Pilot Case Factsheet

Applying Energy Efficiency First in Transmission Grid Planning and Cost-Benefit Analysis

Croatia

December 2025

Background and objectives

The main aim of the Croatian pilot case was the integration of the EE1st (Energy Efficiency First) principle into transmission system planning and the related cost-benefit analysis (CBA) of transmission grid investment projects.

Traditionally, grid investment projects have been justified through technical adequacy assessments and CBAs focused primarily on reliability, congestion management, and least-cost infrastructure expansion. Planning methodologies are generally based on projected load growth and generation patterns, with network reinforcement considered the default solution. In practice, alternatives such as energy efficiency improvements, distributed generation, storage, or demand-side flexibility are not systematically assessed, and National Regulatory Authorities do not always explicitly verify whether such options have been fairly considered. Conventional CBAs typically reflect the perspective of the system operator, emphasising capital expenditures (CAPEX), operational costs (OPEX), and technical indicators, while only partially accounting for wider societal impacts.

The EE1st principle broadens this analytical framework. It requires that grid investment decisions examine whether reducing or reshaping demand could defer, downsize, or eliminate infrastructure needs. Under the oversight of the National Regulatory Authorities, system operators have to systematically assess energy efficiency, demand response, storage, and other flexibility solutions before approving new grid investments. This entails extending CBAs beyond operator-centric metrics to include societal costs and benefits. This shifts grid planning from a predominantly infrastructure-driven approach towards a more integrated system perspective, ensuring that demand-side resources are evaluated on equal footing with supply-side expansion, while fully preserving security of supply as a primary objective.

The Croatian pilot case facilitated compliance with the provisions of Article 3 of the EED (Energy Efficiency Directive (EU) 2023/1791) regarding the assessment of planning and major investment decisions made by the Transmission System Operator (TSO). Moreover, the pilot provided a methodological basis for the implementation of Article 27 of the EED, which requires that TSOs apply the EE1st principle in network planning, network development and investment decisions, and that the National Regulatory Authority verifies that alternatives and wider societal benefits are properly assessed.

More specifically, the pilot examined:

- The preparation of the Ten-Year Transmission Network Development Plan (TYNDP);
- The alignment of transmission planning with the National Energy and Climate Plan (NECP);
- The cost-benefit analysis of a representative 220 kV high-voltage transmission line revitalisation project.

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The Croatian transmission planning framework is formally aligned with NECP scenarios. Energy efficiency measures are embedded in electricity demand forecasts. However, demand-side flexibility, storage and structured non-wire alternatives are not systematically assessed as explicit alternatives to network reinforcement.

The pilot therefore aimed to:

- Assess to what extent the existing planning and CBA methodologies comply with EE1st requirements;
- Identify necessary improvements in planning procedures and CBA practice;
- Clarify roles and responsibilities of the TSO and the National Regulatory Authority in implementing EE1st.

Methodology

The methodological approach developed within the Croatian pilot case focused on analysing and improving the integration of the EE1st principle into transmission system planning and cost-benefit analysis practices.

The starting point of the analysis was a comprehensive review of the existing legal, regulatory and planning framework governing transmission system development in Croatia. Particular emphasis was placed on the preparation of the TYNDP and its alignment with the NECP. The demand and supply scenarios used for grid planning were examined in order to assess how energy efficiency measures are reflected in electricity consumption forecasts and whether flexibility, storage and demand response are considered beyond aggregate demand reductions. For more details about the European and Croatian framework for grid planning and investments, see chapter 3 in (ENEFIRST Plus 2025).

In parallel, the existing CBA methodology applied by the TSO was reviewed. The methodology, which follows established European guidance for transmission projects, was analysed from a societal perspective. The scope of costs and benefits considered in the CBA was examined, including investment and operating costs, reduction of network losses, avoided energy not served, redispatch cost reductions, renewable energy integration, cross-border capacity increases and monetised CO_2 emissions. Particular attention was given to identifying whether wider environmental and social impacts, as well as non-wire alternatives, are systematically included and if not, how this could be achieved.

