Viable Options of Fuel Cycle for Introduction of NPP in Indonesia

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Nuclear Energy as part of National Energy Mix

Legal Basis:

- Indonesian Government Regulation No. 79 Year 2014 concerning “National Energy Policy”
National Energy Policy
Government Regulation No. 79 Year 2014

- to achieve independence and resilience of national energy for supporting sustainable development

- Main Target:

<table>
<thead>
<tr>
<th>Energy Provision and Utilization</th>
<th>2025</th>
<th>2050</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply of Primary Energy</td>
<td>400 MTOE</td>
<td>1,000 MTOE</td>
</tr>
<tr>
<td>Use of Primary Energy per- Capita</td>
<td>1.4 TOE</td>
<td>3.2 TOE</td>
</tr>
<tr>
<td>Generating Capacity of Electricity *)</td>
<td>115 GWe</td>
<td>430 GWe</td>
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<tr>
<td>Use of Electricity per- Capita</td>
<td>2,500 kWh</td>
<td>7,000 kWh</td>
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*) about 52 GWe in 2015
Priority of National Energy Development
GR. 79/2014

- maximizing the use of renewable energy by taking into account its economic;
- minimizing the use of oil/petroleum;
- optimizing the natural gas and new energy utilization; and
- using coal as the main pillar of the national energy supply.

Nuclear is categorized into the New Energy
Consideration of Nuclear Energy Utilization
GR. 79/2014

- to improve the security of national energy supply (on a large scale);
- to reduce carbon emissions; and
- must have a competitive economic value without compromising the safety factor.
Optimal Mix of Primary Energy
GR. 79/2014

<table>
<thead>
<tr>
<th>Source of Energy</th>
<th>2025</th>
<th>2050</th>
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<tbody>
<tr>
<td>New and Renewable Energy</td>
<td>≥ 23%</td>
<td>≥ 31%</td>
</tr>
<tr>
<td>Oil (Petroleum)</td>
<td>&lt; 25%</td>
<td>&lt; 20%</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>≥ 22%</td>
<td>≥ 24%</td>
</tr>
<tr>
<td>Coal</td>
<td>≥ 30%</td>
<td>≥ 25%</td>
</tr>
</tbody>
</table>

**Target for 2015 (by NEC):**
NRE ≥ 10%, Oil < 39%, Gas ≥ 22%, Coal ≥ 29%

Reduce the use of fossil fuels, especially oil, maximizing the use of NRE and gas
Projection of National Primary Energy Supply
INEO – BATAN 2014

Nuclear [4%]
Renewable [24%]
Oil [20%]
Gas [24%]
Coal [28%]
Nuclear Energy Scenario and Strategy
Introduction of Nuclear Power

- Indonesia has for a long period planned for the introduction of nuclear power;

- Act No. 10 Year 1997 on Nuclear Energy. This is the primary legislation in Indonesia;

- Act No.17 Year 2007 on Long-Term National Development Plan of Indonesia for 2005 to 2025. This is the basis act of establishing long term commitment for the use of nuclear energy to meet national energy demand.
Nuclear Power Development Plan

Indonesia has thousands of islands, the following considerations are taken into account:

- Nuclear electricity for regions with high population density and existing grids: LARGE NPPs, and

- Nuclear electricity/heat co-generation for regions rich of natural resources, so that, SMRs with or without co-generation application need to be used.
The Role of Nuclear Power Plan

- To stabilize the supply of electricity
- To conserve strategic oil and gas resources
- To protect environment from harmful pollutants as the results of the use of fossil fuels
Projection of Power Plants Installed Capacity
INEO – BATAN 2014

NPP start operation in 2027
2 GWe

Nuclear 20.940 GWe
Deployment of NPP in Indonesia
INEO – BATAN 2014

LR / PWR
- 2031 – 2000 MWe
- 2040 – 4000 MWe
- 2045 – 6000 MWe
- 2047 – 8000 MWe
- 2050 – 8000 MWe

SMR / HTR
- 2031 – 100 MWe
- 2035 – 200 MWe
- 2041 – 400 MWe
- 2046 – 600 MWe
- 2050 – 800 MWe

