SMR Contributions in Indonesia Net Zero Emission Program

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½ of the world’s population today lives in nuclear states!
Nuclear Energy and SDGs

Key requirements: affordable and reliable energy

Ensuring access to affordable and reliable energy alleviates poverty (SDG 1), which in turn is inextricably linked to hunger (SDG 2).

Affordable and reliable electricity can be transformative in the educational sector (SDG 4) fighting allows, studying hours to be extended, and with access to electricity comes access to computer technology and the internet.

Affordability and reliability are the key energy supply attributes sought by industry (SDG 9).

Key requirement: clean energy

The energy sector is the single biggest contributor to anthropogenic carbon emissions. Fundamentally changing the way we produce energy is essential for achieving meaningful climate action (SDG 13).

By utilizing low-carbon energy sources that do not emit harmful pollutants, damage to ecosystems can be reduced (SDG 14 and 15).

Access to clean energy will allow businesses to adopt more sustainable business practices (SDG 12).

SDG 7 – key to all SDGs

Key requirements: affordable, reliable and clean energy

Access to reliable electricity can empower women (SDG 5). Traditional family roles mean that women and children are typically more likely to suffer from the effects of cooking on open fires, whilst access to productive electrical equipment can significantly reduce the burden on women’s time.

Air pollution from the burning of fossil fuels is known to cause millions of premature deaths each year (SDG 3), whilst the provision of energy and clean water are inextricably linked (SDG 6; see Box 1).

The relationship between reliable, affordable energy and economic growth is well-established. Ensuring that energy is supplied cleanly is essential for reducing urban air pollution and creating sustainable city environments (SDG 11), whilst ensuring that workers are not exposed to undue risks as a product of their employment (SDG 8). Reducing damaging externalities from the use of fossil fuels will benefit the poorest in society most (SDG 10).

A sustainable energy supply must be affordable, reliable and clean. Achieving a sustainable energy supply for all will require and encourage the development of partnerships, fostering peace and justice. (SDG 16 and 17)

**Figure** (a) Global annual emissions of anthropogenic GHGs from 1970 to 2004.5 (b) Share of different anthropogenic GHGs in total emissions in 2004 in terms of CO2-eq. (c) Share of different sectors in total anthropogenic GHG emissions in 2004 in terms of CO2-eq. (Forestry includes deforestation.) {WGIII Figures TS.1a, TS.1b, TS.2b}

Source: An Assessment of the Intergovernmental Panel on Climate Change, This underlying report, adopted section by section at IPCC Plenary XXVII (Valencia, Spain, 12-17 November 2007), represents the formally agreed statement of the IPCC concerning key findings and uncertainties contained in the Working Group contributions to the Fourth Assessment Report.
Indonesia is one of 164 countries who ratified it
Commits to reduce the GHG effect
Requires the development of environmentally friendly energy sources

Source: S. Permana, et al., MBA Thesis., 2022
Public Acceptance of Nuclear Among ASEAN Countries (2022)

Source: The 7th ASEAN Energy Outlook.
future electricity generation is from CD-LINKS Scenario Explorer hosted by IIASA (2020). Estimations of the models were aggregated for the ASEAN region, prorated by Figure 17.

ASEAN depends on nuclear energy even after 2050 or not, clean energy (low-carbon) transition toward the above-vision in the energy transition. Decentralised RE system expansion in urban and remote rural areas, which can be combined out coal power plants. Importantly, if CCS is not seriously scrutinised as a viable option, ASEAN needs to prepare nearly half of total emissions in 2018 (16). In particular, electricity consumption in 2050 is 3.5–10 times larger than that out.

Nuclear energy contribution in EU is fluctuate from 2000 to 2050 at around 10-20%

Nuclear energy contribution in Japan from 6 % in 2019 into 20-22% in 2030 and 2050 at around 30-40%

Nuclear energy contribution in EU is fluctuate from 2010 to 2050 at around 10-19%

High Scenario NPP in ASEAN in 2050 40-48 % and 2070 55-65 % (ASEAN Climate change report 2018)

Low Scenario NPP in ASEAN in 2050 5-16 % and 2070 4-13 % (ASEAN Climate change report 2018)

Source : S. Permana, et all., MBA Thesis., 2022

GDP (PPP) projections of countries for the SSP2 scenario. GDP data is from IIASA (2018).
Scope of analysis can be focused on NPP contribution to national energy plan in Indonesia

