Terms of Reference for
Preparation of Transmission Network Development and Renewable Energy Integration Plan for JSC "Uzbekistan National Power Networks"

A. Background

1. **Country background.** Uzbekistan ranks among the top 10–30 countries with the largest energy and mineral resources, including natural gas, gold, copper, uranium, and coal. The country has also significant potential in renewable energy sources, such as solar, wind, and hydro that can cater to the country's growing energy needs and help the transition to a clean energy economy. Given its strategic location—neighboring with all Central Asian countries and adjacent to some of the largest and fastest-growing economies in the world, including China, India, Russia, and Pakistan—Uzbekistan presents an opportunity to become a crossroads for energy exchange in the Central Asia region.

2. Beginning in 2017, the Government has embarked on a series of ambitious structural reforms that seek to transition from a relatively closed command economy to a market-oriented one. In February of 2017 the Government approved a five-year Development Strategy for 2017-2021. At the core of the Strategy is a broad market-oriented reform policy. The Strategy is guided by an annual state program that is approved every year. The Strategy covers five priority areas: (i) enhancing the state and public institutions; (ii) securing the rule of law and reform of the judicial system; (iii) promoting economic development and liberalization; (iv) fostering the development of the social sphere; and (v) promoting security, inter-ethnic and religious tolerance, and constructive foreign policy.

3. **Energy sector context.** The energy sector is a major contributor to the country's GDP (it accounted for about 20 percent of the total production output and 6 percent of GDP in 2017), one of the large revenue generators (energy exports—predominantly natural gas—accounted for 21 percent of total commodity exports in 2017), a major supporter of capital investments (close to 50 percent of total capital investments in 2016), and among the largest job providers (the sector employs about 170,000 people).

4. In the energy sector, the power system is characterized by its high dependence on natural gas, which, while a major source of commodity exports, is depleting rapidly, thereby prompting the country to seek sustainable energy transition pathways. Natural gas accounts for 86 percent of the total primary energy supply. Electricity generation is also predominantly based on natural gas, with more than 80 percent of the total installed capacity of 12,5GW in Uzbekistan being natural gas-based, followed by hydropower (above 10 percent), and coal (5 percent). The electricity sector is also characterized by rapidly aging energy supply infrastructure, which was largely constructed during Soviet times. On average, the transmission and distribution lines are approximately 30 years old. Electricity losses in Uzbekistan are relatively high, estimated at around 20 percent of net generation. Removing infrastructure bottlenecks constitutes a key element for creating jobs and increasing economic productivity.

5. The electricity sector was managed mainly by the vertically integrated Uzbekenergo (UE) (see Paragraph 7 for the recent UE unbundling). The majority of the generation, transmission, and distribution assets were owned and operated by subsidiaries of UE. Electricity was generated by seven thermal power plants and three combined heat and power plants. Unitary enterprise Energosotish was the single buyer and supplier of electricity in the country. Uzelectroset was the system operator providing dispatch, transmission, and network services, and included seven regional high-voltage (HV) transmission network affiliate operators. Electricity was distributed to end-users by 14 regional electricity distribution companies.

6. **Recent sector reforms.** The Government recognizes that reliable electricity supply is necessary for sustainable economic growth and development. Therefore, the Government is moving ahead with ambitious reforms that seek to introduce competitive market principles in sector management and operations. Several recently undertaken critical reviews have identified the following key objectives for sector reform: (i) improving service delivery and reliability; (ii) leveraging private investment financing in energy generation and distribution; (iii) enhancing the financial viability of the sector; (iv) improving transparency and accountability of sector entities; and (v) unbundling sector SOEs as an initial step towards the adoption of market-based model for the energy sector in the future.

7. With the support of the World Bank (WB), the Government has been undertaking major reforms in the power sector. Sector oversight functions have been consolidated under the Ministry of Energy (MoE) that was established in February 2019. A subsequent decision was made in March 2019 to unbundle UE into separate Generation ("Thermal Power Plants" JSC), Transmission ("National Power Networks of Uzbekistan" JSC / NES), and Distribution ("Regional Distribution Network" JSC) companies.

8. **The role of transmission company (National Power Networks of Uzbekistan, JSC / NES).** According to the Resolution of the President dated March 27, 2019 No.RP-4249, the transmission company is entrusted with the following key functions:

- transmission system operation and development;
- transmission of electricity within the country;
- regional connectivity and electricity trade (export and import);
- dispatch management of the power system;
- single Purchaser of electricity from generation companies, including independent power producers, as well as the sale of electricity to distribution companies.

