

Role of nuclear energy in Croatia's low-carbon sustainable development

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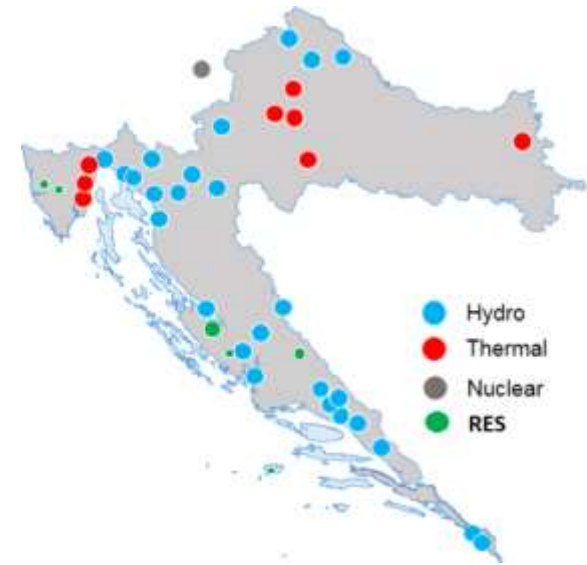
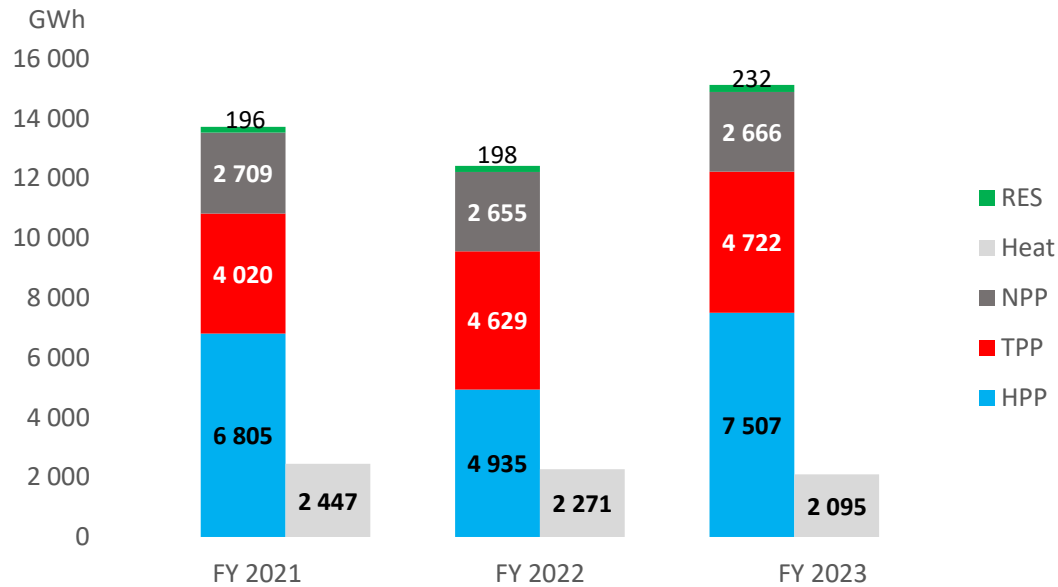
Republic of Croatia - Basic Data



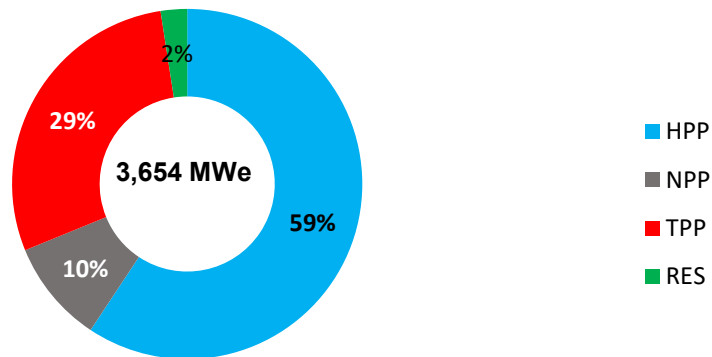
- **Capital:** Zagreb
- **Date of independence:** 25 June 1991 (from Yugoslavia)
- **Position:** South- Eastern Europe
- **Population:** 3.86 million
- **Land area:** 56 594 km²
- **Sea area** 31 479 km²
- **including** 1185 Islands
- **Moderately warm, rainy climate**
- **Strong maritime, agricultural and tourist potential**



