Policy framework and strategic priorities for shallow geothermal energy deployment in Romania: a pathway towards EU climate neutrality targets

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Abstract. This paper examines the policy framework governing shallow geothermal energy (SGE) utilization in Romania and proposes strategic priorities for accelerating market uptake in alignment with European Union climate neutrality objectives. Despite favorable geological conditions and Romania's commitment to achieving 30.7% renewable energy share by 2030 under its National Energy and Climate Plan, SGE remains significantly underutilized. The analysis, based on findings from the Danube GeoHeCo transnational project, reveals key policy gaps including the absence of legal distinction between shallow and deep geothermal energy, lack of dedicated national financial support schemes despite €10.09 billion EU Cohesion Policy allocation for green transition, and limited regulatory harmonization. Romanian cities such as Arad, Bucharest, Oradea, and Cluj-Napoca are increasingly recognizing SGE potential for district heating decarbonization. The paper identifies five strategic priority areas for the 2026-2035 period: regulatory framework harmonization, technology development, education enhancement, financial mechanisms, and capacity building for decision-makers. These findings contribute to the European policy discourse on geothermal energy deployment, responding to the European Parliament's 2024 resolution calling for an EU geothermal strategy.

1 Introduction

The European Union's green transition policy represents a comprehensive framework aimed at achieving climate neutrality by 2050, with intermediate targets for 2030. Energy transition plays a central role in this policy, aiming at decarbonization through more widespread use of renewable energy sources, energy efficiency investments, and sectoral integration. The European Green Deal, launched in 2019, serves as the EU's roadmap to climate neutrality, integrating climate neutrality with circular economy and clean industry objectives [1]. The European Green Deal sets ambitious targets: reducing greenhouse gas (GHG) emissions by at least 55% by 2030 compared to 1990 levels, achieving 42.5% renewable energy share by 2030 with a 42% target for buildings, improving energy efficiency by 11.7% by 2030, and ensuring all buildings become zero-emission by 2050 [2].

The European Green Deal particularly identifies geothermal energy as seriously underutilized, noting that in 2021 only 2.8% of produced renewable energy came from geothermal sources [2]. Due to its significant potential in decarbonizing heating, the European Parliament adopted a resolution on geothermal energy in 2024, calling on the Commission to present an EU geothermal strategy and provide guidance to Member States and local administrations to accelerate geothermal deployment. The resolution addresses cross-border obstacles and exchange of practices, specifically mentioning shallow geothermal potential available in all member states, related permitting processes, and environmental issues including interference with drinking water [3]. Following this action, the European Council called on the Commission to prepare a strategy on decarbonization of heating and cooling, accompanied by a European Geothermal Action Plan [4].

Shallow geothermal energy can be utilized through geothermal heat pumps (GHPs), which are highly efficient heating, ventilation and air conditioning (HVAC) systems that utilize the stable temperature of the earth or surface/sub-surface water to provide heating, cooling, and hot water for residential and commercial buildings. Unlike conventional systems relying on external air temperatures, GHPs extract or dissipate heat through underground pipes, leveraging the earth's thermal stability [5]. GHPs operate on the principle of heat transfer rather than heat generation, using the ground or groundwater as a heat source in winter and heat absorber in summer.

This paper presents an analysis of shallow geothermal energy policy framework in Romania, based on findings from the Danube GeoHeCo project, a

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transnational initiative involving eight countries: Austria, Bosnia and Herzegovina, Croatia, Hungary, Romania, Serbia, Slovakia, and Slovenia. The project focuses on two types of SGE utilization with geothermal heat pumps: exploitation of geothermal energy stored in shallow geological layers (1.5 m to 400 m depth) using closed loop ground source heat pump (GSHP) and open loop groundwater heat pump (GWHP) systems; and utilization of geothermal waste heat using high temperature water source heat pump (WSHP) systems [5]. The Transnational Action Plan (TAP), developed for the period 2026-2035, provides the analytical foundation for this policy-oriented analysis.

