# Republic of Kazakhstan




## TECHNOLOGY NEEDS ASSESSMENT FOR CLIMATE CHANGE MITIGATION

## REPORT II

## BARRIER ANALYSIS AND ENABLING FRAMEWORK (BAEF)

**July 2026**

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## Abbreviations and Acronyms

| | |
|---|---|
| **AD** | Anaerobic Digestion |
| **AIIB** | Asian Infrastructure Investment Bank |
| **BAEF** | Barrier Analysis and Enabling Framework |
| **BESS** | Battery Energy Storage System |
| **BNS** | Bureau of National Statistics |
| **BTR** | Biennial Transparency Reports |
| **CAPEX** | Capital Expenditure |
| **CHP** | Combined Heat and Power |
| **CO2** | Carbon dioxide |
| **CO2-eq** | Carbon dioxide equivalent |
| **DBK** | Development Bank of Kazakhstan |
| **EBRD** | European Bank for Reconstruction and Development |
| **EPC** | Engineering, Procurement, and Construction |
| **EPR** | Extended Producer Responsibility |
| **ESIA** | Environmental and Social Impact Assessment |
| **FiT** | Feed-in Tariff |
| **GHG** | Greenhouse Gases |
| **GPS** | Global Positioning System |
| **IDF** | Industrial Development Fund |
| **IFI** | International Financial Institutions |
| **IoT** | Internet of Things |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IPP** | Independent Power Producer |
| **JSC** | Joint-Stock Company |
| **KEGOC** | Kazakhstan Electricity Grid Operating Company |
| **KG** | Capital Goods |
| **KOREM** | Kazakhstan Operator of Electric Power and Energy Market |
| **kt** | Kiloton ($10^3$ metric tons) |
| **LCOE** | Levelized Cost of Electricity |
| **LFG** | Landfill Gas |
| **LFGtE** | Landfill Gas to Electricity |
| **M** | Mega or million |
| **MCA** | Multi-Criteria Analysis |
| **MENR** | Ministry of Ecology and Natural Resources of Kazakhstan |
| **MRF** | Material Recovery Facility |
| **MSW** | Municipal Solid Waste |
| **MW** | Megawatt |

| | |
|---|---|
| **NDC** | Nationally Determined Contribution |
| **NDE** | National Designated Entity |
| **O&M** | Operations and Maintenance |
| **OPEX** | Operational Expenditure |
| **PAYT** | Pay-As-You-Throw |
| **PPA** | Power Purchase Agreement |
| **PPG** | Publicly Provided Good |
| **PPP** | Public-Private Partnership |
| **PV** | Photovoltaic |
| **R&D** | Research and Development |
| **REC** | Renewable Energy Certificate |
| **ROI** | Return on Investment |
| **SCADA** | Supervisory Control and Data Acquisition |
| **SHP** | Small Hydropower |
| **SME** | Small and Medium Enterprise |
| **t** | metric ton ($10^3$ kilograms) |
| **TAP** | Technology Action Plan |
| **TFS** | Technology Factsheet(s) |
| **TNA** | Technology Needs Assessment |
| **UDP** | UNEP DTU Partnership (formerly URC) |
| **UNDP** | United Nations Development Program |
| **UNEP** | United Nations Environment Program |
| **UNEP-CCC** | UNEP Copenhagen Climate Centre (formerly the UNEP DTU Partnership) |
| **UNFCCC** | United Nations Framework Convention for Climate Change |
| **URC** | UNEP Risø Centre |
| **VGF** | Viability Gap Funding |
| **$** | US Dollar, USD (Currency) |
| **€** | Euro (Currency) |

## Executive Summary

This report presents the Barrier Analysis and Enabling Framework (BAEF) study conducted for the Republic of Kazakhstan's climate change mitigation strategies within the Energy Sector (**Chapter 1**) and the Urban/Circular Economy Sector (**Chapter 2**). The methodology follows the participatory multi-criteria framework outlined in the Technology Needs Assessment (TNA) Step-by-Step Guidebook and the BAEF Guidebook. High-level stakeholders and technical experts evaluated long-listed constraints and enabling options using an online questionnaire, transforming qualitative expert insights to establish a clear pipeline for the final Technology Action Plan (TAP).

The first chapter outlines the climate ambitions, critical diffusion barriers, and strategic programs developed for three prioritized large-scale renewable energy technologies designed to support Kazakhstan's carbon neutrality commitments:

- **Large-Scale On-Grid Solar Farms (0.1–1 GW):** Sited to capitalize on high global tilted irradiation in the southern steppes, the specific deployment target is a 500 MW utility-scale solar PV facility in southern Kazakhstan by 2030, capitalizing on the region's high solar irradiation (1,300–1,800 kWh/m²/year). Stakeholders identified *outdated grid infrastructure and insufficient transmission capacity* as the primary "Killer" barrier (scoring highest at 5 votes), along with *high capital costs* and *intermittent generation risks*. To remove these bottlenecks, the report outlines an enabling package grouping blended public-private financing ($500M–$2B), tariff value optimization via competitive auctions, and heavy grid modernization ($3B–$8B) to safely absorb variable solar energy.
- **Large-Scale On-Grid Wind Farms (0.1–1 GW):** To exploit the high, persistent wind yields across the northern and central steppe regions, the deployment target aims to facilitate 2–4 GW of cumulative new wind capacity by 2035. Mirroring the solar sub-sector, wind technology faces severe bottlenecks concerning high upfront deployment costs, lengthy permitting procedures, remote location grid-interconnection charges, and operational system balancing issues. The corresponding enabling program focuses on establishing stable long-term Power Purchase Agreements (PPAs), deploying utility-scale Battery Energy Storage Systems (BESS) ($0.5B–$3B) to manage grid frequency, and introducing simplified "one-stop-shop" permitting authorities.
- **Small Hydropower Plants (<10 MW):** Targeted for the ecologically vital river networks of southern and north-eastern Kazakhstan, the deployment target focuses on adding small-scale run-of-river installations up to 500 MW by 2035. Diffusion is primarily constrained by high initial construction expenditures, slow investment returns due to suppressed energy prices, technical vulnerabilities during severe freezing cycles, and fragmented water-energy inter-agency coordination. The recommended measures group low-interest concessional credit facilities, climate-resilient civil engineering codes, and centralized hydrological data sharing into a cohesive implementation pathway.

The second chapter addresses urban environmental infrastructure and greenhouse gas reduction by assessing three key urban/circular economy sector mitigation technologies designed to drive Kazakhstan toward circular and sustainable waste management:

- **Multi-Stream Waste Separation in Urban Areas:** To optimize the existing dual-stream model, the deployment target mandates scaling a 5-to-7 stream municipal source separation scheme

to reach 100% operational coverage across all residential, public, and commercial sectors in Astana, Almaty, and Shymkent by **2038**. Baseline multi-criteria analysis isolates secondary material market weakness, ingrained disposal habits, and high upfront CAPEX as the core "Killer" barriers. The enabling framework structures three interactive packages: Program 1 provides subsidized capital financing (€57.5M total CAPEX) through a 3% preferential loan scheme via "Zhasyl Damu" funded by EPR fees; Program 2 legalizes a unit-based "Pay-As-You-Throw" (PAYT) tariff framework indexed to inflation to guarantee utility OPEX self-sufficiency, backed by mandatory industrial recycled content standards; and Program 3 deploys neighborhood-level technical education to eliminate cross-contamination at the waste containers.

- **Anaerobic Digestion (AD) of Sewage Sludge:** Addressing the highest methane mitigation potential in the wastewater sector, the target establishes high-efficiency biogas capture and Combined Heat and Power (CHP) co-generation plants at the municipal wastewater treatment plants in Almaty City and Astana City by **2035**. The barrier screening shows that outdated/decrepit wastewater treatment infrastructure represents a complete non-starter, compounded by the absence of fertilizer market standards and grid injection obstacles. The enabling strategy consists of two complementary packages, linking subsidized capital asset renewal—financed through multilateral funds—with guaranteed feed-in tariffs for green electricity/heat, in order to successfully monetize gas recoveries.
- **Sanitary Landfills with Methane Recovery:** To replace polluting open dumps, the strategic target aims to Implement and fully scale engineered sanitary landfill infrastructure equipped with active methane collection and energy recovery systems in 21 Kazakh cities with populations over 100,000 with high methane recovery potential by **2032**, utilizing multi-layer impervious liners and active landfill gas (LFG) extraction piping networks. The primary bottlenecks are high CAPEX, artificially suppressed waste tariffs, and energy price competition against subsidized fossil fuels. The report establishes a Logistical Consolidation and Automated Enforcement Program that formally builds interconnected, inter-district sanitary disposal hubs to achieve scale economies, enforces automated GPS fleet tracking and IoT cell sensors via the National Waste Management Centre to halt illegal waste leakages, and significantly raises administrative fines for illegal dumping under the environmental legislation.

Across both chapters, the BAEF report identifies a clear structural pattern: climate technology diffusion in Kazakhstan is rarely hindered by hardware limitations, but rather by weaknesses in the underlying regulatory "orgware" and commercial "software" environments. High initial capital requirements are a universal sector barrier. To prevent project failure, the Technology Action Plans (TAPs) for both energy and urban/circular economy sector must avoid isolated infrastructure funding. Instead, they must systematically link upfront state capitalization with long-term, self-sustaining cost-recovery pricing models (such as variable PAYT utility structures and guaranteed green energy feed-in tariffs) to incentivize private sector participation and secure Kazakhstan's net-zero transition.

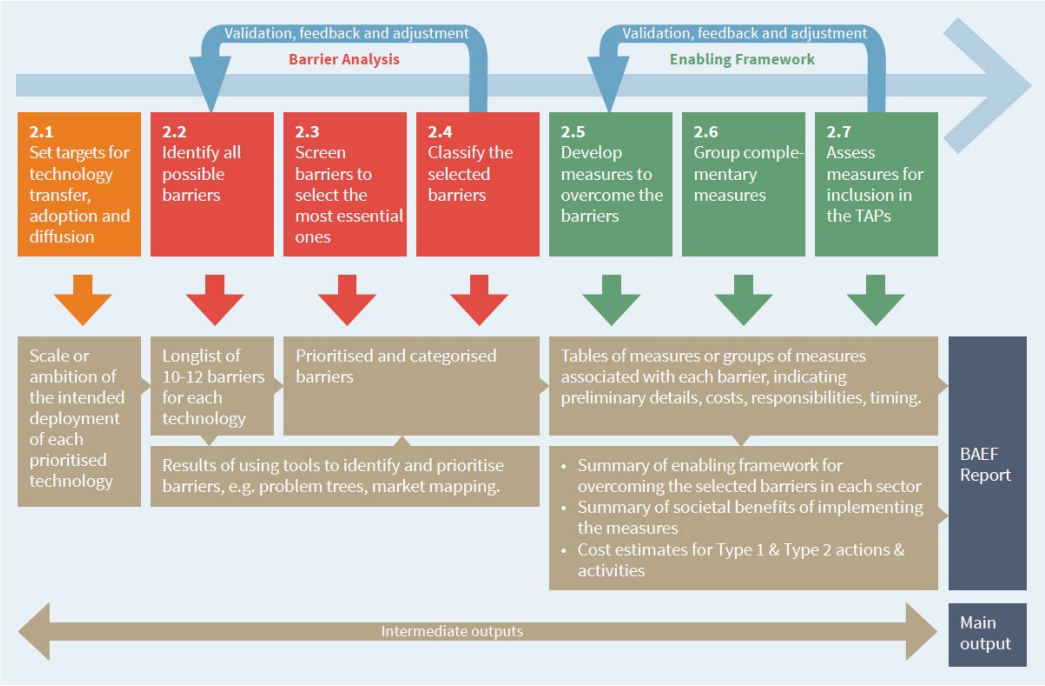
# Chapter 1 Barrier Analysis and Enabling Framework for Energy Sector

In the initial phase of the TNA project for the Republic of Kazakhstan, a structured multi-criteria decision-making framework was executed to systematically rank and prioritize climate change mitigation technologies within the energy sector. Initiated via a comprehensive desk review that identified an expanded baseline of candidate technologies. Through stakeholder consultation, these technologies were filtered to yield a refined long list of technologies compiled into detailed Technology Fact Sheets (TFS).

These long-listed technologies were subjected to a Multi-Criteria Analysis (MCA) based on criteria to evaluate financial costs, technology diffusion capacity, environmental, economic, and social benefits, climate change mitigation potential and compliance with national policies.

This chapter presents the second stage of TNA process named the Barrier Analysis and Enabling Framework (BAEF) study executed for these prioritized technologies. The assessment adhered to the analytical framework outlined in the TNA Guidebook (UNEP-CCC, 2024) and incorporated the specialized methodologies detailed in the BAEF Guidebook (UDP, 2015), utilizing logical problem analysis ("problem tree" and "solution tree") and "market mapping" tools to systematically diagnose barriers and formulate enabling frameworks **(Annex 1, Figures A1.1–A1.6).**

The workflow generally followed the standard BAEF sequence depicted in **Figure 1.1** (UNEP-CCC, 2024).




