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Study on the implementation of NuScale SMR in Doicesti, Romania

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Abstract. The ongoing shift toward low-carbon energy production has renewed interest in advanced nuclear technologies, particularly compact reactor designs. Small Modular Reactors (SMRs) build upon the operating experience of conventional nuclear power plants while introducing a modular and integrated configuration, together with improved passive safety features.

1 Introduction

This paper examines the general engineering aspects of the SMR Doicești Project, addressing its technical concept, environmental considerations, grid integration capability, licensing framework, and potential regional impact. Beyond its contribution to reducing lifecycle CO_2 emissions, the project also represents a significant opportunity for industrial development and long-term economic growth at the regional level.

2 Current situation

2.1 Economic and social impact of the plant closure

The Doicești Power Station was a lignite coal plant that contributed to Romania's electricity production (baseload). Due to European regulations and decarbonisation strategies the plant was closed after 59 years of operation with a plan to change it to a green source of energy.

Some of the effects of the closure were both economic and social, the most visible effect being the loss of employment in the Doicești area, alongside a decline in local service demand. The loss of employment not only hindered the local economy but also induced a workforce migration toward larger urban center like Târgoviște, Pitești, Ploiești and București and reduced the economic attractiveness of the area.

2.2 National grid impact of the plant closure

Because the Doicești Coal Power Plant was designed to function in baseload capacity its closure affected the Romanian national grid with issues ranging from loss of the grid's rotational inertia and stability margin to loss of voltage and frequency support. The retirement of the coal capacity in Doicești also reduced the available firm capacity within the grid, potentially increasing the risk of supply shortages. It also increases the dependence on other alternative sources of energy such as natural gas, hydropower, nuclear generation or renewable sources. From those mentioned before, a clean, reliable (and flexible in case of SMRs) source of energy is the nuclear energy. In Doicești, the implementation of the NuScale SMR will not only fix the previously mentioned deficiencies but will provide social revitalisation of the area.

The local revitalisation of the area will happen based on another existing example in Cernavoda (Cernavoda Nuclear Power Plant). The impact on the community can be divided in five categories.

Economic development: The power plant will be a major employer providing stable jobs during construction as well as during operation.

Urban development: The infrastructure will be improved to accommodate the needs of the workers and the operations of the Nuclear Power Plant (NPP) such as housing and public services.

Health and education: In Cernavodă, a lot of opportunities for vocational trainings appeared after the construction of the NPP as well as hospitals and energy focused high schools. Doicești will follow the same

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example developing the area possibly creating a technological hub as shown in Figure 1.

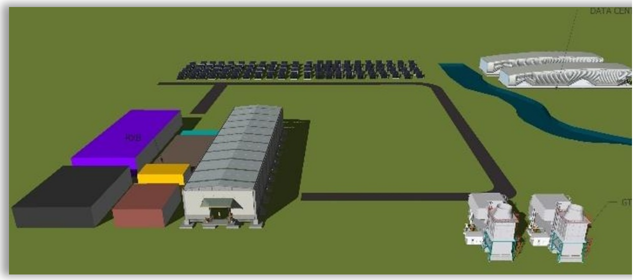

Fig. 1. Hybrid Energy Platform.

Environment and Community: A strict environmental monitorization will be implemented alongside a focus on minimum radiological impact. The community will benefit from a variety of reasons such as public information, grid stability, quality of life, overall development of the area and professional requalification.

As a benefit to be a First-of-a-kind project, this initiative offers not only a regional transformation potential but also an opportunity for Romania to assume a pioneering role as an international leader in the deployment of next-generation nuclear technologies.

3 Technical characteristics of the NuScale SMR

A Small Modular Reactor (SMR) is a nuclear reactor based on the principle of nuclear fission defined through three distinctive characteristics:

1. Small: The reduced dimensions of a conventional reactor with a nominal power of up to 300MW(e) per unit, compared to 1000MW(e) specific for conventional reactors.
2. Modular: The systems and components are fabricated and assembled by the manufacturer, followed by their transportation as a single unit (module) on the site.
3. Reactor: It uses the nuclear fission principle for heat generation then transformed into electricity (or used for industrial heating or district heating)

A key strength of the NuScale SMR design is its reliance on passive systems based on thermosiphon-driven natural circulation. This ensured a continuous core cooling even in the absence of active pumping systems (pump failure) or external power sources (LOOP). The design also features increased nuclear security systems and can provide flexible energy through its load following capacity (single unit or plant).

The technical characteristics of the NuScale design are shown in Table 1 [1].