2 Methodology

This paper employs a qualitative policy analysis methodology based on documentary research and comparative assessment. The primary data source is the Transnational Action Plan (TAP) developed within the Danube GeoHeCo project (Interreg Danube Program), which synthesizes inputs from eight partner countries through structured data collection, thematic working groups, and national consultation forums conducted between March and October 2025. The analysis examines Romania's position within the broader Danube region context, comparing regulatory frameworks, financial instruments, and deployment levels across partner countries. Policy gaps are identified through systematic comparison against EU regulatory requirements and best practices from leading member states. The case study component documents the geothermal heat pump installation at UTCN Swimming Complex based on technical project documentation.

3 Geothermal heat pump technology and benefits

Geothermal heat pumps are categorized into two main types. Open loop systems utilize groundwater or surface water as a direct heat exchange medium, including cold water-based systems (groundwater heat pumps with production and reinjection wells up to 150 m depth) and hot water-based systems utilizing effluent thermal water through high temperature water source heat pumps. Closed loop systems utilize ground heat by circulating antifreeze through underground closed pipe networks, with horizontal loops for properties with sufficient land area, vertical loops for limited space locations, and pond/lake loops using submerged piping in water bodies [5].

GHPs offer numerous advantages over traditional systems. They significantly reduce dependence on fossil fuels by transferring heat rather than burning fuels, decreasing reliance on oil, natural gas, and coal. GHP systems can lower the overall GHG footprint of buildings by up to 50% compared to conventional HVAC systems, especially when paired with renewable electricity sources like photovoltaics. In terms of energy efficiency, geothermal HVAC systems require 25-50% less electricity than traditional air-source heat pumps, with typical GHPs producing approximately 1.5 times higher heating or cooling energy output per kilowatt-hour. Cold water-based open loop systems produce 2-3 times higher cooling energy than conventional air-source heat pumps [5].

The high energy efficiency translates into lower operating costs over system lifetime, counterbalancing higher upfront investment costs. GHP components last over 20 years, while underground piping systems can last over 50 years with maintenance costs not exceeding traditional systems. Unlike air-source heat pumps affected by ambient temperature fluctuations, geothermal systems rely on stable underground or groundwater temperatures, ensuring consistent performance regardless of weather conditions. The versatility of GHPs allows scaling from individual residential units to large-scale district heating systems and industrial processes, making them excellent choices for central heating in communities and commercial facilities [5].

4 European policy framework

The regulatory foundation for geothermal energy deployment in Europe rests on several key instruments. Regulation (EU) 2021/1119 on achieving climate neutrality (European Climate Law) establishes binding targets and includes assessment of national measures consistency [6]. The "Fit for 55" legislative package introduced Directive (EU) 2023/1791 on energy efficiency, emphasizing building retrofits and district heating, including geothermal-based systems alone or in cogeneration [7]. Member States are required to adopt National Energy and Climate Plans (NECP) for the period until 2030, integrating these into relevant national and regional strategic documents through multi-level dialogue involving national, regional, local, and civil stakeholders, with biennial progress reports submitted to the Commission [6].

In terms of heating, natural gas holds the leading position globally (42%), similarly in the EU. District heating, while playing a significant part of the energy mix, remains 90% based on fossil fuels. Renewables account for 25% overall, with heat pumps contributing only 1%, despite substantial untapped potential [8]. The EU leads in global heat pump sales, with approximately 6 million units sold in 2022-2023 and over 54 million total installed in Europe by 2024. However, aerothermal heat pumps dominate with geothermal representing only 3.7% market share. Based on EHPA data, about 90% of sold heat pumps are primarily used for cooling, with hybrid fossil-combined systems dominating many markets. The highest share of geothermal heat pumps is found in Scandinavian countries [9].

Focusing on ground source heat pumps, Sweden and Germany stand out with the largest installations. Per capita figures show significant differences among European countries: Sweden and Finland have 30-60 installed GHP units per 1,000 inhabitants, Austria has 13, Slovenia 8, while Hungary has only around 0.5 per 1,000 inhabitants, with Croatia, Serbia, and Bosnia and

Herzegovina having even fewer [10]. Although geothermal energy is mentioned in all NECPs and national strategies across the Danube region, the current share in energy production remains minimal, mostly from deep geothermal sources. The potential in heating is acknowledged as significant, but application remains in initial phases across most partner countries.