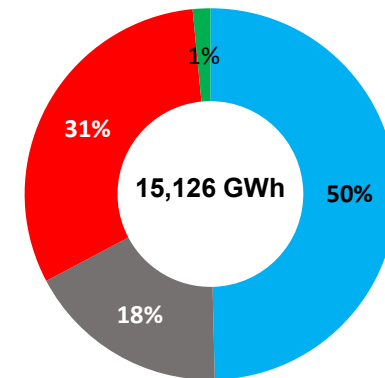
Croatian Electric Utility electricity generation in 2023



Electricity - installed capacity 2023

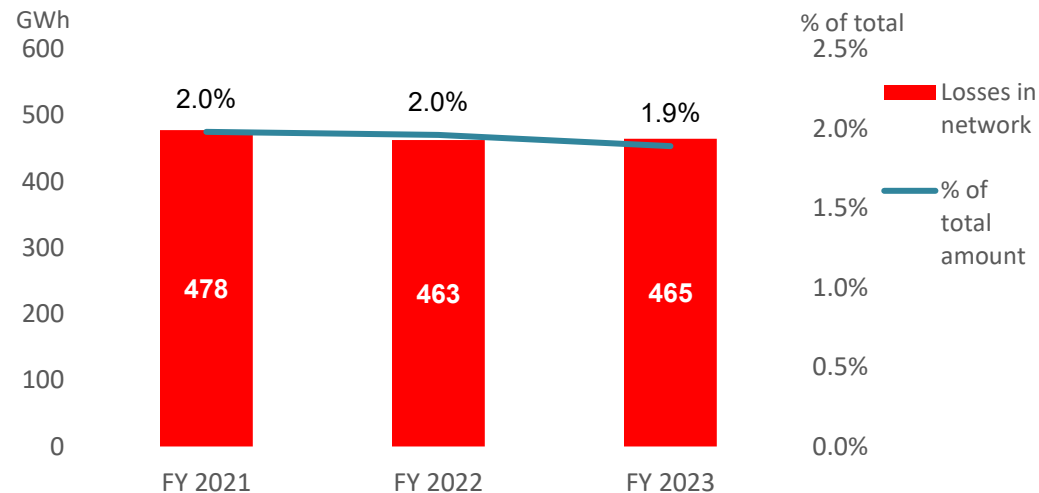


Electricity generation in 2023

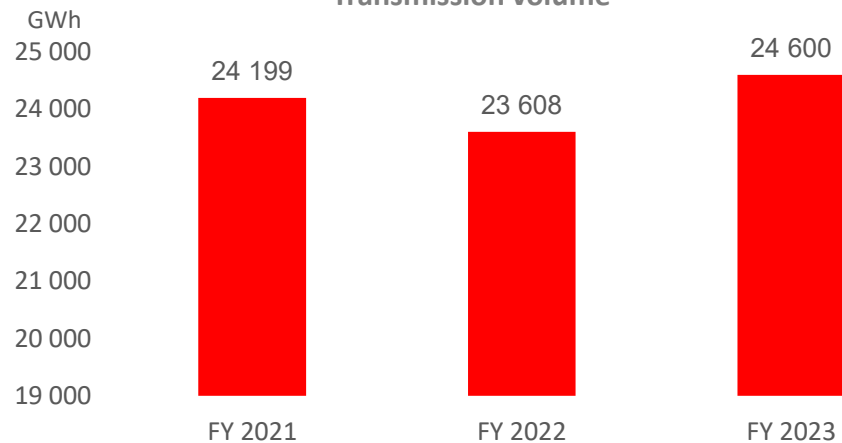


Transmission system

Transmission network losses



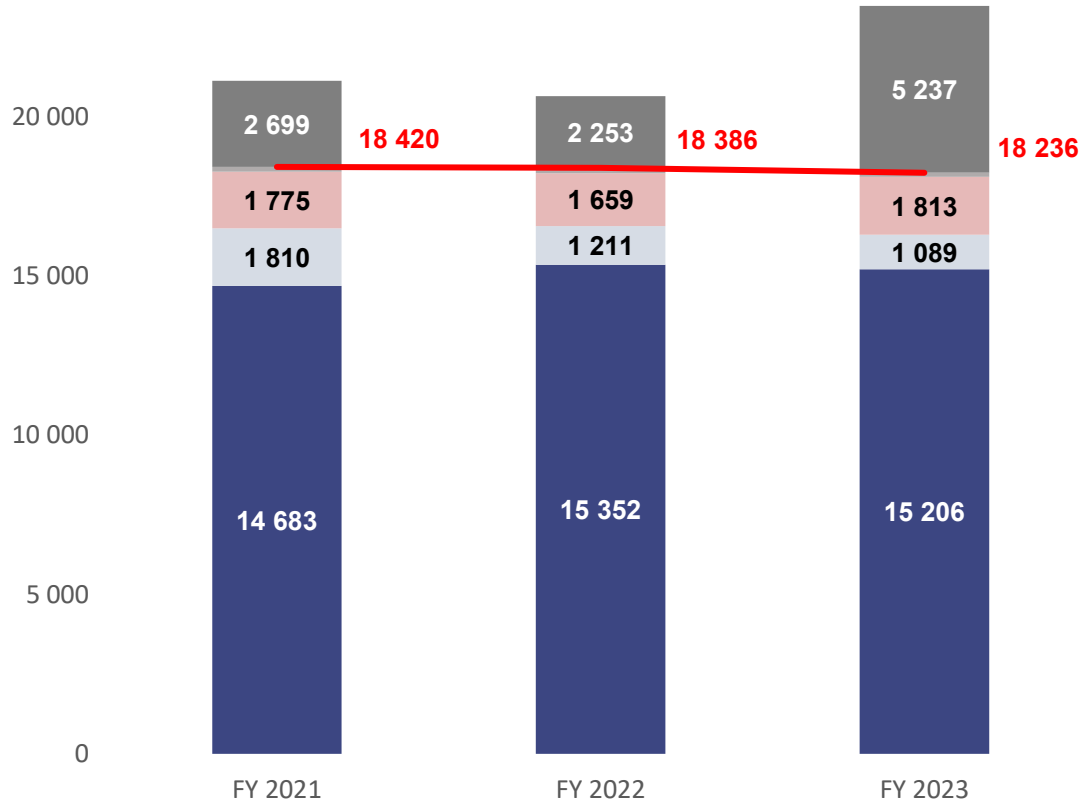
Transmission volume



- Certified TSO under ITO model
- HEP TSO – Co-owner of CROPEX with HROTE

Electricity market in Croatia

GWh
25 000



- Total electricity demand in Croatia for 2023 was 1% lower than in 2020
- 132% higher electricity sale abroad compared to 2022
- The largest issue for Croatia: Demand/Generation = 18,236 GWh/15,127 GWh
- 18% of electricity was imported

- HEP sale abroad
- HEP usage for transmission
- Losses on transmission and distribution
- Sale - others
- HEP sale
- Total electricity demand in Croatia

Sustainable construction and power system development

- HEP 2030 development strategy is focused on building a sustainable energy portfolio focused on renewable energy sources
- a century long tradition of generation from hydropower plants → reconstruction, adaptations and modernization of existing facilities + upgrade of the existing Senj Hydropower System (additional 230 GWh per year)
- 1,500 MW of new generation capacity by 2030, almost half (350 MW each) in wind and solar power plants
- there is a specific provision within the Croatian Energy Policy with an intention to continuously monitor the development of nuclear energy including new technologies of smaller and flexible reactors.

Joint ownership of Krško NPP, Slovenia



About Krško NPP

