Terms of Reference for SHURA study on
"Impact of Locational Marginal Pricing on Power System for Accelerating Renewable Energy Integration"

SHURA Energy Transition Center
İstanbul, Türkiye
June 2024

1.Background

In today's rapidly evolving energy landscape, the concept of the Locational Marginal Price (LMP) of electricity has emerged as a crucial factor in the functioning of electricity markets worldwide. LMP represents the price of electricity at specific locations within a grid or network, and it plays a pivotal role in optimizing the allocation of resources, ensuring grid reliability, and encouraging sustainable energy practices. At the heart of this paradigm shift lies the integration of renewable energy sources, which have fundamentally transformed the dynamics of electricity generation, consumption, and pricing.

The global shift towards renewable energy sources, such as wind and solar, has ushered in a new era in the energy sector. These sources, often dependent on weather conditions and geographical factors, have introduced a level of variability and uncertainty that challenges traditional methods of electricity pricing and distribution. Consequently, understanding and harnessing the potential of renewables within the context of LMP has become a focal point for energy policymakers, market operators, and industry stakeholders. This introduction sets the stage for a comprehensive exploration of LMP in the context of renewables, shedding light on the intricate relationship between electricity pricing and the integration of sustainable energy sources. In the pages that follow, we will delve into the intricacies of LMP, dissecting its components, examining its significance in the energy market, and uncovering how it is shaping the future of renewable energy adoption and grid management.

The Turkish electricity market operates as a PX (Power Exchange) market, where all settlements are traditionally based on a unique Market Clearing Price (MCP). This centralized pricing mechanism, while effective in its own right, faces increasing challenges in the wake of Türkiye's ambitious goals to integrate substantial amounts of renewable energy into its energy mix, as stipulated in the Paris Agreement towards achieving net-zero emissions. Türkiye's vision for a sustainable energy future necessitates a fundamental shift in the way electricity is priced and managed. As renewable energy sources, including wind and solar, become increasingly prominent contributors to the nation's energy portfolio, the inherent variability and intermittent nature of these sources pose unique challenges. The traditional MCP-based model may struggle to account for the dynamic fluctuations in supply and demand that come with the proliferation of renewables. In this context, the move towards adopting the LMP concept becomes not only desirable but also inevitable. LMP, with its ability to capture location-specific variations in electricity prices, is poised to provide a more granular and responsive pricing mechanism that aligns with the diverse geography and generation patterns of Türkiye. By enabling the differentiation of prices based on the specific location

within the grid, LMP facilitates a more accurate reflection of market conditions, promoting efficient resource allocation and grid stability.

Furthermore, the integration of renewables on a significant scale brings forth another crucial consideration: the potential for negative pricing during high renewable energy generation hours. This phenomenon, while indicative of the success in harnessing renewable energy, poses a unique challenge in pricing and market operation. The implementation of negative pricing, essential for incentivizing flexible demand response and energy storage, becomes feasible and efficient primarily through the adoption of the LMP concept.

This study delves into the transformation of the Turkish electricity market, shifting from a Market Clearing Price (MCP) based settlement system to a Locational Marginal Price (LMP) based approach. With the growing prevalence of renewable energy resources, this transition is imperative. The study aims to demonstrate the need for this reformation and how LMP can enhance the overall welfare of all electricity market participants.

2. Objective and Tasks

The study investigates a mid and long-term roadmap for Türkiye concerning the need to move towards the locational electricity pricing concept. The studies show how the electricity network gets under pressure by the proliferation of renewable energy resources and under such circumstances, how the networked constraints should be considered in the electricity market clearance procedure. The study will specifically focus on:

Task 1: Modeling scenarios and associated sensitivities. Task 1 involves the identification of potential scenarios and the exploration of associated sensitivities within the context of Türkiye's evolving electricity market. Here, the latest grid study project of SHURA ("*Integration of Renewable Energy into the Turkish Electricity System*"- April 2022) will be considered as the basis for determining the scenarios. This multifaceted analysis encompasses a range of critical factors, including the expansion of renewable energy source capacities, the composition of other generator capacity fleets, net transfer capacity on interconnections, the phased-out use of coal, shifts in demand, energy efficiency enhancements, electrification efforts (including the integration of electric vehicles), and the evaluation of flexibility solutions. The potential scenarios are business as usual and advanced renewable scenarios (as in SHURA's "*Integration of Renewable Energy into the Turkish Electricity System*" report) considering year 2035 as the target year.

