# Repurposing of coal power plants with

# Nuclear Methanol hybrid energy system

A South African case study

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**Abstract**

As the world makes strides towards achieving climate goals and reducing carbon emissions, it is worthwhile to consider the opportunities of repurposing coal power plants that have been mothballed or are reaching their end of life. Coal still dominates the South African energy mix by providing 80% of the total system load. Hybrid energy systems are perfect candidates to address the current energy demands by reducing carbon emission challenges caused by coal power plants. A Nuclear Methanol system is investigated as a proposed case study for the repurposing of a coal power plant with Small Modular Reactor (SMR) operation. Methanol is well known as ‘liquid Hydrogen’ which is more stable and less flammable and is thus a more attractive option because it presents much lower storage and transportation risk. Factors that need to be considered include, but not limited to, site zoning, multi-module plants, operational and safety challenges, regulatory and licensing challenges, etc. The viability of the hybrid energy system with specific focus on the South African landscape will be investigated along with the challenges and opportunities presented for the deployment of SMRs to the established sites.

## INTRODUCTION

The present and future projected global trends of climate change have impacted the way the world utilises it’s resources. South Africa has a role to play in the global challenge to reduce greenhouse gas (GHG) emissions and honour its international obligations and commitments to be a fair contributor to the global climate change response. In this stride, the Parliament of the Republic of South Africa, has enacted the Climate Change Bill [B9B-2022] on Thursday, 25 April 2024. This legislation provides a platform for the enablement of an effective climate change response and development of a long-term just energy transition geared towards a low-carbon and climate-resilient economy along with a sustainable society.

Main objective of the bill is to foster a stakeholder-aligned national energy transition that strives to meet decarbonisation targets whilst balancing energy security along with affordable access for all South Africans [1]. In South Africa, coal still dominates the South African energy mix by providing 80% of the total system load. Coal Power Plants (CPP) are major contributors to GHG, which include carbon dioxide, sulphur dioxide and other particulate matter that affects our environment and health.

## Nuclear Methanol Hybrid Energy System

### Repurposing of CPPs with SMRs

The general definition of repurposing is to find a new use of an existing object for a purpose other than its original intention of use. Repurposing may constitute an alternate way of utilising the object or a modification to the original object in order to fulfil a new purpose of the object.

Globally, CPPs are gearing towards retirement, either because of government regulations, aging and/or market pressures. The existing CPP sites are ideal candidates for deploying new generation technologies. There is still value for the use of CPPs, and one such example is the repurposing and re-engineering of CPPs to Nuclear Methanol hybrid energy systems that can contribute to energy security, reduce GHGs and provide additional non-electric applications.

CPP have an established generating site with infrastructure in place and an established community. Water resources are readily available for the plant site and there are workforce personnel that can be reskilled or upskilled to operate nuclear power plants [2].

Small Modular Reactors (SMRs) are fast attracting attention due to its’ benefits of being a clean and stable energy source that can replace fossil fuels and reduce GHGs as compared to the conventional coal and natural gas-fired power plants. When considering repurposing of CPPs, the other added cost benefit of deploying SMRs, is that between both plants there is similarity in the steam cycle system. In essence the turbine island of CPPs can be re-used by powering it with the steam generated by SMRs. SMRs are modular in design, providing flexibility in the choice of physical plant layout and because of certain inherent safety design options will reduce licencing complexity.

### Methanol Economy

The concept “Methanol Economy” was proposed in 1990, by Nobel Prize winner George A. Olah whereby renewable methanol is used to replace fossil resources [3]. Methanol is touted as tomorrow’s hydrogen, today. Being a liquid at ambient conditions, Methanol is an efficient hydrogen carrier, stored and transported as a liquid and has the highest hydrogen to carbon ratio of liquid fuels, thereby storing more energy in one simple alcohol molecule than can be found in hydrogen alone. Some of the other notable benefits of Methanol are as follows:

* For fuel transportation industries presenting lower complexities and logistics cost;
* Methanol for export purposes;
* Has low carbon intensity and a green pathway to carbon neutral transport;
* Methanol can be easily transformed for hydrogen applications, generating on-demand hydrogen at the point of use;
* Transportation vehicles utilising onboard Methanol reformation, have lower capex and opex for extended periods, shorter refuelling time and lower emissions. It is to be noted that Methanol is preferred over Ammonia as a fuel for sea transport due to the high toxicity levels of Ammonia.