5 Romania's energy policy and SGE context

5.1 National energy and climate plan

Romania has set a target for net-zero emissions by 2050. The Romanian NECP establishes a 30.7% renewable energy share target by 2030, with policies focused on phasing out coal, promoting energy independence, and hydrogen storage. Geothermal energy is identified as a key tool in this policy framework [11]. Romania's energy mix demonstrates significant renewable capacity, with hydropower accounting for approximately 25% of supply among the highest in the Danube region while solar and wind comprise up to 16% of the energy mix. The project area remains dependent on traditional fossil-based capacities inherited from the former Socialist era, with oil and natural gas playing significant roles across all partner countries [5].

5.2 Geological potential and current utilization

5.2.1 Geological framework and reservoir characteristics

The Danube region's geothermal potential is primarily associated with the Pannonian Basin, a sedimentary basin characterized by elevated heat flow values compared to the European continental average. The basin's sedimentary fill consists predominantly of Neogene clastic sequences including sandstones, siltstones, and clays, which function as both geothermal reservoirs and aquitards. For shallow geothermal applications, the upper 400 m comprises Quaternary and Upper Pliocene unconsolidated semi-consolidated sediments providing favorable conditions for ground source heat pump installations. Large portions of the target area lie on the Pannonian Plain, where sedimentary rocks, sandstone, clay, and limestone dominate, creating excellent conditions for SGE with underground water temperatures between 40 and 90°C at depths of 1000-2000 m.

5.2.2 Regional comparison

Significant variations exist across the Danube region. The geothermal gradient ranges from 0.03°C/m in mountainous areas (Austria, parts of Serbia and Slovenia) to 0.04-0.07°C/m in lowland regions (Hungary, Croatia, parts of Romania). Romania's western regions, particularly areas near Oradea and Arad, benefit from the Pannonian Basin's elevated thermal regime. Most wells provide water temperatures in the 20-40°C range, sufficient for shallow geothermal utilization. Romania and Hungary have the highest proportion of high-temperature wells (>40°C) in the region.

The geological characteristics directly influence system selection: the Pannonian Basin's favorable thermal regime supports both open-loop GWHP systems in areas with adequate groundwater yield and closed-loop GSHP installations where aquifer access is limited. Romania's predominantly closed-loop installations (90% of geothermal heat pumps) reflect both regulatory simplicity for systems under 100 m depth and the broader applicability of vertical borehole heat exchangers across diverse geological settings.

5.2.3 Current utilization and exploitation level

Romanian district heating companies are increasingly recognizing shallow geothermal potential. The cities of Arad, Bucharest, and Oradea operate geothermal systems, while Cluj-Napoca foresees incorporating heat pumps in district heating to reduce CO_2 emissions. According to available data, Romania has approximately 20,000 aerothermal and 20,500 geothermal heat pumps installed, with approximately 90% of geothermal installations being closed-loop systems. Despite favorable conditions, exploitation rates remain low. Per capita GSHP installation rates illustrate this gap: Sweden and Finland lead with 30-60 units per 1,000 inhabitants, Austria achieves 13, Slovenia 8, while Romania with approximately 20,500 geothermal units serving 19 million inhabitants has a rate of approximately 1.1 units per 1,000 inhabitants—representing less than 5% of the Scandinavian benchmark.

5.2.4 Technical barriers

Key technical barriers limiting exploitation include insufficient geological and hydrogeological data for system design optimization; limited drilling capacity and expertise for vertical borehole heat exchangers; absence of standardized thermal response testing protocols; and challenges with ground thermal imbalance in heating-dominated climates without seasonal cooling loads.

5.3 Regulatory framework analysis

Extraction and utilization of Earth's resources in Romania are regulated by Mining Act no. 85/2003, with permits issued by the National Agency for Mineral Resources (NAMR). Significantly, no permit is required if the borehole is for personal/private use (residential, small public buildings), depth is less than 100 meters, there is no commercial thermal water use, extracted water flow is less than 5 liters per second, and no protected mineral or geothermal resource is intercepted. In these cases, interventions are considered common/local interest resources with only local permission procedures applying [12].

Permits are required when boreholes exceed 100 meters depth, there is intention of commercial thermal water or geothermal energy use, the site is within a NAMR-licensed concession area, flow exceeds 5 liters/second, or geothermal fluids (typically >20°C) are extracted for heating purposes. In Romania, shallow geothermal is considered under 400 m depth. A notable policy gap is the absence of legal distinction between shallow and deep geothermal energy, unlike other Danube region countries which apply varying depth thresholds (150-400 m) for regulatory purposes [12].