Task 2: Market and network simulation studies. Based on the conduced literature review and the identified scenarios, the market and network simulations will be conducted. This task includes the following subtasks:

- Task 2.1. Data preparation for market and network simulations under each scenario and sensitivity
- Task 2.2. Development of module for uniform settlement (MCP) and locational settlement (LMP)
- electricity price calculation
- Task 2.3. Uniform settlement (MCP)-based market and network simulation analysis
- Task 2.4. Locational settlement (LMP)-based market and network simulation analysis

The simulations will be performed at hourly resolution and for 4 typical days representing the four different seasons plus one extreme day such as religious holidays.

Task 3: Comparison of uniform settlement (MCP) and locational settlement (LMP) mechanisms from market role players perspective. Task 3 is focused on providing a comprehensive analysis of the two primary electricity market settlement mechanisms, Uniform Settlement (MCP) and Locational settlement (LMP), with a specific emphasis on understanding their impact and implications from the perspective of various market role players. The comparison will be made considering the Uniform Settlement (MCP) as the basis and the Locational settlement (LMP) will be normalized accordingly. Here, the number of LMP regions should be defined carefully to represent the changes in wholesale electricity prices when switching from uniform settlement (MCP) to locational settlement (LMP). One option can be the 9 load dispatching centers introduced by TEİAŞ. The other option can be four main regions east, north, south and Trakya regions. The number of LMP regions and the clustering criteria will be determined based on the acquired simulation results. This task entails a meticulous examination of how each mechanism influences and interacts with stakeholders such as generators, consumers, regulators, and the TSO. By evaluating factors like pricing transparency, resource allocation efficiency, risk management, and market competitiveness, the task also aims to offer valuable insights into which mechanism aligns best with the diverse interests and objectives of market participants. This analysis plays a crucial role in shaping informed decisions and strategies for the evolving energy landscape.

Task 4: A policy maker-friendly report that derives policy recommendations that are necessary for the implementation of locational pricing mechanisms and its implementation. The draft final report will be submitted to SHURA for concurrence and comments. The Consultant will prepare the final report considering SHURA's comments. The Consultant shall document the overall study results in a comprehensible manner in a final report that includes at least the following elements:

- A concise summary in English and Turkish at native level.
- A long version of the study results, with a focus on the strong visual representation of the results, and a transparent description of the methodological approach;
- Appendices with descriptions of the models, data sets, and assumptions used;
- A PowerPoint presentation of the overall study results.

■ Some more details on the process:

1. The study will be based on SHURA's latest grid study ("*Integration of Renewable Energy into the Turkish Electricity System*") in terms of scenarios and the gris model to be used.
2. The Consultant, based on know-how and input received by SHURA, prepares key parameters for discussions and presents them to SHURA. These will need to be agreed upon and approved by SHURA.
3. The work will be carried out in consultation with SHURA's project management team: At least biweekly progress meetings will be organized and all task results will be discussed with SHURA. Task outputs will need to be agreed upon and approved by SHURA.

4. At least one stakeholder workshop will be held by the Consultant with the support of SHURA. The results of the stakeholder meetings will be used by the consultant/s to adjust the model.

