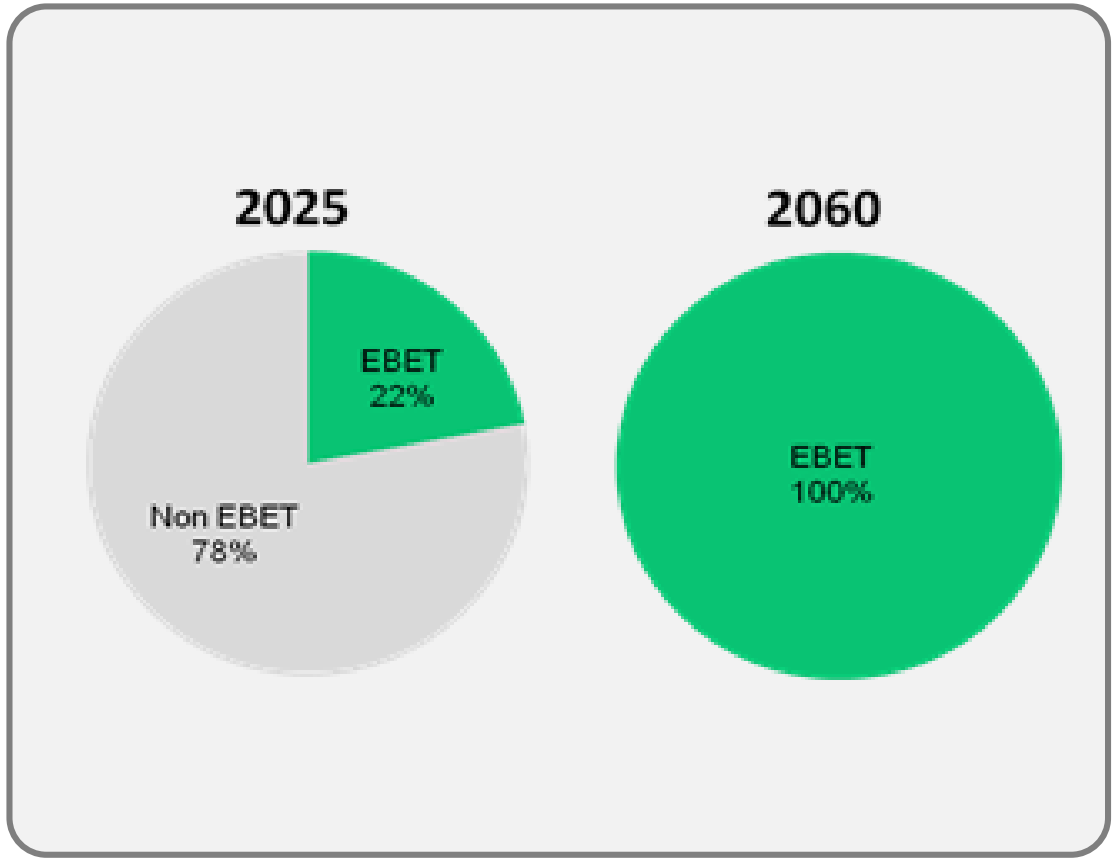


Pada tahun 2025, bauran EBET diperkirakan dapat mencapai 22% yang ditopang oleh *cofiring* biomasa dengan porsi rata-rata 5% pada seluruh PLTU kecuali IPP yang bekerjasama dengan PLN. Bauran EBET akan terus meningkat setelah 2025 dengan adanya pengembangan pembangkit EBET secara masif dan diperkirakan dapat mencapai 100% pada tahun 2060. Emisi CO2 tahun 2023 mencapai sekitar 290 juta ton CO2 dan mendekati tahun 2030 terjadi puncak emisi CO2 sebesar 478 juta ton CO2 kemudian akan terus turun pada tahun berikutnya. Pada tahun 2055, emisi pada pembangkitan tenaga listrik akan mendekati nol.

2023
379 TWh

2060
1849 TWh

Regarding NZE 2060 Target ….



Nuclear power plants (NPPs) are one option of New and Renewable Energy (NRE) to meet the NZE target.

NPP Target in Indonesia (still in RUKN draft)

4. Kapasitas pembangkit pada tahun 2060 diproyeksikan mencapai 722 GW. PLTS mendominasi kapasitas dengan porsi sekitar 64%. Kapasitas pembangkit energi baru seperti PLTN termasuk *Small Modular Reactor* (SMR) diproyeksikan sekitar 2% dari total kapasitas. Operasi komersial PLTN pertama kali mulai tahun 2032 sebesar 0,4 GW. Sisa 34% berasal dari pembangkit EBET lainnya seperti PLTA, PLTB, PLTBio, PLTAL, PLTP, Ammonia dan Hidrogen.

2060
722 GW

Solar PP
64%

Other NRE
34%

NPP
Max 2%

PLTN start small
2032: 400 MW

Up to

2060: 14 GW
2060

NPP's Project Characteristics

- ✓ Capital Intensive
- ✓ Long Lead time
- ✓ Quite high uncertainty

Indonesia has no experience in building NPPs, so the **project risks** (delays, cost overrun) **must be avoided**.

How to compare energy source options in electricity generation

Even though they serve the same output (electricity), each energy source is created differently.

- ❑Dispatchibility
- ❑Land use
- ❑Social impact
- ❑Environmental impact
- ❑Safety
- ❑Scarcity

So, What's the equivalent criteria? → LCOE

LCOE (levelized cost of electricity)

- The **unit cost at a constant generating level**, if **multiplied by electricity sales** during its **lifetime** will **cover all costs** incurred in the same period (break even).
- Assuming all cash flows are **brought to present value** and taking into account the **time value of money** (via discount rate)
- **Allows comparison of different energy technologies**, regardless of differences: capacity, lifetime, Capex, Opex, associated risks
- As an **early indicators** for project **GO/ no GO**

LCOE (levelized cost of electricity) – Cont'd

Formulasi LCOE

$$LCOE = \frac{\sum_{t=1}^{N} \frac{(I_t + O_t + F_t + D_t)}{(1+r)^t}}{\sum_{t=1}^{N} \frac{E_t}{(1+r)^t}}$$

Annual costs include:
I = Investment
O = O&M
F = Fuel
D = Decommissioning
C = Carbon (not included here)

Eq. 2

$$PV(all\ costs) = PV(all\ revenues)$$

$$PV\ Cost_1 + PV\ Cost_2 + PV\ Cost_3 \ldots + PV\ Cost_N = PV\ Rev_1 + PV\ Rev_2 + PV\ Rev_3 \ldots + PV\ Rev_N$$

$$\frac{Cost_1}{(1+r)^1} + \frac{Cost_2}{(1+r)^2} + \frac{Cost_3}{(1+r)^3} \ldots + \frac{Cost_N}{(1+r)^N} = \frac{LCOE \times E_1}{(1+r)^1} + \frac{LCOE \times E_2}{(1+r)^2} + \frac{LCOE \times E_3}{(1+r)^3} \ldots + \frac{LCOE \times E_N}{(1+r)^N}$$

$$\frac{Cost_1}{(1+r)^1} + \frac{Cost_2}{(1+r)^2} + \frac{Cost_3}{(1+r)^3} \ldots + \frac{Cost_N}{(1+r)^N} = LCOE \times \left(\frac{E_1}{(1+r)^1} + \frac{E_2}{(1+r)^2} + \frac{E_3}{(1+r)^3} \ldots + \frac{E_N}{(1+r)^N} \right)$$

$$LCOE = \frac{\frac{Cost_1}{(1+r)^1} + \frac{Cost_2}{(1+r)^2} + \frac{Cost_3}{(1+r)^3} \ldots + \frac{Cost_N}{(1+r)^N}}{\frac{E_1}{(1+r)^1} + \frac{E_2}{(1+r)^2} + \frac{E_3}{(1+r)^3} \ldots + \frac{E_N}{(1+r)^N}}$$

Eq. 1

Time Value of Money

Illustration:

In **Jan 2025**, you have **USD 2,000,-**. You will put your money in a bank. So you will request the bank to give you an amount of "compensation" (**called interest**). If the bank give you 5%/ years, in the next 5 years (**Jan 2030**) your money would be **USD 2,553,-**

