

# TRANSFORMATION OF THE OIL INDUSTRY IN THE ENERGY TRANSITION: A CASE STUDY OF NIS J.S.C. NOVI SAD, REPUBLIC OF SERBIA

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*Integrated energy modeling is increasingly important for planning industrial energy transitions. This study examines Serbia's oil and gas sector through NIS j.s.c. Novi Sad, analyzing energy flows, material balances, and strategic pathways. An Integrated Energy Model was developed in Low Emissions Analysis Platform (LEAP) for 2023 using a bottom-up approach, with projections to 2030 and 2050. Three scenarios were considered: Baseline, Energy Efficiency, and Green Agenda (Renewables combined with Energy Efficiency). The Baseline scenario forecasts total energy use rising by about 4% by 2030 and 2% by 2050. The Energy Efficiency scenario reduces consumption by 6%, while the Green Agenda achieves a 32% decline through full renewable integration and demand-side optimization. Oil, gas, and derivatives remain dominant, though production drops slightly in the Baseline and up to 50% under transition scenarios. Processing grows moderately in the Baseline but falls significantly in alternative paths. Electricity generation expands in the Baseline, while transition scenarios reduce demand and shift toward renewable sources. Greenhouse gas emissions remain almost flat in Baseline but fall by 32% in Energy Efficiency and 73% in the Green Agenda by 2050. Blue hydrogen from the Pancevo refinery is included, while green hydrogen emerges as an additional lever. Findings show that quantified, operational measures, supported institutionally, are essential for oil companies to move beyond declarative strategies and secure an optimal long-term energy mix.*

*Key words: integrated energy model, oil industry, energy efficiency, sustainable development, energy transition*

## **1. Introduction**

The energy transition involves systemic changes in how energy is produced, distributed, and consumed to build more sustainable, efficient systems with lower greenhouse gas emissions [1]. While often linked to renewables and reduced fossil fuel use, it is a broader process of technical, economic, regulatory, and social transformation [2]. Rather than abandoning existing sources, it focuses on adapting and integrating them into new energy flows.

For oil and gas companies, this transition is challenging. Their operations rely on large inputs of raw materials, energy, and equipment, with energy and material flows concentrated within the same system [3]. Since these companies depend on fossil resources such as feedstock and energy, assessing

their current state and outlook is critical. The complexity of such systems demands comprehensive approaches and specialized modeling tools.

International oil companies have begun to respond, but progress is limited by structural and market realities. Shell, BP, and TotalEnergies support climate targets, yet investments in renewables rarely exceed 5% of capital expenditure [4]. Shell advances in e-mobility, BP plans a 40% cut in oil output by 2030, and NAM in the Netherlands shows that success depends on institutional support and internal reorganization [5].

Global transition cannot succeed without oil industry involvement, especially in major producing countries [6]. However, unstable markets and weak institutional mechanisms slow diversification [7,8]. In Serbia, NIS j.s.c. Novi Sad offers a relevant case. Beyond oil and gas, NIS produces electricity and heat from conventional and renewable sources [9,10]. This paper develops an energy model of NIS using LEAP, calibrated with 2023 data, and evaluates three scenarios—Baseline, Energy Efficiency, and Green Agenda—up to 2050, linking transition measures to measurable outcomes in energy use, production, and fuel mix.

## **2. Materials and methodology**

Energy modeling is a key tool for analyzing and planning energy system transitions. Two main approaches are used: top-down, based on macroeconomic indicators and aggregated flows, and bottom-up, starting from technologies and processes, offering greater technical detail for industrial systems [5–7]. Hybrid approaches often combine system-level integration with technological precision [5]. Internationally, tools such as MARKAL/TIMES, MESSAGE, OSeMOSYS, PRIMES, and LEAP are applied, with choice depending on goals, data, and resolution [6].

LEAP (Low Emissions Analysis Platform) is widely used for its flexibility, sector integration, transparent data entry, and scenario-building capacity [11]. Unlike optimization models, LEAP simulates multiple scenarios without prescribing an “optimal” outcome, making it suitable for early strategic planning under uncertainty [7,8].

This study applies a bottom-up approach using LEAP to model company-level energy flows from primary supply to end-use, with sectors for production, transformation, and demand. Public data and engineering assumptions define the baseline. Three scenarios were developed:

- Business-as-usual (BaU) – continuation under current conditions,
- Energy Efficiency (EE) – adoption of efficiency measures,
- Green Agenda (GA) – renewable deployment and GHG restrictions.

Scenario modeling evaluates how technology and energy mix changes affect emissions and consumption. Integrated models combine economic, material, social, and ecological factors to project future pathways [3,7]. Simplifications focus on electricity, industry, transport, and heating, aiming for a sustainable, reliable energy mix. For oil and gas, modeling identifies efficiency gains and renewable integration amid rising environmental expectations and regulatory pressures [4].

Against this background, the integrated modeling approach provides a structured framework, linking current energy flows with scenario-based projections to guide transition strategies in Serbia’s oil and gas sector and other energy-intensive industries.