- Krško NPP (Westinghouse, 2 loop PWR, 701 MWe), started commercial operation in 1983 and was built as a joint venture of Slovenia and Croatia when both countries were still a part of Yugoslavia
- 18-month refueling cycle (started with 12 months, transition period with 15 month-cycle and ended up with an 18 month-cycle)
- In 1991 both countries became independent and the NPP became a temporary source of disagreements between both countries
- Today both Parties are cooperating successfully and the Krško NPP is highly reliable and profitable (intergovernmental agreement)
- A decision has been reached by both Parties to extend the Krško NPP lifetime until 2043



Role of nuclear energy in Croatia's energy transition

- Krško NPP is a very important electricity source, 15-18% of total electricity consumption in Croatia, will be in operation until 2043
- Slovenia is considering construction of Krško 2 NPP, there is an option for an agreement between Slovenia and Croatia similar to Krško 1 NPP, political agreement is necessary
- Croatia is also considering construction of SMRs in the future, first „baby” steps have been undertaken

Nuclear infrastructure development

- Although we own 50% of an NPP in Slovenia, we have to launch a nuclear power programme in Croatia in order to introduce clean reliable baseload power in our energy mix
- A lot of preparatory work and activities:
 - building national institutions (including an independent regulatory body)
 - establishing a legal and regulatory framework
 - developing human resources and financial strategies
 - addressing radioactive waste management
 - involving stakeholders
- Most important step: knowledgeable consensus political decision