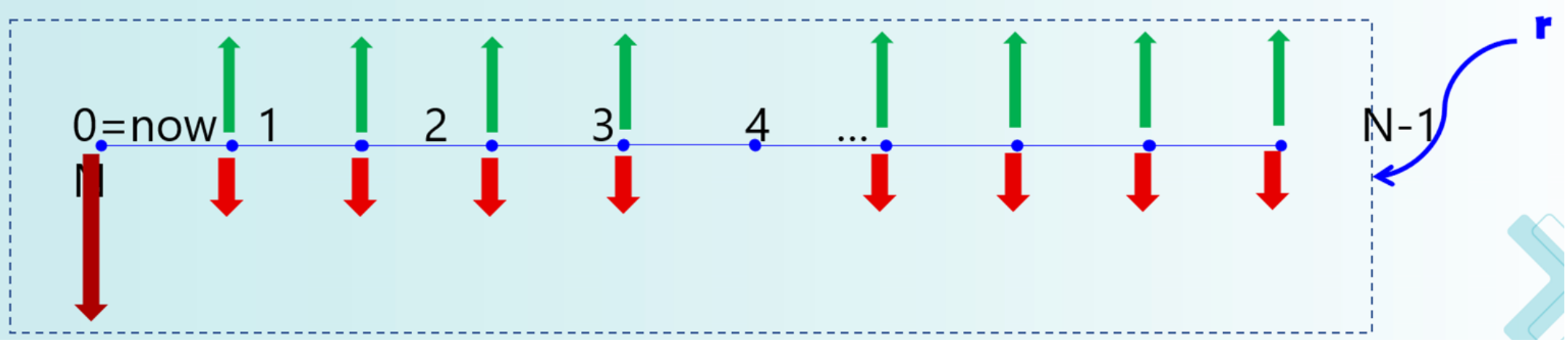
- USD 2,000,- now is different value with USD 2,000,- in the next 5 years (because of **time value of money**)
- 5%/year (USD 553,- along 5 years) is called **expected return** if you invest your money in a bank

Note:

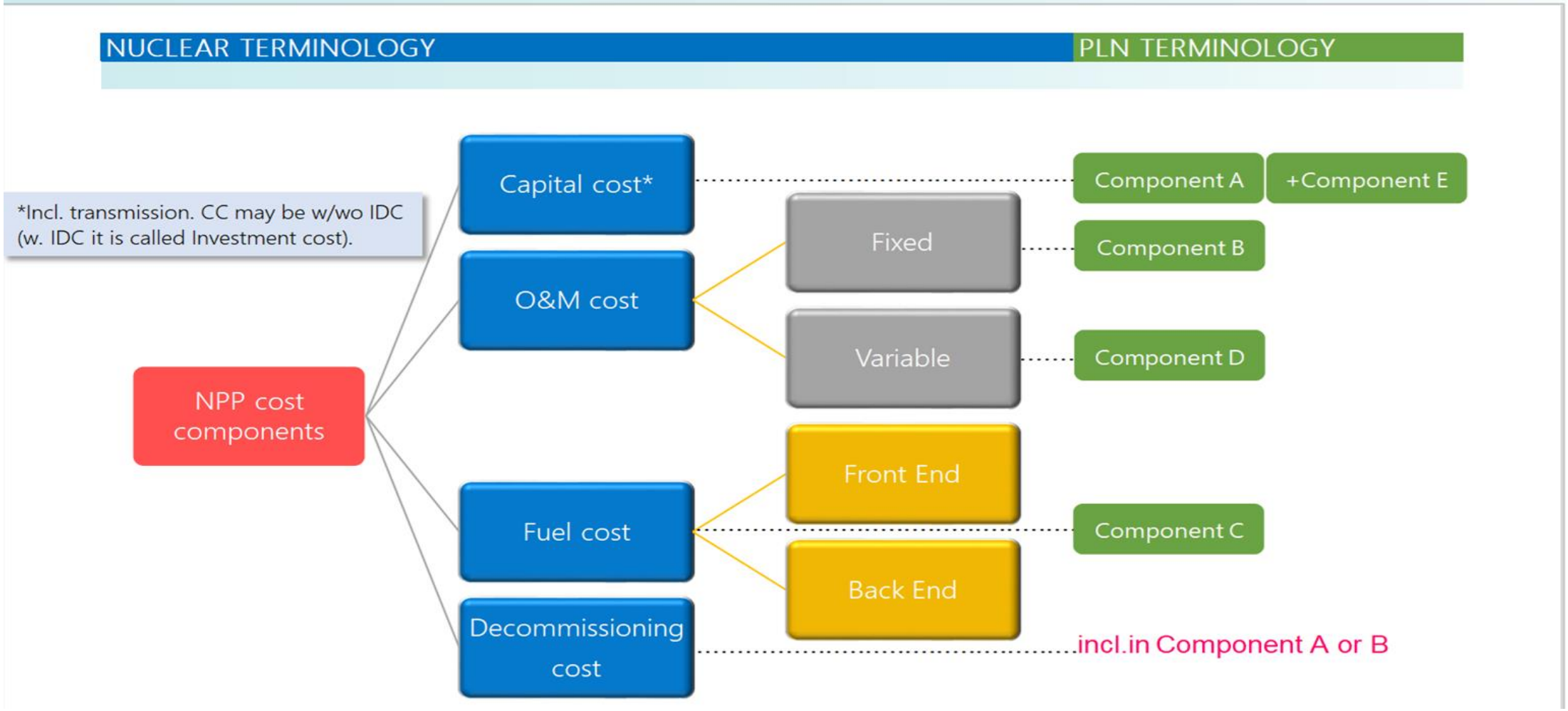
FV : Future Value
PV : Present value
r : Discount Rate
t : Time

Cash Flow Diagram

- A **model of cash flows** that **occur throughout the project's lifetime**
- As a **guide** to **when and how much, projected costs & revenues will occur** (not yet actually occurred/ex-ante).
- Subject to discount rate (r) □ discounted cash flow



Structure of Electricity Generation Cost



Case of Feasibility Study For Bangka Nuclear Power Plant Project - Non Site Aspect, PLN 2013 as an example

Breakdown of Costs

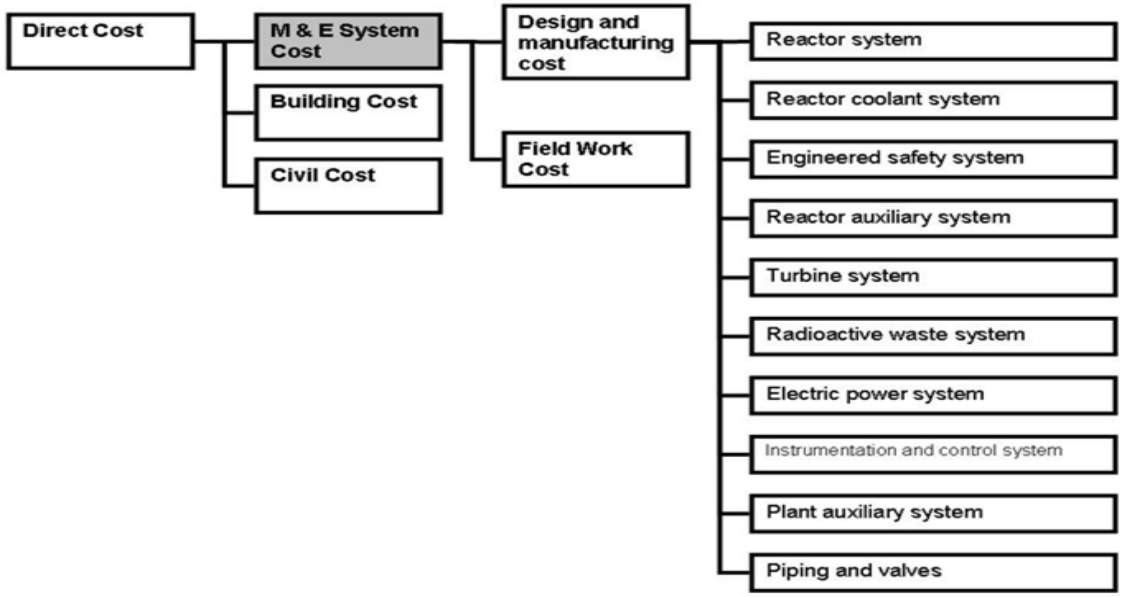
A. Investment Cost Also Called Construction Cost