Table 1. Main Technical Characteristics of the SMR Unit

Parameter	**Specification**
Reactor Technology	Integral Pressurized Water Reactor (PWR)
Electrical Output	462 MWe (77 MWe × 6 modules)
Design Lifetime	60 years
Fuel Type	Low-enriched uranium dioxide (UO_2), enriched up to 5%
Moderator / Coolant	Light water (H_2O)
Refuelling Interval	Every 18 months (planned outage)
Refuelling & Maintenance	Refuelling and maintenance activities performed simultaneously
Safety System Concept	Passive safety systems based on natural physical phenomena (gravity and natural circulation)
Emergency Planning Zone	Significantly reduced exclusion zone (approximately 112 m)

As shown in Figure *2*, the integral small modular reactor design incorporates all primary reactor components within a single pressure vessel and shares a compact building configuration that enables modular construction and simplified on-site assembly. A section of how the reactor building would look like in a six-module configuration is show below.

Fig. 2. NuScale reactor building cutaway [2]

For the plant to have a high level of safety some passive systems are needed such as ECCS (Emergency Core Cooling System), UHS (Ultimate Heat Sink) and DHRS (Decay Heat Removal System).

The ECCS is designed to maintain the cooling function of the reactor core in case of a LOCA (Loss of Cooling Accident) or other abnormal conditions. On the other hand, the DHRS is actuated after reactor shutdown to extract the decay heat and prevent fuel overheating.

The UHS works alongside the DHRS, that is essentially a heatsink, and disperses the heat in the reactor pool (UHS) contributing to the passiveness of the design.

Because of these passive systems and its relatively small footprint the NuScale design can be placed much closer to population centres than conventional nuclear power plants. One way to quantify this is through the exclusion zone which for the NuScale SMR is much smaller (112m) compared to normal exclusion zone which can vary from 1 km to 10 km in radius.

4 Impact of coal to nuclear transition

Replacing a coal-fired facility with an SMR plant affects the region in technical, economic and social terms.

4.1 The following will explore the ways in which the region benefits

Employment: Construction and commissioning create a short-term spike in employment; long-term operation, a potential data centre staffing and supplier activities provide more stable and higher-value jobs than the coal baseline.

As shown in Figure 3, employment follows a structured transition. After a temporary decline during the planning phase, a significant peak occurs during the construction period, which begins around 2028. This is followed by stable, long-term operational jobs and retained supply-chain positions.

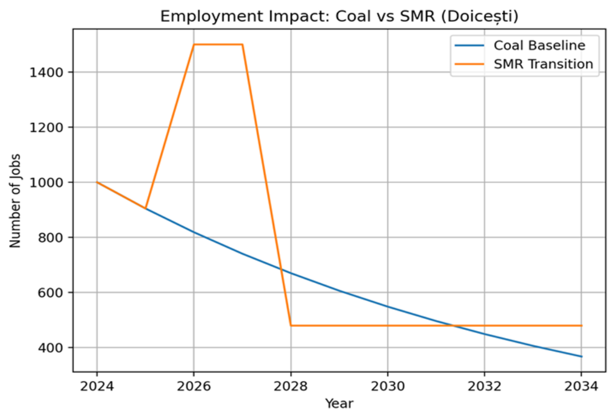

Fig. 3. Employment Impact.

Economic output: SMR operation, long-term power sales increase the region's GDP and tax revenues compared to a decommissioned coal plant.

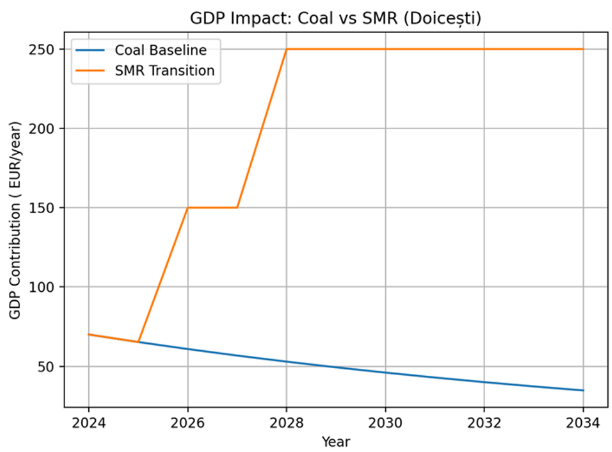

Fig. 4. GPD Impact.

Figure 4 illustrates the trajectory of regional GDP, clearly showing the divergence between the declining coal baseline and the sustained economic contribution generated by SMR operations and related industrial activities.

Figure 5 illustrates the fiscal impact, showing that tax revenues increase substantially during construction and stabilise at a higher long-term level than in the post-closure coal scenario.