The Water Framework Directive is implemented through Romanian Water Act no. 107/1996, Government Decision no. 188/2002 on wastewater discharge standards, and Order no. 662/2006 on permitting procedures. Water management permits are required for any geothermal heat pump system that abstracts groundwater for heating/cooling, injects/discharges water into the environment, involves drilling or modification of existing water sources, or may affect water quality or aquifer balance. Construction regulations under Acts no. 50/1991 and no. 10/1995 require permits for boreholes exceeding 30 m depth. Environmental protection requirements under Act no. 195/2005 and GEO no. 195/2005 apply, with permits required from the National Environmental Protection Agency for systems above certain capacity thresholds [12]. According to energy efficiency regulations, geothermal heat pumps are classified as renewable sources with no specific permit restrictions from this perspective.

6 Financial and institutional framework

6.1 EU-level instruments

The REPowerEU initiative responds to market disruptions caused by the Russian invasion of Ukraine, promoting energy saving, supply diversification, and clean energy production, with targets for downsizing imports of gas, oil, and nuclear materials. A distinctive pillar aims at securing affordable energy through the Action Plan for Affordable Energy, promoting lower energy costs, completing the Energy Union, attracting investment, and improving crisis readiness [13]. The Recovery and Resilience Facility (RRF) serve as the centerpiece financing mechanism. Romania's RRF focuses on renewable deployment, with plans to use degraded state lands for green energy production and establish one-stop-shops for energy efficiency renovations. However, among Romania's RRF projects, solar energy utilization dominates with no SGE projects being implemented [14].

EU Cohesion Policy for 2021-2027 supports green transition under Policy Objective 2, with Specific Objective 2 promoting renewable energy solutions funded through ERDF, Cohesion Fund, and Just Transition Fund. The latter particularly supports industrial transition areas phasing out coal and other fossil fuels, with specific mention of upgrading district heating networks using renewable sources [15]. Romania receives the highest Cohesion Policy funding allocation for green transition among Danube region countries: €10.09 billion through Sustainable Development and eight Regional Programs. This substantially exceeds allocations to Hungary (€7.04 billion, partially frozen due to rule of law concerns), Slovakia (€5.61 billion), Croatia (€2.87 billion), Slovenia (€1.12 billion), and Austria (€0.49 billion) [16].

6.2 National support gaps and energy pricing

A critical finding is that Romania has neither national, regional, nor local financial schemes for energy efficiency and SGE, apart from EU-financed instruments [12]. This contrasts with Austria, where the Renewable Energy Expansion Act (EAG) and Renewable Heat Act (EEC) support transition from fossil fuels with grants for heat pumps, and multiple regions offer funding for heat pump systems. Slovenia's Eco Fund provides subsidies and soft loans for environmental protection including energy efficiency and renewable energy measures. Croatia's Bank for Reconstruction and Development offer credit lines for green projects, while Hungary's Swiss Fund supports geothermal energy promotion [5].

Regarding energy pricing, Romania has several energy and gas supplier companies with various prices. Although Romania provides one of the lowest energy prices in Europe, there is a general price growth tendency. As an incentive for SGE promotion, a reduced 5% VAT is applied for heat pumps and photovoltaic system installation for private homes and public buildings, though not available for private companies [12]. However, the electricity-to-gas price differential significantly affects heat pump competitiveness. In contrast, Hungary provides a reduced electricity price rate ("H tariff") to cover heat pump electricity needs during heating season for smaller systems, while Slovenia's increasing energy prices have promoted shallow geothermal penetration, with the country applying price caps and tax exemptions on renewable electricity [12].

6.3 Education and training framework

In all partner countries, secondary education does not include geothermal or energy system topics. Gradual higher education offers bachelor programs in mechanical and electrical engineering including renewable energy elements. The Technical University of Cluj-Napoca offers a targeted master program on geothermal energy, representing one of the few specialized postgraduate offerings in the region. Formation courses, workshops, and installer certification courses are available in Romania. However, a mismatch exists between education sector outputs and labor market needs for practical knowledge, an issue common across partner countries for general mechanical engineering graduates.