## 2.1. Overview of the Current Energy System of NIS j.s.c.

For this analysis, input data were taken from the NIS Sustainability Report 2023 [3], prepared in line with Global Reporting Initiative (GRI) standards [12] and independently audited. Supplementary sources included company publications on green transition goals and projects [5], as well as operational, production, and financial data from the Annual Business Report 2023 [9] and the company’s development strategy.

Beyond its core activities—oil and gas production, refining, and trade—NIS also operates in energy generation, primarily through the Pancevo refinery power plant, small gas-fired plants (GFP) at oil and gas fields, and photovoltaic facilities (PV) at company sites. It additionally produces and supplies heat, via cogeneration (combined heat & power, CHP) [9,10]. As such, energy is significant within the NIS system, both for internal use and external sales.

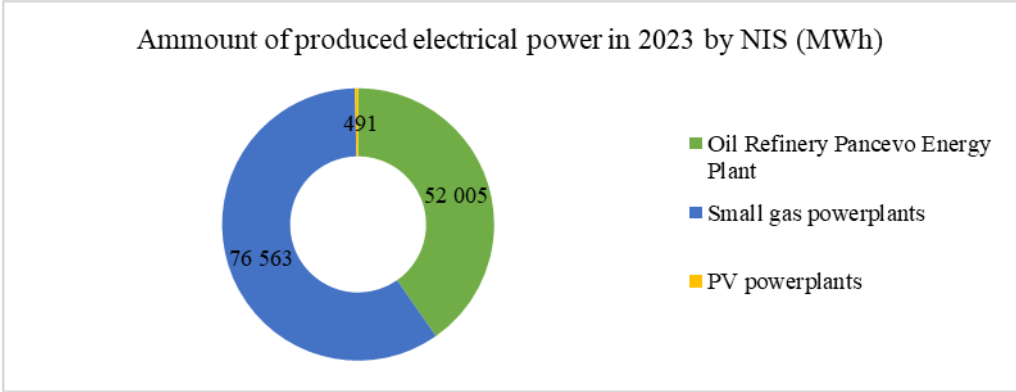
In 2023, NIS produced a total of 605,198 toe of energy across its operations (Tab. 1), confirming its role as a major domestic producer [10]. More than 86% originated from the company’s own hydrocarbon resource base and intermediate products from oil and gas refining, while steam production also accounted for a notable share (Fig. 2).

**Table 1. Overview of produced and consumed energy sources in NIS for 2023, according to [10], modified.**

Energy Source	Unit	Produced energy (in units)	Produced energy (toe)	% of Energy Produced	Consumed Energy (in units)	Consumed Energy (toe)	% of Energy Consumed
Natural and Flare Gas	m <sup>3</sup>	199,146,544	160,701	26.6	177,174,900	142,971	28.20%
Self-consumed fuels	t	433,850	251,472	41.6	433,850	251,472	49.60%
- petrol, diesel	t	4,376	4,691	0.8	4,376	4,691	0.90%
- fuel oil, refinery gas, petroleum coke oil, of gas	t	429,474	246,781	40.8	429,474	246,781	48.70%
LPG	t	103,497	108,918	18	210	221	0.00%
Water vapor (high pressure)	t	946,718	73,010	12.1	946,718	73,010	14.40%
Electric power	MWh	129,059	11,097	1.8	448,484	38,562	7.60%
- from suppliers	MWh				382,909	32,924	6.50%
- produced internally	MWh				65,575	5,638	1.10%
Heat power	MWh	-	-	-	7,398	636	0.10%
<b>Total (toe):</b>	-	-	<b>605,198</b>	<b>100%</b>	-	<b>506,872</b>	<b>100%</b>

In 2023, NIS generated 129,059 MWh of electricity [10], mainly from the Pancevo refinery power plant (52,005 MWh; 40.3%) and small GFP at oil and gas fields (76,563 MWh; 56.3%), with a minor share from PV facilities (491 MWh; 0.4%) (Fig. 1). These figures exclude output from the Pancevo CHP, a separate legal entity in which NIS holds a 49% stake [10]. For production and

operations, NIS purchased 125,444 toe of energy from external suppliers [10], primarily natural and associated gas (73%), electricity (26%), and heat (~1%). The gas was used at the Pancevo refinery and other process plants, as well as for heat generation, while electricity supplied sites without in-house sources or where self-produced energy was insufficient.



**Figure 1. Electrical energy production of NIS in 2023 by sources, according to [10], modified.**

In 2023, NIS consumed 506,872 toe of energy across all operations—exploration, production, refining, distribution, power generation, as well as service and planning activities [10] (Tab. 1). This represented 83.8% of internally produced energy and positioned NIS as a notable national consumer, with a 0.12% share in Serbia’s total final energy use [13]. At the same time, 96.1% of energy demand was met from in-house sources, indicating a prominent level of self-sufficiency and resilience to external markets.