Net Zero emission program and NPP contribution

De-dieselization program

Gap analysis for NPP to be used in Net Zero Emission Program

Roadmap Nuclear Energy Implementation

Composition for Java-Sumatera Island and other island in Indonesia

For industrial complex and some special industrial zone

Multi-usage of Nuclear Energy such as co-generation utilization

Source: S. Permaka, et al., MBA Thesis, 2022

SMR Contributions in Indonesia Net Zero Emission Program

21st INPRO Dialogue Forum on the Deployment of Small Modular Reactor Projects and Technologies to Support the Sustainable Development Goals, Saint Petersburg, Russian Federation, 28 August - 1 September 2023
Implementation – Small Modular Reactors

SMR: Rationale of developments

A nuclear option to meet the need for flexible power generation for wider range of users and applications

**Economic**
- Lower Upfront capital cost
- Economy of serial production

**Modularization**
- Multi-module
- Modular Construction

**Flexible Application**
- Remote regions
- Small grids

**Smaller footprint**
- Reduced Emergency planning zone

**Replacement for aging fossil-fired plants**

**Potential Hybrid Energy System**

**Better Affordability**
- Shorter construction time

**Wider range of Users**

**Site flexibility**

**Reduced CO₂ production**
- Integration with Renewables

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### Options for Archipelagic Countries

<table>
<thead>
<tr>
<th>Programme #1</th>
<th>Land-based on-grid province (First Concrete Date: 2023 – 2028)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Technology</td>
<td>Water-cooled reactors, proven design, licensed / under-construction or in-operation in the country of origin, experienced builder, reference plants</td>
</tr>
<tr>
<td>Power range / modes</td>
<td>2 x 100 MWe or 4 x 60 MWe, baseload and load-follows</td>
</tr>
<tr>
<td>Target applications</td>
<td>Eliminate import of electricity, synergetic with fossils and renewables</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Programme #2</th>
<th>Small islands, remote regions (FCD: 2025 – 2030)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Technology</td>
<td>Microreactors: high-temperature gas-cooled, molten-salt reactors</td>
</tr>
<tr>
<td>Power range / modes</td>
<td>(5 – 10) MWe, baseload</td>
</tr>
</tbody>
</table>
| Target applications | • Reduce dependency on diesel fuel,  
  • Cogeneration of electricity and industrial process heat |

<table>
<thead>
<tr>
<th>Programme #3</th>
<th>Marine-based and floating power unit (2028 – 2033)</th>
</tr>
</thead>
</table>
| Type of Technology | • Compact PWRs for floating power unit and molten-salt reactors (R&D stage)  
  • Capacity building with national ship industries |
| Power range / modes | (5 – 50) MWe, baseload |
| Target applications | Power supply for offshore oil/gas platform  
  Ocean/Sea Transportation (Tol Laut) |

Nuclear Power Reactor Types

Nuclear Reactor

- Power Reactor
  - electricity
  - heat
  - pure water
  - hydrogen
  - others

- Fission Reactor
  - ADS

- Fusion Reactor

- Light Water Reactor
  - Heavy Water Reactor
  - Gas Cooled Reactor
  - Fast Reactor
  - Molten Salt Reactor
  - Others

- Research Reactor
- Medical Reactor
- Isotope Production Reactor
- Transmutation Reactor
- Ship Reactor
- Space Reactor
- Others

Source: Nuclear Engineering Course, Tokyo Institute of Tech., 2002
Can SMR type Nuclear Reactors accelerate the Nuclear Implementation in Indonesia?

Source: IAEA ARIS 2022
Small Modular Reactors (SMR) vs Small and medium Reactor (SMR)

In the beginning there were just small reactors

World NPP Construction Landscape

Claimed construction times
(from first concrete to grid connection)

Main vendor offerings

Current SMRs concepts

SMR Presentation IOP 250516
Small Modular Nuclear Reactors

1. WATER COOLED SMALL MODULAR REACTORS (LAND BASED)
2. WATER COOLED SMALL MODULAR REACTORS (MARINE BASED)
3. HIGH TEMPERATURE GAS COOLED SMALL MODULAR REACTORS
4. FAST NEUTRON SPECTRUM SMALL MODULAR REACTORS
5. MOLTEN SALT SMALL MODULAR REACTORS
6. MICRO-SIZED SMALL MODULAR REACTORS
Nuclear Energy: Electricity and Co-generation

Multi-Use of Nuclear Energy Utilization and Synergy with renewable energy

Source: NuScale
José N. Reyes, Jr. John Hopkins, A Promising Innovation in Nuclear Energy, The 7th Round-Table for Studying Energy Situations, Next-Generation Technologies and Innovation for Decarbonization, February 27th, 2018

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The economic pillar: Affordability

Grid-level system costs for dispatchable and renewable technologies (source: OECD Nuclear Energy Agency, 2018)

Comparative LCOE (USD/MWh) of each power plant (IEA, 2020)

Note: Values at 7% cost of capital.