7 Strategic priorities for policy action

The Transnational Action Plan identifies five priority areas with specific interventions for the 2026-2035 period, requiring coordinated action involving government and public sector bodies, academia and research institutions, industry and SMEs, and civil society organizations [5].

Priority 1 – Resources and Regulations: SGE represents significant untapped potential in partner countries, particularly in the Pannonian Basin with favorable geological conditions. However, missing and inconsistent resource data hinder sector growth. Concepts and definitions of SGE differ across countries including drilling depth and water temperature thresholds. Romania notably lacks legal distinction between shallow and deep geothermal. Regulatory harmonization requires establishing standardized vocabulary and categories, conducting gap analysis of overlapping legislation, clarifying responsibilities, and drafting missing regulations potentially as separate bylaws. A policy paper on regulatory harmonization should be elaborated and communicated to the European Heat Pump Association (EHPA). Estimated budget for this priority: €1,000,000 [5].

Priority 2 – Technology and Design: Despite excellent conditions, a significant technical gap exists between partner countries in design practices, modelling tools, and performance monitoring. Technology development and demonstration investments are needed including pilot projects. Romania's initiative for establishing a modelling network represents a positive step. Application of GHPs in district heating deserves particular attention given existing urban applications in Arad, Bucharest, Oradea, and planned deployment in Cluj-Napoca. Optimization of drilling to cope with limited geological data and smart control system application for better integration with existing heating systems are key technical interventions [5].

Priority 3 – Education and Training: Harmonized higher educational programs on SGE are required to address the mismatch between academic training and labor market needs. Standardized vocational and training programs for installers and performance monitoring professionals must be developed. Stronger academia-industry partnerships are essential, alongside establishment of open-access knowledge sources to eliminate language barriers in knowledge transfer across the Danube region. Adult education through established institutions and professional bodies (chambers, associations) plays a key role in training practicing professionals [5].

Priority 4 – Financing: Tailored financial support schemes for shallow geothermal investments must be established at national and regional levels to complement EU instruments. Romania's current absence of dedicated schemes represents a critical gap despite having the largest EU funding envelope in the region. Energy price schemes promoting wider SGE use should be designed to address the significant electricity-gas price differential affecting heat pump competitiveness. Ideally, EU-level, national, regional, and local instruments should establish a complementary system promoting energy transition at all levels [5].

Priority 5 – Awareness Raising: Awareness raising for the public about SGE solutions addresses current limited understanding of technology benefits. Critically, capacity building for decision-makers and institutional stakeholders is essential, as district heating companies and municipal authorities require targeted information to recognize and act upon SGE potential. Deployment of geothermal heat pump technology can stimulate local manufacturing, installation, and maintenance sectors, creating demand for skilled technicians, engineers, and installers, supporting local job creation and economic development [5].

7.1 Case study: UTCN swimming complex geothermal heat pump installation

7.1.1 System overview and context

The Technical University of Cluj-Napoca has implemented a closed-loop ground source heat pump (GSHP) system at its Swimming Complex located on Str. Splaiul Independenței no. 8, Cluj-Napoca. The complex consists of a main building housing an Olympic-sized swimming pool and a children's pool, as well as an outdoor Olympic-sized swimming pool. The geothermal system was designed to prepare domestic hot water (DHW) for the facility's showers, partially replacing the existing natural gas boiler system.

7.1.2 Existing system configuration

The original heat source for DHW preparation consisted of two natural gas boilers with a combined thermal power of 2 × 1600 kW, which also serve the pool water heating, HVAC system, and auxiliary heating systems. DHW is prepared in two storage tanks, each with a capacity of 4000 liters (4 m^3), maintained at approximately 35°C, with cold water inlet temperature of approximately 10°C. The monthly cold-water consumption of the complex is approximately 1200 m^3 (40 m^3/day), of which approximately 60% (24 m^3/day) is converted to DHW, corresponding to an average mass flow rate of 0.28 kg/s.

7.1.3 Geothermal system technical specifications

The implemented solution comprises a water-to-water heat pump with a thermal power of approximately 20 kW, coupled to a closed-loop geothermal system consisting of 4 vertical boreholes, each with a depth of 100 m (Figure 1, Figure 2). The system configuration allows the geothermal heat pump to heat one of the two storage tanks, while the existing gas boilers continue to serve the second tank. The thermal power requirement was calculated based on heating 4000 kg of water from 10°C to 35°C over an 8-hour period, yielding a required capacity of 14.5 kW. Table 1 summarizes the key technical parameters of the installation.