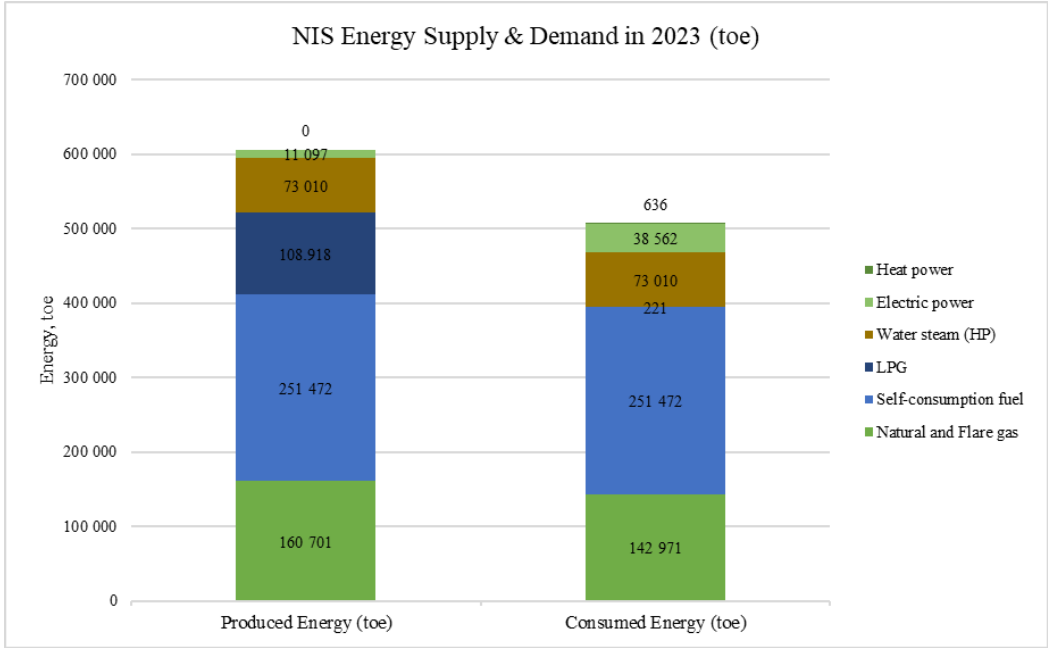
Consumption was geographically dispersed, reflecting the distribution of facilities in Belgrade, Novi Sad, Pancevo, and oil fields across Vojvodina [14]. The main energy carriers were self-produced fuels (~50%), natural and associated gas (28.2%), and steam (14.4%) (Fig. 2), consistent with the energy intensity of oil and gas production and refining relative to retail, logistics, and administrative sectors. Progress in the energy transition was also evident in renewable energy systems (RES) projects, particularly PV installations at fuel stations and selected industrial and office facilities [14]. By the end of 2023, 45 PV plants (1.5 MWp total) had been built, of which 25 plants (0.87 MWp) were commissioned, with the remainder scheduled for 2024-2025. Generated electricity is primarily used on-site, with surplus delivered to the grid.

In 2023, NIS prepared projects for additional PV plants totaling 8.5 MWp at oil storage facilities, office buildings, and refinery units. Further expansion is planned at six locations with confirmed feasibility, amounting to 21 MWp [9]. These trends highlight the growing role of RES in the company’s energy system.

Energy efficiency (EE) also represents a core focus. Key measures include: (1) monetization of associated gas through small GFP, (2) RES development, (3) programs to reduce consumption and improve efficiency in production and refining, and (4) in-house electricity and heat generation [9,10,14]. Within the gas monetization program, eight oil and gas fields were equipped with CHP units totaling 14 MW. The most significant EE projects in 2023 targeted the refining sector, followed by oil and gas production. Combined measures generated total energy savings of 332,265 toe, primarily in heat and process fuels [10].

A milestone was the commissioning of the Pancevo CHP plant, a joint project in which NIS holds a 49% stake. The 189 MW natural-gas plant supplies heat to the Pancevo refinery and sells

electricity to the Serbian market [14,15]. In 2023, it produced 1.1 million MWh of electricity [10], significantly reducing refinery self-consumption and external energy dependence.



**Figure 2. Energy production (supply) and energy consumption (demand) of NIS in year 2023 by different energy sources, according to [10], modified.**

Overall, these initiatives have strengthened NIS’s energy balance and improved efficiency across production and refining operations.