Resource efficiency and material throughput

Nuclear: Lowest cost and clean energy solution

Sumber: https://www.nei.org/advantages/jobs

The nuclear energy industry is a powerful engine for job creation. The U.S. nuclear energy sector directly employs nearly 100,000 people in high-quality, long-term jobs. This number climbs to 475,000 when you include secondary jobs.
What are the safest and cleanest sources of energy?

Death rate from accidents and air pollution:
- Measured as deaths per terawatt-hour of energy production
- 1 terawatt-hour is the annual energy consumption of 27,000 people in the EU.

- Coal: 24.6 deaths (25% of global energy)
- Oil: 18.4 deaths (32% of global energy)
- Natural Gas: 2.8 deaths (22% of global energy)
- Nuclear Energy: 0.2 deaths (4% of global energy)
- Hydropower: 0.07 deaths (4% of global energy)
- Wind: 0.04 deaths (2% of global energy)
- Solar: 0.02 deaths (1% of global energy)
- Biomass: 4.6 deaths (7% of global energy)

Greenhouse gas emissions:
- Measured in emissions of CO₂ equivalents per gigawatt-hour of electricity over the lifecycle of the power plant.
- 1 gigawatt-hour is the annual electricity consumption of 350 people in the EU.

- Coal: 820 tonnes (820 times higher than nuclear energy)
- Oil: 273 tonnes (273 times higher than nuclear energy)
- Natural Gas: 720 tonnes (720 times higher than nuclear energy)
- Nuclear Energy: 490 tonnes (490 times higher than wind energy)
- Hydropower: 34 tonnes
- Wind: 4 tonnes
- Solar: 5 tonnes
- Biomass: 78-220 tonnes

Nuclear Energy: Green and Safe Energy Producer

*Life cycle emissions from biomass vary significantly depending on fuel (e.g., crop residues vs. forestry) and the treatment of biogenic sources.
*The death rate for nuclear energy includes deaths from the Fukushima and Chernobyl disasters as well as the deaths from occupational accidents (largely mining and milling).

Nuclear Energy Utilization Profile

Relative land use (fuel mining and generating footprint) of electricity generation options per unit of electricity (source: Brook & Bradshaw, 2015)

- Nuclear Energy: Less land use for power plant utilization

**SMR Contributions in Indonesia Net Zero Emission Program**

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Nuclear Energy Utilization: Rich Pictures Approach

Environment Aspect
- Reduce Climate Change
- Ecosystem Protection
- Low CO2
- Low GHG
- Preservation & Opportunity Cost
- High Resource Efficiency
- Low Cost
- Low Material Throughput

Economy Aspect
- Low Waste
- Low Land Used
- Low Water Used
- Low Radiation
- Affordability
- High Employment Rate
- High GDP Obtained
- Sustainable High Rates of Low-Carbon Electricity Growth
- High EROI

Energy Ability
- Safest Energy
- Clean Energy
- Energy Efficiency
- Stability and Secure Supply
- Flexibility and Scalability
- Based Load and Load Following
- Multi-Purpose Energy Producer
- Less Population and Remote

Social Aspect
- Nuclear Energy Utilization
- Long-Term Program
- Electricity and Co-Generation
- Industrial Complex
- Storage Facility for Excess Power
- High GDP Obtained
- Community Involvement
- High Employment Rate
- Low Radiation

Special Energy Utilization
- Special Energy Utilization
- SDG-7: Affordable-Clean Energy
- SDG-7: Support other SDGs Direct and Indirect
- P&T Tech and Management
- Recycle-Used Spent Fuel
- Less Storage and Waste

Waste Management
- Waste Management
- Food & Animal Livestock Industry
- Iron & Steel Industry
- Desalination Industry
- Hydrogen Industry
- Logging and Tracer Utilization
- Storage Management