Methanol can be produced from different sources such as feedstock from municipal solid waste, agriculture, captured CO2 and other renewable pathways.

### Nuclear non-electric application

SMRs can be coupled with Methanol reactors for non-electric applications. Process heat or electricity generated by SMRs can be utilised as an energy source for the production of Hydrogen that is required for the chemical processing of Methanol. Carbon captured from sources such as fossil plants or biogas can be used in the Methanol production process. The chemical equation is:

$$CO\_{2} + 3H\_{2 }\rightarrow CH\_{3}OH + H\_{2}O Eq1$$

The carbon dioxide and hydrogen gas are fed into a fixed bed reactor with a suitable catalyst for the methanol reaction. During the production process methanol and water are the main products. It is worthy to note that in a water scarce country such as South Africa, the water product can then be re-utilised either by recycling into the plant or if required elsewhere to fulfil similar needs. A schematic diagram of the process is given in Fig. 1*.*



*FIG. 1. Schematic diagram of Nuclear Methanol hybrid system.*

## Case study – South AfricaN landscape

Eskom, is South Africa’s main utility, supplying almost 90% of the country’s electricity and also generates on average 30% of the electricity that is used in Africa. Various technologies are used to generate electricity and is usually referred to as the ‘plant mix’. Eskom currently operates 14 coal-fired power plants as base load power generators, almost 80% of the plant mix that operate 24 hours a day to meet the demand for electricity. The total installed capacity of these CPPs is approximately 43 600 MW. Eskom also operates South Africa’s only nuclear power station, namely Koeberg which also contributes 1 934 MW of base load power to the plant mix. In Table 1, a list of CPP’s that were operating as at June 2022 and their installed capacity is given.

TABLE 1. LIST OF ESKOM CPPs [4]

|  |  |  |
| --- | --- | --- |
| CPP | Location | Capacity (MW) |
| Arnot  | Middelburg | 2 220 |
| Camden  | Ermelo | 1 561 |
| Duvha  | Emalahleni | 3 000 |
| Grootvlei | Balfour | 1 180 |
| Hendrina  | Middelberg | 1 723 |
| Kendal  | Emalahleni | 4 116 |
| Komati  | Middelburg | 990 |
| Kriel | Bethal | 2 790 |
| Kusile | Ogies | 3 196 |
| Lethabo | Vereeniging | 3 708 |
| Majuba | Volksrust | 4 110 |
| Matimba | Lephalale | 3 990 |
| Matla | Bethal | 3 600 |
| Medupi | Lephalale | 4 764 |
| Tutuka | Standerton | 3 654 |

The Komati Power Station in Middleburg, Mpumalanga province, has been fully operational since March 1966 and as of 31 October 2022 was officially shutdown. Following this event, Eskom has plans to further decommission 10 other power stations by 2040 and 2050. There is immense opportunity for repurposing and repowering of the targeted sites. Following Komati, Grootvlei, Camden and Hendrina will be the next site in focus, adopting lessons learnt from Komati’s which was used as the pilot site for repurposing and repower.

### Komati repurposing and repowering

Komati power station has a renewed purpose after being decommissioned in 2022. It now operates with a capacity of producing renewable energy, a mix of 150 MW of photovoltaic solar, 70 MW of wind and 150 MW of battery storage. In Fig. 2*.* a picture of Komati Power Plant is shown.

Komati also hosts a Microgrid assembly line which provide additional employment opportunities within the community. The training centre has been refurbished into a Renewable energy training facility where Eskom employees and other qualifying members of the community are trained in the development of technical skills.