A representative 220 kV high-voltage transmission line revitalisation project was selected as a case study to test the practical application of the EE1st principle. The traditional CBA results were compared with an EE1st-informed assessment, focusing on whether demand-side efficiency, flexibility solutions or operational measures could meaningfully influence the investment decision. The interaction between upstream planning assumptions and project-level evaluation was carefully analysed.

The methodological approach was supported by structured exchanges with key stakeholders, including the Croatian TSO (HOPS), the National Regulatory Authority (HERA) and the Ministry of Economy as a competent authority for energy sector. In addition, the EIHP expert team combined specialists in energy efficiency policy and modelling with experts in transmission grid planning and system operation. This interdisciplinary composition ensured that both demand-side and grid reliability perspectives were systematically reflected in the assessment and in the formulation of recommendations.

Overall, the methodology combined regulatory analysis, planning review, quantitative CBA assessment and stakeholder consultation in order to identify where EE1st can be most effectively embedded within transmission system decision-making processes.

Main results

Transmission system planning in Croatia is formally aligned with the NECP, as electricity demand forecasts used in the TYNDP are derived from national scenarios. The NECP incorporates energy efficiency measures in aggregate electricity consumption projections, meaning that demand reduction effects are reflected at a macro level. However, the assessment demonstrated that not all dimensions of the EE1st principle are systematically embedded in these scenarios. In particular, demand response, storage, flexibility resources and the temporal and geographical characteristics of demand are not explicitly modelled as structured planning variables.

At the same time, it is fully justified that transmission planning primarily focuses on topological requirements, reliability criteria and security of supply. Ensuring safe and stable system operation is the core mandate of the TSO. The limited integration of flexibility and demand-side resources in transmission planning is therefore not a consequence of methodological shortcomings, but rather of institutional responsibilities and the macro-level design of energy scenarios. Where EE1st considerations are not explicitly embedded in national planning assumptions, TSOs operate within the boundaries of their mandate and available inputs.

Regarding the examined 220 kV high-voltage transmission line revitalisation project, the applied CBA methodology follows established European guidance and adopts a societal perspective. It includes investment and operating costs (CAPEX and OPEX), reduction of network losses, avoided energy not served, redispatch cost reductions, enabled renewable energy integration, increased cross-border capacity and monetised CO_2 reductions.

From an EE1st perspective, it was confirmed that the CBA primarily compares different infrastructure configurations but does not systematically compare reinforcement with portfolios of demand-side efficiency or flexibility measures. In cases such as the one examined, where the transmission asset is several decades old and faces increasing reliability and operational challenges, non-wire solutions are considered primarily as operational measures rather than as structural alternatives. Flexibility, demand response or dynamic operational tools may help optimise system operation or temporarily relieve constraints, but they cannot be regarded as viable substitutes for the physical revitalisation of ageing high-voltage infrastructure. Their role is therefore complementary rather than alternative in nature.

The only efficiency-related benefit directly captured at project level is the reduction of transmission losses. While broader socio-environmental externalities such as health, biodiversity or land-use impacts are not monetised in the applied CBA framework, their inclusion at project level for transmission line revitalisation faces methodological and proportionality constraints. Unlike end-use energy efficiency measures, where local environmental and health effects can be directly quantified, transmission infrastructure primarily generates system-level impacts. CO_2 reductions are therefore the most robust and proportionate externality to monetise, as they can be directly linked to changes in system dispatch. Other environmental impacts are typically addressed through environmental impact assessment procedures rather than integrated into the economic CBA.

An important outcome of the pilot was the interdisciplinary learning process within the expert team and among stakeholders. Bringing together energy efficiency experts and transmission planning specialists revealed different professional perspectives: while energy efficiency experts emphasised stronger integration of demand-side options and flexibility in planning scenarios, grid experts focused primarily on topology, reliability criteria and operational security. The structured dialogue between these perspectives proved highly valuable. It clarified where demand-side integration is realistically feasible and where reinforcement remains unavoidable due to system security constraints. This exchange contributed to embedding the EE1st principle not only in methodologies but also in the practical understanding of transmission planning.

Conclusion

Overall, the pilot concluded that while targeted improvements in CBA methodology are useful, the upstream planning and scenario development play the central role in implementing the EE1st principle in transmission infrastructure. Integrating flexibility, storage and demand-side measures more explicitly at the planning stage would allow reinforcement needs to be better optimised before individual investment decisions (i.e. at project level) are assessed.