Nuclear Industry
- Nuclear Fuel
- Nuclear Batteries
- Nuclear Power
- Nuclear Fuel Storage Management
- Less Storage and Waste

International NPP Community
- IAEA
- WNA
- Nuclear Industry Network
- ASEAN Nuclear Community
- ASIA Pacific Nuclear Community
- Nuclear Batteries

4% World Primary Energy Mix
- 10% World Electricity Mix
- More 30 Countries of NPP
- More 60 New Unit NPP

Target: SDG's
- SDG-7: Affordable-Clean Energy
- SDG-1: Reduced Poverty
- SDG-3: Good Health and Well-Being
- SDG-9: Infrastructure
- SDG-11: Sustainable Cities
- SDG-13: Climate Action

Balance: Environment, Social and Economic
- Reduce Volume and Radiotoxicity
- Affordability

Source: S. Permana, et al., MBA Thesis., 2022

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Nuclear Power Plant Technology: Rich Pictures Approach

Net Zero Emission (NZE) Contributions

Energy Utilization: Electric and Co-Generation Application

Multi-Use of Nuclear Energy

Nuclear Energy Utilization

Excess Heat Utilization

Electricity Utilization

Ionizing Radioisotope Utilization

Non-Energy Utilization: Radiation and Radionuclide

Heat Storage

EOR

Coal Gas-Liquifaction

Desalination

Hydrogen Fuel

Electricity Supply

Electric Storage

Oil Prod.

Transportation

Electric Vehicle

Electric Train

Ship

Smelter

Industrial Complex

Less-remote population

Resort area

De-Dieselization

Special Energy Utilization

Electricity load

Industry use

Residential use

Food & Animal Livestock

Ionizing Radioisotope Utilization

Nuclear Battery

RTG

Iron & Steel industry

Logging and tracer utilization

Medical-Pharmacy

Food & Animal Livestock

Industry & Applied Research

Basic Research

Accelerator Based

Neutron Based

Detection and characterisation

Sterilization/Disinfection

Environment application

Material modification

Source: S. Permana, et al., MBA Thesis, 2022

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Causal Loop Diagram (CLD) Approach: Energy contribution for Nuclear Energy Program

Ecosystem and Environment Protection

Electricity Production and Capacity

Multi use of nuclear energy production

Multi use of nuclear energy utilization

NZE target on GHG Reduction

Source: S. Permana, et all., MBA Thesis., 2022
Electricity Demand Distribution and Nuclear Contribution in Indonesia

Electricity Composition of NPP contribution (18%) in NZE program in 2060

Nuclear energy: 18% is equal to 324 TWh in 2060 as a part of NZE program. From total 324 TWh, it shows Java Island will be 214 TWh electricity NPP, Sumatra Island 64 TWh and the other island Kalimantan, Sulawesi and the rest will use 14.4 TWh, 16.7 TWh and 14.2 TWh, respectively.

Electricity Demand Composition each province in 2060 for total 1800 TWh

Electricity demand [TWh] transforms into the power capacity of power plant. 324 TWh of NPP equal to 46 GWe power capacity. The estimation of installed capacity for Java island is 30.3 GWe, Sumatra island for 9 GWe and other island requires 2-2.4 GWe install capacity.

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Implementation Plan: Nuclear Energy Contribution for NZE 2060 Program

Map of Electricity Demand Each Island for NPP Utilization in 2060 for NZE Program

18% NPP contribution to NZE Program
324 TWh (46 GWe)

- Java Island ±30.3 GWe 214.8 TWh
- Sumatra Island ±9.0 GWe 64 TWh
- Kalimantan Island ±2.03 GWe 14.4 TWh
- Sulawesi Island ±2.36 GWe 16.7 TWh
- Rest Island ±2.0 GWe 14.2 TWh

Source: S. Permana, et al., MBA Thesis, 2022
Electricity need for Special Industrial Zone

Persebaran Kawasan Industri Secara Nasional
Distribution Area of Industrial Zone In Indonesia (Kemenperin, 2020).