Other Islands
- 2041 – 35 MWe
- 2046 – 70 MWe
- 2049 – 140 MWe
- 2050 – 140 MWe

Jawa & Bali
- 2027 – 200 MWe
- 2036 – 4000 MWe
- 2041 – 6000 MWe
- 2046 – 8000 MWe
- 2047 – 10000 MWe
- 2048 – 12000 MWe
- 2050 – 12000 MWe

Total in 2050: 20,940 MWe
Nuclear Fuel Cycle Policy

- Implementation of once through fuel cycle or fuel cycle without spent fuel reprocessing domestically;

- Implementation of U-Th once through fuel cycle for thermal reactor when it techno-economically viable and does not interfere with the safety performance of the reactor.
Viable Option of Fuel Cycles

FRONT END

- Procurement of natural uranium (U₃O₈ or yellow cake) will be done through several suppliers in the international market with long-term contracts. Although Indonesia has uranium reserves but which have been identified are limited. The use of domestic uranium will only intended for emergency;

- Conversion of U₃O₈ to nuclear grade UF₆ will be carried out through several processing company in the international market with long-term contracts. The establishment of conversion facilities domestically is not economical if only for self-sufficiency;

- Service of enrichment will be ordered from various processing countries (International market) through long-term contracts;

- Fuel assembly will ordered from various manufacturers (International market) through leasing and or long-term contract. Fuel assembly will be supplied step wisely by Domestic Industry if it is economically justifiable.

**Long term security of supply of LEU is the main consideration**
The concept of spent fuel take-back to the country of origin will be implemented if it is economically beneficial, in particular at the initial stage of NPP introduction. This concept is considered to be able to increase public acceptance with respect to NPP option.

Spent fuel directly disposed in a geological disposal facility. Because of the initial high heat emission of the fuel, this can be effectively carried out only after a certain cooling period, which can extend to several decades. This strategic option requires storage facilities (ISF), an encapsulation plant before disposal, and a state of the art disposal facility.
Option for Spent Fuel Take-back

- The concept of fuel leasing or spent fuel take-back is the best option at the moment for the development of nuclear energy in Indonesia; or

- Spent fuels shipped to disposal / repository facilities outside Indonesia if it is commercially available.

- Both of the above options will increase public acceptance of the NPPs deployment in Indonesia (increase sustainability of NPP development)
Options for Enhanced Nuclear Energy Sustainability
Options for Enhanced NE Sustainability:

1. Advanced Technology, and

2. International Cooperation
Once-Through Th-U Fuel in Light Water Reactor (PWR)

- The use of Th-U in PWR with the seed blanket concept is attractive due to the lower spent fuel and plutonium discharge rates and degraded plutonium isotopic.

- However, this fuel cycle requires much more natural uranium than the once through UOX fuel cycle.

- The once through Th-U fuel cycle in PWR is only viable if there is no burden regarding uranium resources.

Indonesia is ready as soon as possible to use the system if there is a guarantee of the availability of supply on the international market.
Th - U FUEL CYCLE IN PWR

Conversion Enrichment Fabrication

- Nat Uranium 247.74 tU
- 4.91 tU Fresh UOX
- 4.175 tHM Fresh ThUOX [0.543 tU]

Depleted U: 242.29 tHM

Seed Fuel Assembles
- PWR: 1 GWe-yr
- 4.91 tHM Spent UOX Fuel
  - 1.97% TRU, 1.56% Pu, 14.5% FP
- 4.175 tHM Spent ThUOX Fuel
  - 0.51% TRU, 0.45% Pu, 8.8% FP

Blanket Fuel Assembles

Seed Assembly
- UOX Fuel (Enrichment 20% U-235)
- 7.703 t HM discharged and replaced every cycle
- Spent Fuel = 1.97% TRU, 1.56% Pu, 14.5% FP

Blanket Assembly
- (UTh)OX Fuel with 87% ThOX and 13% UOX [Enrichment: 10% U-235]
- 58.997 t HM discharged and replaced every 9 cycles
- Spent Fuel = 0.51% TRU, 0.45% Pu, 8.8% FP

HLW DISCHARGED
- 117.95 kg TRU
- 95.33 kg Pu
- 1.078 t FP

Reactor Generates: 1.570 GWe-yr [18 months cycle length]
Plutonium Recycle with MOX Fuel in PWR (Pu Mono-Recycle)

- The single pass recycling of plutonium in MOX fuel offers modestly-attractive uranium resources savings.