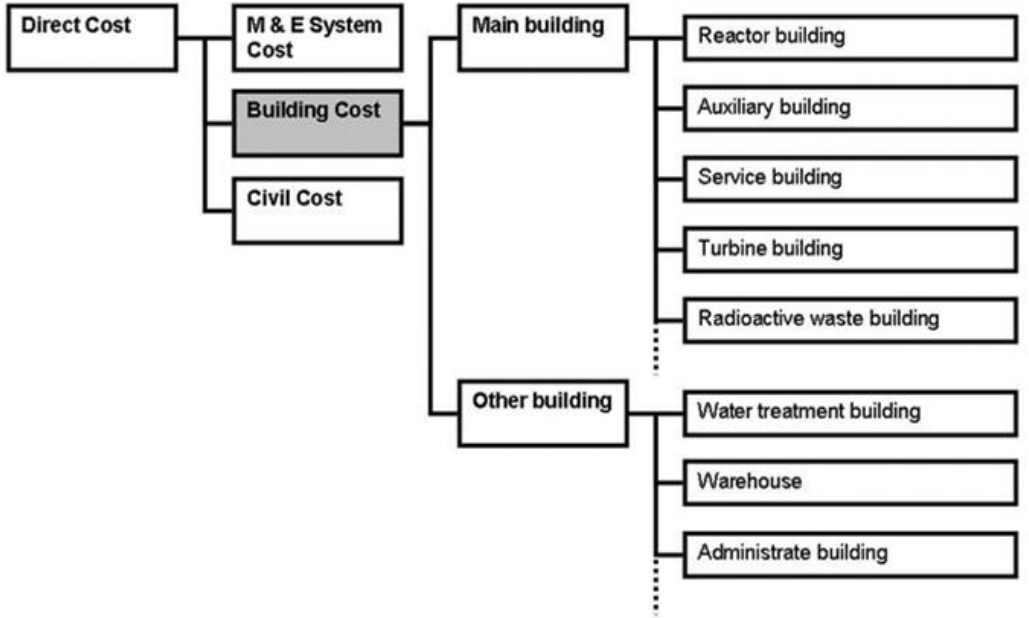
Note:

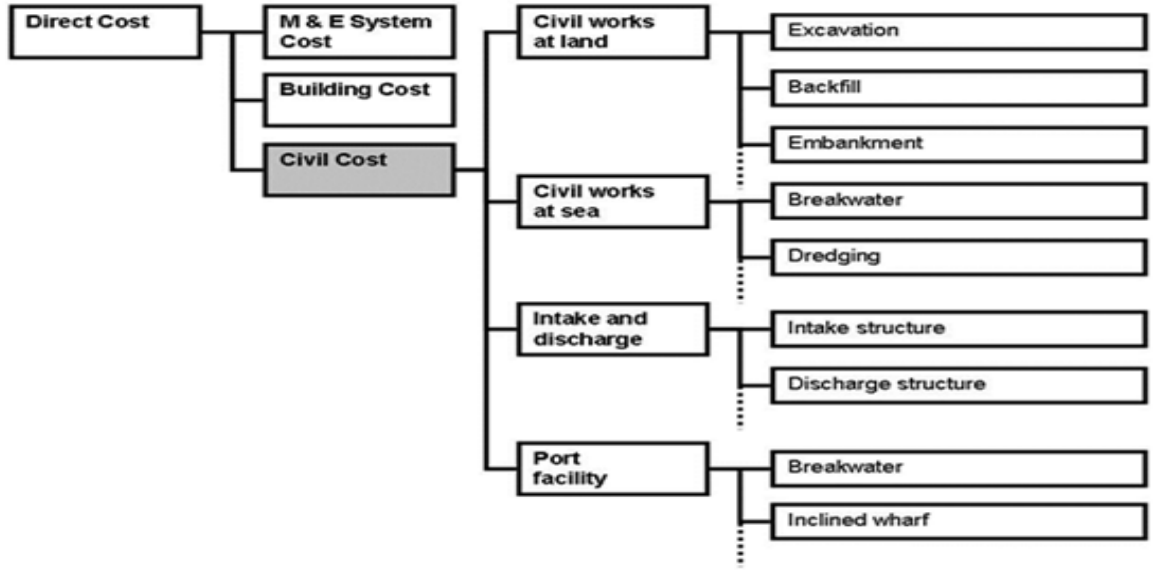
- Before the financing cost is taken into account, the investment cost is known as an **overnight cost (OC)**, namely the costs incurred if the NPP is completed in one night.
- Sometimes, also added contingency ± 15 – 20% of OC
- If: **OC+ Financing cost (Financing fee & IDC) + Contingency** ☐ **Capital Expenditure (CaPex)**
- **VAT** ☐ **Value Added Tax (11%).** In some cases, also added **transport cost (± 5% of OC) and PPh 22 for impor goods (± 2%)** ☐ Gov't also can enforce **Tax holiday**

Breakdown of Investment Costs

A.1 Direct Cost







Breakdown of Investment Costs

A.1 Direct Cost in Bangka's FS Case

Based on the case of 2 x Atmea1 and 2 x AP1000 NPPs, respectively for West Bangka (WB) and South Bangka (SB).

Mechanical & Electrical System Cost

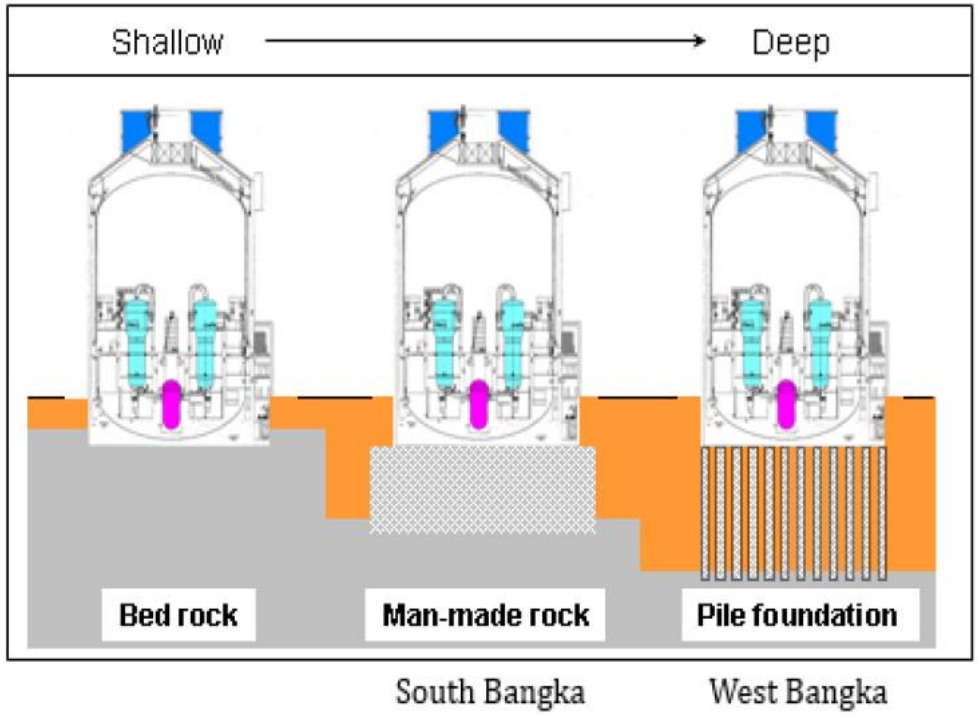
No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Design and manufacturing cost	4,462	4,462	4,284	4,284
II	Field work cost	1,947	1,947	1,823	1,823
	Total	6,609	6,609	6,107	6,107

Breakdown of Investment Costs

A.1 Direct Cost in Bangka's FS Case

Building Cost

No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Main building	778	696	563	476
II	Other building	70	63	96	95
	Total	848	760	659	571



Breakdown of Investment Costs

A.1 Direct Cost in Bangka's FS Case

Civil Cost

No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	City works at Land	336	240	282	214
II	City works at sea	195	191	195	191
III	Intake and discharge structure	467	475	466	465
IV	port facility	119	119	117	117
	Total	1147	1025	1060	987

Breakdown of Investment Costs

A.1 Direct Cost in Bangka's FS Case

Initial Core Fuel

No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Initial core fuel cost	498	498	553	553
	Total	498	498	553	553

Depend on the term of contract, initial core fuel can be included in the EPC contract, or can be separate

Breakdown of Investment Costs

A.2 Indirect Cost

1. Owner's Cost

Item of Owner's Cost

No.	Item
I	Electricity supply system
II	Temporary house cost on site
III	Cost for land resettlement, compensation
IV	Project management cost
V	Consultancy cost
VI	Miscellaneous costs
VII	Transmission between java and Sumatra
VIII	Training center
IX	Cost of land
	Total

2. Financing Cost

- **Financing Fee (a% of Overnight Cost)**
- **IDC** ☐ Costs incurred during the construction period due to the NPP company **don't have sufficient cash yet for loan repaymant** (principal + interest) thus **increasing the loan principal**

Breakdown of Investment Costs

A.2 Indirect Cost

1. Owner's Cost

Owner's Cost

No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Electricity supply system	8	8	8	8
II	Temporary house cost on site	6	6	6	6
III	Cost for land resettlement, compensation	52	52	52	52
IV	Project management cost	17	17	16	15
V	Consultancy cost	70	66	64	62
VI	Miscellaneous costs	26	26	26	25
VII	Transmission between java and Sumatra	1,126	1118	1126	1118
VIII	Training center	98	98	98	98
IX	Cost of land	2	1	2	1
	Total	1,405	1,392	1,398	1,385