## 1.1 Large scale on-grid solar farms (0.1-1 GW)

### 1.1.1 General description and target for large scale on-grid solar farms (0.1-1 GW)

Utility-scale on-grid solar farms are large photovoltaic (PV) power plants — from ~100 MW to 1,000 MW — built to supply electricity directly into the transmission grid. They use fields of fixed-tilt and/or

single-axis tracking PV modules, ground-mount racking, inverters, step-up substations and medium-/high-voltage transmission lines. Modern large plants favor high-efficiency crystalline silicon modules, centralized or string inverters, automated cleaning and monitoring systems, and increasingly integrate battery energy storage systems (BESS) to firm output and provide ancillary services.

A typical 100 MW plant covers tens to a few hundred hectares, generates electricity during daylight hours (peaking at midday) and is sized with a DC:AC ratio (nameplate module DC relative to inverter AC) optimized for local irradiance and grid rules. Developers design the plant around resource data (irradiance, soiling, snow), grid connection capability, land availability and offtake arrangements (power purchase agreements or merchant sales). Construction timelines for utility projects are short relative to thermal plants — often 6–18 months for a 0.1 GW project — and the bulk of cost is module + BOS (balance of system), land preparation, civil works and grid interconnection.

Operationally, utility PV offers predictable hourly profiles, low marginal cost (near zero fuel cost), and low staffing needs (O&M largely remote monitoring plus periodic preventative maintenance). Integration into grids with high fossil generation requires planning for variability: grid codes, dispatchable reserve, and often storage or flexible generation to maintain reliability.

Solar resource: Kazakhstan has good solar resources — annual global tilted irradiation in southern regions ranges roughly 1,300–1,800 kWh/m²/yr (southern regions higher; average GHI (Global Horizontal Irradiance) ~3.8–4.6 kWh/m²/day in many areas). This is attractive for utility PV.

Land & siting: Large sparsely populated areas, steppe and semi-desert in the south offer abundant land with low competing uses. Solargis/Global Solar Atlas confirms high-insolation zones suitable for large farms.

Grid & market: Kazakhstan's grid is dominated by coal and large thermal generation; integrating large PV requires transmission upgrades and flexibility mechanisms. Existing experience (Burnoye 50→100 MW and other 50–100 MW plants) demonstrates feasibility but also the need for planning at scale. (Agora Energiewende, ECOJER, 2023)

**Preliminary Deployment Target:** The preliminary deployment target is a 500 MW utility-scale, grid-connected solar photovoltaic (PV) power plant located in southern Kazakhstan by 2030, where annual global tilted irradiation ranges from 1,300–1,800 kWh/m²/year and average solar irradiation reaches approximately 4.5–5.0 kWh/m²/day. The facility is expected to occupy approximately 1,000–1,200 hectares of semi-arid land and will utilize around 1.2–1.3 million high-efficiency monocrystalline silicon PV modules rated at 550–600 W each. Single-axis tracking systems will be deployed to increase annual energy yield by 15–25% compared with fixed-tilt (Ministry of Energy of the Republic of Kazakhstan, 2022) installations. The plant will be connected to the national transmission grid through a 220–500 kV step-up substation and associated transmission infrastructure.

### 1.1.2 Identification of barriers for large scale on-grid solar farms (0.1-1 GW)

Under the BAEF Guidebook methodology (UDP, 2015), large-scale on-grid solar farms are classified as a Capital Goods (KG) technology because their deployment depends primarily on substantial investments in physical infrastructure, equipment procurement, and supporting grid facilities. Several barriers can hinder the large-scale diffusion of this technology.

The most significant barrier is the high upfront capital requirement associated with solar photovoltaic (PV) modules, inverters, transmission infrastructure, land acquisition, and grid interconnection facilities. Limited access to long-term, low-cost financing and perceived investment risks can further constrain project development. In addition, regulatory and policy uncertainties, such as inconsistent renewable energy policies, lengthy permitting procedures, and unclear power purchase agreement (PPA) frameworks, may discourage private-sector participation.

Technical and infrastructure barriers also exist. In many regions, transmission networks may lack sufficient capacity to integrate large amounts of variable solar generation, leading to grid congestion and curtailment risks. Furthermore, inadequate technical expertise in project design, operation, and maintenance can affect project performance and reliability. Land availability and environmental permitting requirements may create additional challenges, particularly for projects requiring large contiguous areas.

To address these barriers, several enabling measures can be implemented. Governments can establish stable and transparent renewable energy policies, including competitive procurement mechanisms, long-term PPAs, and clear grid-connection regulations. Financial barriers can be reduced through concessional loans, green bonds, investment guarantees, tax incentives, and public-private partnership arrangements. Investments in transmission infrastructure, grid modernization, and energy storage systems can enhance system flexibility and facilitate higher solar penetration. Capacity-building programs for utilities, regulators, and project developers can strengthen technical capabilities and improve project implementation. Streamlined permitting procedures and integrated land-use planning can further reduce project development timelines and transaction costs, thereby accelerating the deployment of large-scale on-grid solar farms. (UNEP-CCC, 2022; UNEP-CCC, 2024)

#### 1.1.2.1 Preliminary list of barriers

Preliminary list of barriers was developed by the national and regional consultants to be screened, discussed and prioritized by the working group (**Table 1.1**).

***Table 1.1*** *Identified Barriers to Large scale on-grid solar farms (0.1-1 GW)*

| Category | Specific Barrier | Description of the Barrier |
|---|---|---|
| **1. Economic & financial** | 1 High capital costs | Large-scale PV requires substantial upfront spending for land, modules, inverters, mounting structures, site preparation, substation equipment and grid reinforcements. Those capital needs create a high entry barrier: many local developers lack the balance-sheet capacity to carry multi-year development risks before revenue begins. Example: a 100 MW plant can require tens of millions of dollars before a single kilowatt-hour is generated. |
| | 2 Limited access to financing | Domestic banks and financial markets often lack low-cost, long-tenor project finance instruments tailored to renewables. Without established green lending products, developers face higher interest rates, shorter loan maturities, and onerous collateral requirements that inflate levelized cost of electricity (LCOE) or force projects to be equity-heavy. |
| | 3 Currency and macroeconomic risks | Solar equipment is mostly imported, so exchange rate volatility increases capex and operating cost uncertainty. Foreign investors demand currency-risk premiums or dollar-linked contracts, raising financing costs. Depreciation spikes can make an otherwise viable project unaffordable mid-construction. |

| | | |
|---|---|---|
| | 4 Dependence on state-backed auction tariffs | Many projects rely on government auctions or feed-in tariffs for revenue certainty. When auctions are the primary route to secure a long-term off-taker, projects that fall outside these mechanisms struggle to obtain bankable offtake agreements, making market-driven development difficult. |
| | 5 High costs of connection to the electrical grid | Prime solar sites are often remote, requiring long transmission lines, substations, or upgrades to existing lines. Developers frequently must front these costs or enter complex cost-sharing arrangements, which delays projects and increases upfront investment. |
| | 6 Competition with cheap fossil fuel generation | Kazakhstan's historically coal-based system keeps wholesale prices low, compressing margins for new renewables. When coal or gas plants set low market prices- often supported by state policies - solar projects find it harder to compete without subsidies or market reforms. |
| **2. Market conditions** | 7 Limited market competition in electricity sector | A partially monopolistic sector reduces the incentive for innovation, transparent pricing, and third-party access. Dominant state or incumbent utilities control dispatch and grid investment decisions, limiting opportunities for independent power producers (IPPs). |
| | 8 Insufficient demand incentives for "green" electricity | Corporate and retail demand for certified green power is still nascent. Few long-term PPAs for "green" electricity exist domestically, so developers cannot rely on premium green off-take or hedge production via corporate buyers. |
| | 9 Uncertain long-term market signals | Frequent regulatory changes, evolving auction designs, and shifting subsidy regimes produce policy risk. Investors require clear, predictable frameworks to commit capital for 20–25-year projects; uncertainty raises required returns or halts investment. |
| | 10 Geographic mismatch between generation and demand | The best solar irradiance is concentrated in southern regions, while major load centers (industry, population) are in northern and central areas. This spatial mismatch increases transmission needs, creates congestion, and may necessitate long, costly wheeling arrangements. |
| **3. Legal & regulatory** | 11 Regulatory uncertainty and frequent policy changes | Inconsistent laws, retroactive policy adjustments, or unclear timelines for reforms deter long-term investors. Predictable rules for auctions, tariffs, and grid access are essential to attract both domestic and foreign capital. |
| | 12 Insufficiently developed procedures for land allocation and land use | Lack of streamlined, transparent land permitting processes, unclear land-use classifications (agricultural vs. industrial), and slow interagency coordination create delays and add legal risk. Competing claims or protracted zoning negotiations can stop projects early. |
| | 13 Lack of clear rules for grid access and connection | If technical standards, queue management, connection costs and timelines are undefined or opaque, developers cannot plan reliably. Uncertain interconnection studies and last-minute grid charges increase project risk. |
| | 14 Local content requirements in auctions | While intended to build domestic industry, strict local content rules can raise costs by protecting higher-priced local suppliers or complicating procurement. They can also deter foreign bidders who cannot meet the clauses, reducing auction competitiveness. |
| **4. Human skills** | 15 Shortage of specialists in renewable energy | There are too few engineers, planners, and technicians experienced in utility-scale PV, battery integration, and long-term asset management. This skills gap raises reliance on expensive foreign contractors and increases risks. |

| | | |
|---|---|---|
| | 16 Lack of experience in large-scale project development | Local firms often lack GW-scale EPC and financing track records. Without a domestic pipeline of completed large projects, international investors and insurers may require additional guarantees or higher premiums. |
| | 17 Skills gap in grid management for renewables | System operators need training and tools for forecasting solar output, dispatching variable resources, and implementing advanced grid codes. Without that capacity, integrating high shares of PV risks grid instability and curtailment. |
| **5. Social and cultural** | 18 Ambiguous public perception of technology deployment processes | Large PV farms can provoke local opposition over land use, visual impact, or perceived loss of agricultural land if engagement is poor. Ambiguity about compensation, land acquisition, and environmental impacts increases social license risk. |
| | 19 Institutional resistances from traditional energy sector | Utilities and coal sector stakeholders may see renewables as a threat to their revenue streams. That resistance can slow permitting, delay grid upgrades, or influence policy to maintain incumbent advantages. |
| **6. Information** | 20 Lack of data on grid capacity | Developers need timely, accurate information on available connection points, existing loads, and contingency margins. When such data are proprietary or poorly maintained, project siting and financial modeling become speculative. |
| | 21 Limited data on solar resource and project performance | Sparse, localized irradiance measurements or limited historical project performance data increase uncertainty in yield estimates. Developers must therefore use conservative assumptions or fund expensive resource assessment campaigns. |
| **7. Technical** | 22 Outdated grid infrastructure, insufficient capacity | Aging transmission assets with high losses (reported up to ~15%) impose technical limits on the volume of new generation that can be accommodated and increase the cost of delivering power to load centers. |
| | 23 Grid capacity constraints and bottlenecks | Thermal limits, substation overloads, and constrained corridors create congestion that forces curtailment of solar generation or necessitates expensive grid upgrades before projects can operate. |
| | 24 Intermittent generation, need for balancing and dispatching of the power system | Solar's variability requires new system services: balancing, frequency control, reserve capacity, and fast ramping. Without market mechanisms or storage solutions to value these services, high PV penetration raises system operation costs and reliability concerns. |

### 1.1.3 Screening of barriers for large scale on-grid solar farms (0.1-1 GW)

For the screening step, the sectoral TNA working group firstly determined seven main barrier categories for the prioritized mitigation technologies in the energy sector: (1) economic & financial, (2) market conditions, (3) legal & regulatory, (4) human skills, (5) social & cultural, (6) information, and (7) technical. These categories consolidate the twelve most important barriers resulting from the expert assessment.

The prioritization exercise was implemented using Google Forms to ensure transparency, consistency, and ease of participation. The working group consisted of 12 active members (See Annex 3), each of whom was required to assess and prioritize the barriers independently.

To systematically filter and prioritize the comprehensive longlist of constraints and interventions, the energy sectoral working group conducted a participatory screening and scoring exercise via an online structured questionnaire. Stakeholders evaluated each barrier's relative severity on technology

diffusion using a five-tier qualitative hierarchy (Killer/Non-starter, Crucial, Important, less important, or Insignificant), while simultaneously assessing the aligned enabling measures using a three-tier priority scale (High, Medium, or Low). These qualitative judgements were subsequently translated into discrete numerical values, assigning number of votes for most popular tier.