**2.2. Integrated Energy Model of NIS j.s.c.**

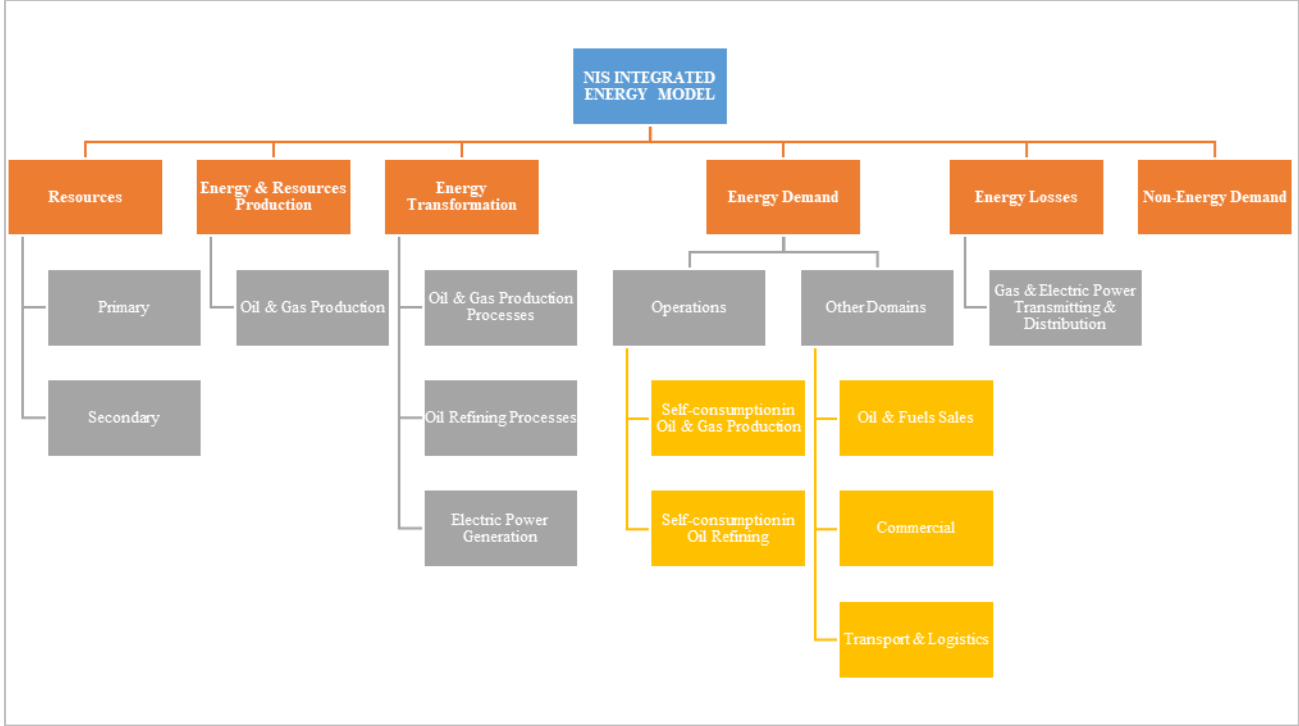
Considering the specificities of the NIS energy system, an Integrated Energy Model (IEM) was developed for the base year 2023 to assess the current system, sustainability targets, and prospects. The model was built using available data on energy and material flows and implemented in the Low Emissions Analysis Platform – LEAP (v. 2020.1.0.113) [11].

The IEM structure comprised two main domains: Energy Demand and Production & Transformation, with a supporting Resources domain. Energy Demand included: (1) industrial processes (own consumption in oil and gas production and refining), (2) petroleum product distribution, (3) commercial activities, and (4) transport. Each sector modeled processes such as power, heat, electric drive, heating/cooling, lighting, and transport drive. Production & Transformation covered: (1) electricity generation within NIS (excluding Pancevo CHP and Plandiste wind farm), (2) oil and gas production at Serbian fields, and (3) refining at Pancevo oil- and Elemir gas refineries. Transmission losses of electricity and gas were also included.

The Resources domain comprised primary (oil, natural gas, solar) and secondary resources (electricity, gasoline, kerosene, lubricants, avgas, LPG, heat and steam, diesel, fuel oil). Shortages, fossil fuels, were assumed to be covered by imports. Figure 3 shows the model structure.

Operational parameters for 2023 were adopted directly: hydrocarbon production – 1,158,300 t; refining – 4,092,300 t; distribution – 3,999,500 t; office area – 90,000 m<sup>2</sup>; transport mileage – 40,000,000 km; electricity production – 129,059 MWh. Model verification compared actual and modeled energy consumption across domains, with deviations of –0.17% overall and –0.55% to +0.11% by domain,

considered satisfactory for projections. Based on the verified IEM, forecasts were analyzed for 2024–2030 with projections to 2050, aligned with NIS sustainability and energy goals.



**Figure 3. Basic structure of the NIS integrated energy model with key domains considered.**

To clarify potential future developments of the NIS system, all key parameters in the model were assessed under three scenarios: (1) Baseline (business-as-usual), representing continuation of current operations; (2) Energy Efficiency (EE), reflecting rational reductions in energy use across core business processes; and (3) Green Agenda, combining a higher share of renewable energy sources (RES) with significant EE measures. Comparison of results across scenarios and time horizons enables identification of major trends and the formulation of key conclusions on the development potential of the NIS energy system.