Based on PP No. 27 of 2009, the licensing fee for construction, commissioning and operations reaches US$ 203,638 included in the project management cost

Breakdown of Investment Costs

A.2 Indirect Cost

2. IDC

IDC

No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	IDC	1,535	1,508	1,435	1,411
	Total	1,535	1,508	1,435	1,411

Breakdown of Investment Costs

A.2 Indirect Cost

3. VAT

VAT □ in this case 10%

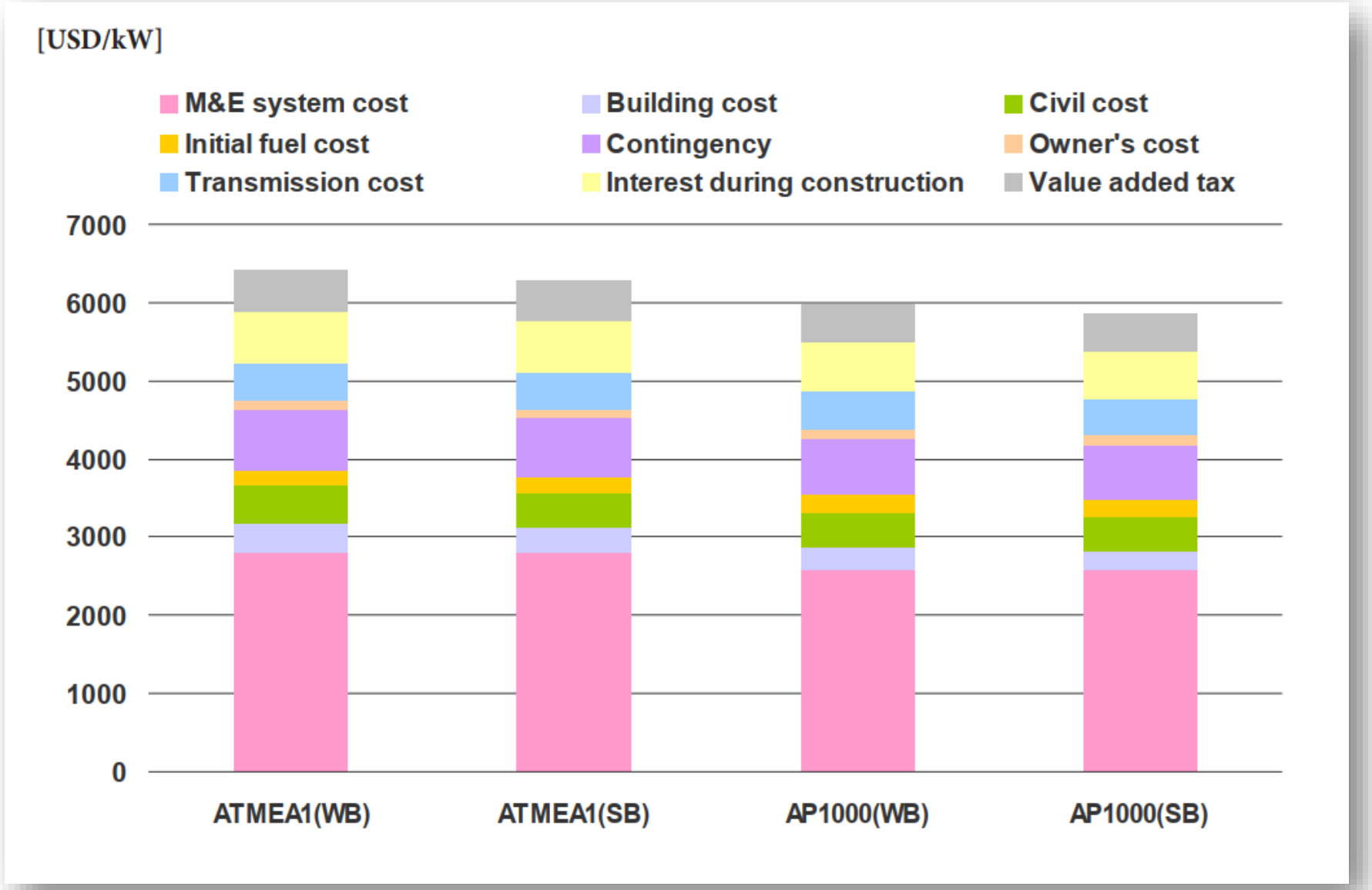
No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	VAT	1,233	1,206	1,145	1,125
	Total	1,233	1,206	1,145	1,125

Summary of Investment Costs

Investment Cost

No.	Item	Cost (million USD)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	M & E system cost	6,609	6,609	6,107	6,107
II	Building cost	848	760	659	571
III	Civil cost	1,147	1,025	1,060	987
IV	Initial core fuel cost	498	498	553	553
V	Contingency	1,821	1,779	1,676	1,644
VI	Owner's cost	1,405	1,392	1,398	1,385
VII	IDC	1,535	1,508	1,435	1,411
VIII	VAT	1,233	1,206	1,145	1,125
	Total (Unit cost: USD/kW)	15,095 (6,396)	14,777 (6,261)	14,033 (5,946)	13,783 (5,840)

Summary of Investment Costs



Output = 1180 MWe

Factors that affects Investment Costs

1. Cost of local components Local material prices and labor wages vary from country to country.
2. Building on a new site is more expensive than on a site where a NPP already exists.
3. Building in seismically active areas is more expensive.
4. The size of the unit capacity (economy of scale)
5. Techonogy, *First of Kind* or*Nth of Kind*
6. The amount of incentives and guarantees provided by the government for NPP projects varies greatly from country to country.

B. Operation &Maintenance Cost

Item of O & M Cost

No	Item
1	Personel Cost
2	Repair/ Maintenance Cost
3	Insurance Cost

Note:

1. Personel Cost

- The salary to be paid to the employees of NPP (includes retirement benefit & welfare expenses.
- Personel cost consists of:
  - General Affairs & Management
  - O & M Technical Staff

2. Repair Cost

- Costs required for replacing parts & maintaining damage parts in order to maintain the function of NPP
- depend on the output of the plant ☐ Often called as **Variable O & M Cost**

3. Insurance Cost

- Compensation for nuclear damage
- To cover such tremendous amount of payment cannot be covered by a single private insurance company or even the insurance industry in a single country.
- Each country **organizes an 'atomic energy insurance pool'**, gathering insurance companies in the country and **insurance pools of each country mutually concludes reinsurance agreements** in order to ensure stability for underwriting the insurance

Insurance Cost

- Also called nuclear energy liability insurance
- In Indonesia called as Nuclear Loss Liability. Regulated in more detail in Presidential Regulation Number 74 of 2012

No.	Kategori	Besar Batas Pertanggungjawaban (Rp)
1.	Reaktor daya komersial dengan daya lebih dari 2.000 MWe	4.000.000.000.000,00
2.	Reaktor daya komersial dengan daya lebih dari 1.500 MWe sampai dengan 2.000 MWe	2.000.000.000.000,00
3.	Reaktor daya komersial dengan daya lebih dari 1.000 MWe sampai dengan 1.500 MWe	1.000.000.000.000,00
4.	Reaktor daya komersial dengan daya lebih dari 500 MWe sampai dengan 1.000 MWe	500.000.000.000,00
5.	Reaktor daya komersial dengan daya sampai dengan 500 MWe	250.000.000.000,00
6.	Reaktor daya nonkomersial	75.000.000.000,00
7.	Reaktor nondaya komersial	100.000.000.000,00
8.	Reaktor nondaya nonkomersial dengan daya lebih dari 30 MWt	50.000.000.000,00
9.	Reaktor nondaya nonkomersial dengan daya lebih dari 10 MWt sampai dengan 30 MWt	25.000.000.000,00
10.	Reaktor nondaya nonkomersial dengan daya lebih dari 2 MWt sampai dengan 10 MWt	10.000.000.000,00
11.	Reaktor nondaya nonkomersial dengan daya sampai dengan 2 MWt	5.000.000.000,00
12.	Instalasi fabrikasi bahan bakar nuklir	5.000.000.000,00
13.	Fasilitas penyimpanan bahan bakar nuklir bekas	5.000.000.000,00
14.	Pengangkutan bahan bakar nuklir	1.000.000.000,00
15.	Pengangkutan bahan bakar nuklir bekas	1.000.000.000,00