3. Timeline and Project Plan

The proposed timeline and project plan are as follows:

Deliverables	**Responsible**	**Timeline**
Contract starts	SHURA	July 2024
Task 1- **Modeling scenarios and associated sensitivities.**	Consultant	July-August 2024
Task 2- **Market and network simulation studies**	Consultant	August-September 2024
Task 3 - **Comparison of uniform settlement (MCP) and locational settlement (LMP) mechanisms from market role players perspective**	Consultant	September-November 2024
Task 4 -Reporting	Consultant	December 2024

4. Consultant Qualifications

The project will be based on grid and market simulations. The consultant must have a state-of-the-art grid network simulation model proven in SHURA's latest grid study, "*Integration of Renewable Energy into the Turkish Electricity System*". The project will be based on the scenarios and assumptions developed in this study. The consultant firm must have commercially developed security-constrained-unit-committment (SCUC) simulation software capable of calculating nodal LMP prices. The firm must prove at least one successful sale and deployment of its SCUC software in a transmission grid. Additionally, the consultant firm must have completed at least three successfully finished projects related to SCUC analysis of power systems in at least three different countries (to be proven). The firm should also have proven records of conducting at least two different SCUC analysis studies on the Turkish power system.

The consultant must also have project experience in:

- market and grid simulation model development, power system analyses, scenario development, forecasting techniques and technology assessment for Türkiye's power system
- energy efficiency, electrification, renewable energy, flexibility technologies and grid integration policies and regulations in Türkiye or in countries that have similar characteristics to Türkiye's power system,
- comprehensive planning and optimization for transmission and distribution networks
- utilization of probabilistic methods in power system analysis
- development of power sector and renewable energy roadmaps that encompass multiple technologies, approaches, sectors and stakeholders,

- engagement with stakeholders from Türkiye's energy sector, regulator, market system operator, transmission system operator, private sector,
- drafting policy-maker-friendly reports that draws conclusions from complex analyses.

Consultant's team members should have the following minimum key expertise:

- Team Leader, with at least 20 years of professional experience in
    - Leading/supporting large projects with large data inputs, where multiple stakeholders with different views are involved and where the final goal is to create an impact on policy-making
    - Modelling and analysis of power systems
    - Proven record in drafting policy-maker-friendly reports from complex datasets and analytical findings
    - Fluency in both Turkish and English
- At least two technology experts, with a minimum of 10 years of professional experience in
    - Knowledge of power system transformation technology, strategy, policy and approaches
    - Proven skills in power system modeling and model development
    - Fluency in both Turkish and English
- One or more technology expert(s), with preferably 5 years of professional experience in
    - Data collection and optimization skills on power system characteristics, technologies, policies
    - Good knowledge of English and preferably Turkish

The consultants' qualifications should be demonstrated by solid experience and previous work and the proposal that will be submitted as part of the offer for the consultancy. The proposal to be submitted should clearly state and elaborate the methodology and types of background data to be used in the study and include information regarding the qualifications stated above.

5. Criteria for Evaluation of Proposals

If the submitted proposal contains all the documents specified in Sabancı University's tender offer and the requirements in this TOR, it will be evaluated according to the following criteria:

Criteria for Evaluation for SHURA's Study "Impact of Locational Marginal Pricing on Power System for Accelerating Renewable Energy Integration"		
Technical Bid-70 points		
Criteria	**Minimum Requirement**	**Scoring**
Understanding of the TOR	Proposal displays a good understanding of the TOR	10
Scope of Work	Scope of work fulfills all requirements of the TOR	10
Methodology and Its Strength	Methodology for each task is presented in detail. The methodology proposed is sound and well-suited to the tasks identified.	10
Final Deliverables	Final deliverables are in line with the TOR.	10
Time Line	Time line is in line with the TOR	10
Team Composition	Proposed team is in line with the qualifications stated in the ToR.	10
Previous Work References	The proposal includes references displaying the consultant's expereince in line with the qualifications stated in the ToR	10
Financial Bid-30 points		
Criteria	**Minimum Requirement**	**Scoring**
Financial Bid	The offered price meets the entire service requested in TOR	30
Final Weighted Score (70% Technical/30 % Financial)		**to be calculated**
Minimum Qualification Threshold		**70**