B. Preparation of Transmission Investment and Renewable Energy Integration Plan

9. The Government has also approved a development program for the electricity sector for the period of 2019-2030 that builds on a Least Cost Electricity Generation Expansion Plan (LCP) and a Power Sector Master Plan 2019 prepared with support provided by the World Bank and the Asian Development Bank (ADB) respectively. The LCP and Master Plan have been performed with multiple scenarios of power system development including base, low and high demand

forecasts, generation rehabilitation and retirements scenarios, domestic and export price for natural gas, and renewable energy penetration scenarios. As such, the Government development program for the electricity sector calls for installed capacities at 5000 MW for Solar and 3000 MW for Wind by 2030. The JSC "National Power Networks of Uzbekistan" (NES) has also developed an indicative list of priority investments required for the period 2020-2025 for modernization and upgrade of aging transmission substations and reinforcement of capacity of the transmission system.

10. The Government development program as well as the LCP and Master Plan give, in particular for renewable power projects, only type, size, and year of commissioning of the new power plants under different planning scenarios without their site-specific locations. Such results present uncertainties for transmission system planning because of many uncertainties related to different possible locations for the renewable projects and their impact on the transmission network. Furthermore, the intermittent characteristic of renewable energy generation will increase the uncertainties to the transmission expansion planning, generation scheduling and system balancing which functions the newly created NES is responsible for.

11. NES has received financing from the World Bank and is seeking services of a consulting firm ("the Consultant") for this transmission planning and renewable integration analysis assignment to support the newly established company develop a transmission investment plan and renewable energy integration plan over the period of 2020-2030.

C. Objective of Work

12. The objective of this assignment is to conduct transmission network analyses and prepare the country's 10-year transmission network development plan to sustain growth in electricity demand and investments in power generation, both conventional and renewable energy. The assignment is also aimed to analyze potential issues on the power system due to increasing renewable integration and then identify measures to address those issues.

D. Scope of Work

13. The development of the 10-year transmission network development plan will encompass results and findings of multiple and interconnected type of analyses that will be carried out by the Consultant including:

- Transmission network analyses that aim to define transmission investment criteria and uniform methodology and network analyses (Load Flow, Short Circuit and Stability Analysis) for identification and prioritization of candidate projects for transmission network reinforcements and expansion over the period 2020-2030 and which will be necessary to maintain security and quality of electricity supply and reliability of the transmission networks in Uzbekistan;
- Renewable energy network and interconnection analyses (Load Flow, Short Circuit and Stability Analysis) that aim to define transmission capacity allocation criteria, methodology, and upgrades required for connecting renewable energy projects (solar and wind) to various locations (transmission substations) of the transmission grid taking into

consideration government plans for development of renewable energy resources over 2020-2030; and

- Renewable energy system dispatch and balancing analyses to assess technical and economic impacts, and mitigation measures, of renewable energy integration on the operation of Uzbekistan power system, with particular focus on the flexibility, balancing, reserve, and regulations.

14. **Task 1: Data collection and development of power system models for 2020, 2025, and 2030.**

15. The Consultant shall start with the data collection in order to develop the transmission network models for the year 2020, 2025, and 2030. Peak and off-peak cases will be developed for the specified years. Neighboring power systems will be also incorporated in the models as much as in detail. For the data collection, a questionnaire for the required input data for modelling and calculation (including data about shunts, phase shifting transformers, etc.) will be prepared and shared with NES. The collected data shall be verified by the Consultant. Network model data and single-line diagrams in agreed format will be prepared by the Consultant and delivered after the end of the study.

16. Reasonable assumptions on load and supply will be developed. The Consultant shall develop reasonable base and sensitivity case scenarios on load growth, load distribution among nodes, conventional generation developments, renewable energy development, cross-border interconnections etc. The following government's concept and precedent studies among others shall be analysed and incorporated where appropriate:

- Concept for provision of power supply for the Republic of Uzbekistan for 2020-2030;
- World Bank's Least Cost Generation Expansion Plan;
- World Bank's Renewable Site Screening Exercise;
- ADB's Power Sector Master Plan 2019;
- ADB's Regional VRE Integration Analysis.

17. The planned studies should also be coordinated with the USAID program in region "Energy of the Future", which aims to build the knowledge potential of Central Asian countries for the subsequent cost-effective, reliable and sustainable integration of renewable energy sources in the energy system and the Central Asia Regional Electricity Market (CAREM) project, one of the tasks of which is to assess the current state of national electricity transmission systems and provide recommendations on their development, rehabilitation and modernization.