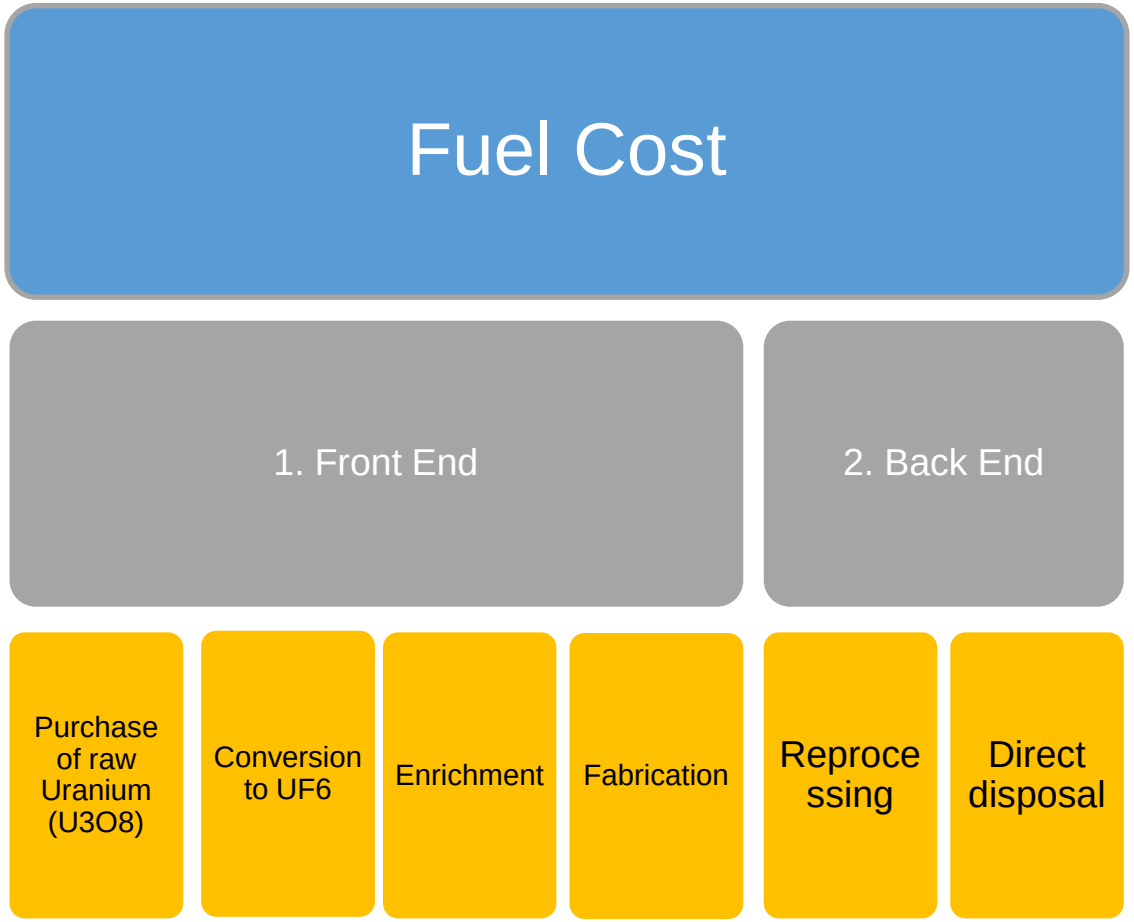
Summary of O & M Cost

No.	Item	Cost (UScent/kWh)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Personnel cost	0.10	0.10	0.10	0.10
II	Maintenance cost	1.02	1.02	0.97	0.97
III	Insurance cost	0.03	0.03	0.03	0.03
	total	1.16	1.16	1.10	1.10

Fuel Cost

Nuclear Fuel Cost is the sum of:

- costs before fuel is fed into the reactor (Front-end)
- costs after fuel is remove into the reactor (back-end)

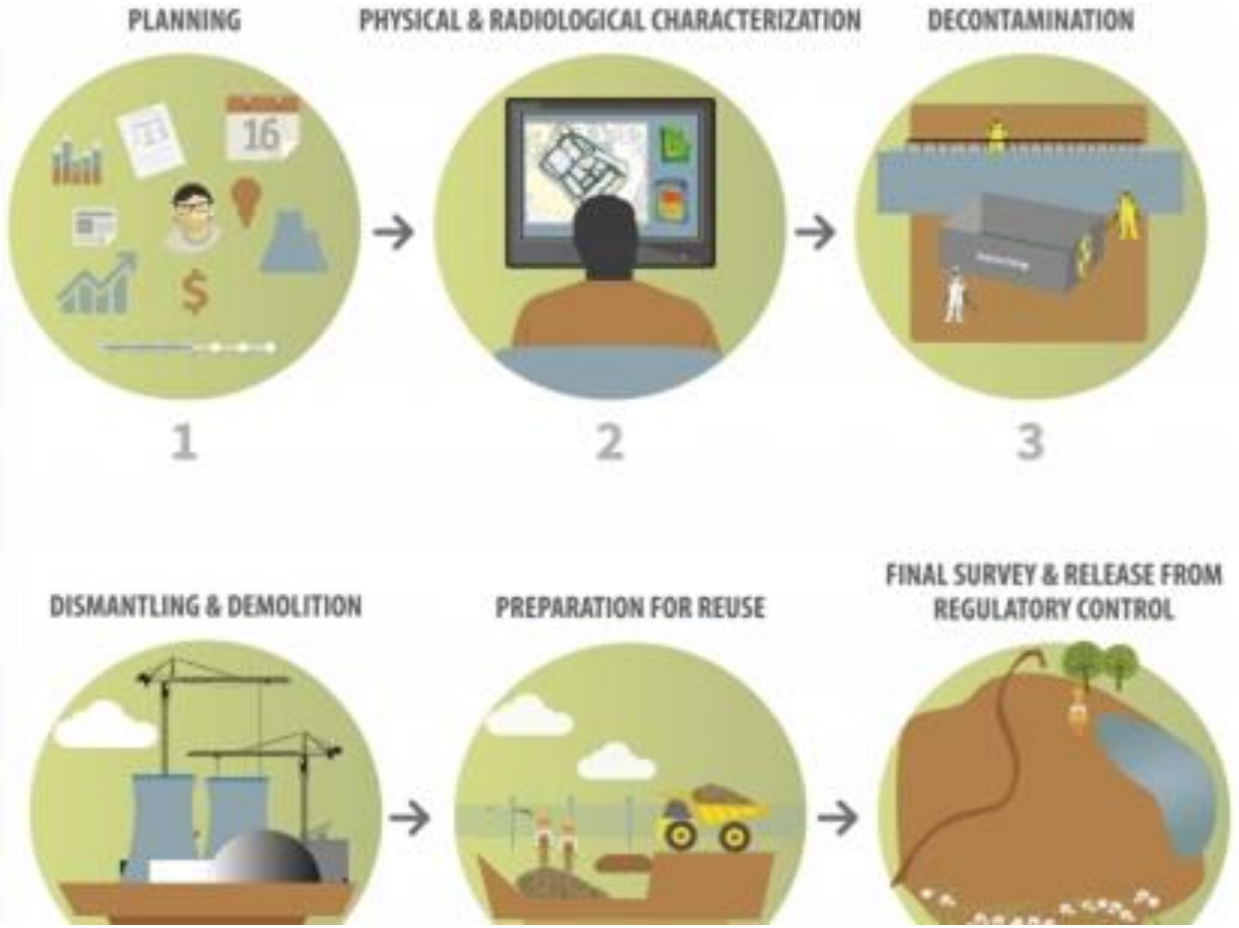


Summary of Fuel Cost

No.	Item	Cost (UScent/kWh)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Front-end cost	1.13	1.13	1.19	1.19
II	Back-end cost	0.03	0.03	0.03	0.03
	Total	1.16	1.16	1.22	1.22

Decommisioning Cost

Definition:
administrative and technical measures taken to remove all or part of regulatory control from an authorized facility so that the facility and its premises can be reused (IAEA).