More than 80% of members (10 feedbacks) of the working group completed the prioritization procedure. The individual scores were aggregated, and each barrier received a total number of evaluations reflecting the collective assessment of the group.

By summarizing the votes from the expert group, tiers were identified for each barrier based on the highest votes. The same was done for the measures. The results for the barrier longlist are presented in the rightmost column of **Table 1.2**. (UNEP-CCC, 2022b)

### 1.1.4 Classification of barriers for large scale on-grid solar farms (0.1-1 GW)

Specific barriers for large scale on-grid solar farms (0.1-1 GW) are represented in **Table 1.2** below:

***Table 1.2*** *Classification of Barriers to Large scale on-grid solar farms (0.1-1 GW)*

| Category | Specific Barrier | Description of the Barrier | **Score (votes)** |
|---|---|---|---|
| **1. Economic & financial** | High capital costs | Utility-scale solar requires massive initial investment (land, panels, grid connection), which creates entry barriers despite long-term returns | Important (7 votes) |
| | Limited access to financing | Domestic financial markets offer limited low-interest loans or project finance instruments for renewable energy | Important (4 votes) |
| | High costs of connection to the electrical grid | Developers often must finance transmission upgrades or long-distance connections due to remote locations | Important (6 votes) |
| **2. Market conditions** | Insufficient demand incentives for "green" electricity | Lack of PPAs (Power Purchase Agreements) for the green energy and undeveloped green energy market | Important (5 votes) |
| **3. Legal & regulatory** | Lack of clear rules for grid access and connection | Technical and legal requirements and rules for grid connection are underdeveloped | Less important (5 votes) |
| | Insufficiently developed procedures for land allocation and land use | Legal requirements and rules for land allocation and land use are underdeveloped | Important (5 votes) |
| **4. Human skills** | Shortage of specialists in renewable energy | Limited domestic expertise in utility-scale PV design and integration | Important (8 votes) |
| **5. Social and cultural** | Ambiguous public perception of technology deployment processes | Large solar farms may face opposition due to land use (especially agricultural land) | Less important (5 votes) |
| **6. Information** | Lack of data on grid capacity | Developers often cannot access reliable information about available connection points | Important (5 votes) |
| **7. Technical** | Outdated grid infrastructure, insufficient capacity | Transmission losses (up to ~15%) and outdated networks limit integration capacity | Killer (non-starter) (5 votes) |
| | Intermittent generation, need for balancing and dispatching of the power system | Solar variability creates balancing and frequency control issues in the grid | Crucial (5 votes) |

### 1.1.5 Measures for technology large scale on-grid solar farms (0.1-1 GW)

Specific measures for large scale on-grid solar farms (0.1-1 GW) are represented in **Table 1.3** below:

***Table 1.3*** *Suggested measures grouped with the Barriers to Large scale on-grid solar farms*

| Barrier and measure category | Barrier description | Possible measures | Score (votes) |
|---|---|---|---|
| Economic and financial | High capital costs<br><br>Limited access to financing<br><br>High costs of connection to the electrical grid | Blended public-private financing, development of risk mitigation mechanisms<br>• Introduce capital subsidies or viability gap funding (VGF) for utility-scale solar projects<br>• Provide tax incentives (VAT exemptions, accelerated depreciation) for solar equipment<br>• Enable public–private partnerships (PPPs) for large-scale solar parks<br>• Facilitate sovereign guarantees to reduce investor risk | High<br>(8 votes) |
| | | Strengthening banks' capacity to mobilize "green" loans, concessional financing<br>• Develop green financing instruments (green bonds, climate funds) via national banks<br>• Partner with international institutions like AIIB and Asian Development Bank<br>• Establish a state-backed renewable energy financing facility<br>• Offer interest rate subsidies or blended finance mechanisms<br>• Encourage local banks to build renewable project finance capacity | High<br>(6 votes) |
| Market conditions | Insufficient demand incentives for "green" electricity | Introduction of feed-in tariffs for solar electricity to ensure long-term project profitability and predictable revenue | Medium<br>(7 votes) |
| | | Financing the development of electrical grid infrastructure<br>• Introduce cost-sharing mechanisms between developers and grid operators<br>• Develop government-funded transmission corridors to renewable zones<br>• Implement standardized and transparent connection tariffs<br>• Establish solar energy zones with pre-built grid infrastructure<br>• Allow connection cost recovery through tariffs over time | High<br>(9 votes) |
| Legal and regulatory | Lack of clear rules for grid access and connection | Simplification of permitting procedures<br>• Develop clear grid codes and interconnection standards for renewables<br>• Implement transparent and time-bound permitting procedures | High<br>(8 votes) |

| | | | |
|---|---|---|---|
| | Insufficiently developed procedures for land allocation and land use | • Establish “one-stop-shop” permitting authorities | |
| | | Development of energy market rules in line with international practices<br>• Align regulations with international best practices (e.g., ISO, EU grid codes) | High<br>(6 votes) |
| Human skills | Shortage of specialists in renewable energy | Education and workforce development, sector-specific training<br>• Introduce university programs and certifications in solar engineering<br>• Partner with international firms for knowledge transfer and training<br>• Create vocational training centers for PV installation and O&M<br>• Provide government-funded scholarships in renewable energy fields<br>• Encourage local workforce requirements in solar projects | Medium<br>(8 votes) |
| Social and cultural | Ambiguous public perception of technology deployment processes | Public engagement in decision-making, ensuring local community support<br>• Conduct public consultations and community engagement programs<br>• Provide local economic benefits (jobs, revenue-sharing schemes)<br>• Run public awareness campaigns on renewable energy benefits | Medium<br>(7 votes) |
| | | Optimization of land use<br>• Promote use of non-arable or degraded land for solar farms<br>• Introduce agrivoltaics (dual-use agriculture + solar systems) | High<br>(5 votes) |
| Information | Lack of data on grid capacity | Digitalization and planning tools, ensuring access to data from the system operator and grid companies<br>• Develop publicly accessible grid capacity maps and databases<br>• Require grid operators to publish real-time hosting capacity data<br>• Implement digital platforms for connection applications and tracking<br>• Standardize data reporting formats across utilities<br>• Use GIS-based planning tools for renewable integration | Medium<br>(6 votes) |
| Technical | Outdated grid infrastructure, insufficient capacity<br><br>Intermittent generation, need for balancing and dispatching of the power system | Modernization of electrical grids to increase capacity<br>• Invest in grid modernization and rehabilitation programs<br>• Deploy smart grid technologies (automation, monitoring systems)<br>• Reduce transmission losses through high-efficiency equipment upgrades | High<br>(10 votes) |
| | | Increasing energy system flexibility through integration of energy storage | High<br>(9 votes) |

| | | | |
|---|---|---|---|
| | | • Deploy utility-scale battery energy storage systems (BESS)<br>• Implement advanced forecasting systems for solar output<br>• Develop ancillary service markets (frequency regulation, reserves)<br>• Upgrade grid control systems for real-time balancing<br>• Define priority dispatch rules for renewable energy | |

### 1.1.6 Grouping complementary measures and assessment of measures for inclusion in the TAP for large scale on-grid solar farms (0.1-1 GW)

Grouping complementary measures and assessment of measures for inclusion in the TAP for large scale on-grid solar farms (0.1-1 GW) are represented in **Table 1.4** below:

***Table 1.4*** *Summary Assessment Matrix for TAP Inclusion: Large scale on-grid solar farms*

| # | Measures | Priority | Why it is important? | Who should do it? | How should they do it? | Time scale | MRV by which organization | Estimated Costs in USD |
|---|---|---|---|---|---|---|---|---|
| | **Economic and financial** | | | | | | | |
| **1** | Blended public-private financing, development of risk mitigation mechanisms | High | Reduces upfront capital costs and perceived risks, which are the main barriers for utility-scale solar investments in emerging markets like Kazakhstan. | Ministry of Energy, Ministry of Finance, National development banks, Sovereign wealth fund (e.g., Samruk-Kazyna), IFIs (ADB, AIIB, World Bank) | • Establish a national renewable financing facility<br>• Provide VGF and guarantees for early projects<br>• Structure PPP frameworks for solar parks | Short–medium term (1–5 years) | Ministry of Energy + national audit bodies + IFIs | $500 million – $2 billion (depending on scale of subsidies and guarantees) |
| **2** | Strengthening banks' capacity to mobilize "green" loans, concessional financing | High | Ensures long-term capital availability and reduces reliance on public budgets. | National Bank of Kazakhstan, commercial banks, Ministry of Finance, international partners | • Issue sovereign green bonds<br>• Create co-financing platforms with IFIs<br>• Train local banks in project finance | Medium term (2–6 years) | National Bank + international partners | $50 million – $200 million (capacity + structuring; capital mobilized much larger) |
| | **Market conditions** | | | | | | | |
| **3** | Introduction of feed-in tariffs for solar electricity to ensure long-term project profitability | Medium | Predictable revenue streams are critical to attract IPPs and reduce cost of capital. | Ministry of Energy, market operator (KOREM), large industrial consumers | • Expand competitive auctions for EPC developers<br>• Standardize corporate PPAs<br>• Introduce REC markets and quotas | Short term (1–3 years) | Market operator + Ministry of Energy | Low direct cost (<$50 million), |
| **4** | Financing the development of electrical grid infrastructure | High | Grid access uncertainty is a major bottleneck for large-scale solar deployment. | Grid operator (KEGOC), Ministry of Energy | • Define transparent connection tariffs<br>• Develop renewable energy zones with | Medium term (3–7 years) | Energy regulator + KEGOC | $1–3 billion (grid infrastructure) |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | pre-built infrastructure<br>• Allow cost recovery via tariffs | | | |
| | **Legal and regulatory** | | | | | | | |
| **5** | Simplification of permitting procedures | High | Reduces project delays and administrative risks. | Government (Ministry of Energy, local authorities) | • Create centralized permitting authority<br>• Digitize approval processes<br>• Set statutory timelines | Short term (1–2 years) | Government oversight bodies | $10–30 million |
| **6** | Development of energy market rules in line with international practices | High | Ensures system stability and investor confidence. | Energy regulator, KEGOC | • Update grid codes<br>• Mandate priority dispatch<br>• Align with EU/international standards | Short–medium term (1–4 years) | Energy regulator | $5–20 million |
| | **Human skills** | | | | | | | |
| **7** | Education and workforce development, sector-specific training | Medium | Builds local expertise for design, construction, and O&M of solar plants. Reduces reliance on foreign expertise and increases local economic benefits. | Ministry of Education, universities, technical institutes. Government + private developers + international firms | • Introduce solar engineering degrees<br>• Fund scholarships<br>• Develop certification systems<br>• Establish training centers<br>• Require local hiring quotas<br>• Enable knowledge transfer partnerships | Medium–long term (3–8 years) | Ministry of Education Ministry of Labor + project developers | $50–150 million |
| | **Social and cultural** | | | | | | | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **8** | Public engagement in decision-making, ensuring local community support | Medium | Prevents land-use conflicts and builds public support. | Local governments, developers | • Conduct stakeholder consultations<br>• Run awareness campaigns | Continuous | Local authorities | $5–20 million |
| **9** | Optimization of land use | High | Minimizes environmental and social conflicts while maximizing benefits. | Ministry of Agriculture, Kurultai, developers | • Prioritize degraded land<br>• Introduce revenue-sharing schemes | Medium term (3–6 years) | Ministry of Ecology, Environmental agencies | $20–100 million |
| | **Information** | | | | | | | |
| **10** | Digitalization and planning tools, ensuring access to data from the system operator and grid companies | Medium | Enables better project planning and reduces uncertainty for investors. Improves efficiency, coordination, and planning accuracy. | KEGOC, Ministry of Energy + grid operators | • Publish real-time grid data<br>• Develop open-access platforms<br>• Deploy GIS-based planning<br>• Digitize connection processes<br>• Standardize reporting | Medium term (2–5 years) | Energy regulator Ministry of Digital Development | $20–80 million |
| | **Technical** | | | | | | | |
| **11** | Modernization of electrical grids to increase capacity | High | Core enabler—without grid capacity, large-scale solar cannot be integrated. | KEGOC, Ministry of Energy, international financiers | • Expand transmission to southern regions<br>• Upgrade substations<br>• Deploy smart grid technologies | Medium–long term (5–10 years) | KEGOC + Ministry of Energy | $3–8 billion |
| **12** | Increasing energy system flexibility through integration of energy storage | High | Ensures grid stability with high solar penetration. | Grid operator, private investors, government | • Deploy utility-scale battery storage<br>• Introduce ancillary service markets<br>• Improve forecasting systems | Medium term (3–7 years) | Energy regulator + system operator | $1–4 billion |

## 1.2 Large-scale on-grid wind farms (0.1–1 GW)

### 1.2.1 General description and target for large-scale on-grid wind farms (0.1–1 GW)

Large-scale on-grid onshore wind farms are collections of utility-scale wind turbines (from dozens to hundreds) connected to the electricity grid through substations and transmission lines. Typical project sizes in the range from 100 MW (0.1 GW) up to ~1,000 MW (1 GW). A modern large onshore plant uses multi-MW turbines (3–6+ MW each), medium- to high-hub heights (100–170 m) and long rotor diameters to capture steadier winds and higher capacity factors. Plant design balances turbine spacing, site topography, access roads, grid connection and environmental constraints. Power is sold either via market contracts, PPAs (Power Purchase Agreement), or through auctioned feed-in arrangements[1]. Many projects now pair wind with battery storage or grid reinforcement to firm output. Construction timelines for 0.1–1 GW projects typically run from ~18–36 months once permits and financing are in place. Operational life is usually 20–30 years with opportunities for repowering (replacing turbines with newer, larger machines) after ~15–20 years. The development of wind energy is characterized by the following features.