**Table 2. Comparison of NIS energy demand (total and by domains), actual in the 2023 base year and in IEM modeled in LEAP.**

Energy Demand, toe	Total (2023)	Upstream	Downstream	Commercial	Sales	Transport & Logistics
Actual	506,872	63,992	405,619	15,324	18,902	3,036
Modeled (LEAP)	506,004	63,730	405,138	15,300	18,798	3,039
<b>Difference (toe)</b>	<b>-868</b>	<b>-262</b>	<b>-481</b>	<b>-24</b>	<b>-104</b>	<b>+3</b>
Deviation (%)	-0.17%	-0.41%	-0.12%	-0.16%	-0.55%	+0.11%

The future development targets of the NIS energy system, based on published data and reports [10,14], were integrated into the IEM to the maximum extent possible in forecasting scenarios up to 2030 and 2050. Key goals include: continued modernization of oil and gas refining facilities; diversification of energy-related operations; achieving at least 50% of electricity production from RES

by 2030; construction of at least 20 MWp of new PV capacity; annual reductions in specific energy consumption of  $\geq 1.5\%$  through EE measures; expansion of small GFP at oil and gas fields; and a 30% reduction in carbon intensity by 2030 compared to 2018.

Within the IEM, only measures and targets linked to the core domains of NIS operations: oil and gas production, refining, and supporting in-house electricity generation, were included. Goals outside these domains, or under the management of affiliated entities (e.g., the Plandiste wind farm, grid-oriented PV projects, Pancevo CHP), were not considered.

In the domain of energy demand and resource use/production, modeled parameters included operational indicators (by sector) and energy intensities of major sources. For production and transformation, the model incorporated: total energy, feedstock, and product outputs (oil, gas, derivatives, electricity); process efficiency indicators; and installed capacities of relevant facilities (small GFP, PV plants, and refinery power units).

### 3. Results and discussion

Based on the defined development targets of the NIS energy system and the developed Integrated Energy Model (IEM), results were obtained on the future dynamics of key indicators for the period 2024–2030, with projections to 2050. These results highlight the main trends of the modeled system, its structural patterns, and tendencies across the domains of energy demand and production, allowing broader conclusions about its characteristics and scale.

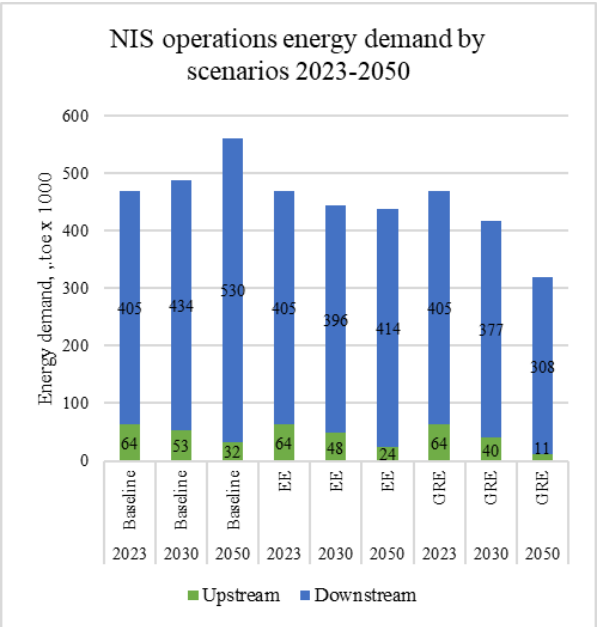
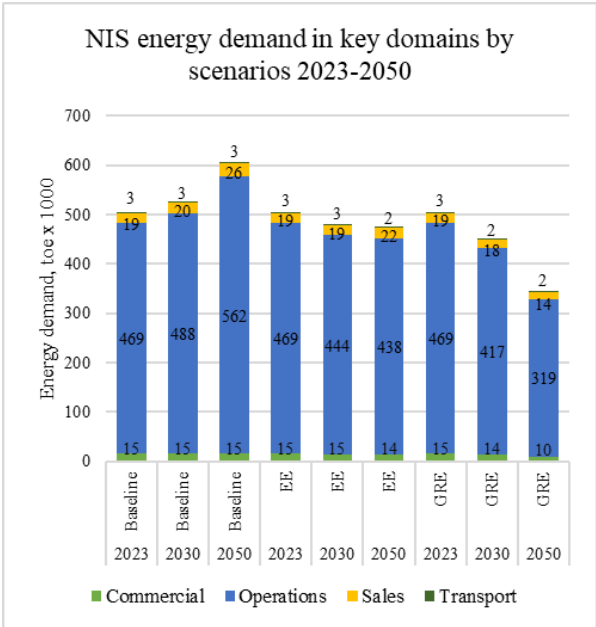
IEM results for total energy consumption by sector show that under the Baseline scenario, overall demand gradually increases by about 4% by 2030 and up to 20% by 2050, in line with global industry trends (Fig. 4). In contrast, due to the implementation of EE measures, fuel substitution (primarily through cogeneration), and new RES capacities, the EE scenario achieves a reduction of 5.9%, while the Green Agenda scenario (EE+RES) leads to a decrease of up to 31.7%. Comparison confirms that adopted transition goals and measures, especially the introduction of new RES capacities, can significantly reduce total energy consumption in the NIS system during the observed period.