SMR Contributions in Indonesia Net Zero Emission Program
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List Of Electricity Infrastructure demand for Industrial Zone in Indonesia (Kemenperin, 2020)

<table>
<thead>
<tr>
<th>No</th>
<th>Industrial Zone (IZ)</th>
<th>Existing electricity Supply</th>
<th>Electric Demand</th>
<th>Program</th>
<th>Power and Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IZ Teluk Weda</td>
<td>±600 MW</td>
<td>RPJMN</td>
<td>Medium/SMR 300-700 MWe</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>IZ Ketapang</td>
<td>electric supply from PLN 87 MW</td>
<td>PRPJMN-PSN</td>
<td>SMR 50-100 MWe</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>IZ Galang Batang</td>
<td>350 MW</td>
<td>RPJMN</td>
<td>SMR/Medium 300-700 MWe</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>IZ Suryo Borneo</td>
<td>Power Plant Turbine 2 x 7.5 MW</td>
<td>RPJMN</td>
<td>VSMR 1-10 MWe</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>IZ Sadai</td>
<td>112 MW</td>
<td>RPJMN</td>
<td>SMR 100-300 MWe</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>IZ Tanjung Enim</td>
<td>Coal PP Sumsel 8 for 2x620 MW</td>
<td>RPJMN</td>
<td>Medium/Large 600-1200 MWe</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>IZ Batulicin</td>
<td>PLN 50 MW, Coal PP 3.5 MW and 6 MW, Plan for 2x100 MW</td>
<td>633 MW</td>
<td>RPJMN-PSN</td>
<td>Medium/SMR multi 300-700 MWe</td>
</tr>
<tr>
<td>8</td>
<td>Bintan Aerospace</td>
<td>Power Plant 21 MW + 2 x 15 MW coal fired Under Construction, and 10.3 MW diesel PP</td>
<td>200 MW</td>
<td>RPJMN</td>
<td>SMR 100-300 MWe</td>
</tr>
<tr>
<td>9</td>
<td>IZ Jorong</td>
<td>Coal PP Asam-Asam 2 x 100 MW and increase to 4 x 100 MW. Total electricity need is 200 MW</td>
<td>1000 MW (Potential hydro electri Kayan River)</td>
<td>RPJMN-PSN</td>
<td>Large 1000-1500 MWe</td>
</tr>
<tr>
<td>10</td>
<td>IZ Tanah Kuning</td>
<td>500 MW (potential Gas/wind PP), 5 MW liquid industry</td>
<td>RPJMN-PSN</td>
<td>PRPJMN</td>
<td>SMR 300 MWe</td>
</tr>
<tr>
<td>11</td>
<td>IZ Kuala Tanjung</td>
<td>500 MW up to 2025</td>
<td>RPJMN</td>
<td>SMR/Medium 200-500 MWe</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>KEK Sei Mangkei</td>
<td>2 x 100 MW, MoU PLN 35 MW</td>
<td>RPJMN</td>
<td>SMR 10-50 MWe</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>IZ Kemingking</td>
<td>25 MW</td>
<td>PRPJMN-PSN</td>
<td>SMR 100-300 MWe</td>
<td></td>
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<tr>
<td>14</td>
<td>IZ Teluk Bintuni</td>
<td>240 MW</td>
<td>PRPJMN-PSN</td>
<td>SMR 100-300 MWe</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>KEK Palu</td>
<td>240 MW</td>
<td>PRPJMN-PSN</td>
<td>SMR 100-300 MWe</td>
<td></td>
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<tr>
<td>16</td>
<td>IZ Bangkalan (KKISM)</td>
<td>450 MW</td>
<td>RPJMN</td>
<td>Medium/SMR multi 300-500 MWe</td>
<td></td>
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<tr>
<td>17</td>
<td>IZ Tanggamus</td>
<td>150 kV</td>
<td>RPJMN</td>
<td>SMR 10-50 MWe</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>IZ Tenayan</td>
<td>120 MW</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
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<tr>
<td>19</td>
<td>IZ Brebes</td>
<td>150 MW</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>IZ Tanjung Buton</td>
<td>1000 kW up to 2025</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>IZ way Pisang</td>
<td>600 MW</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>IZ Katibung</td>
<td>600 MW</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>IZ Pesawaran</td>
<td>500 MW up to 2025</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>IZ Ledong</td>
<td>500 MW up to 2025</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>IZ Batanajung</td>
<td>1000 kW up to 2025</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>IZ Takalar</td>
<td>1000 kW up to 2025</td>
<td>RPJMN</td>
<td>SMR 100-200 MWe</td>
<td></td>
</tr>
</tbody>
</table>

List Of Electricity Infrastructure demand for Industrial Zone in Indonesia based on RPJMN program that shows each industrial zones has their own electricity demand. Based on 26 industrial zones, it has the electricity demand range 10 MWe up to 1000 MWe power range.
The Need of Electrical Supply for Industrial Zones in Indonesia