18. The data collection and development of power system models for 2020, 2025, and 2030 shall be based on the DigSilent software format.

19. **Task 2: Transmission Network Analyses.** This Task aims to identify and assess candidate transmission projects, including smart grid technologies, for transmission network reinforcements and expansion required for the period 2020-2030. The Task will also define transmission investment criteria and uniform methodology for transmission project prioritization to sustain growth in electricity demand, investments in power generation and regional electricity interconnection. The identified candidate projects have to be evaluated by using predefined

investment criteria and prioritization methodology developed by the Consultant at the inception stage and agreed with NES. Nevertheless, such technical criteria for transmission system planning could include:

- Security (n-1) criterion;
- Voltage and reactive power criterion;
- Short-circuit criterion; and
- Stability criterion.

20. Further economic criteria should also be considered by the Consultant in evaluating potential transmission projects and prioritization to include the following, in particular, benefits and costs:

- benefit due to reduction of expected annual undelivered electricity costs;
- benefit due to improved supply reliability;
- benefit due to annual losses reduction;
- benefit due to reduction of annual re-dispatching costs;
- benefit due to annual congestion costs reduction.
- investment costs;
- operation and maintenance costs; and
- Renewable energy integration requirements as developed under Task 3.

21. Typical transmission network analyses which will be carried out under this task shall include:

- Load flow analyses shall identify voltage violations and overloads for the analyzed buses and lines under both normal operation conditions and contingency situations. If violations/overloads are identified, potential measures shall be analyzed. Those measures could include transformer upgrade, new transmission line, new substation, reactive power compensation etc. Reliability aspects shall be taken into consideration in identification of measures such as the number of transformers and overhead line circuits. Conditions and ages of existing equipment shall be also considered.
- Short circuit current analyses taking into consideration short circuit current capacities of existing and planned circuit breakers. Necessary reinforcements and upgrades shall be identified based on short circuit analyses.
- Dynamic analyses shall examine immediate fault conditions and inspect the critical fault clearing time (CFCT). Both active and reactive power responses shall be analyzed to ensure frequency and voltage stabilities. Any measures to mitigate harmful impacts shall be analyzed and identified.

22. **Task 3: Renewable Energy Network and Interconnection Analyses**. This task will aim to identify transmission investments and connection plan for renewable energy integration to the transmission network. The task will develop a methodology utilizing power system models and transmission network analyses (defined under Task 1 and Task 2) to assess impact on the Uzbekistan Power System of renewable energy (solar and wind) projects (up to 5000 MW of

solar and 3000 MW of wind) planned for development by the Government over the period 2020-2030 and to allocate transmission capacity to facilitate their interconnection to the grid. While locations for solar and wind projects to be developed in the short term have been identified, however locations for renewable projects to be developed in the medium term to meet government renewable energy objective for 2030 are not certain and will be defined with progress made in scaling up renewable energy development toward 2030 renewable energy objectives. Therefore, the Consultant will start this task with data collection related to renewable energy resources (solar and wind) potentials in Uzbekistan and develop maps for indicative favorable areas for development of renewable energy projects for the period of 2020-2030 taking also into account any existing sites that have been identified for development of solar and wind power projects.

The consultant will conduct analyzes of the power transmission network to assess the impact on the transmission network of renewable energy development planned for the period 2020-2030, and will also identify feasible transmission network and appropriate energy nodes in areas favorable for the development of renewable energy (in order to avoid additional loading of controlled sections of power transmission lines of the power system, overloading of transformers of system substations of 500 and 220 kV, eliminating possible damage to renewable energy objects during emergency operation, emphasize proposals for connecting renewable energy objects to distribution networks (110 kV and below), i.e. to outdoor switchgear-110 kV system substations or distribution substations).

The consultant will also identify transmission network reinforcement and expansion projects to strengthen and expand power transmission network facilities (lines and transformer capacities) that will be required to prepare in advance to facilitate the connection to the network of renewable energy projects, the implementation of which is scheduled by 2025, as well as over the period until 2030.

23. Based on the results of the above analyzes, the Consultant, in coordination with the NES, will determine the impact of the connecting renewable energy sources on the limits of the transmission line capacity for each of the specific power transmission nodes, which can be affected by projects for connecting renewable energy sources.

24. **Task 4: Renewable Energy Integration Impact on Power System Regulation, Balancing, and Reserves**. This task will aim to analyze technical and economic impacts of the variability of renewable energy integration into Uzbekistan power system over the period of 2020-2030, with particular focus on the flexibility, ramping, balancing, reserve, and regulations of the power system. The Consultant will start this task with developing an hourly dispatch model (using industry modeling software to be agreed with NES) for the Uzbek power system based on the information collected by the Consultant related to power system historical hourly dispatch and analyzing expected renewable energy generation variable patterns (solar and wind) for Uzbekistan.