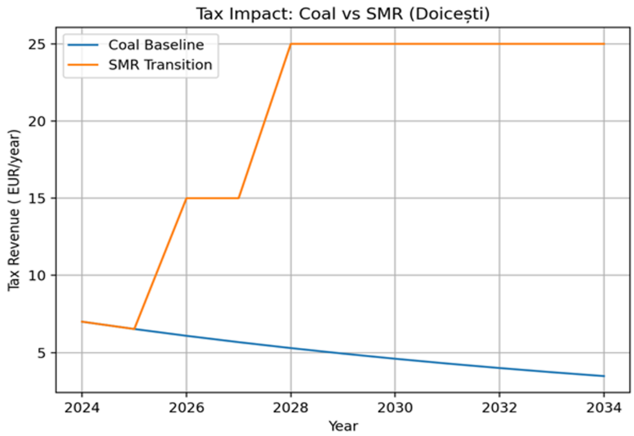

Fig. 5. Tax Impact.

Infrastructure Reuse: Existing high-voltage connections and cooling water infrastructure reduce CAPEX and speed up the permitting process.

As shown in Figure 6, CO_2 emissions decrease sharply once the SMR is operational, reflecting the shift from coal generation, which has a high emission rate, to nuclear energy, which has a low emission rate over its entire lifecycle.

Environmental: A dramatic reduction in local CO_2 and particulate emissions improves air quality and public health.

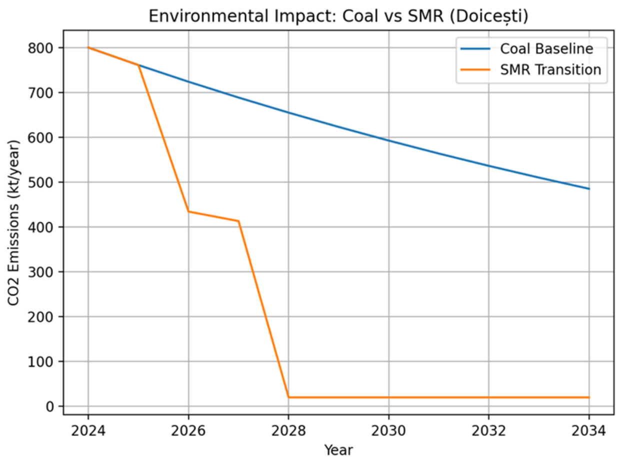

Fig. 6. Environmental Impact.

Strategic positioning: The combined energy-digital cluster attracts investment and establishes technological leadership.

4.2 Potential integration of a data centre within the SMR energy hub

The proposed SMR configuration consists of [1]:

$$6\ modules \times 77\ MWe = 462\ MWe \quad (1)$$

Total installed electrical capacity (2):

$$P_{SMR,total} = 462\ MWe \quad (2)$$

Assuming a nuclear capacity factor of 0.92 ($CF = 0.92$). Nuclear power plants typically operate with capacity factors exceeding 90%, providing reliable baseload electricity [3]. The annual energy production is calculated with the equation (3).

$$E_{annual} = P_{SMR,total} \times CF \times t_{year} \quad (3)$$

$E_{annual} = 462 \times 0.92 \times 8760$

$E_{annual} \approx 3.72\ TWh/year$

Thus, the plant can generate approximately 3.7 TWh per year of stable baseload electricity (where 8760 means hours in a year).

A typical hyperscale data center may have for example an IT load of 100 MW [4] and a Power Usage Effectiveness (PUE) of 1.3.

There are two possible scenarios: one in which we supply a data centre with several modules and another in which we use almost all the power produced to power a maximum number of data centres.

Total electrical demand (4):

$$P_{DC} = P_{IT} \times P_{UE} \quad (4)$$

Modern hyperscale data centers typically operate with Power Usage Effectiveness (PUE) values between 1.2 and 1.4 [5].

$P_{DC} = 100 \times 1.3 = 130\ MW$

Annual energy consumption (5):

$$E_{DC} = P_{IT} \times t_{year} \quad (5)$$

$E_{DC} = 130 \times 8760 = 1.139\ TWh/year$

In the case of the first option in which we supply a data centre with several modules the following calculations have been made:

Each SMR module produces 77Mwe ($P_{module} = 77$ Mwe). To supply 130 MW, 2 modules would be needed (130 / 77 = 1.69).

This provides us with a viable solution for using multiple modules dedicated to a data centre:

- 2 modules (154 MWe) would be required per data centre
- Reserve margin: 24 MW

This margin improves operational reliability and redundancy.

The second option is oriented towards a nuclear power plant that only serves data centres:

The total SMR capacity is 462 MWe ($P_{total} = 462$ MW) and the maximum number of 130 MW data centres is ≈ 3 (462 / 130 = 3.55).