- **Modular and scalable:** easily built in phases (e.g., 2×50 MW stages to reach 100 MW).
- **Rapid learning & maturity:** turbine sizes and performance have improved steadily, costs dropped substantially over the past decade.
- **Low variable costs:** fuel-free generation with predictable O&M profiles.
- **Integrability:** increasingly paired with batteries or hybrid gas/battery to manage variability.

Kazakhstan has excellent onshore wind resources across northern and central steppe regions (strong, persistent winds) and significant technical potential. The government's Power Sector Development plans include several GW of new renewables including wind energy. By early-to-mid 2025 Kazakhstan had ~3 GW of renewables installed (wind ~1.6 GW), and the state approved auctions for multi-GW of new capacity (2024–2027), including wind + storage tenders. That creates a favorable policy window for 0.1–1 GW projects (Qazaq Green, 2026; Ministry of Energy of the Republic of Kazakhstan, 2022) but still there are possibilities for increasing the planning and installing capacity.

**Preliminary Deployment Target:** A preliminary target is to facilitate the development of multiple utility-scale wind projects totaling 2–4 GW of new installed capacity by 2035, with individual projects ranging from 100 MW to 1 GW depending on site conditions and grid availability. This target aligns with Kazakhstan's ongoing renewable energy auctions, increasing deployment of wind-plus-storage systems, and long-term power sector decarbonization objectives. Achieving this level of deployment would capitalize on the country's significant technical wind potential, strengthen energy security, diversify the electricity generation mix, and contribute substantially to national greenhouse gas emission reduction goals while supporting regional economic development and private-sector investment. (Ministry of Energy of the Republic of Kazakhstan, 2022; Government of the Republic of Kazakhstan, 2020)

[1] Auctioned feed-in arrangements for wind power are a hybrid support model: developers compete in auctions, and the winners receive a fixed or premium payment for the electricity they generate. This replaces a pure, administratively set feed-in tariff with a market-based allocation process designed to lower costs and limit how much capacity gets subsidized.

### 1.2.2 Identification of Barriers for large-scale on-grid wind farms (0.1–1 GW)

According to the BAEF Guidebook methodology (UDP, 2015), large-scale on-grid wind farms are categorized as a Capital Goods (KG) technology because their deployment requires substantial investments in wind turbines, electrical infrastructure, transmission systems, and associated civil works. The large-scale adoption of this technology can be constrained by several financial, technical, regulatory, and institutional barriers.

One of the primary barriers is the high initial capital cost of wind farm development, including turbine procurement, transportation, installation, grid connection, and supporting infrastructure. Limited access to affordable long-term financing and the perception of investment risks can reduce investor confidence and delay project implementation. Regulatory barriers, such as lengthy permitting processes, complex land acquisition procedures, and uncertainty regarding renewable energy policies and power purchase agreements (PPAs), can further increase project costs and development timelines.

Technical challenges also affect deployment. Suitable high-wind resource locations are often situated far from major demand centers, requiring significant investments in transmission infrastructure. Grid integration of variable wind power may pose operational challenges for electricity system operators, particularly where grid flexibility is limited. In addition, insufficient local expertise in wind resource assessment, project development, operation, and maintenance can affect project performance and increase reliance on foreign technical support. Social and environmental concerns, including land-use conflicts, visual impacts, and potential effects on wildlife, may also create barriers to project approval and public acceptance. (UNDP, 2018)

To overcome these barriers, governments and stakeholders can implement a range of enabling measures. Stable and transparent renewable energy policies, competitive procurement schemes, and long-term PPAs can improve investment certainty. Financial support mechanisms such as concessional loans, risk-sharing facilities, tax incentives, and green financing instruments can reduce capital costs and mobilize private investment. Investments in transmission expansion, grid modernization, and forecasting systems can facilitate the integration of large-scale wind generation. Capacity-building programs for developers, utilities, regulators, and technical personnel can strengthen local expertise. Furthermore, streamlined permitting procedures, stakeholder engagement processes, and environmental planning frameworks can help reduce project risks and improve social acceptance, thereby accelerating the deployment of large-scale on-grid wind farms (World Bank Group, 2022; Russia-Kazakhstan regional energy study, 2021).

#### *1.2.2.1* Preliminary list of barriers

Preliminary list of barriers was developed by the national and regional consultants to be screened, discussed and prioritized by the working group; the result is presented in the **Table 1.5**.

***Table 1.5*** *Identified Barriers to Large-scale on-grid wind farms (0.1–1 GW)*

| Category | Specific Barrier | Description of the Barrier |
|---|---|---|
| **1. Economic & financial** | 1 Low electricity tariffs | Electricity prices in Kazakhstan remain relatively low, largely because coal-fired generation still dominates the power mix. As a result, wind projects often struggle to achieve attractive returns without policy support, since market revenues may not be sufficient to cover high upfront costs and long payback periods. |

| | | |
|---|---|---|
| | 2 High capital costs | Utility-scale wind power requires substantial initial investment in turbines, foundations, land preparation, substations, and grid connection. Although operating costs are relatively low once a project is built, the large upfront financing requirement creates a major entry barrier for developers. |
| | 3 Limited access to financing | Domestic financial institutions often provide only limited long-term, low-interest financing for renewable energy projects. This makes it difficult for developers to secure the kind of project finance structure that wind farms typically require, especially when revenue certainty is weak. |
| | 4 Currency and macroeconomic risks | Wind projects in Kazakhstan are exposed to exchange-rate volatility because much of the equipment is imported and priced in foreign currency. If the local currency weakens, project costs rise and investor returns become less predictable, which increases perceived financial risk. |
| | 5 High costs of connection to the electrical grid | Many of the best wind sites are located far from major demand centers and existing transmission infrastructure. Developers may therefore need to finance long-distance lines or grid upgrades themselves, which significantly increases total project cost and can delay implementation. |
| **2. Market conditions** | 6 Dominance of coal-based generation | Coal remains the backbone of Kazakhstan's electricity system, giving conventional generation a strong cost advantage. This makes it difficult for wind power to compete on price alone, especially in the absence of stronger carbon constraints or market reform. |
| | 7 Uncertain long-term tariffs and PPA conditions | Investors need stable revenue streams to justify large capital commitments, but uncertainty around tariffs and power purchase agreement terms can undermine confidence. When pricing rules are not clearly predictable over the life of the project, lenders and investors tend to demand higher returns. |
| | 8 Insufficient demand incentives for green electricity | The market for green electricity remains underdeveloped, and demand-side incentives are still limited. Without a mature corporate PPA market or strong consumer preference for clean power, wind developers have fewer opportunities to secure premium buyers. |
| | 9 Weak demand signals for renewables | In many electricity markets, carbon pricing, renewable portfolio standards, or similar policy tools create demand for clean generation. Where such signals are weak or absent, the market does not sufficiently reward low-carbon investment, reducing the attractiveness of wind projects. |
| **3. Legal & regulatory** | 10 Regulatory uncertainty and frequent policy changes | Frequent changes in policy, rules, or implementation practice make long-term investment planning more difficult. Because wind projects require many years of development and operation, investors value stable and predictable regulation. |
| | 11 Complex permitting procedures | Large wind projects often require multiple approvals from different public authorities, which can make the development process slow and costly. Delays in permits, environmental clearances, and land-related approvals increase uncertainty and can discourage investment. |
| | 12 Lack of clear rules for grid access and connection | The legal and technical framework for interconnection is often not sufficiently clear or transparent. When developers do not know in advance how connection studies, queue procedures, or cost allocation will work, project timelines and budgets become harder to manage. |

| | | |
|---|---|---|
| | 13 Insufficiently developed land allocation procedures | Wind farms require significant land areas, and the rules governing land allocation and land-use change are not always well developed. Unclear procedures can create delays, increase legal risk, and complicate negotiations with local authorities and land users. |
| **4. Human skills** | 14 Shortage of specialists in renewable energy | Kazakhstan has limited domestic experience in designing, developing, and operating utility-scale wind farms. This shortage of qualified engineers, planners, and technicians can reduce project quality and increase dependence on external expertise. |
| | 15 Dependence on foreign expertise | Because local firms may lack experience with large wind projects, developers often rely on international contractors and consultants. While this can help fill technical gaps, it also raises costs and may slow knowledge transfer to the local market. |
| | 16 Limited R&D and technical training programs | A weak domestic innovation and training ecosystem limits the growth of local capabilities in wind technology. Without stronger universities, vocational training, and applied research, it is difficult to build a skilled workforce and support long-term sector development. |
| **5. Social and cultural** | 17 Low public awareness of renewable benefits | Public understanding of wind energy's environmental and economic benefits remains limited in some areas. This can reduce social support for projects and make it harder to build acceptance for new infrastructure. |
| | 18 Preference for traditional energy sources | Kazakhstan's long dependence on coal has shaped both public expectations and policy priorities. This historical reliance can make it more difficult for wind power to gain broad political and social momentum. |
| | 19 Ambiguous public perception of technology deployment processes | Large wind farms may face opposition if local communities are uncertain about land use, visual impacts, or compensation arrangements. Concerns are especially likely in agricultural areas where communities may fear competition with existing land uses. |
| **6. Information** | 20 Insufficient high-resolution wind data | Accurate project design depends on detailed long-term wind measurements, but such data may be limited or unevenly distributed. Without reliable local resource data, developers face greater uncertainty in estimating output and financial performance. |
| | 21 Lack of data on grid capacity | Developers often cannot easily access up-to-date information on available grid capacity or connection points. This makes it difficult to identify viable sites early in the development process and increases the risk of costly redesign. |
| | 22 Limited awareness among investors | Information gaps about project feasibility, market conditions, and policy stability can reduce investor confidence. When the sector is not well understood, investors may view wind projects as too risky compared with more familiar assets. |
| **7. Technical** | 23 Outdated grid infrastructure, insufficient capacity | Aging transmission networks and high system losses limit the ability of the grid to absorb additional variable generation. In some cases, weak infrastructure creates bottlenecks that reduce the value of new wind power and increase the need for reinforcements. |
| | 24 Intermittent generation and balancing needs | Wind output varies over time, which creates challenges for dispatch, balancing, and frequency control. Without flexible generation, storage, or improved grid management, higher wind penetration can increase system operating complexity. |
| | 25 Geographic mismatch between wind resources and demand centers | The strongest wind resources are often located far from Kazakhstan's main load centers. This spatial mismatch increases the need for transmission investment and may reduce the economic attractiveness of otherwise high-quality sites. |

| | | |
|---|---|---|
| | 26 Harsh climate conditions | Extreme winters, icing, strong winds, and difficult logistics can all complicate construction and operation. These conditions may increase maintenance costs, reduce turbine availability, and require equipment adapted to local weather extremes. |

### 1.2.3 Screening of barriers for large-scale on-grid wind farms (0.1–1 GW)

For the screening step, the sectoral TNA working group firstly determined seven main barrier categories for the prioritized mitigation technologies in the energy sector: (1) economic & financial, (2) market conditions, (3) legal & regulatory, (4) human skills, (5) social, (6) information, and (7) technical. These categories consolidate the twelve most important barriers resulting from the expert assessment.

The prioritization exercise was implemented using Google Forms to ensure transparency, consistency, and ease of participation. The working group consisted of 14 members (See Annex 3), each of whom was required to assess and prioritize the barriers independently.

To systematically filter and prioritize the comprehensive longlist of constraints and interventions, the energy sectoral working group conducted a participatory screening and scoring exercise via an online structured questionnaire. Stakeholders evaluated each barrier's relative severity on technology diffusion using a five-tier qualitative hierarchy (Killer/Non-starter, Crucial, Important, Less important, or Insignificant), while simultaneously assessing the aligned enabling measures using a three-tier priority scale (High, Medium, or Low). These qualitative judgements were subsequently translated into discrete numerical values, assigning number of votes for most popular tier.

More than 80% of members of the working group (10 feedbacks) completed the prioritization procedure. The individual scores were aggregated, and each barrier received a total number of evaluations reflecting the collective assessment of the group.

By summarizing the votes from the expert group, tiers were identified for each barrier based on the highest votes. The same was done for the measures. The results for barriers longlist are presented in the rightmost column of **Table 1.6**.