At the domain level, results across all three scenarios show the continued dominance of core industrial processes (oil and gas production and refining) over distribution, commercial, and transport activities. This indicates that NIS will remain a highly energy-intensive system in the future, even with the full implementation of EE measures and ongoing RES investment cycles. Importantly, refining processes will continue to account for the largest share of energy demand ( $\approx 86\%$ ) relative to oil and gas production, which explains why most transition measures are focused on this sector (Fig. 5).

In terms of the share of main energy sources (natural gas, petroleum products, electricity, and heat), the results show the continued dominance of petroleum products and electricity in the future energy mix (Fig. 5). In the BaU scenario, alongside these two sources meeting rising demand, natural gas consumption also increases. In the alternative scenarios, however, the overall reduction in energy demand reinforces the dominance of electricity, which substitutes for traditional use of petroleum products. Heat consumption remains stable throughout the period.

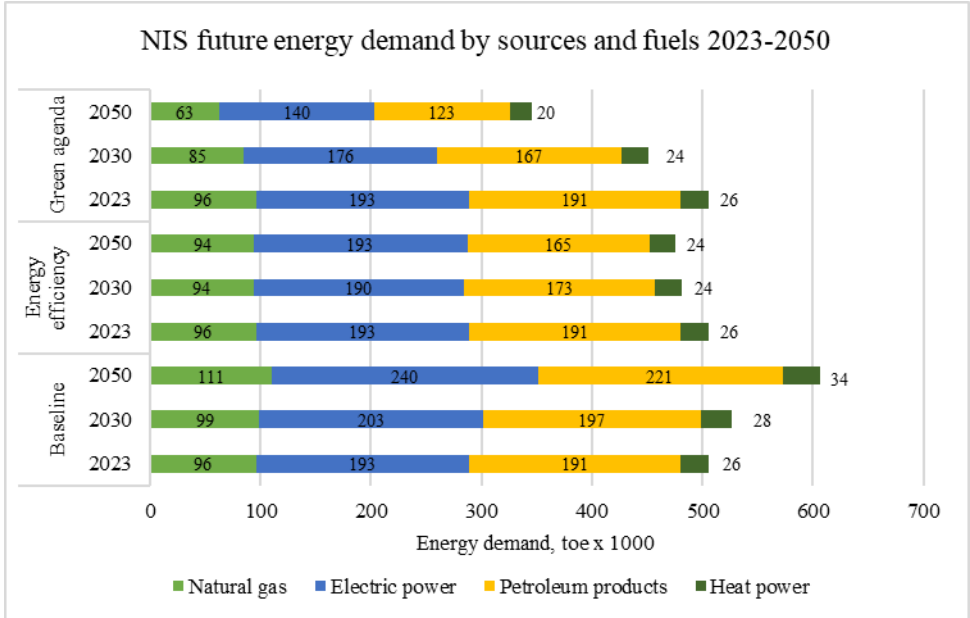
The results of the IEM of NIS provided forecasts for future production of oil and gas, refining of oil, gas, and derivatives, as well as electricity generation from existing and new capacities up to 2030, with projections to 2050. In the domain of oil and gas production, all scenarios indicate a decline (Fig. 6). In the BaU scenario, the decrease is minimal (-3% by 2030 and -12.7% by 2050), reflecting sustained demand for oil and gas as primary inputs for refining and their continued market relevance [4]. Under

the EE scenario, the decline is more pronounced (-10% by 2030, -33.5% by 2050) due to reduced demand for oil derivatives. The GA scenario shows the steepest fall, with output decreasing by 16% by 2030 and up to 50% by 2050, driven by the substitution of fossil fuels with RES and alternative fuels across multiple sectors [16,17].



**Figure 4. Future NIS energy demand from 2023 to 2050, by key domains and scenarios (“Operations” includes upstream and downstream domains)**