Summary of Decommisioning Cost

No.	Item	Cost (UScent/kWh)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Reserve for decommissioning	0.20	0.20	0.17	0.17
	total	0.20	0.20	0.17	0.17

Bangka's NPP Generation Cost (LCOE)

Summary of Electricity Generation Cost

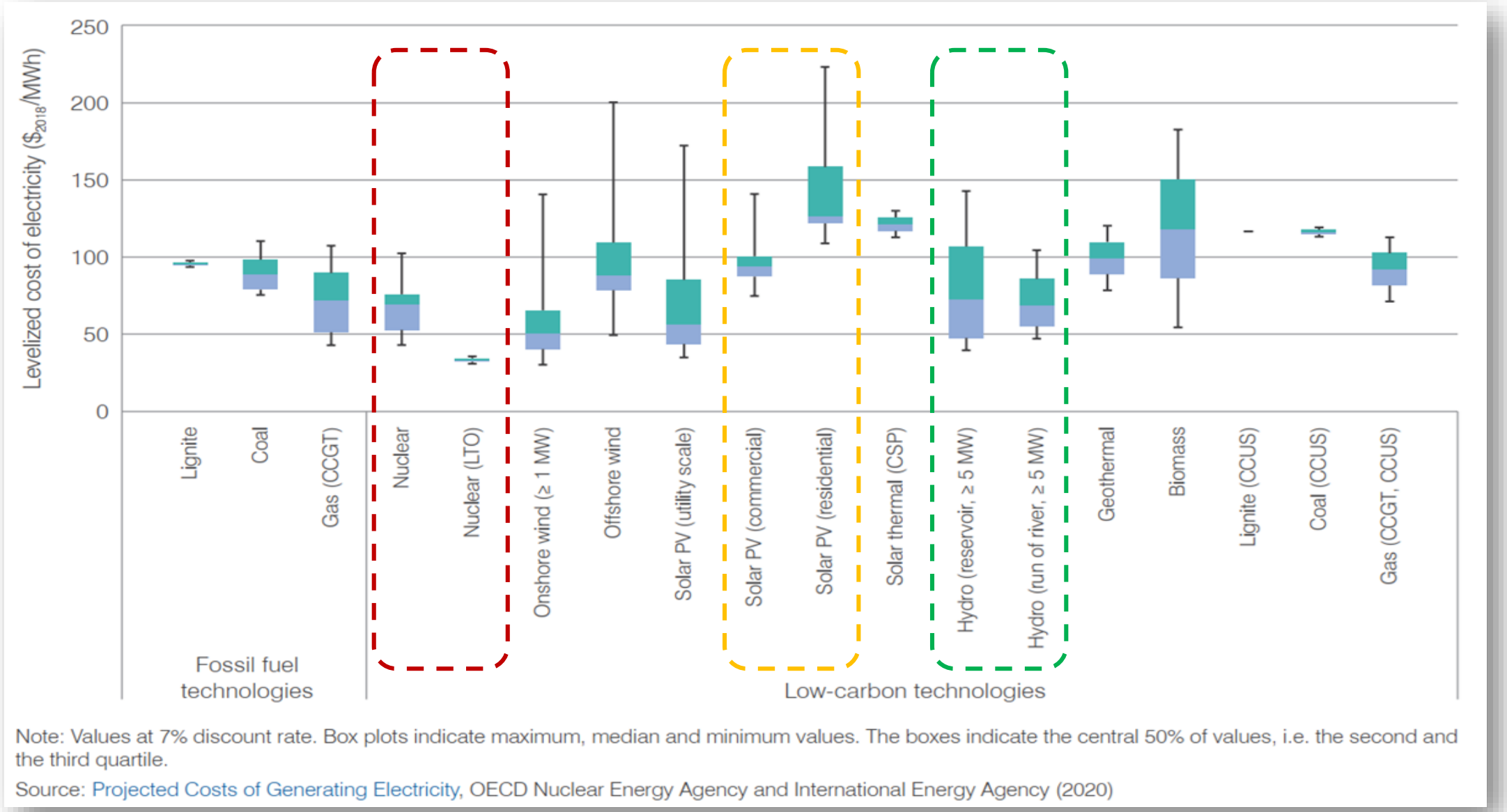
Discount rate = 10%

Table 6.2-6 Generation cost

No.	Item	Cost (UScent/kWh)			
		ATMEA1 (W. Bangka)	ATMEA1 (S. Bangka)	AP1000 (W. Bangka)	AP1000 (S. Bangka)
I	Capital cost	3.91	3.81	3.59	3.53
II	Operation and maintenance cost	1.16	1.16	1.10	1.10
III	Fuel costs	1.16	1.16	1.22	1.22
IV	Decommissioning cost	0.20	0.20	0.17	0.17
	Total	6.42	6.33	6.07	6.01

LCOE becomes the basis for utility to determine tariffs, or basis for Special Purpose company (SPC) to determine tariff in PPA (Power Purchasing Agreement)

Nuclear LCOE Vs Other Energy Source

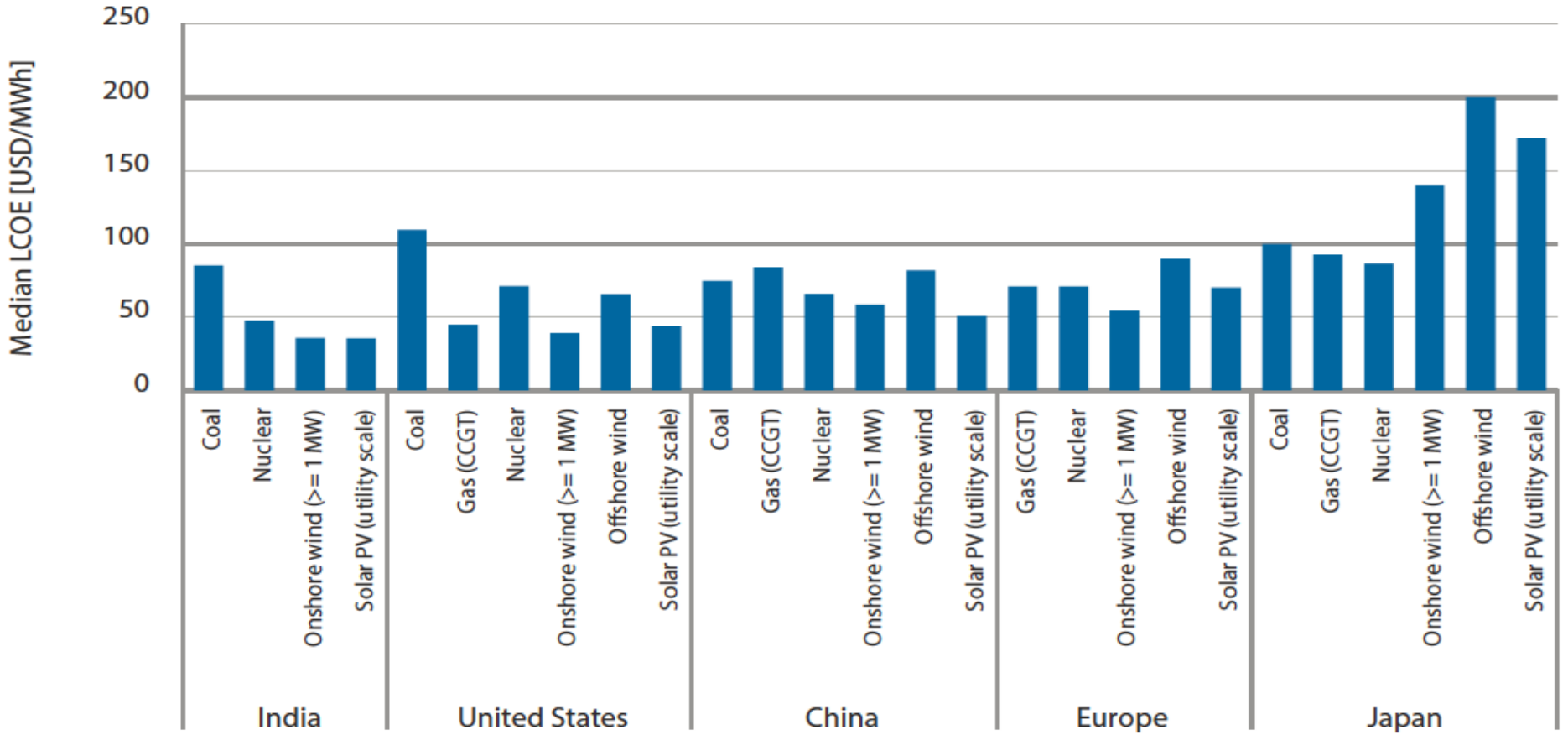


Note: Values at 7% discount rate. Box plots indicate maximum, median and minimum values. The boxes indicate the central 50% of values, i.e. the second and the third quartile.

Source: Projected Costs of Generating Electricity, OECD Nuclear Energy Agency and International Energy Agency (2020)

Nuclear LCOE Vs Other Energy Source

Figure ES2: Median technology costs by region



Note: Values at 7% discount rate.

Source: OECD/IEA-NEA, *Projected Costs of Generating Electricity*, 2020

Source of Funding of NPP Project

There are 2 portions:

1. Equity Portion
2. Debt Portion

Equity Portion:

- ❑ About 15% - 30%. The more the better
- ❑ From the utility itself or and from government
- ❑ Utility's internal cashflow
- ❑ In case utility's internal funds are insufficient, utility can form an equity consortium.
- ❑ Usually (but not always) in local currency, allocated for owner's costs (site preparation, etc.)