### 1.2.4 Classification of barriers for large-scale on-grid wind farms (0.1–1 GW)

Specific barriers for large-scale on-grid wind farms (0.1–1 GW) are represented in **Table 1.6** below:

***Table 1.6*** *Classification of Barriers to Large-scale on-grid wind farms (0.1–1 GW)*

| Category | Specific Barrier | Description of the Barrier | **Score (votes)** |
|---|---|---|---|
| **1. Economic & financial** | High capital costs | Utility-scale wind power requires massive initial investment (land, equipment, grid connection), which creates entry barriers despite long-term returns. | Important (6 votes) |
| | Limited access to financing | Domestic financial markets offer limited low-interest loans or project finance instruments for renewable energy. | Crucial (4 votes) |
| | High costs of connection to the electrical grid | Developers often must finance transmission upgrades or long-distance connections due to remote locations | Important (6 votes) |

| | | | |
|---|---|---|---|
| **2. Market conditions** | Insufficient demand incentives for "green" electricity | Lack of PPAs (Power Purchase Agreements) for the green energy and undeveloped green energy market | Crucial (5 votes) |
| **3. Legal & regulatory** | Lack of clear rules for grid access and connection | Technical and legal requirements and rules for grid connection are underdeveloped | Important (5 votes) |
| | Insufficiently developed procedures for land allocation and land use | Legal requirements and rules for land allocation and land use are underdeveloped | Important (6 votes) |
| **4. Human skills** | Shortage of specialists in renewable energy | Limited domestic expertise in utility-scale wind farms design and integration. | Crucial (6 votes) |
| **5. Social and cultural** | Ambiguous public perception of technology deployment processes | Large wind farms may face opposition due to land use (especially agricultural land). | Important (6 votes) |
| **6. Information** | Lack of data on grid capacity | Developers often cannot access reliable information about available connection points | Important (4 votes) |
| **7. Technical** | Outdated grid infrastructure, insufficient capacity | Transmission losses (up to ~15%) and outdated networks limit integration capacity | Killer (non-starter) (6 votes) |
| | Intermittent generation, need for balancing and dispatching of the power system | Wind variability creates balancing and frequency control issues in the grid | Killer (non-starter) (5 votes) |

### 1.2.5 Measures for large-scale on-grid wind farms (0.1–1 GW)

Specific measures for large-scale on-grid wind farms (0.1–1 GW) are represented in **Table 1.7** below:

***Table 1.7*** *Suggested measures grouped with the Barriers to Large-scale on-grid wind farms*

| Barrier and measure category | Barrier description | Possible measures | Score (votes) |
|---|---|---|---|
| Economic and financial | High capital costs<br><br>Limited access to financing<br><br>High costs of connection to the electrical grid | Blended public-private financing, development of risk mitigation mechanisms<br>• Introduce capital subsidies or viability gap funding (VGF) for utility-scale wind projects<br>• Provide tax incentives (VAT exemptions, accelerated depreciation) for wind generation equipment<br>• Enable public–private partnerships (PPPs) for large-scale wind parks<br>• Facilitate sovereign guarantees to reduce investor risk | High (6 votes) |
| | | Strengthening banks' capacity to mobilize "green" loans, concessional financing<br>• Develop green financing instruments (green bonds, climate funds) via national banks<br>• Partner with international institutions like AIIB and Asian Development Bank<br>• Establish a state-backed renewable energy financing facility | High (6 votes) |

| | | | |
|---|---|---|---|
| | | • Offer interest rate subsidies or blended finance mechanisms<br>• Encourage local banks to build renewable project finance capacity | |
| Market conditions | Insufficient demand incentives for "green" electricity | Introduction of feed-in tariffs for wind electricity to ensure long-term project profitability and predictable revenue | Medium (6 votes) |
| | | Financing the development of electrical grid infrastructure<br>• Introduce cost-sharing mechanisms between developers and grid operators<br>• Develop government-funded transmission corridors to renewable zones<br>• Implement standardized and transparent connection tariffs<br>• Establish wind energy zones with pre-built grid infrastructure<br>• Allow connection cost recovery through tariffs over time | High (9 votes) |
| Legal and regulatory | Lack of clear rules for grid access and connection<br><br>Insufficiently developed procedures for land allocation and land use | Simplification of permitting procedures<br>• Develop clear grid codes and interconnection standards for renewables<br>• Implement transparent and time-bound permitting procedures<br>• Establish "one-stop-shop" permitting authorities | Medium (7 votes) |
| | | Development of energy market rules in line with international practices<br>• Align regulations with international best practices (e.g., ISO, EU grid codes) | High (5 votes) |
| Human skills | Shortage of specialists in renewable energy | Education and workforce development, sector-specific training<br>• Introduce university programs and certifications in wind engineering<br>• Partner with international firms for knowledge transfer and training<br>• Create vocational training centers for wind farms installation and O&M<br>• Provide government-funded scholarships in renewable energy fields<br>• Encourage local workforce requirements in wind projects | High (6 votes) |
| Social and cultural | Ambiguous public perception of technology deployment processes | Public engagement in decision-making, ensuring local community support<br>• Conduct public consultations and community engagement programs<br>• Provide local economic benefits (jobs, revenue-sharing schemes)<br>• Run public awareness campaigns on renewable energy benefits | Medium (5 votes) |
| | | Optimization of land use<br>• Promote use of non-arable or degraded land for wind farms | Medium (6 votes) |

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| | | • Introduce dual-use agriculture + wind systems | |
| Information | Lack of data on grid capacity | Digitalization and planning tools, ensuring access to data from the system operator and grid companies<br>• Develop publicly accessible grid capacity maps and databases<br>• Require grid operators to publish real-time hosting capacity data<br>• Implement digital platforms for connection applications and tracking<br>• Standardize data reporting formats across utilities<br>• Use GIS-based planning tools for renewable integration | Medium (7 votes) |
| Technical | Outdated grid infrastructure, insufficient capacity<br><br>Intermittent generation, need for balancing and dispatching of the power system | Modernization of electrical grids to increase capacity<br>• Invest in grid modernization and rehabilitation programs<br>• Deploy smart grid technologies (automation, monitoring systems)<br>• Reduce transmission losses through high-efficiency equipment upgrades | High (11 votes) |
| | | Increasing energy system flexibility through integration of energy storage<br>• Deploy utility-scale battery energy storage systems (BESS)<br>• Implement advanced forecasting systems for wind output<br>• Develop ancillary service markets (frequency regulation, reserves)<br>• Upgrade grid control systems for real-time balancing<br>• Define priority dispatch rules for renewable energy | High (11 votes) |

### 1.2.6 Grouping complementary measures and assessment of measures for inclusion in the TAP for large-scale on-grid wind farms (0.1–1 GW)

Grouping complementary measures and assessment of measures for inclusion in the TAP for large-scale on-grid wind farms (0.1–1 GW)») are represented in **Table 1.8** below:

***Table 1.8*** *Summary Assessment Matrix for TAP Inclusion: Large-scale on-grid wind farms*

| # | Measures | Priority | Why it is important? | Who should do it? | How should they do it? | Time scale | MRV by which organization | Estimated Costs in USD |
|---|---|---|---|---|---|---|---|---|
| | **Economic and financial** | | | | | | | |
| **1** | Blended public-private financing, development of risk mitigation mechanisms | High | Reduces high upfront capital costs and perceived risks, unlocking private investment in large-scale wind. | Ministry of Energy, Ministry of Finance, sovereign wealth fund (Samruk-Kazyna), national development banks, IFIs (EBRD, ADB, AIIB) | • Establish a sovereign-backed green fund<br>• Issue green bonds<br>• Structure PPP frameworks<br>• Provide guarantees and co-financing with IFIs | Short–medium term (1–5 years) | Ministry of Energy + national statistics agency + IFIs (annual reporting on mobilized capital, MW installed) | $500 million – $2 billion (public capital mobilization, leveraging larger private flows) |
| **2** | Strengthening banks' capacity to mobilize "green" loans, concessional financing | High | Ensures long-term capital availability and reduces reliance on public budgets. | National Bank of Kazakhstan, commercial banks, Ministry of Finance, international partners | • Issue sovereign green bonds<br>• Create co-financing platforms with IFIs<br>• Train local banks in project finance | Medium term (2–6 years) | National Bank + international partners | $50 million – $200 million (capacity + structuring; capital mobilized much larger) |
| | **Market conditions** | | | | | | | |
| **3** | Introduction of feed-in tariffs for wind electricity to ensure long-term project profitability | Medium | Ensures predictable revenue streams, critical for investor confidence. | Energy regulator, market operator, national utility | • Run competitive auctions for EPC developers<br>• Standardize 15–25-year PPAs<br>• Ensure currency/inflation indexation<br>• Strengthen off-taker credit guarantees | Short term (1–3 years) | Energy regulator (auction results, tariff levels, PPA performance) | Low direct cost; contingent liabilities up to billions |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **4** | Financing the development of electrical grid infrastructure | High | Grid access uncertainty is a major bottleneck for large-scale wind deployment. | Grid operator (KEGOC), Ministry of Energy | • Define transparent connection tariffs<br>• Develop renewable energy zones with pre-built infrastructure<br>• Allow cost recovery via tariffs | Medium term (3–7 years) | Energy regulator + KEGOC | $1–3 billion (grid infrastructure) |
| | **Legal and regulatory** | | | | | | | |
| **5** | Simplification of permitting procedures | Medium | Reduces delays and administrative risk. | Ministry of Energy, Ministry of Justice, local authorities | • Create centralized permitting agency<br>• Digitize workflows<br>• Standardize timelines | Short term (1–3 years) | Government audit bodies (approval time, number of permits issued) | $10–50 million |
| **6** | Development of energy market rules in line with international practices | High | Ensures fair and predictable grid access. | National system operator (KEGOC), regulator | • Update grid codes<br>• Define connection cost rules<br>• Guarantee renewable dispatch priority | Short–medium term (1–4 years) | Regulator + KEGOC (grid connection times, curtailment rates) | $20–100 million (regulatory + system upgrades) |
| | **Human skills** | | | | | | | |
| **7** | Education and workforce development, sector-specific training | High | Addresses shortage of skilled labor for construction and O&M. | Ministry of Education, universities, technical institutes | • Develop renewable energy degrees<br>• Launch technician certification programs<br>• Partner with industry<br>• Include local content clauses<br>• Require training programs in contracts | Medium term (3–6 years) | Ministry of Education (graduates, certifications issued)<br>Ministry of Labor (local employment share) | $20–100 million |

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|---|---|---|---|---|---|---|---|---|
| | **Social and cultural** | | | | | | | |
| **8** | Public engagement in decision-making, ensuring local community support | Medium | Prevents social resistance and builds local support. | Developers, local governments | • Conduct early consultations<br>• Establish community funds<br>• Prioritize local hiring | Continuous | Local authorities + independent auditors | 1–3% of project cost (~$10–30 million per GW) |
| **9** | Optimization of land use | High | Minimizes environmental damage and reputational risk. | Developers, Ministry of Ecology | • Conduct transparent ESIAs<br>• Use spatial planning tools | Short term (pre-construction) | Ministry of Ecology, Environmental regulator | $5–20 million |
| | **Information** | | | | | | | |
| **10** | Digitalization and planning tools, ensuring access to data from the system operator and grid companies | Medium | Reduces uncertainty and improves investment decisions. Ensures optimal siting and system planning. | KEGOC, Ministry of Energy | • Build real-time data platforms<br>• Publish grid capacity maps<br>• Publish open-access datasets | Short–medium term (1–4 years) | Ministry of Digital Development | $20–80 million |
| | **Technical** | | | | | | | |
| **11** | Modernization of electrical grids to increase capacity | High | Enables integration of large-scale wind capacity. | KEGOC, Ministry of Energy | • Build HV lines and substations<br>• Deploy smart grid technologies<br>• Upgrade infrastructure | Medium–long term (3–10 years) | KEGOC + regulator (grid capacity, losses) | $1–5 billion |
| **12** | Increasing energy system flexibility through integration of energy storage | High | Maintains grid stability with variable wind generation. | KEGOC, private sector, regional partners | • Deploy batteries and BESS<br>• Improve forecast systems<br>• Expand interconnections across Central Asia | Medium–long term (3–10 years) | System operator (curtailment rates, balancing costs) | $500 million – $3 billion |