The plant could theoretically support 3 hyperscale data centres (100 MW IT each) with a total load for 3 centres of 390MW (3 × 130 = 390 MW).

The remaining export capacity is 72 MW (462 − 390 = 72 MW) and can be exported to the national grid (SEN), supplied to district heating, support hydrogen production or provide operating reserves.

4.3 Integration of a gas turbine generator (GTG) backup system

To enhance energy security and data centre resilience, a Gas Turbine Generator (GTG) can be integrated as an emergency or peak backup system.

1) The power balance for the integrated system is shown in equation (6).

$$P_{SMR}(t) + P_{GTG}(t) + P_{grid}(t) + P_{SP}(t) = P_{DC}(t) + P_{aux}(t) \quad (6)$$

Where:

- P_{SMR} (t) = SMR output
- P_{GTG}(t) = Gas turbine backup output
- P_{grid} (t) = grid exchange
- P_{DC} (t) = data centre demand
- P_{aux} (t) = auxiliary loads
- P_{SP} (t) = Solar panels and batteries output

2) GTG Sizing

A common approach is to size the GTG to cover one module trip (77 MW) or the full critical data centre load. If protecting one 130 MW data centre that would mean that the power of the gas turbine should be above 130MW ($P_{GTG,required} \geq 130$ MW) or with a more conservative design more than 150MW ($P_{GTG} = 150$ MW).

This allows the hub to have blackstart capability, fast ramping during SMR outage and a grid contingency support.

3) GTG Operating Role

The GTG would operate only during planned SMR maintenance, unplanned reactor trip grid disturbance or peak shaving events.

Assuming GTG operates 5% of the year that would translate to 438 hours/year (8760 × 0.05 = 438 hours/year).

Annual GTG energy is 65.7 GWh/year (150 × 438 = 65.7 GWh/year). This represents less than 2% of total annual SMR output, maintaining low overall carbon intensity.

4) CO_2 Reduction Impact

If one 130 MW data centre were supplied by coal (for example 900 gCO_2/kWh) it would put into the atmosphere around 1 million tons of CO_2/year (1.139 × 109 × 0.9 = 1.025 million tons CO_2/year) [6].

If the same load is supplied by nuclear power (12 gCO_2/kWh) (1.139 × 109 ×0 .012 = 13,668 tons CO_2/year), it would reduce the amount of CO_2 emissions by 99.9% with a reduction of around ≈ 1.01 million tons

CO_2/year per data centre. With three data centres the reduction would amount to approximately ≈ 3 million tons CO_2/year avoided [6].

5) Total Energy Hub Structure

Table 2 shows the loads if 3 data centres are connected:

Table 2. 3 data centre loads

SMR capacity	462 MW
Data centre load	390 MW
Export to grid	72 MW
GTG backup: (standby)	150 MW
Solar panels capacity	80MW + 80MW BESS
P_{hub}	462 MW baseload+150 MW backup

There are solar panels already installed next to the site with an installed power of 80MW and another 80MW of BESS (Battery Energy Storage System) that can be coupled furthermore into the SMR platform in Doicești.

This creates a hybrid nuclear-digital energy cluster with a high reliability, carbon neutral baseload, backup resilience and a grid stabilization capability.

The calculations presented in this section are based on publicly available technical parameters for the Doicești SMR project, combined with typical performance indicators for nuclear power plants and hyperscale data centres reported by international energy organizations and industry studies [1]– [7].

5 Strategic conclusion

The integration of hyperscale data centres within the SMR platform allows it to maximize the baseload utilization through the addition of the gas turbines. Furthermore, it can attract digital infrastructure investments and regional economic output alongside the dramatic reduction of the CO_2 emissions. The modular structure of the SMR allows dedicated module allocation, enabling a flexible balance between digital consumption and national grid supply.

It should be noted that the calculations are performed using the gross electrical capacity of the plant and do not include the station house load required for internal plant operation.

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Abbreviations

SMR	Small Modular Reactor
CO_2	Carbon Dioxide
NPP	Nuclear Power Plant
LOOP	Loss of Offsite Power
PWR	Pressurised Water Reactor
H_2O	Light Water
ECCS	Emergency Core Cooling System
DHRS	Decay Heat Removal System
UHS	Ultimate Heat Sink
LOCA	Loss of Coolant Accident
GDP	Gross Domestic Product
CAPEX	Capital Expenditure
CF	Capacity Factor
IT	Electrical Power Consumed By Itself
PUE	Power Usage Effectiveness
SEN	Romanian National Grid (Sistemul Energetic National)
GTG	Gas Turbine Generator
BESS	Battery Energy Storage System
DC	Data Centre
IAEA	International Atomic Energy Agency
MWe	Mega Watt Electric

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