Potential For Small Modular Reactors Deployment

Source: KEBUTUHAN INFRASTRUKTUR LISTRIK YANG MENDUKUNG KAWASAN INDUSTRI PRIORITAS, 2020, DIREKTORAT PERWILAYAHAN INDUSTRI, Kementrian Perindustrian Republik Indonesia

Source: S. Permana, et all., MBA Thesis., 2022

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The distribution of 5200 unit of diesel power plant in about 2130 locations in Indonesia (PLN, 2021)

As shown, the distribution of de-dieselization program very scatter in all island in Indonesia and those area has electricity demand depending on the area which is shown for the electricity demand range from 0.6 MWe up to 550 MWe electricity demand.

Maluku has the highest electricity demand for this program and it followed by papua, sulteng and Kalbar as the big electricity demand area.

Source: S. Permana, et all., MBA Thesis., 2022
### List Of Electricity Infrastructure demand for de-dieselization Zone in Indonesia

<table>
<thead>
<tr>
<th>No</th>
<th>Proyek Name</th>
<th>Power [MW]</th>
<th>COD</th>
<th>Note</th>
<th>NPP Type</th>
<th>Power Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>PLTS De-dieselization Kalbar</td>
<td>69.84</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>SMR single</td>
<td>50-100 MW</td>
</tr>
<tr>
<td>2</td>
<td>PLTS De-dieselization Kalsel</td>
<td>1.2</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>3</td>
<td>PLTS De-dieselization Kaltara</td>
<td>4.55</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>4</td>
<td>PLTS De-dieselization Kalteng</td>
<td>8.67</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>5</td>
<td>PLTS De-dieselization Kaltim</td>
<td>24.81</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>6</td>
<td>PLTS De-dieselization Kalbar</td>
<td>10.5</td>
<td>2025</td>
<td>De-dieselization Isolated system</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>7</td>
<td>PLTS De-dieselization Kalsel</td>
<td>2.0</td>
<td>2025</td>
<td>De-dieselization Isolated system</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>8</td>
<td>PLTS De-dieselization Kalteng</td>
<td>9.83</td>
<td>2025</td>
<td>De-dieselization Isolated system</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>9</td>
<td>PLTS + Baterei De-dieselization Sulut</td>
<td>31.02</td>
<td>2023</td>
<td>De-dieselization program NRE</td>
<td>MSR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>10</td>
<td>PLTS + Baterei De-dieselization Sulteng</td>
<td>80.24</td>
<td>2023</td>
<td>De-dieselization program NRE</td>
<td>MSR single</td>
<td>50-100 MW</td>
</tr>
<tr>
<td>11</td>
<td>PLTS + Baterei De-dieselization Sulsel</td>
<td>0.59</td>
<td>2023</td>
<td>De-dieselization program NRE</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>12</td>
<td>PLTS + Baterei De-dieselization Sulsel</td>
<td>4.06</td>
<td>2025</td>
<td>De-dieselization program NRE</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>13</td>
<td>PLTS + Baterei De-dieselization Sultra</td>
<td>9.84</td>
<td>2023</td>
<td>De-dieselization program NRE</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
<tr>
<td>14</td>
<td>PLTS + Baterei De-dieselization Sultra</td>
<td>17.963</td>
<td>2025</td>
<td>De-dieselization program NRE</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>15</td>
<td>PLTS + Baterei De-dieselization maluku</td>
<td>548.07</td>
<td>2023</td>
<td>De-dieselization program NRE</td>
<td>SMR Multi/Medium NPP-Single</td>
<td>300-700 MW</td>
</tr>
<tr>
<td>16</td>
<td>PLTS + Baterei De-dieselization maluku utara</td>
<td>22.43</td>
<td>2023</td>
<td>De-dieselization program NRE</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>17</td>
<td>PLTS + Baterei De-dieselization papua</td>
<td>113.85</td>
<td>2023/2025</td>
<td>De-dieselization program NRE</td>
<td>SMR-Single</td>
<td>100-300 MW</td>
</tr>
<tr>
<td>18</td>
<td>PLTS + Baterei De-dieselization papua barat</td>
<td>50.12</td>
<td>2023/2025</td>
<td>De-dieselization program NRE</td>
<td>SMR single</td>
<td>50-100 MW</td>
</tr>
<tr>
<td>19</td>
<td>PLTS + Baterei De-dieselization NTTB</td>
<td>28.474</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>20</td>
<td>PLTS De-dieselization NTT</td>
<td>40.76</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>21</td>
<td>PLTS De-dieselization NTT</td>
<td>29.53</td>
<td>2023</td>
<td>De-dieselization Isolated system</td>
<td>SMR single</td>
<td>10-50 MW</td>
</tr>
<tr>
<td>22</td>
<td>PLTS De-dieselization NTT</td>
<td>5</td>
<td>2025</td>
<td>De-dieselization Isolated system</td>
<td>VSMR-Single</td>
<td>&lt; 10 MW</td>
</tr>
</tbody>
</table>