## 1.3 Small hydropower (<10 MW) in south and north-east Kazakhstan

### 1.3.1 General description and target for small hydropower (<10 MW) in south and north-east Kazakhstan

Kazakhstan has strong potential for small hydropower (SHP <10 MW), especially in the southern (Almaty, Zhambyl, Turkestan) and north-east (East Kazakhstan) regions where mountains and rivers support renewable generation. SHPs can improve electricity access in rural areas, reduce transmission losses, and advance a greener economy. In the south, rivers from the Tien Shan (Talas, Aksu, Ili) offer favorable run-of-river sites; the Irtysh basin in the NE provides low- to medium-head options near existing lines for easy grid integration. Run-of-river technology minimizes environmental impact by returning water to the river, avoiding large reservoirs. Advances in automation, modular turbines, and prefabricated components reduce costs, shorten construction, and ease maintenance, while digitalization helps SHPs feed smart grids for reliable rural power. SHP projects also generate construction and operations jobs and supply clean power to rural industries, with a smaller ecological footprint and fewer social disruptions than large dams, aided by standard environmental measures (fish passages, sediment control, seasonal flow regulation). Overall, SHP development in southern and NE Kazakhstan can diversify supply, strengthen energy independence, stabilize rural electricity, and support the 2060 carbon neutrality goal. (OSCE Academy, 2019; Nazarbayev University, 2021)

Kazakhstan SHP technical potential exceeds 13–15 TWh/year, with Ili, Talas, Irtysh, and Bukhtarma basins ideal for low- to medium-head SHP sites using run-of-river designs that minimize reservoirs and environmental impacts. The policy framework supports SHP within the 2030 renewables target (15%) and 2060 carbon neutrality, via feed-in tariffs, auctions, and laws guaranteeing permitting and grid access. SHPs suit remote rural and mountainous areas, enabling off-grid or hybrid operations with solar or wind, boosting energy security and local development. Environmental benefits include low land use and measures for ecological flow and fish migration. Development prospects focus on southern run-of-river schemes and north-eastern cascade opportunities, modernization of Soviet-era SHPs, and the growth of automation and modular turbines to enhance grid integration and cost-competitiveness. (OSCE Academy, 2019; University of Applied Sciences and Arts Northwestern Switzerland, 2022)

**Preliminary Deployment Target:** to install up to 500 MW of additional SHP capacity by 2035, primarily in the southern regions (Almaty, Zhambyl, and Turkestan) and the north-eastern region (East Kazakhstan). This target would prioritize run-of-river schemes on rivers within the Ili, Talas, Irtysh, and Bukhtarma basins, as well as the rehabilitation and modernization of existing small hydropower facilities. Achieving this target would contribute to Kazakhstan's renewable energy objectives, support the national goal of obtaining 15% of electricity from renewable sources by 2030, and advance the country's long-term commitment to carbon neutrality by 2060 while promoting regional economic development and environmentally sustainable energy generation. (Qazaq Green, 2026; Ministry of Energy of the Republic of Kazakhstan, 2024)

### 1.3.2 Identification of Barriers for small hydropower (<10 MW) in south and north-east Kazakhstan

According to the BAEF Guidebook methodology (UDP, 2015), small hydropower plants (SHPPs) are classified as a Capital Goods (KG) technology because their deployment requires significant investment in civil works, electro-mechanical equipment, transmission infrastructure, and site

development. In Kazakhstan, particularly in the mountainous regions of the south and north-east where hydropower potential is concentrated, several barriers constrain the wider adoption of small hydropower projects.

A major barrier is the high upfront investment cost associated with feasibility studies, hydrological assessments, construction of water intake structures, turbines, generators, and grid connection facilities. Access to affordable long-term financing remains limited, especially for private developers and small investors. In addition, hydrological uncertainty related to seasonal river flows and the potential impacts of climate change on water availability can increase project risks and reduce investor confidence.

Technical and infrastructure barriers are also significant. Many promising hydropower sites are located in remote mountainous areas where access roads, transmission lines, and supporting infrastructure are insufficient or absent, increasing development costs. Limited domestic expertise in the design, operation, and maintenance of modern small hydropower systems may further constrain project implementation. Regulatory challenges, including lengthy permitting procedures, complex water-use licensing requirements, and environmental impact assessment processes, can delay project development and increase transaction costs.

To address these barriers, several enabling measures can be introduced. Financial incentives such as concessional loans, investment subsidies, guarantees, and preferential renewable energy tariffs can improve project viability and attract private investment. Strengthening renewable energy policies and streamlining permitting and water-use approval procedures would reduce administrative burdens and increase investor certainty. Public investments in rural transmission networks and access infrastructure can lower development costs in remote areas. Capacity-building programs for project developers, local authorities, and technical specialists can enhance national expertise in hydropower planning and operation. Furthermore, improved hydrological monitoring and resource assessment programs can reduce uncertainty and support more reliable project design. Together, these measures can accelerate the sustainable deployment of small hydropower plants in southern and north-eastern Kazakhstan, contributing to energy diversification, rural development, and greenhouse gas emission reductions. (Kazakhstan Journal of Law and Justice, 2020; UNCTAD, 2023)

#### *1.3.2.1* Preliminary list of barriers

Preliminary list of barriers was developed by the national and regional consultants to be screened, discussed and prioritized by the working group; the result is presented in the **Table 1.9**

***Table 1.9*** *Identified Barriers to Small hydropower in south and north-east Kazakhstan*

| Category | Specific Barrier | Description of the Barrier |
|---|---|---|
| **1. Economic & financial** | 1 High capital costs | Small hydropower projects still require significant upfront investment in civil works, turbines, electromechanical equipment, transmission links, and grid connection. Although these projects can offer long-term returns, the heavy initial capital burden creates a major barrier for new developers. |
| | 2 Limited access to financing | Domestic financial markets often provide limited low-interest or long-term project finance for renewable energy. As a result, developers may face high borrowing costs, strict collateral requirements, and difficulties securing funding for early-stage development. |

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| | 3 Currency and exchange rate risks | Many of the key components used in small hydropower projects are imported and priced in foreign currencies. This makes project budgets sensitive to exchange-rate fluctuations between the tenge and currencies such as the US dollar or euro, increasing financial uncertainty. |
| | 4 High costs of connection to the electrical grid | Because promising sites are often located in remote or mountainous areas, developers may need to finance new transmission lines or significant grid upgrades. These connection costs can be disproportionately high for relatively small projects and may reduce overall project viability. |
| **2. Market conditions** | 5 Dominance of fossil fuels and centralized generation | Kazakhstan's power system is still heavily shaped by coal, oil, and large centralized generation facilities. This structure makes it difficult for small hydropower to compete, not only economically, but also in terms of market access and institutional priority. |
| | 6 Weak tariff and revenue mechanisms | Where tariff structures are unstable or not clearly designed for small-scale generation, investors face uncertainty about future revenues. The absence of predictable and uniform pricing mechanisms makes it harder to secure financing and increases perceived risk. |
| | 7 Insufficient demand incentives for green electricity | The market for green electricity remains underdeveloped, and there are few strong incentives that would encourage buyers to pay for clean power. Without active demand from corporate buyers or a mature PPA market, small hydropower projects struggle to secure bankable off-take arrangements. |
| | 8 Grid operator preference for large generators | System operators typically prioritize large, stable generation units that are easier to dispatch and integrate into the grid. Small hydropower plants may therefore receive less favorable treatment, even when they could provide useful local energy supply. |
| **3. Legal & regulatory** | 9 Lack of clear rules for grid access and connection | Technical and legal requirements for connecting small hydropower plants to the grid are often underdeveloped. When interconnection rules are unclear, developers face delays, higher transaction costs, and uncertainty about whether a project can be connected on reasonable terms. |
| | 10 Lack of tailored policies for small-scale hydropower | Many renewable energy regulations are designed with large projects in mind and do not reflect the specific needs of small hydropower. Without simplified procedures, differentiated tariffs, or dedicated incentives, smaller projects remain at a disadvantage. |
| | 11 Overlapping institutional responsibilities | Water, energy, and environmental authorities often share responsibility for approving hydropower projects. This fragmented governance structure can lead to slow decision-making, administrative confusion, and inconsistent requirements. |
| | 12 Insufficiently developed land allocation procedures | Land allocation and land-use rules are not always clearly defined for small hydropower development. This creates uncertainty around site access, legal approvals, and the time required to secure project land. |
| **4. Human skills** | 13 Shortage of specialists in renewable energy | Kazakhstan has limited domestic expertise in the design, construction, and operation of small hydropower plants. This shortage of trained professionals can slow project delivery and increase dependence on external consultants. |
| | 14 Weak vocational and technical training programs | Regional educational institutions often do not offer enough specialized training in renewable energy technologies. As a result, the workforce may lack the practical skills needed for hydropower design, operation, maintenance, and safety management. |

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| | 15 Brain drain to larger cities or abroad | Skilled workers often leave remote regions in search of better jobs in major cities or outside the country. This is especially problematic for small hydropower projects, which are frequently located in rural or isolated areas with limited labor availability. |
| | 16 Limited experience with modern digital and automation systems | Small hydropower increasingly depends on digital monitoring, SCADA systems, and smart-grid integration. A lack of local expertise in these technologies can reduce operational efficiency and make plants harder to manage over time. |
| **5. Social and cultural** | 17 Ambiguous public perception of technology deployment processes and water use | Small hydropower projects may face resistance if local communities are unsure how water rights, land use, or compensation arrangements will be handled. Concerns about fairness and transparency can make it harder to build public support. |
| | 18 Limited stakeholder trust and institutional transparency | If institutions are seen as inefficient or opaque, private investors and community groups may be reluctant to engage. Low trust can increase the perceived risk of project approval, operation, and long-term enforcement of rules. |
| | 19 Concerns over water use and environmental impacts | Local residents, especially farmers, may worry that hydropower development could reduce water availability for irrigation or affect river ecosystems. Even when projects have limited physical impact, such concerns can delay or complicate implementation. |
| | 20 Preference for traditional energy sources | Long-standing familiarity with centralized fossil-based electricity can make it harder for small-scale renewables to gain acceptance. This cultural and institutional inertia may reduce interest in decentralized energy solutions. |
| **6. Information** | 21 Lack of data on promising sites for small hydropower construction | Reliable hydrological data are often limited, especially for small rivers in mountainous southern regions and seasonal rivers in the northeast. Without good site data, developers face higher uncertainty in identifying technically and financially viable projects. |
| | 22 Insufficient feasibility studies and site assessments | Many projects do not progress far because early-stage feasibility work is incomplete or too costly. Without detailed technical and economic assessments, it is difficult to determine whether a site can support a viable hydropower plant. |
| | 23 Lack of data on grid capacity | Developers often do not have access to reliable information about available connection points or local grid constraints. This makes site selection more difficult and increases the chance of investing in locations that cannot be connected economically. |
| | 24 Low transparency in market and regulatory information | Investors may struggle to obtain clear, current information on tariffs, procedures, permits, and technical requirements. When rules are difficult to access or interpret, project development becomes slower and more expensive. |
| **7. Technical** | 25 Outdated grid infrastructure, insufficient capacity | Remote areas in southern and northeastern Kazakhstan often lack modern grid infrastructure, and existing networks were not designed for decentralized generation. This limits the ability of the system to absorb small hydropower output reliably. |
| | 26 Aging infrastructure and equipment | Many existing small hydropower installations date back to Soviet times and suffer from wear, depreciation, and outdated technology. This highlights broader challenges in modernization, maintenance, and system renewal. |
| | 27 Seasonal variability of water flow | River flow in many regions changes sharply by season, especially in southern and northeastern Kazakhstan. This variability affects generation reliability and can reduce the consistency of electricity output across the year. |

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| | 28 Difficult terrain and limited access for construction | Mountainous regions create logistical challenges for transporting equipment, building access roads, and carrying out construction work. These physical constraints increase project complexity and raise total development costs. |

### 1.3.3 Screening of barriers for small hydropower (<10 MW) in south and north-east Kazakhstan

For the screening step, the sectoral TNA working group firstly determined seven main barrier categories for the prioritized mitigation technologies in the energy sector: (1) economic & financial, (2) market conditions, (3) legal & regulatory, (4) human skills, (5) social, (6) information, and (7) technical. These categories consolidate the twelve most important barriers resulting from the expert assessment.

The prioritization exercise was implemented using Google Forms to ensure transparency, consistency, and ease of participation. The working group consisted of 14 members (See Annex 3), each of whom was required to assess and prioritize the barriers independently.

To systematically filter and prioritize the comprehensive longlist of constraints and interventions, the energy sectoral working group conducted a participatory screening and scoring exercise via an online structured questionnaire. Stakeholders evaluated each barrier's relative severity on technology diffusion using a five-tier qualitative hierarchy (Killer/Non-starter, Crucial, Important, Less important, or Insignificant), while simultaneously assessing the aligned enabling measures using a three-tier priority scale (High, Medium, or Low). These qualitative judgements were subsequently translated into discrete numerical values, assigning number of votes for most popular tier.

More than 80% of members of the working group (10 feedbacks) completed the prioritization procedure. The individual scores were aggregated, and each barrier received a total number of evaluations reflecting the collective assessment of the group.

By summarizing the votes from the expert group, tiers were identified for each barrier based on the highest votes. The same was done for the measures. The results for the barrier longlist are presented in the rightmost column of the **Table 1.10**.