25. On the basis of analyzed renewable energy generation patterns expected for Uzbekistan, and power system reliability, balancing, regulations and reserve requirements and best practices defined by relevant national technical norms and procedures, the Consultant will carry out hourly economic dispatch simulation to analyze impact of renewable energy planned for development over 2020-2030 on the power system including analysis to system balancing and ramping requirements during daily peak and off peak periods . The analysis shall include:

- Impact on wholesale prices and implications for consumers (tariff increases);
- Impact on electricity producers from traditional energy sources, including the amount of costs for generating electricity, utilization rate, number of starts / shutdowns;
- Requirements for ramps and their availability;
- Factors to limit the minimum load, as well as the technical and economic impact of the insufficient capacity of power plants from traditional energy sources;
- Power system capacity for hourly regulation of power deviations;
- Requirements for reserves and their availability;
- Assessment of the need for maneuvering capacities and operational power reserves to regulate the adverse effects associated with growing imbalances from variable RES and forecast errors;
- Curtailment of intermittent generation from renewable energy sources.

26. The hourly dispatch simulations should answer the following key questions:

- What is the impact on required all types of system reserves? Is there a need for additional reserve to ensure the flexibility and reliability of the power system? In case of the latter, what is the required additional reserve in terms of capacity, recommended technology, etc.?
- What is the impact of the ancillary system costs?
- Whether the system meets ramp requirements for daily peak and off-peak and what are constraints and measures?
- Power system flexibility and ramp constraints considering also gas supply constraints (infrastructure and resources availability)[1]

27. Detailed analysis of power system behavior of Uzbekistan including the forecast of area control error fluctuation and ranges for different renewable energy integration scenarios will be determined on the basis of: historic hourly deviation patterns of Uzbekistan (Area Control Error (ACE) and requested/activated secondary and tertiary balancing reserve), variable renewable energy generation patterns for Uzbekistan, and renewable forecast errors. On the basis of forecasted imbalance patterns, requirements and best practices defined by relevant national technical norms and procedures (System Operation Guidelines, Synchronous Area Operational Agreement on Load Frequency Control and Reserves), the sizing of required balancing reserve needs in both upward and downward direction will be done, as well as detailed breakdown to

[1] The power system has already experienced gas transmission pressure constraints during peak consumption and cold temperature periods that lead to reduced output of power stations (typically at peak demand which Uzbekenergo estimated to account for 3 TWh of unserved energy in 2017/2018). The gas constraints could be identified in the Task 3 as a key barrier to increase VRE integration level. A high-level gas pressure analysis has been conducted in the ADB's Uzbekistan Power Sector Master Plan. A detailed analysis based on a gas network model will be carried out separately to fully identify the constraints within the system and hence determine potential debottlenecking measures required to reduce or eliminate current problem areas.

secondary and fast tertiary reserves. For calculated required reserve levels in Uzbekistan under different regimes (with/without regional cooperation), cost of additional and ancillary services and balancing will be quantified.

28. Based on above simulations the Consultant will identify various potential solutions and measures (if any) to improve renewable energy integration to the level envisaged by the Government for the period of 2020-230 while maintaining required power system reliability, balancing, regulations and reserve. Such measures could include:

- Flexible generation sources;
- Measure to improve gas constraints;
- Cross border interconnections;
- Regional market integration;
- Balancing cooperation with neighboring countries;
- Energy storage;
- Advanced VRE forecasting;
- Regulatory measures;
- Market design solutions;

29. The identified potential measures will be tested in the hourly dispatch simulation models. The energy storage option shall be extensively analyzed, including consideration of the Government plan to scale up RE by 8000 MW by 2030. Then high-level cost-benefit analysis for each measure will be carried out, based on which Professional recommendations will be produced.

30. **Task 5: Preparation of a 10-Year Transmission Network Development and Renewable Energy Integration Plan.** Based on analyses and results of above tasks, the Consultant will prepare a 10-Year Transmission Network Development and Renewable Energy Integration Plan (2020-2030) for NES. For each of the identified transmission projects and renewable energy interconnection schemes included in the Plan, the Consultant shall provide detailed description, concept, and high-level cost benefit analyses. To prepare the 10-Year Network Development Plan, it is necessary to analyze existing substation equipment and transmission lines based on those conditions and ages in order to identify the need for rehabilitation and upgrade of those elements in conjunction with the expansion and reinforcement needs identified in the modeling analysis. The Plan shall include proposed investments for the existing elements.