Table 1. Technical specifications of the UTCN Swimming Complex GSHP installation.

Parameter	Value
Heat pump type	Water-to-water (closed-loop GSHP)
Thermal power	20 kW
Number of boreholes	4
Borehole depth	100 m each
Total borehole length	400 m
DHW storage capacity	2 × 4000
lDHW target temperature	35°C
Cold water inlet temperature	10°C
Temperature lift	25 K

7.1.4 Operating strategy and energy performance

The automation and control system was redesigned to operate with dual heat sources, giving priority to DHW preparation via the heat pump while maintaining the capability to switch to gas boilers when necessary to ensure continuous DHW availability. In this configuration, the geothermal heat pump provides approximately 50% of the total domestic hot water consumption of the swimming complex. Any excess consumption beyond heat pump capacity can be covered by the gas boilers, which can heat their associated storage tank in approximately 4-5 minutes.

Based on the system's thermal capacity of 20 kW and estimated operating hours, the annual thermal energy contribution is projected at approximately 50-60 MWh, displacing an equivalent natural gas consumption and contributing to the facility's decarbonization objectives. Performance monitoring data collection is ongoing to validate these projections.

7.1.5 Demonstration and educational value

Beyond its operational function, the installation serves as a practical demonstration site for students enrolled in UTCN's geothermal energy master program, directly addressing the TAP's Priority 3 objectives for establishing on-campus pilot installations and strengthening academia-industry partnerships. The system enables hands-on training in GSHP operation, performance monitoring, and system integration with conventional heating infrastructure.

Fig. 1. Outdoor ground source heat pump unit (20 kW) and borehole access point connected to the 4 × 100 m vertical ground heat exchanger array at UTCN Swimming Complex

Fig. 2. Indoor thermal storage tanks (2 × 4000 l) and piping network of the GSHP installation at UTCN Swimming Complex, Cluj-Napoca.

The UTCN installation follows similar institutional GSHP implementations in the Danube region. Comparable systems at university facilities in Austria and Slovenia typically achieve seasonal coefficient of performance (SCOP) values of 4.0-5.0 for DHW applications. The Cluj-Napoca system, designed for a 25 K temperature lift (10°C to 35°C), operates within parameters consistent with these regional benchmarks, demonstrating that Romanian institutions can successfully deploy SGE solutions within existing regulatory and financial frameworks.

8 Conclusions

Romania possesses favorable geological conditions for shallow geothermal energy utilization and has received the largest EU Cohesion Policy funding allocation for green transition among Danube region countries (€10.09 billion). Despite this, SGE remains significantly underutilized. The analysis reveals critical policy gaps: absence of legal distinction between shallow and deep geothermal energy unlike other regional countries applying 150-400 m thresholds; lack of dedicated national financial support schemes apart from EU instruments; complex permitting procedures across multiple regulatory domains; and limited awareness among decision-makers regarding SGE potential.

The emerging recognition of SGE potential by Romanian district heating companies in cities such as Arad, Bucharest, Oradea, and Cluj-Napoca demonstrates market readiness that policy frameworks must actively support. Romania's existing base of approximately 20,500 geothermal heat pumps predominantly closed loop systems provides foundation for accelerated deployment. The 5% reduced VAT for heat pump installations represents a positive incentive, though comprehensive national support schemes matching those in Austria or Slovenia remain absent.

Achieving Romania's 30.7% renewable energy target by 2030 and net-zero emissions by 2050 requires accelerated deployment of all available renewable technologies. The five strategic priorities identified regulatory harmonization, technology development, education enhancement, tailored financing, and awareness raising provide an actionable framework for policy intervention during 2026-2035. Romania's participation in transnational initiatives such as the Danube GeoHeCo project facilitates knowledge transfer and best practice exchange essential for accelerating market uptake. Responding effectively to the European Parliament's 2024 resolution and contributing to the anticipated EU Geothermal Strategy requires coordinated national action across these priority areas, transforming Romania's significant geothermal potential into realized contributions to European climate neutrality objectives.

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