### 1.3.4 Classification of barriers for small hydropower (<10 MW) in south and north-east Kazakhstan

Specific barriers for small hydropower (<10 MW) in south and north-east Kazakhstan are represented in the table below:

***Table 1.10*** *Classification of Barriers to Small hydropower in south and north-east Kazakhstan*

| Category | Specific Barrier | Description of the Barrier | **Score (votes)** |
|---|---|---|---|
| **1. Economic & financial** | High capital costs | Small hydropower projects require requires massive initial investment (land, equipment, grid connection), which creates entry barriers despite long-term returns. | Crucial (7 votes) |
| | Limited access to financing | Domestic financial markets offer limited low-interest loans or project finance instruments for renewable energy. | Crucial (5 votes) |

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|---|---|---|---|
| | High costs of connection to the electrical grid | Developers often must finance transmission upgrades or long-distance connections due to remote locations | Important (6 votes) |
| **2. Market conditions** | Insufficient demand incentives for "green" electricity | Lack of PPAs (Power Purchase Agreements) for the green energy and undeveloped green energy market | Crucial (4 votes) |
| **3. Legal & regulatory** | Lack of clear rules for grid access and connection | Technical and legal requirements and rules for grid connection are underdeveloped | Important (4 votes) |
| | Insufficiently developed procedures for land allocation and land use | Legal requirements and rules for land allocation and land use are underdeveloped | Important (4 votes) |
| **4. Human skills** | Shortage of specialists in renewable energy | Limited domestic expertise in small-hydropower design and integration. | Crucial (5 votes) |
| **5. Social and cultural** | Ambiguous public perception of technology deployment processes, limited opportunities for water resource use | Small hydropower plants may face opposition due to land and water use. | Crucial (8 votes) |
| **6. Information** | Lack of data on grid capacity | Developers often cannot access reliable information about available connection points | Crucial (3 votes) |
| | Lack of data on promising sites for small hydropower construction | Insufficient hydrological data (especially for small rivers in mountainous southern regions and seasonal rivers in the northeast) increases uncertainty and project risk. | Crucial (5 votes) |
| **7. Technical** | Outdated grid infrastructure, insufficient capacity | Remote areas (especially in south and north-east Kazakhstan) often lack adequate grid infrastructure, and existing networks are not designed for decentralized generation. | Crucial (7 votes) |
| | Difficult terrain and limited access for small hydropower construction | Mountainous regions in southern and north-eastern Kazakhstan increase construction complexity and logistics costs. | Crucial (6 votes) |

### 1.3.5 Measures for small hydropower (<10 MW) in south and north-east Kazakhstan

Specific measures for small hydropower (<10 MW) in south and north-east Kazakhstan are represented in **Table 1.11** below:

***Table 1.11*** *Suggested measures grouped with the Barriers to Small hydropower (<10 MW) in south and north-east Kazakhstan*

| Barrier and measure category | Barrier description | Possible measures | Score (votes) |
|---|---|---|---|
| Economic and financial | High capital costs<br><br>Limited access to financing<br><br>High costs of connection to the electrical grid | Blended public-private financing, development of risk mitigation mechanisms<br>• Introduce capital subsidies or viability gap funding (VGF) for small hydropower projects<br>• Provide tax incentives (VAT exemptions, accelerated depreciation) for hydropower generation equipment<br>• Enable public–private partnerships (PPPs) for small hydropower projects | High (6 votes) |

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|---|---|---|---|
| | | • Facilitate sovereign guarantees to reduce investor risk | |
| | | Strengthening banks' capacity to mobilize "green" loans, concessional financing<br>• Develop green financing instruments (green bonds, climate funds) via national banks<br>• Partner with international institutions like AIIB and Asian Development Bank<br>• Establish a state-backed renewable energy financing facility<br>• Offer interest rate subsidies or blended finance mechanisms<br>• Encourage local banks to build renewable project finance capacity | High<br>(8 votes) |
| Market conditions | Insufficient demand incentives for "green" electricity | Introduction of feed-in tariffs for hydropower electricity to ensure long-term project profitability and predictable revenue | High<br>(5 votes) |
| | | Financing the development of electrical grid infrastructure<br>• Introduce cost-sharing mechanisms between developers and grid operators<br>• Develop government-funded transmission corridors to renewable zones<br>• Implement standardized and transparent connection tariffs<br>priority SHP development zones on the Ili, Talas, Irtysh and Bukhtarma basins<br>•<br>• Allow connection cost recovery through tariffs over time | High<br>(7 votes) |
| Legal and regulatory | Lack of clear rules for grid access and connection<br><br>Insufficiently developed procedures for land allocation and land use | Simplification of permitting procedures<br>• Develop clear grid codes and interconnection standards for renewables<br>• Implement transparent and time-bound permitting procedures<br>• Establish "one-stop-shop" permitting authorities | Medium<br>(6 votes) |
| | | Development of energy market rules in line with international practices<br>• Align regulations with international best practices (e.g., ISO, EU grid codes) | Medium<br>(6 votes) |
| Human skills | Shortage of specialists in renewable energy | Education and workforce development, sector-specific training<br>• Introduce university programs and certifications in small hydropower engineering<br>• Partner with international firms for knowledge transfer and training<br>• Create vocational training centers for small hydropower projects installation and O&M<br>• Provide government-funded scholarships in renewable energy fields | Medium<br>(5 votes) |

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|---|---|---|---|
| | | • Encourage local workforce requirements in small hydropower projects | |
| Social and cultural | Ambiguous public perception of technology deployment processes, limited opportunities for water resource use | Public engagement in decision-making, ensuring local community support<br>• Conduct public consultations and community engagement programs<br>• Provide local economic benefits (jobs, revenue-sharing schemes)<br>• Run public awareness campaigns on renewable energy benefits | High (5 votes) |
| | | Optimization of land and water use<br>• Promote community-based hydropower projects (cooperative ownership models).<br>• Engage communities early through consultation and participatory planning.<br>• Demonstrate successful pilot projects in rural areas.<br>• Provide local benefit-sharing mechanisms (e.g., revenue sharing).<br>• Promote run-of-river technologies with minimal water diversion. | High (5 votes) |
| Information | Lack of data on grid capacity<br><br>Lack of data on promising sites for small hydropower construction | Digitalization and planning tools, ensuring access to data from the system operator and grid companies<br>• Develop publicly accessible grid capacity maps and databases<br>• Require grid operators to publish real-time hosting capacity data<br>• Implement digital platforms for connection applications and tracking<br>• Standardize data reporting formats across utilities<br>• Use GIS-based planning tools for renewable integration | Medium (7 votes) |
| | | Digitalization and planning tools, water resource mapping, ensuring data access<br>• Develop a national database of small hydropower potential sites.<br>• Provide open-access hydrological and topographical data. | High (6 votes) |
| Technical | Outdated grid infrastructure, insufficient capacity<br><br>Difficult terrain and limited access for small hydropower construction | Modernization of electrical grids to increase capacity<br>• Invest in grid modernization and rehabilitation programs<br>• Deploy smart grid technologies (automation, monitoring systems)<br>• Reduce transmission losses through high-efficiency equipment upgrades | High (8 votes) |
| | | Development of transport infrastructure and logistical support | High (7 votes) |

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| | | • Use modular and prefabricated equipment to reduce on-site construction complexity.<br>• Improve access infrastructure (roads, bridges) through public investment.<br>• Apply innovative construction techniques (e.g., helicopter transport, small-scale machinery).<br>• Optimize project design for local terrain conditions.<br>• Provide logistical support incentives for remote-area projects. | |

### 1.3.6 Grouping complementary measures and assessment of measures for inclusion in the TAP for small hydropower (<10 MW) in south and north-east Kazakhstan

Grouping complementary measures and assessment of measures for inclusion in the TAP for small hydropower (<10 MW) are represented in **Table 1.12** below:

***Table 1.12*** *Summary Assessment Matrix for TAP Inclusion: Small hydropower (<10 MW) in south and north-east Kazakhstan*

| # | Measures | Priority | Why it is important? | Who should do it? | How should they do it? | Time scale | MRV by which organization | Estimated Costs in USD |
|---|---|---|---|---|---|---|---|---|
| | **Economic and financial** | | | | | | | |
| **1** | Blended public-private financing, development of risk mitigation mechanisms | High | Reduces high upfront CAPEX barriers and perceived investment risk, which are the main constraints for small hydropower in Kazakhstan. | Ministry of Energy, national development banks (e.g., DBK), private investors, IFIs (e.g., AIIB, EBRD, World Bank). | • Provide 20–40% CAPEX grants<br>• Establish green credit lines and guarantees<br>• Structure PPP risk-sharing models<br>• Issue green bonds and mobilize climate finance | Short–medium term (1–5 years) | Ministry of Energy + DBK (track installed MW, disbursed finance, project pipeline) | $200–500 million (public + leveraged private capital) |
| **2** | Strengthening banks' capacity to mobilize "green" loans, concessional financing | High | Ensures long-term capital availability and reduces reliance on public budgets. | National Bank of Kazakhstan, commercial banks, Ministry of Finance, international partners | • Issue sovereign green bonds<br>• Create co-financing platforms with IFIs<br>• Train local banks in project finance | Medium term (2–6 years) | National Bank + international partners | $50 million – $200 million (capacity + structuring; capital mobilized much larger) |
| | **Market conditions** | | | | | | | |
| **3** | Introduction of feed-in tariffs for hydropower electricity to ensure long-term project profitability | High | Ensures predictable revenue streams, critical for attracting investors. | Ministry of Energy, electricity market operator, utilities. | • Introduce technology-specific FiTs<br>• Guarantee 15–20-year PPAs<br>• Apply inflation and FX indexation | Immediate–short term (1–2 years) | Energy regulator (tariff compliance, contracts issued) | $100–300 million/year (tariff support, depending on scale) |
| **4** | Financing the development of electrical grid infrastructure | High | Grid access uncertainty is a major bottleneck for small hydropower deployment. | Grid operator (KEGOC), Ministry of Energy | • Define transparent connection tariffs<br>• Develop renewable energy zones with pre-built infrastructure<br>• Allow cost recovery via tariffs | Medium term (3–7 years) | Energy regulator + KEGOC | $1–3 billion (grid infrastructure) |

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| | **Legal and regulatory** | | | | | | | |
| **5** | Simplification of permitting procedures | Medium | Reduces delays and administrative burden, a major barrier in Kazakhstan. | Ministry of Energy, Ministry of Ecology, local authorities. | • Create centralized digital permitting platform<br>• Set approval timelines (<6–12 months)<br>• Simplify EIA for low-impact projects | Short term (1–2 years) | Government audit bodies (approval time, number of permits issued) | $5–20 million |
| **6** | Development of energy market rules in line with international practices | Medium | Provides policy clarity and tailored support for small-scale projects. | Parliament (Kurultai), Ministry of Energy. | • Develop national small hydro strategy<br>• Introduce separate legal category<br>• Align with renewable energy targets | Medium term (2–4 years) | Ministry of Energy (policy implementation tracking) | $10–30 million |
| | **Human skills** | | | | | | | |
| **7** | Education and workforce development, sector-specific training | Medium | Addresses shortage of skilled engineers and technicians. Builds localized expertise in key regions (south and north-east). | Universities, technical institutes, Ministry of Education, international organizations (UNEP, UNDP, IRENA). | • Develop specialized curricula<br>• Establish certification schemes<br>• Integrate apprenticeships in pilot projects<br>• Facilitate expert exchange programs | Medium term (2–5 years) | Ministry of Education (graduates, certifications issued) Ministry of Energy (training delivered, projects supported) | $20–60 million |
| | **Social and cultural** | | | | | | | |
| **8** | Public engagement in decision-making, ensuring local community support | High | Builds public acceptance and reduces social resistance. | Local governments, developers, NGOs. | • Conduct participatory planning<br>• Promote cooperative ownership<br>• Implement revenue-sharing mechanisms | Ongoing (project lifecycle) | Local authorities (community satisfaction, participation rates) | $5–15 million |
| **9** | Optimization of land and water use | High | Increases trust and understanding of | Ministry of Energy, NGOs, media. | • Showcase successful pilot projects | Short term (1–3 years) | Ministry of Energy, Ecology | $5–20 million |