Possible role of SMRs in Croatian grid

- No need for 1000 MW operating reserve - common rule of thumb is that one single source of power generation should not exceed 10-15% of the grid size
 - grid could be subject to stability risk or power concerns when one large plant goes offline
- Can be used as both incremental and distributed generation sources.
- Easier voltage regulation in the grid
- Reactive power compensation
- Reduce losses in the grid
- Load following – integration with renewables

Economic analysis of SMRs

- No economies of scale, but benefits of economies of multiples and simplicity to counterbalance, greater factory construction
- First-of-a-Kind Challenges - unique regulatory, technology and financial risks that most companies are unable or unwilling to accept
- No possibility of a power purchase agreement in Croatia – maybe a contract for difference?
- Reduction of operational staff

Description of economic models and key assumptions (1)

- We developed two economic models for construction of new nuclear power plants in 2022: one model is using in-house developed methodology and the other is based on a model developed by MIT
- For the in-house model:
 - unit size: 1000 Mwe
 - plant construction: 8 years
 - investment cost: 6,034,000,000 euros
 - cost distribution: 5% for year one, 5% for year two, 20% for year three, 20% for year four, 20% for year five, 10% for year six, 10% for year seven and 5% for year eight
 - yearly fixed operation and maintenance costs were taken as 103.31 EUR/kW, whereas variable operation and maintenance costs were taken as 2.37 EUR/MWh
 - assumed future prices of electricity were given by our in-house experts

Description of economic models and key assumptions (2)

Factor	Value
L = annual capacity factor, [actual kWh _e /rated kWh _e]	0,85
Φ = levelized fixed charge rate, [yr ⁻¹]	0,10
I/K = specific capital cost, [EUR/kW _e]	5000
K = Plant capacity [MW _e]	1000
O/K = annual operating cost, [EUR/yr-kW _e]	70
C_f = total [net] fuel cycle cost [EUR/kg]	2500
B = fuel burnup at discharge [MWD _{th} /MTU]	50,000
η = plant thermal efficiency [kW _e /kW _{th}]	0.33
N = assumed plant economic life [years]	40

- The result of the MIT LCOE calculation is 67.72 EUR/MWh. If we were to take the total investment value of 6,034,000,000 euros as in our in-house model, the LCOE result would be 78.12 EUR/MWh
- The calculated in-house result was LCOE = 57.07 EUR/MWh. The IRR was calculated as 3.51%, and the payback period as 20 years.

Risk analysis

- Political and policy risks
 - The new energy strategy (implementation programme) still hasn't been prepared
 - No clear dedication to nuclear power as a base load low carbon technology, NIMBY (Not In My Back Yard) approach
 - Future carbon charges
- Business and economic risks
 - Price of imported electricity could return to low values
 - Banks and other financial entities are not inclined to support nuclear projects
 - Selection of improper discount rate
 - Inflation of costs
- Social risks
 - general public and other stakeholders currently strongly oppose nuclear power
- Technical risks
 - Construction duration and delayed commercial operation
 - Mechanical or safety issues
- Legal and regulatory risks
 - Licensing issues
 - Changes in laws and regulations with respect to use of nuclear energy

Nuclear programme in Croatia

- On 11 February 2025 a nuclear energy task force (working group, NEPIO) has been formed under the Ministry of the Economy
- First task is to adjust the regulatory framework in order to again form an independent competent regulatory body
- Following tasks are to make a knowledgeable decision on constructing an SMR, identify potential locations, contact SMR vendors, join the European Industrial Alliance on SMRs, form new nuclear university programmes, etc.

Stakeholder Involvement

- Nuclear science and technology often face unique challenges with regard to public understanding and acceptance
- One of the biggest mistakes we can make - nuclear projects are too complicated for the average citizen to understand
- Stakeholder involvement is one of the 19 infrastructure issues covered in the IAEA's Milestones approach
- Our ultimate goal - open dialogue between the government, the regulatory body, the owner/operator and other stakeholders – successful project

Conclusion

- The fundamental problem of nuclear power new build is cost. Other generation technologies have become cheaper in recent decades, while new nuclear plants have only become costlier. This disturbing trend undermines nuclear energy's potential contribution and increases the cost of achieving deep decarbonisation
- Other problems in Europe are lengthy testing/licensing, field construction, very large plants, selling a commodity (electrons to the grid)
- Cost reduction opportunities may come from smaller, simpler, serial manufactured nuclear systems with accelerated testing/licensing
- A lot of issues need to be resolved in Croatia to seriously consider nuclear energy as a viable and attractive solution for low carbon energy security, strong government commitment and support is crucial
- Decisions concerning a nuclear programme involve major expenditures and public interest - well-defined and knowledgeable national position

Thank you for your attention!