**Figure 5. Energy consumption of NIS operational activities by scenarios from 2023 to 2050**

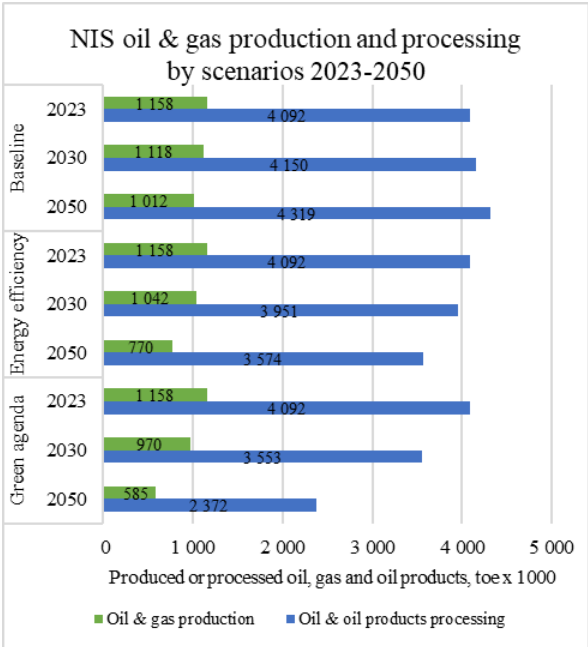


**Figure 6. Future NIS energy demand by sources and fuels from 2023 to 2050**

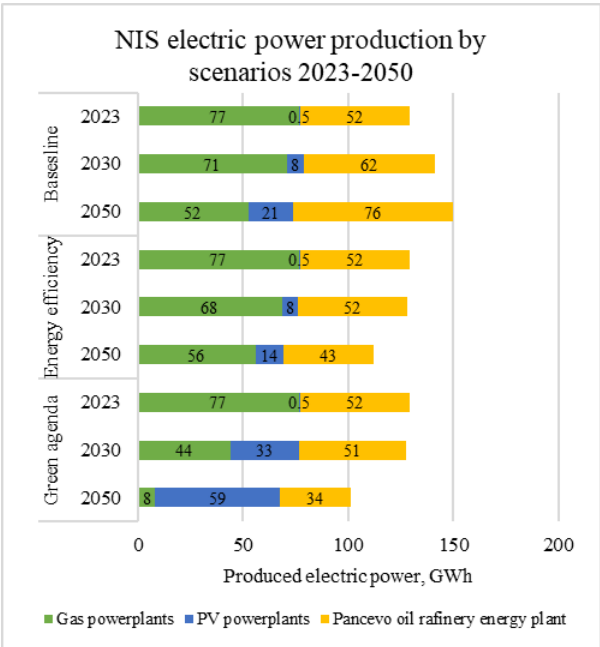
In the domain of oil, gas, and petroleum product refining, the BaU scenario projects a slight increase in total refining volumes (+1.4% by 2030 and +5.5% by 2050), consistent with expected global demand growth for fossil fuels, particularly under conditions of reduced energy security and shortages

of base-load energy. By contrast, the EE scenario shows a decline of 3.4–13%, reflecting both efficiency measures and lower demand. The GA scenario indicates a much sharper contraction, with refining volumes falling by 13.2% by 2030 and up to 42% by 2050, due to reduced use of fossil fuels in industry and transport, in line with transition targets (Fig. 7) [4].

For electricity generation, the BaU scenario shows an overall increase of 9–16%, driven by higher global energy demand, particularly in industrial facilities, despite partial substitution of fossil fuels with renewables (Fig. 8). In the EE scenario, generation declines by 0.5–12%, primarily due to reduced electricity demand across all domains, especially oil and gas production and refining. The GA scenario also shows a decline (-1.3–21%), though with a significantly higher share of renewables in the generation mix. Small GFP remains dominant in both the BaU and EE scenarios [10]. In the BaU, process power plants increase output due to continued high refining activity. In the EE scenario, their generation declines as operational indicators fall, while PV capacity rises as new plants are commissioned. The GA scenario projects PV as the leading source, reaching over 55% of total electricity production [10].



**Figure 7. NIS future production and processing of oil, gas, and products by scenarios until 2050**



**Figure 8. Future NIS electric power production by sources and scenarios until 2050**

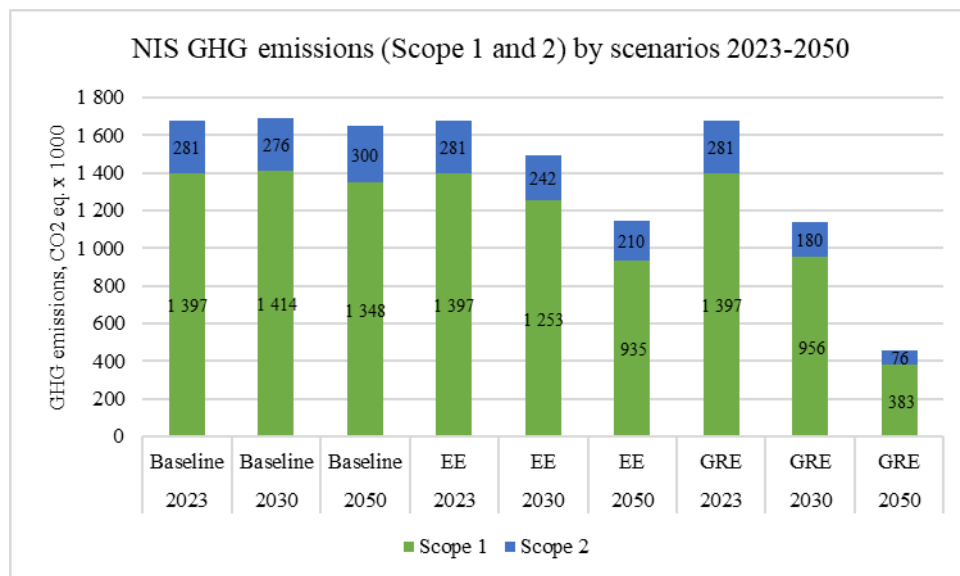
Alongside the analysis of energy flows and production–consumption characteristics, the IEM in LEAP also included calculations of GHG emissions for the modeled scenarios (Fig. 9). Results show that under the BaU scenario, emissions (Scope 1 and 2) remain constant through 2030, with only a slight decline of 1.75% by 2050. The EE scenario achieves a reduction of about 31.7%, while the GA scenario projects a substantial decrease of up to 72.7% compared to the 2023 baseline.