Note: PLTS (Solar PV), Data from reference (PLN, 2021) and estimated NPP power utilization and reactor type

For the potential of NPP utilization for the de-dieselization program is listed in Table for the estimation for power scale and reactor types which is depending on the electricity demand each province or zone.

Source: S. Permana, et al., MBA Thesis, 2022
Evaluation of Large Reactor and SMR by levelized cost of electricity (LCOE)

LCOE in Europe are about 42 – 102 USD/MWh (capacity factor 85 %, discount rate 7%)

LCOE in Asia are about 50 USD/MWh up to 87 USD/MWh

Over all LCOE of those countries are around 42 USD/MWh up to 102 USD/MWh which is depending on the country cost estimation

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Levelised cost of electricity for nuclear plants at 85% capacity factor - New build 7 % discount

Investment (USD/MWh)  Decommissioning (USD/MWh)  Fuel (USD/MWh)  O&M (USD/MWh)  LCOE (USD/MWh)

France  Japan  Korea  Russian Federation  Slovak Republic  United States  China  India

0.00  20.00  40.00  60.00  80.00  100.00  120.00

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Whereas renewables are very competitive in most countries participating in this report, the data provided for this report shows that they still have higher costs than fossil fuel- or nuclear-based generation in some countries (in this report Japan, Korea and Russia). Also within countries, different locational conditions can lead to differences in generation costs at the subnational and local level. In Europe, both onshore and offshore wind as well as utility scale solar installations are competitive to gas and nuclear energy.

In the United States, gas-fired power plants benefit from the expected low fuel prices in the region, although fuel price assumptions are in general uncertain. Nevertheless, in terms of the LCOE of the median plant, onshore wind and utility scale solar PV are, assuming emission costs of USD 30/tCO², the least cost options. Natural gas CCGTs are followed by offshore wind, nuclear new build and, finally, coal.

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In China and India, variable renewables are having the lowest expected levelised generation costs: utility scale solar PV and onshore wind are the least-cost options in both countries. Nuclear energy is also competitive, showing that both countries have promising options to transition out of their currently still highly carbon-intensive electricity generation.

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Note: Values at 7% cost of capital.

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In Figure 3.5: Median technology costs by region, the costs are presented for different technologies across various regions. The figure highlights the competitive nature of renewables in most countries, particularly in Europe and China. However, the costs in countries like Japan, Korea, and Russia still reflect higher costs compared to traditional fossil fuels and nuclear energy. The location-specific conditions can significantly impact the generation costs at the subnational and local levels.

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In terms of cost, the figures for capital costs and operating costs are provided. The capital cost of SMRs for all participating companies ranges from a minimum of 50,782 USD to a maximum of 90,129 USD, with an average of 60,479 USD. The operating costs range from 21 USD to 30 USD, with an average of 26 USD. The levelized cost of electricity is also noted, indicating the cost-effectiveness of SMRs in the deployment of small modular reactors for net zero emission programs.

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SMR Contributions in Indonesia Net Zero Emission Program

21st INPRO Dialogue Forum on the Deployment of Small Modular Reactor Projects and Technologies to Support the Sustainable Development Goals, Saint Petersburg, Russian Federation, 28 August - 1 September 2023

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Source : IEA, 2020

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Source : Energy Options Network, 2018

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Source : S. Permana, et all., MBA Thesis., 2022

**Renewable Energy Potential (GWe)**

1. **Power Capacity [GWe]: Depending on Potential**
2. **Capacity Factor (CF) [-]: Depending on Energy Sources**
3. **Annual Time Hours [Hours]:** 24x365 = 8760 Hours
4. **Transmission-Distribution Loss [%]:** 10 % loss