Where/how implementing EE1st makes a difference

The Croatian pilot case demonstrated that the implementation of the EE1st principle in transmission infrastructure makes the greatest difference at the planning stage rather than at the level of individual project cost-benefit analyses.

Transmission system operators are rightly mandated to ensure system reliability and security of supply. Planning therefore primarily focuses on topological requirements and compliance with operational criteria. This is both legitimate and necessary. However, if demand scenarios embedded in national and network development plans do not explicitly incorporate energy efficiency, demand response, storage and flexibility as structured planning variables, reinforcement needs become largely predetermined before individual investment decisions are assessed.

In such a framework, project-level CBAs can optimise the technical solution – such as selecting the most cost-effective revitalisation option – but they cannot fundamentally reassess the need for reinforcement itself. The pilot therefore showed that while targeted methodological improvements in CBA (e.g. structured screening of non-wire alternatives) are useful, the decisive leverage point for the EE1st principle lies in integrated scenario development and upstream planning.

Embedding EE1st consistently into national demand forecasting and transmission planning would allow grid investments to be better sized from the outset. Once planning confirms that reinforcement is required to meet reliability standards and accommodate renewable energy development, the CBA can appropriately compare alternative technical configurations to identify the most socio-economically justified option. In this sense, planning is the primary vehicle for operationalising EE1st, while CBA functions as a refinement tool within the boundaries set by that planning framework.

The pilot also clarified the proportionality limits of CBA in transmission projects. While CO_2 reductions can be robustly monetised due to their direct link to system dispatch and established carbon pricing mechanisms, broader socio-environmental externalities (such as health or biodiversity impacts) are more difficult to quantify in a transmission line revitalisation context. These impacts are typically addressed through environmental assessment procedures rather than economic CBA. The EE1st gap in transmission planning therefore lies less in expanding monetisation categories and more in ensuring that flexibility and demand-side resources are properly considered at macro level.

Finally, the pilot demonstrated the importance of interdisciplinary cooperation. The collaboration between energy efficiency specialists and transmission planning experts enabled constructive dialogue between different professional perspectives. This exchange strengthened mutual understanding of system constraints, data limitations and policy objectives, contributing to the gradual integration of the EE1st thinking into transmission planning practice.

Overall, the Croatian case shows that implementing the EE1st in transmission infrastructure does not mean weakening security-of-supply principles or replacing necessary grid investments. Rather, it means strengthening planning coherence, clarifying regulatory responsibilities and ensuring that demand-side resources are consistently reflected in macro-level energy scenarios before infrastructure decisions are made.

About Enefirst Plus

Enefirst Plus is a 3-year project (November 2023 – October 2026) co-funded by the EU LIFE programme. Building on the previous Horizon 2020 Enefirst project, the aim of Enefirst Plus is to provide key stakeholders in all Member States with the technical support needed to effectively implement Energy Efficiency First across various sectors, particularly focusing on key decision-making processes.

Energy Efficiency First (EE1st) is an overarching principle for planning, policies and major investments having an impact on energy consumption. EE1st is about considering **energy efficiency and demand-response as energy resources** in the energy system, just as supply-side resources (e.g. generation capacities, network infrastructures). Implementing EE1st means that in planning exercises, policy design or decision-making about investments, the options considered include energy efficiency and demand-response, and that these options are compared with supply-side options on a **fair basis**, considering **multiple impacts and a long-term perspective**.

Implementing EE1st is easier said than done. Therefore, the general approach of Enefirst Plus is to complement existing resources to **plug EE1st in the decision making** for investments in energy infrastructure, energy planning, and designing incentives and policies.

Enefirst Plus is testing this approach in four countries (Croatia, Italy, Greece and Poland) and scrutinise the implementation of EE1st with **pilot cases** in each country. Two cycles, with four pilot cases each, will provide a diversity of **real-life examples** addressing typical situations where EE1st should be implemented. The new resources and pilot cases produced by the project, as well as experiences from other countries, serve as foundational elements for capacity building and experience sharing activities, and for the development of a community of practice.

Enefirst Plus' partners

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