Potential Equity Contributors:

- ➢ Utility companies
- ➢ Equipment (vendors) and service suppliers
- ➢ Energy-intensive industries
- ➢ Local municipalities
- ➢ Neighboring countries
- ➢ Venture capital firms
- ➢ International investors

Source of Funding of NPP Project

Debt Portion:

- Domestic bonds;
- Local bank credit from commercial sources or development banks credit from public entities;
- Stand-by facilities for cost increases;
- Long-term payable for goods and services of project.
- Usually (but not always) in foreign currency, allocated for import of equipments

International debt:

- Export Credit Agencies (ECA)
- Equipment supplier's credit
- International Commercial Sources:
  - Commercial Bank Loans
  - International Bonds (Eurobond, Yankee Bond, Samurai Bond)
  - International Leases
  - Barter trade

Source of Funding of NPP Project

Export Credit Agencies (ECA):

- Definition:

  A **financing or credit facility provided to exporters** to **enable them to sell** goods and services in **foreign markets**.
- Typically involves **a two-tier systems:** a dedicated **government's entity** providing **appropriate insurance or credit guarantees**, and an **official financial institution providing funds** jointly or in parallel.
- The **currency** used is generally the **national currency of the exporting country**.
- Financing **covers up to 85%** of the cost of services and equipment from the exporting country
- Maturities (tenor) are generally **longer than conventional** financial markets (12 – 15 years for NPP)
- There is an extended payment **grace period**
- Sometimes **subsidized interest rates** are offered for **very low income countries**, which are lower than commercial interest rates.

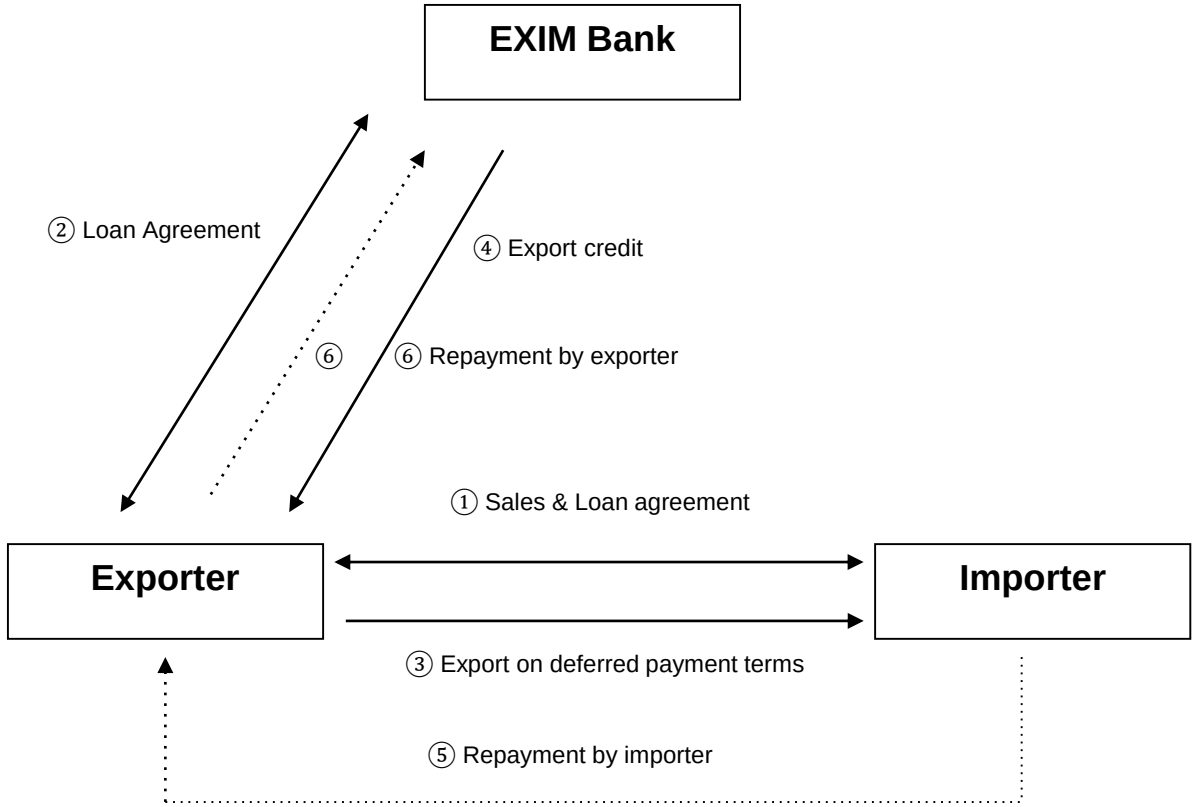
Source of Funding of NPP Project

Export Credit Agencies (ECA):

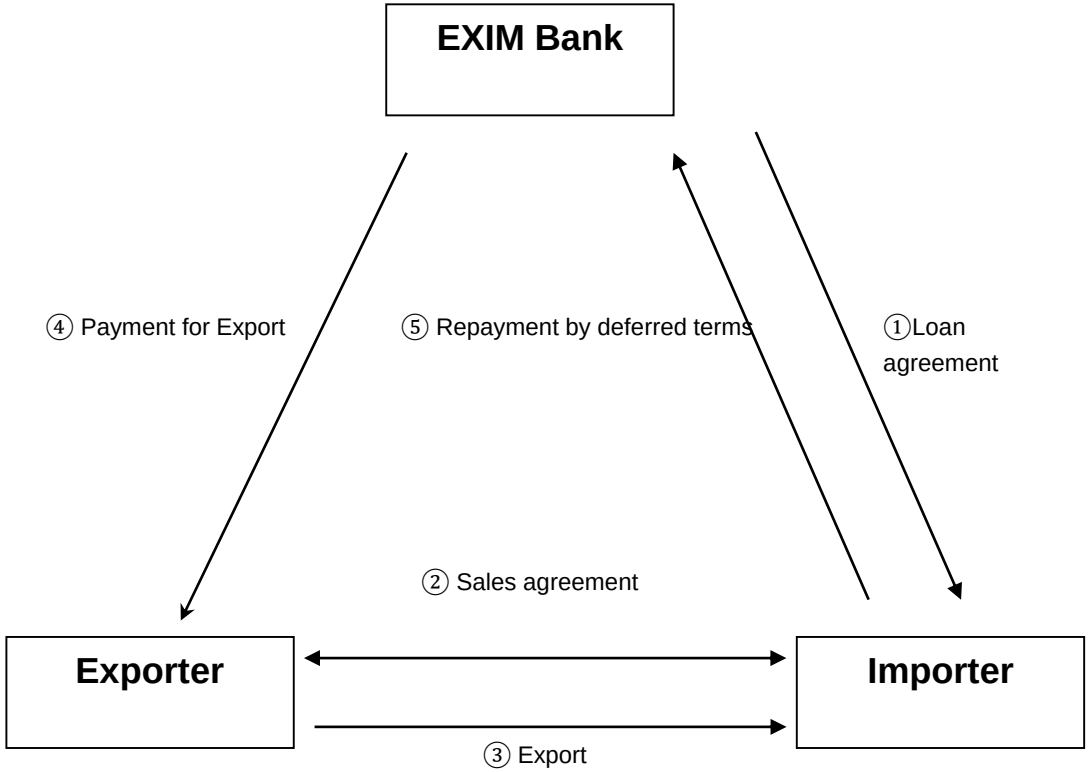
- Korea: Korea Export-Import Bank (KEXIM), Korea Export Insurance Corporation;
- Canada: Export Development Corporation (EDC);
- France: Compagnie francaise d'assurance pour le commerce exterieur (COFACE), Banque francaise du commerce exterieur (BFCE) ;
- Germany: Hermes Kreditversicherungs AG, Ausfuhrkredit-Gesellschaft mbH (AKA), Kreditanstalt fur Wiederaufbau (KfW) ;
- Japan: Export-Import Bank of Japan, Ministry of International Trade and Industry (MITI);
- Sweden: Exportkreditnamnden (EKN), AB Svenska Export (SEK);
- United Kingdom : Export Credits Guarantee Department (ECGD)
- United States of America: Export-Import Bank of the United States (EXIM); Private Export Funding Corporation (PEFCO), Overseas Private Investment Corporation (OPIC).