**Electricity Production from Potential RE [TWh]**

Equation: 
\[ \text{Electricity Production from Potential RE [TWh]} = \text{Pow} \times \text{CF} \times \text{AnTime} \times (1 - \text{Loss}) \]

**Energy NRE Potential in Indonesia Based on the Type of Energy Sources**

<table>
<thead>
<tr>
<th>Energy NRE</th>
<th>Potential (GW)</th>
<th>CF USA (EIA 2013)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geothermal</td>
<td>23,08</td>
<td>71</td>
</tr>
<tr>
<td>Solar</td>
<td>207,08</td>
<td>24,6</td>
</tr>
<tr>
<td>Wind</td>
<td>60,07</td>
<td>34,6</td>
</tr>
<tr>
<td>Water</td>
<td>94,06</td>
<td>37,1</td>
</tr>
<tr>
<td>Bioenergy</td>
<td>31,07</td>
<td>63,5</td>
</tr>
<tr>
<td>Tidal **</td>
<td>17,09</td>
<td>25</td>
</tr>
<tr>
<td>Total</td>
<td>432.45</td>
<td></td>
</tr>
</tbody>
</table>

**Electricity Production from Potential RE [TWh]**

- **Total Potential Electric Production (TWh):** 2060 (about 1800 TWh)
- **Electricity Demand Gap:** [640 TWh] 1800 TWh

**Source:** S. Permana, et al., MBA Thesis., 2022
Electricity and Percentage Composition of RE and fossil to Nuclear [%]

<table>
<thead>
<tr>
<th>Percentage of Fossil and Nuclear Electricity Supply Gap [%]</th>
<th>RE</th>
<th>Fossil</th>
<th>Nuclear</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>1159</td>
<td>1159</td>
<td>1159</td>
</tr>
<tr>
<td>80</td>
<td>1159</td>
<td>1159</td>
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</tr>
<tr>
<td>50</td>
<td>1159</td>
<td>1159</td>
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<td>30</td>
<td>1159</td>
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<td>20</td>
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</tr>
<tr>
<td>0</td>
<td>1159</td>
<td>1159</td>
<td>1159</td>
</tr>
</tbody>
</table>

Electricity Supply Gap for 100% Potential: 641 TWh
Supply by: Fossil or/and Nuclear

Electricity Supply Gap from 100% RE Potential: 1159 TWh

Source: S. Permana, et al., MBA Thesis., 2022
Conclusion

For energy applications, including for nuclear power plants (NPP) and energy co-generation applications, such as water desalination, hydrogen production, for coal gasification and liquefaction applications and enhanced oil recovery (EOR) applications. As general NPP feature, it also can be used to reduce the CO2 production to replace for fossil fired plants aging and diesel power plant in remote and isolated area. As part of flexibility of NPP, it can be integrated with renewable system as hybrid energy systems and some load follower power plant. Small and medium-sized or modular reactors (SMR) are an option to fulfil the need for flexible power generation for a wider range of users and applications.

Nuclear provide clean and eco-friendly, reliable, safe and affordable that NPP utilization in the world and technology advancement on NPP program have been enhanced with more than 65 years NPP commercialization in the world. Economy competitiveness of NPP has been shown by adopting LCOE for large and SMR power technology. LCOE of NPP in Europe are about 42 - 102 USD/MWh, and in USA at around 71 USD/MWh. LCOE in Asia are about 50 - 87 USD/MWh. LCOE for SMR type in average value of 60 USD/MWh and the maximum is about 90 USD/MWh. As general NPP feature, it also can be used to reduce the CO2 production to replace for fossil fired plants aging and diesel power plant in remote and isolated area. As part of flexibility of NPP, it can be integrated with renewable system as hybrid energy systems and some load follower power plant.

Scalability of Nuclear Power has been shown by utilization of Small and medium-sized or modular reactors (SMR) for flexible power generation for a wider range of users and applications. SMR, deployable either as single or multi-module plant, offer the possibility to combine nuclear with alternative energy sources, including renewables. The utilization of NPP analysis for special zone has been conducted such for industrial zone. Based on industrial zones, the electricity demand range 10-1200 MWe depends on the area. The distribution of de-dieselization program very scatter in all islands in Indonesia and those area has electricity demand depending on the area for the electricity demand ranges from 0,6 MWe up to 550 MWe
SMR Contributions in Indonesia Net Zero Emission Program

Rosatom Technical Academy, Saint Petersburg, Russian Federation, 28 August - 1 September 2023

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