*FIG. 2. Komati Power Station [5].*

Eskom and South Africa at large, have gained a lot of experience from Komati, especially on economic ventures; infrastructure and services; community development and engagements, which can be easily applied to similar repurposing projects. Other established engagements between government, private sector, organised labour, environmental and social studies can easily form the foundations for future undertakings.

### Future plans for other CPPs

There are discussions and plans in place for other power stations, namely: Camden, Grootvlei and Hendrina (shown in Fig. 3.) to be shutdown in a staggered fashion and transitioned into a repurposed site. It would be of great value if nuclear is also evaluated for this purpose and the site re-engineered to deploy SMRs to match the identified CPPs generating capacity. Lessons learnt from Komati repurposing can be easily adapted for the implementation of decommissioning and repurposing proposals with nuclear methanol hybrid systems. However, when proposing a modular unit and coupling with non-nuclear applications there are further considerations to be investigated such as the licencing strategy and the relevance of current nuclear policy to legislate new designs.

|  |  |  |
| --- | --- | --- |
|  | A large factory with smoke stacks  Description automatically generated | A large smokestack in a field  Description automatically generated |

*FIG. 3. Images of Camden, Grootvlei and Hendrina Coal Power Plants [5].*

### Opportunities and challenges

Opportunities and challenges exist with any new developments, especially when such developments have not been established before. Fortunately for South Africa, it is the first country to actually repurpose a CPP. The lessons learnt can become the blueprint for future work. Below are some considerations for future work:

* Lessons learned from Komati can be applied to the repurposing of CPP with nuclear power plants;
* Licencing (multi-module plants) and how to approach the licencing, etc;
* The site zoning with multi-module plants and the associated operational and safety challenges;
* Whether current regulatory and licencing policies are adequate or need amendment for incorporating new plant design;
* Radiological and chemical risk;
* Economic analysis of nuclear methanol hybrid systems. It is noted that the United States government has recognised the benefit of repurposing coal-fired power plants. To this end the US has encouraged repurposing by introducing investment tax incentives in the Inflation Reduction Act (IRA) for new advanced nuclear projects. There are also bonuses for plants built in fossil energy communities.

The key benefits of this CPP transition to other energy sources is that there are savings in grid infrastructure costs, capital costs, and a marginal effort is needed to amend the environmental impact assessments. When it comes to the cost savings associated with grid infrastructure, the existing electrical infrastructure built for a CPP could be re-engineered for use in a nuclear power plant, resulting in lesser new transmission and distribution infrastructure being built to accommodate new generation capacity being added to the system.

Some of the capital cost savings include the equipment at a CPP that could still be re-engineered for use into the new plant. However, an age analysis and compatibility must be done to ensure the lifecycle and suitability of such equipment. These equipment include steam turbines, heat sinks (cooling tower, open loop cooling or air-cooled condensers) [6]. Other utilities such as water treatment plants are readily available for the plant processes.

Communities around CPPs have skilled workers that can be easily trained to work in the new plant. As seen from the Komati repurposing project, communities were integrated into the repurposed plant ensuring economic sustainability of the workers.

Because the conditions of the environmental site are known, there is the added advantage of a reduced turnaround time with the review and amendment of environmental and societal assessments and policies.

However, there are some challenges that still present itself such as the availability of nuclear fuel, experienced personnel, and nuclear waste management. But these can be overcome by mitigation strategies like training, with partnerships, local, national and international co-operation with experienced organisations rendering their experience of operating nuclear power plants.

## Conclusion

In the wake of climate change, there is sound benefit of deploying SMRs to existing CPPs sites given the offset in some of the infrastructure costs, site zoning and availability of established communities. Applying non-electric applications, such as Methanol production that utilises thermal or electrical energy for the supply of Hydrogen for the process, is equally favoured for improving the economic viability of SMR’s in nuclear hybrid systems. It is recommended that further site-specific studies be conducted to support the repurposing of existing CPPs with nuclear methanol hybrid systems.

## Further information

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