Source of Funding of NPP Project

Schemes of ECA:



Supplier's Credit Schemes



Buyer's Credit Schemes

Credit Rating

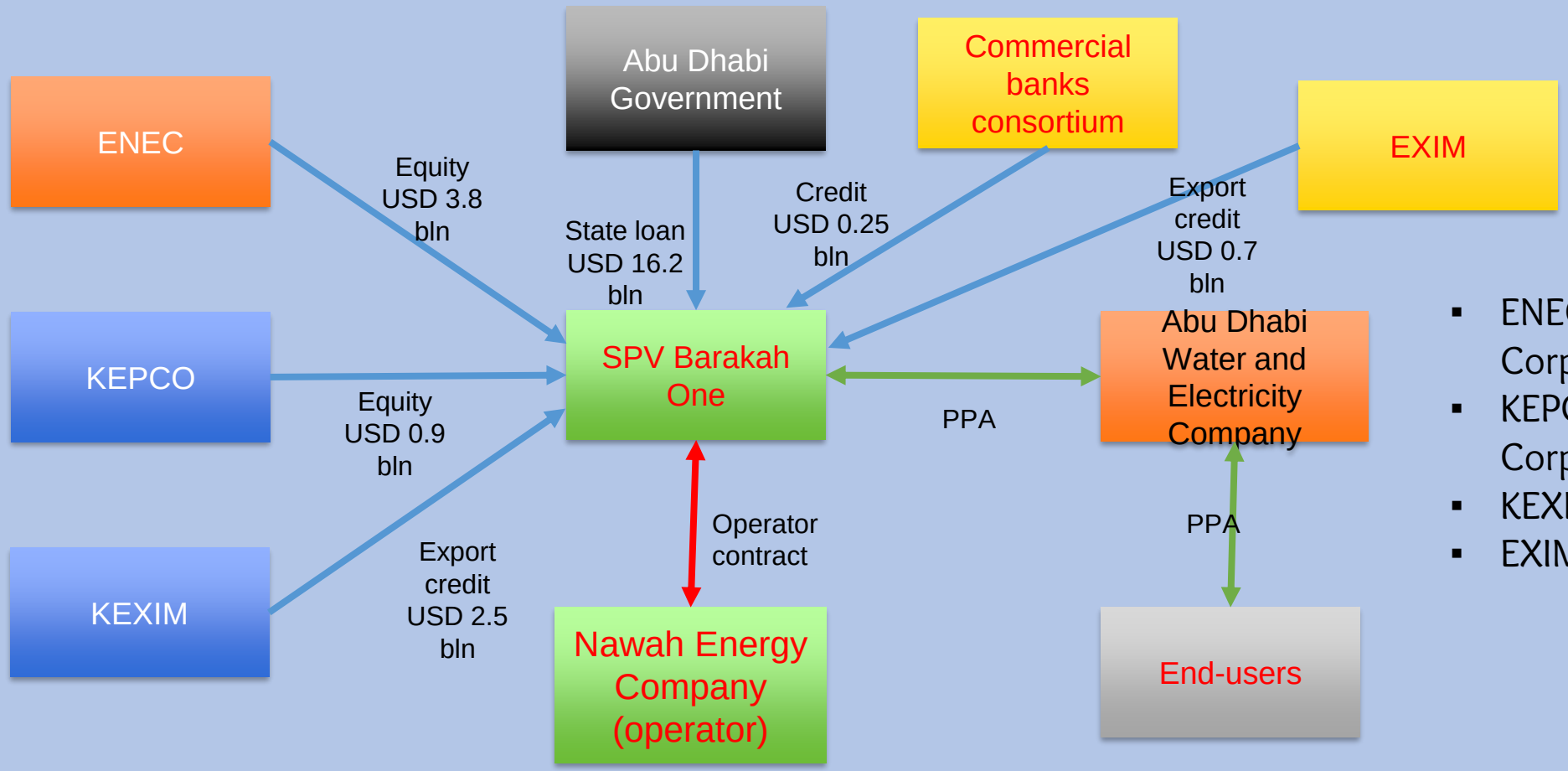
	Fitch	Standard & Poors	Moody's
Investment Grade	AAA	AAA	Aaa
	AA+	AA+	Aa1
	AA	AA	Aa2
	AA-	AA-	Aa3
	A+	A+	A1
	A	A	A2
	A-	A-	A3
	BBB+	BBB+	Baa1
	BBB	BBB	Baa2
	BBB-	BBB-	Baa3
Speculative Grade	BB+	BB+	Ba1
	BB	BB	Ba2
	BB-	BB-	Ba3
	B+	B+	B1
	B	B	B2
	B-	B-	B3
	CCC	CCC+	Caa1
		CCC	Caa2
		CCC-	Caa3
	CC	CC	Ca
	C	C	C
Default	D	D	C

Easier to borrow: lower interest rate

Tough to borrow: higher interest rates

Source of Funding of NPP Project

Barakah NPP's project Ownership and financing

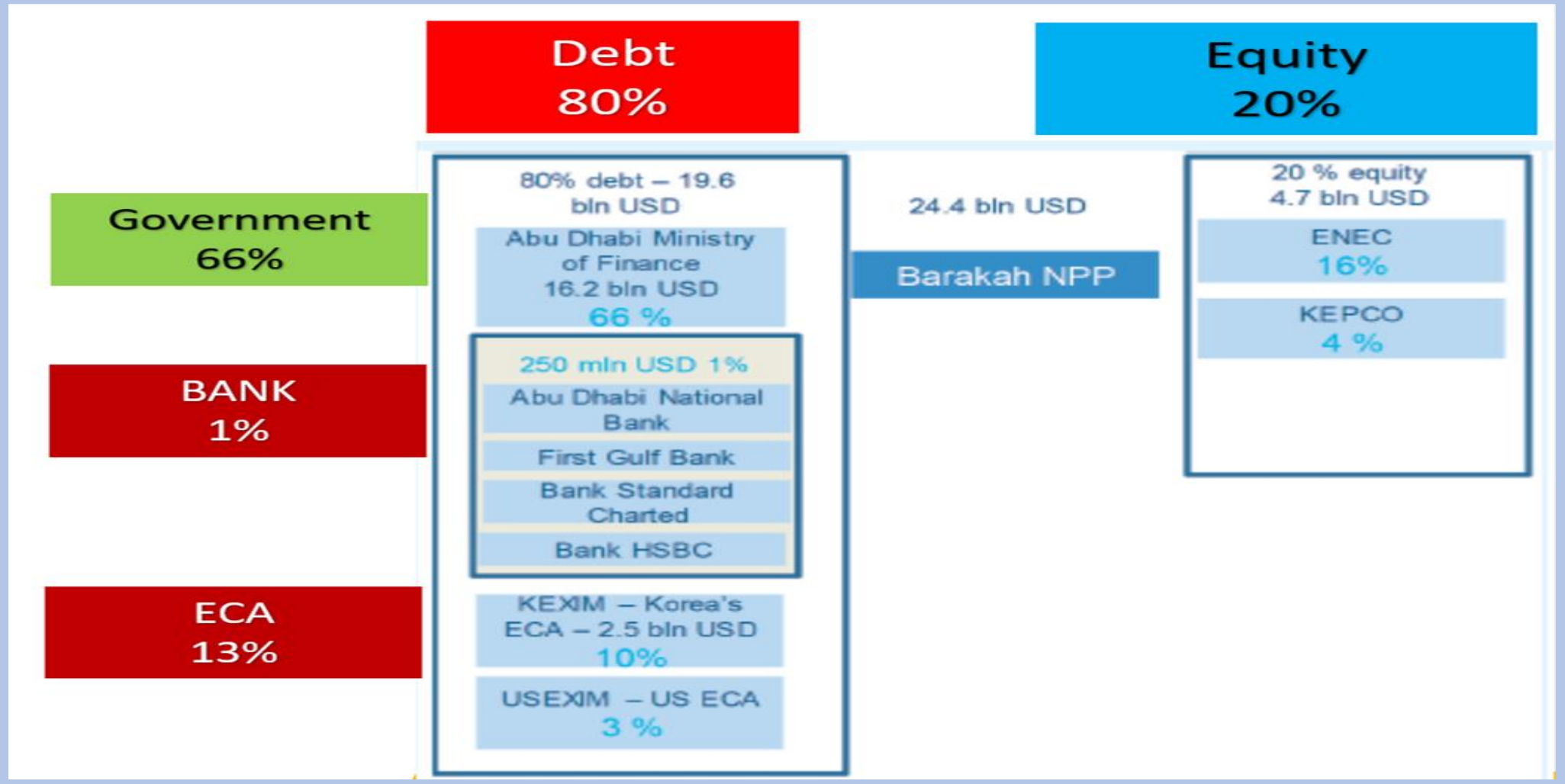


- ENEC: Emirates Nuclear Energy Corporation
- KEPCO: Korea Electric Power Corporation
- KEXIM: Korea Export-Import Bank
- EXIM: Export-Import Bank of the US

Scheme: Public Private Partnership (PPP)

Source of Funding of NPP Project

Funding scheme of Barakah NPP's project



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