The dominant reductions occur in direct emissions (Scope 1), driven by process optimization and substitution of fossil fuels with renewables. A smaller but notable decline in indirect emissions (Scope 2) results from lower electricity consumption and a cleaner generation mix within the NIS energy

system. These findings confirm that the NIS system has strong potential for decarbonization and for significantly lowering its carbon intensity through the implementation of transition measures.

In the context of emission analysis and the decarbonization potential of oil and gas refining, the role of hydrogen emerges as particularly important for the future development of the NIS energy system. At present, hydrogen is produced at the Pancevo oil refinery using natural gas, classified as “blue hydrogen”, and already included in the model’s energy consumption and emissions calculations. Although this production is not reported separately, projections to 2050 leave room for further development of “green hydrogen”, produced via electrolysis from renewable sources. Such technology could play a crucial role in reducing emissions and enhancing the sustainability of refining within the NIS energy system.

The results confirm significant potential for altering the overall energy balance of NIS in the alternative scenarios of full EE implementation and the GA. These pathways would markedly reduce the system’s overall energy intensity and enable the formation of an optimal energy mix for the 2023–2050 period. Conversely, continuation along the Baseline trajectory, without the necessary corrective measures, would increase the overall energy burden of the system, both in consumption and production. This could undermine the long-term sustainability of NIS’s core activities. Overall, the findings highlight the importance of implementing all declared and adopted energy transition measures and sustainability pathways, confirming their critical role for the future development of the oil and gas sector.



**Figure 9. Estimated future NIS direct and indirect GHG emissions (Scope 1 and 2) by scenarios until 2050, according to [10]**

#### 4. Conclusion

This paper presented an Integrated Energy Model (IEM) as a tool for analyzing complex energy flows and planning future development of energy systems in oil companies. Such models provide an objective basis for strategic decision-making in the context of energy transition, particularly in balancing conventional fossil fuels with an increasing share of renewables. Oil companies, as key actors in the global energy landscape, face the challenge of reconciling economic interests, regulatory requirements, and growing societal expectations for sustainability.

The model was applied to NIS j.s.c. Novi Sad, one of the largest energy companies in Southeast Europe. The analysis enabled a detailed assessment of current energy flows and prospective development scenarios to 2050, distinguishing between a Baseline trajectory (BaU) and alternative pathways that emphasize energy efficiency (EE) and the Green Agenda (GA).

Compared with some international oil majors, often criticized for declaring ambitious climate targets without proportional investments (so-called “greenwashing”), the NIS approach demonstrates greater consistency, supported by tangible projects in EE and RES. Still, as with other sector players, realization of ambitious goals is subject to regulatory, market, and institutional constraints, underscoring the need for stronger systemic support, transparent reporting, and monitoring mechanisms to ensure strategies translate into real transformation rather than symbolic commitments.

The results of the IEM highlight the complexity of NIS’s current energy system and its potential for sustainable development. In the BaU scenario, total energy consumption increases by 4% to 2030 and 20% to 2050, with refining volumes rising modestly (+1.4% and +5.5%) and fossil fuels, especially petroleum products and natural gas, remaining dominant. In contrast, the EE scenario projects consumption reductions of up to 5.9%, while the GA scenario achieves even deeper cuts of 31.7%, alongside a shift in electricity generation, where renewables account for over 55% by 2050. All scenarios foresee a gradual decline in oil and gas production, most pronounced under the GA (–50% by 2050).

If fully implemented, EE and GA measures would reduce the energy intensity of core industrial processes and ensure long-term sustainability of NIS operations, strengthening their competitive position in the regional market. Conversely, continued reliance on Baseline trajectory risks higher energy costs, reduced competitiveness, and long-term vulnerability.

From a broader perspective, oil companies will play a dual role in the energy transition, continuing to secure supply of traditional fuels while simultaneously expanding renewable capacities and efficiency measures. Their sustainability will depend on achieving a balanced energy mix and adapting to evolving regulatory, market, and technological conditions. For NIS, the findings confirm that a consistent application of sustainable development strategies and concrete transition projects is essential for ensuring future stability and resilience.

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## **Nomenclature**

MWh – Megawatt-hour [Wh]

GWh – Gigawatt-hour [Wh]

MWp – Megawatt-peak [W]

toe – tons of oil equivalent

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