31. **Task 6: Develop Policies and Procedures for NES Transmission and Investments Planning Departments**: The Consultant shall develop policies and procedures which will be followed by NES transmission planning and investment departments in order to carry out the entire process of transmission expansion and investment planning functions. The Consultant shall also identify required resources, systems, software and staffing skills that NES needs to have to carry its transmission expansion and investment planning functions.

32. **Task 7: Capacity Building and Knowledge Transfer.** The Consultant shall carry out the assignment in a manner to facilitate transferring knowledge and expertise to NES, in order to develop its capacity to continue following this assignment in undertaking its responsibility for

transmission planning analyses. The assignment shall be designed and carried out in a way that builds in ample time for discussions, including data gathering and consolidation, through regular calls, video-conferences and meetings in Tashkent with NES and relevant stakeholders. The developed transmission network model in the DigSilent (modeling software to be agreed with NES) format and the hourly dispatch models shall be transferred to NES. During the assignment, the Consultant shall maximize the transfer of knowledge and training of staff of NES on models and software simulation developed under the assignment for transmission system planning and renewable energy integration including organizing in Tashkent the following three workshops:

- Workshop 1: Four-day Workshop Transmission System Planning;
- Workshop 2: Four-day Workshop Renewable Energy Integration;
- Workshop 3: A three-day workshop on the final results of the assignment and recommendations.

E. Deliverables

33. The expected duration of this assignment is 12 months.

34. The Consultant should submit the assignment's deliverables as follows

- An Inception Report one month after the Contract signing;
- Presentation slides based on the initial result of the analysis and present the findings (Workshops 1 and 2) to the counterparts no later than six months after the Contract signing;
- Draft Final Report no later than eight months after Contract signing;
- Workshop 3 no later than ten months after the Contract signing;
- Final Report one month after receiving comments to the Draft Final Report.

35. All reports shall be delivered in both English and Russian languages. The Consultant will be responsible for arrangement of translation of the assignment's deliverables into Russian as well as translations of any data/information provided from NES into English.

36. The Consultant should transfer consolidated data and simulations models and scenarios to NES.

F. Working Arrangements and Data Collection

37. A Special Committee will be established by NES for this assignment. The Committee will facilitate the Consultant access to required data and information, manage any delay that may arise in the Consultant obtaining adequate data in time, and provide copy of the draft reports prepared by the Consultant for the Uzbekistan counterparts to comment on within 15 working days. NES will have final responsibility of approving the Final Report.

38. The Consultant is encouraged to carry out as much work as possible in Uzbekistan. NES will provide the Consultant with adequate office space at its headquarters to undertake work while the Consultant team is in Uzbekistan. Hotel and other accommodation including travel, transport and private expenses are to be at the Consultant's cost.

39. The Consultant is expected to collect all the necessary data to complete the assignment. The Consultant can benefit from an existing load flow model developed for the Uzbekistan power system using DigSilent which could be available at NES, and CDC Energia. The Consultant may need to enter in agreement with local design institute(s) to obtain data required for developing the power system models.Consultant can also benefit from the information and reports available at NES, including reports prepared by other Consultants and by development agencies such as the World Bank and the Asian Development Bank. Such reports include:

- World Bank's Least Cost Generation Expansion Plan;
- World Bank's Renewable Site Screening Exercise;
- ADB's Master Plan;
- ADB's Regional VRE Integration Analysis.

G. Qualifications and Team Composition Requirements

40. The selected Consultant will be a qualified firm or Joint Venture of firms that have demonstrated significant experience and knowledge in transmission network planning and renewable energy grid integration studies. The Consultant should have experience in, at least, three similar studies to this assignment in other countries.

41. The Consultant will propose a team capable of carrying out all aspects of this Terms of Reference with hands-on experience and actual program implementation including a team of key experts of, but not limited to, the following:

- Transmission System Planning and Network Analysis Expert;
- Renewable Energy Grid Integration Expert;
- Power System Operation Expert;
- Electricity Economist.

42. The Consultant should staff its team adequately to carry out activities under all Tasks in parallel and within the stipulated time frame. Other team members may include key or non-key experts that may be deemed necessary by the Consultant for the implementation of the Contract. The consultant should include in its team local staff and/or partner with local firm(s), with knowledge and data on the Uzbekistan power system to facilitate data collection, system modeling and knowledge transfer. The Consultant shall appoint one of the above key experts as Project Manager.