- Also, the waste production per unit energy generated is lower than waste production in the once-through UOX fuel cycle.

- This system has a high risk of proliferation. Therefore, Indonesia would not process it in the nation but uses processing services through international markets.

Indonesia will take advantage of this system, if economically viable, and when preparing the ISF facility is constrained by the location of the nuclear power plant, i.e. spread over long distances.
PLUTONIUM MONO-RECYCLE

Conversion

Enrichment

Fabrication

Fresh UOX

18.34 tU

4.3% U-235

PWR - UOX

0.8714 GWe-yr

PWR - MOX

0.1286 GWe-yr

Spent UOX

Spent MOX

18.34 tHM (Pu: 216.56 kg)

2.71 tHM

MOX FUEL

FABRICATION

Depleted U

2.49 tU

Pu: 149.43 kg

MA: 14.62 kg

FP: 139.41 kg

U: 2403.53 kg

PUREX

UOX Fuel

- Enrichment = 4.3% U-235
- Burnup = 51 GWD/THM
- Spent Fuel = 1.197% Pu, 0.1% MA, 5.264% FP

MOX Fuel

- Fresh MOX = 8.1% Pu, 91.9% DU
- Burnup = 51 GWD/THM
- Spent Fuel: 5.52% Pu, 0.54% MA, 5.15% FP

Depleted Uranium

160 tU

0.3% U-235

178.34 t U

Nat Uranium
Synergistic Fuel Cycle of LWR–FR (TRU burners)

- Fuel cycles involving multi-pass recycling of tranuranics would send only very small amounts of plutonium to the repository. Furthermore, the isotopic composition of this plutonium is highly degraded due to the multiple high burnup irradiations.

- If compared to the once through fuel cycle, this nuclear energy system can reduce the TRUs content in the discharged HLW up to 99.7%, and can save up to 38.4% of required natural uranium.

Indonesia will take advantage of this system, if economically viable, and when the technology available in the international market. It will be carried out in the beginning of the next century, if there are any unresolved problems in the management of spent fuel.
The concept of fuel leasing or spent fuel take-back is the best option at the moment for the development of nuclear energy in Indonesia;

Under nuclear fuel leasing scheme, the supplier fabricate and deliver fresh nuclear fuel to Indonesia and then take back the used fuel after it has been irradiated. This arrangement offers a number of advantages.

For Indonesia, storage of the spent fuel in the reactor ponds becomes shorter thus more efficient, in addition no final repository is needed.

For the supplier, the spent fuel carries economic value for it can be reprocessed and recycled to recover the uranium and plutonium.
The problem today is only few countries willing to exercise the concept of leasing fuel, e.g. Russian Federation.

The condition will certainly reduce the reliability of the supply of fuel for NPPs in Indonesia, as well as reducing the degree of freedom of Indonesia in the procurement of fresh fuel.

And also vulnerable to unilateral termination by the owner, either because of political or other issues.
International Cooperation # 3

- Indonesia expect the current leasing fuel concept could be expanded into multilateral arrangements. And it is very possible because the more countries that do not currently operate NPP in the future will use the NPP to increase the reliability and security of electricity supply in the country.

- The expansion of NPP in the world should certainly encourage the owner-countries of nuclear technology to implement closed fuel cycle system through the operation of fast reactors - TRUs Burner.
International Cooperation # 4

- In an effort to increase the fuel supply assurance, leasing fuel from various vendors need to be done. And then the leased fuel once removed from the reactor and cooled down, could be returned to its country of origin, or to a third party State or to a multinational or a regional advanced fuel cycle centre located elsewhere for burning TRUs.

- HLW from processing spent fuel could be sent back to Indonesia.
THANK YOU VERY MUCH