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| | | | small hydropower benefits. | | • Run national/regional campaigns | | (public awareness surveys) | |
| | **Information** | | | | | | | |
| **10** | Digitalization and planning tools, ensuring access to data from the system operator and grid companies | Medium | Reduces early-stage uncertainty and development costs. | Ministry of Energy, hydrometeorological services. | • Develop open-access database<br>• Provide GIS-based tools | Short–medium term (1–3 years) | Government data agencies (data usage, site identification rates) | $10–30 million |
| **11** | Digitalization and planning tools, water resource mapping, ensuring data access | High | De-risks early-stage investments and validates technical potential. | Government, development partners. | • Fund pre-feasibility studies<br>• Support pilot installations | Short term (1–3 years) | Ministry of Energy, Ecology | $30–80 million |
| | **Technical** | | | | | | | |
| **12** | Modernization of electrical grids to increase capacity | High | Grid constraints are a major bottleneck in remote regions. | Grid operators, Ministry of Energy. | • Upgrade grid infrastructure<br>• Deploy mini/off-grid systems<br>• Introduce tailored interconnection standards | Medium–long term (3–8 years) | Grid operators (connection capacity, reliability metrics) | $300–800 million |
| **13** | Development of transport infrastructure and logistical support | High | Reduces costs and delays in remote mountainous areas. | Developers, Ministry of Energy, Ministry of Infrastructure. | • Use prefabricated systems<br>• Improve roads/bridges<br>• Provide logistics incentives | Medium term (2–5 years) | Ministry of Infrastructure (project completion time, cost reductions) | $100–300 million |

## 1.4 Common barriers and measures in Energy Sector

For the prioritized technologies (Large scale on-grid solar farms (0.1-1 GW), Large-scale on-grid wind farms (0.1–1 GW), Small hydropower (<10 MW) in south and north-east Kazakhstan) the following common barriers and measures could be highlighted (**Table 1.13**):

***Table 1.13*** *Common barriers and measures in Energy Sector*

| Category | Common Barrier | Description of the Barrier | Common Measure |
|---|---|---|---|
| **1. Economic & financial** | 1 High capital costs | Projects face high upfront investment costs combined with limited access to affordable and long-term financing, increasing overall project risk. | Blended public-private financing, development of risk mitigation mechanisms. |
| | 2 Limited access to financing | Domestic financial markets offer limited low-interest loans or project finance instruments for renewable energy. | Strengthening banks' capacity to mobilize "green" loans, concessional financing. |
| **2. Market conditions** | 3 Insufficient demand incentives for "green" electricity | Lack of PPAs (Power Purchase Agreements) for the green energy and undeveloped green energy market. | Introduction of long-term feed-in tariffs to ensure predictable revenue. Financing the development of electrical grid infrastructure. |
| **3. Legal & regulatory** | 4 Lack of clear rules for grid access and connection | Technical and legal requirements and rules for grid connection are underdeveloped. | Simplification of permitting procedures. |
| | 5 Insufficiently developed procedures for land allocation and land use | Legal requirements and rules for land allocation and land use are underdeveloped. | Implement transparent and time-bound permitting procedures |
| **4. Human skills** | 6 Shortage of specialists in renewable energy | Limited availability of engineers and technical specialists in renewable energy. | Invest in education, vocational training, and partnerships with international experts. |
| **5. Social and cultural** | 7 Ambiguous public perception of technology deployment processes | Resistance due to land use conflicts and visual/environmental concerns. | Implement stakeholder engagement strategies and fair land compensation mechanisms. |
| **6. Information** | 8 Lack of data on grid capacity | Limited access to reliable data on grid capacity and market conditions increases uncertainty. | Develop open-access data platforms for grid and market information. |
| | 9 Lack of data on promising sites | Lack of detailed site assessments and resource mapping hinders project planning. | Digitalization and planning tools, water resource mapping, ensuring data access. |

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| **7. Technical** | 10 Outdated grid infrastructure, insufficient capacity | Aging infrastructure and limited grid capacity create bottlenecks for integrating renewables. | Modernize grid infrastructure and expand transmission networks. |
| | 11 Intermittent generation, need for balancing and dispatching of the power system | Variability of solar and wind creates grid stability issues. | Invest in energy storage, grid flexibility solutions, and smart grid technologies. |
| | | | |

Kazakhstan has strong potential for renewable energy development, particularly in large-scale solar and wind, as well as small hydropower. However, deployment is constrained by a combination of financial, regulatory, technical, and institutional barriers. The most critical challenges stem from high upfront investment costs, limited access to affordable financing, and weak revenue certainty, which collectively deter private sector participation (World Bank Group, 2022; UNDP Kazakhstan, 2022).

At the market level, weak demand signals and the geographic mismatch between resource-rich areas and demand centers further complicate project viability. Regulatory inefficiencies, including unclear grid access rules and lengthy permitting procedures, add additional delays and risks. Meanwhile, technical barriers such as aging grid infrastructure, limited capacity, and intermittency issues hinder system integration. (Agora Energiewende, 2023; UNDP, 2018)

Human capacity gaps and insufficient technical expertise reduce the country's ability to plan, implement, and maintain renewable energy systems effectively. Social factors, including public resistance and environmental concerns—especially for hydropower—also play a role in slowing project development. Finally, a lack of transparent data and insufficient feasibility studies increases uncertainty for investors and developers. (Charlery & Trærup, 2019; Dodgson et al., 2009)

Addressing these barriers requires a coordinated approach: strengthening financial mechanisms, improving regulatory clarity, upgrading grid infrastructure, building human capital, and enhancing public engagement. With targeted reforms and investments, Kazakhstan can unlock its renewable energy potential and accelerate its transition toward a more sustainable energy system.

# Chapter 2 Barrier Analysis and Enabling Framework for Urban/Circular Economy Sector

In the initial phase of the TNA project for the Republic of Kazakhstan, a structured multi-criteria decision-making framework was executed to systematically rank and prioritize climate change mitigation technologies within the circular economy sector. Initiated via a comprehensive desk review that identified an expanded baseline of 24 candidate technologies across waste collection/disposal, energy/material recovery, legacy dumpsite rehabilitation, and wastewater treatment domains. Through stakeholder consultation, these technologies were filtered through stakeholder consultations to yield a refined long list of 12 technologies compiled into detailed Technology Fact Sheets (TFS).

These long-listed technologies were subjected to a rigorous Multi-Criteria Analysis (MCA) encompassing 10 discrete sub-criteria to evaluate financial costs, technology diffusion capacity, environmental, economic, and social benefits, climate change mitigation potential and compliance with national policies. Stakeholder feedback was incorporated during the determination of the MCA criteria and the assignment of their respective weights. Following robustness validation through a triad-scenario sensitivity analysis (evaluating economy-focused, environment-focused, and equal-weight stress tests), the evaluation culminated in the prioritization of the top three technologies to advance to the barrier analysis stage:

1. Multi-stream waste separation in urban areas
2. Anaerobic digestion of sewage sludge
3. Sanitary landfills with methane recovery

This chapter presents the Barrier Analysis and Enabling Framework (BAEF) study executed for these three prioritized technologies in the circular economy sector. The assessment adhered to the analytical framework outlined in the TNA Guidebook (UNEP-CCC, 2024) and incorporated the specialized methodologies detailed in the BAEF Guidebook (UDP, 2015), utilizing logical problem analysis ("problem tree" and "solution tree") and "market mapping" tools to systematically diagnose barriers and formulate enabling frameworks. Although the workflow generally followed the standard BAEF sequence depicted in **Figure 1.1** (UNEP-CCC, 2024), a key procedural modification was introduced: the barrier identification and enabler development steps were carried out simultaneously. Consequently, sectoral stakeholders were provided with a comprehensive intermediate document pairing each decomposed constraint with its corresponding enabling measure prior to filling an online questionnaire to screen barriers (Step 2.3). This synchronized approach optimized the evaluation timeline while ensuring stakeholders were thoroughly informed and better equipped to screen and prioritize the targeted barriers.

## 2.1 Multi-Stream Waste Separation in Urban Areas

### 2.1.1 General description and target for Multi-Stream Waste Separation

Multi-Stream Waste Separation involves upgrading the existing dual-stream ("wet" vs. "dry") municipal solid waste collection system in Kazakhstan's urban areas to a more granular scheme at the source, separating waste into five or more distinct categories, including dedicated bins for paper/cardboard, plastics, metals, glass, textiles, food waste and residual waste. This technological shift directly addresses challenges facing the currently employed dual-stream collection scheme, which is mandated

by the 2021 Environmental Code. The primary objective of this technology is to drastically reduce cross-contamination among waste fractions. By ensuring a cleaner, high-quality feedstock for facilities that process and recover recyclable materials and organics, this collection framework significantly enhances recycling yields and supports a circular economy. Currently, existing sorting facilities operate at very low utilization rates due to the poor quality and insufficient quantity of the incoming material stream (Glazyrin et al., 2024; Orazbekov, 2025).

The deployment of this scheme can be an essential mechanism for attaining Kazakhstan's national policy targets across a structured timeline of solid waste collection, sorting, and recycling mandates. Backed by the 2021 "Environmental Code" (Republic of Kazakhstan, 2021), which enforces phased landfill bans on recyclable materials (plastics, paper, glass) and organic/construction waste, strategic planning documents establish clear benchmarks to accelerate a circular economy. In near-term, the "Concept for the Management of All Types of Waste (2026–2030)" (Republic of Kazakhstan, 2025) mandate 100% population waste collection coverage by 2030 and a minimum 10% reduction in municipal landfill disposal volumes. In Mid- to long-term, the country aims for a 40% recycling rate by 2035 under NDC 3.0 (MENR, 2025) and 50% by 2050 under the "Action Plan for the Green Economy (2024–2030)" (Republic of Kazakhstan, 2024). The "Strategy for Achieving Carbon Neutrality by 2060" (Republic of Kazakhstan, 2023) mandates 100% sorting of municipal solid waste (MSW) by 2040 to facilitate circular business models.

To justify the logistical complexities and capitalize on high waste volumes, this technology is suggested to be prioritized for Kazakhstan's major, densely populated urban centers: cities of Astana, Almaty, and Shymkent. In Kazakhstan, Astana, Almaty, and Shymkent are classified as "cities of republican significance," meaning their local administrations (*akimats*) function independently of surrounding provinces (*oblasts*) on the same administrative tier, report directly to the central government, and exercise the powers of both a municipal government and a regional authority. Based on 2025 statistics, the cities of Astana, Almaty, and Shymkent house 25.8% of the total population and generate 33.5% of the total municipal solid waste collected and transferred nationwide (BNS, 2026). In the same year, on average, 83.6% (by weight) of the collected municipal solid waste in these three cities (excluding waste from self-collecting enterprises) was reported to be discarded as unseparated mixed waste (BNS, 2026).

**Preliminary Deployment Target:** To implement and fully scale a 5-to-7 stream municipal solid waste source separation scheme to achieve 100% operational coverage across all residential, public, and commercial sectors in the cities of Astana, Almaty, and Shymkent by **2038**, supported by specialized container networks and dedicated vehicle fleets.

### 2.1.2 Identification of barriers and possible enabling measures for Multi-Stream Waste Separation

The barrier analysis commenced by identifying the core problem: the ineffective implementation of and low public participation in multi-stream waste separation systems within urban municipalities. Structural mapping via problem tree analysis demonstrated that the central bottleneck preventing technology diffusion is fundamentally contingent upon public compliance and behavioral change, rather than factors that can be solved through isolated engineering adjustments or internal administrative fixes (**Figure A2.1** in Annex 2). By inverting these negative states, the solution tree

establishes a framework confirming that purely financial or technological fixes will fail without regulatory and human compliance (**Figure A2.2**).

Based on the BAEF Guidebook methodology (UDP, 2015), this technology was categorized as a Publicly Provided Good (PPG). Although market mapping is conventionally designed for consumer goods (CG) or capital goods (KG), it can be adapted to delineate the broader technology landscape and service delivery chain. For a PPG, the traditional market chain is more accurately described as a service delivery chain, representing how infrastructure is procured, deployed, and utilized by the public (UDP, 2015). Accordingly, a comprehensive market map was constructed to pinpoint systemic vulnerabilities by covering the entire technology landscape across the service delivery chain, enabling environment, and auxiliary support services (**Figure A2.3**). While the collection framework is mostly a publicly managed urban service reliant on municipal allocations and public infrastructure, downstream outputs fully behave as market-driven commodities. Recovered fractions are processed into secondary raw materials and transacted within commercial markets subject to competitive supply-demand dynamics (CG category). Furthermore, modern material recovery facilities (MRFs) and collection fleets frequently involve private ownership models (KG category). Consequently, the deployment path mimics a market-based structure, validating the utility of market mapping for identifying structural bottlenecks. While active participation from citizens and local businesses is critical for effective source separation, the "Primary Producers" citizen group is considered to be the weakest link in the service chain due to a lack of organization and technical awareness.

### 2.1.3 Screening of barriers and possible enabling measures for Multi-Stream Waste Separation

For the screening step, the sectoral TNA working group firstly determined eight main barrier categories for the prioritized mitigation technologies in the circular economy sector: (1) economic & financial, (2) market conditions, (3) legal & regulatory, (4) institutional capacity, (5) human skills, (6) social & behavioral, (7) information & awareness, and (8) technical. Synthesizing information from the national context study executed during the technology prioritization phase, the technical data compiled within the TFS of Multi-Stream Waste Separation, and the structural insights derived from the problem tree, solution tree, and market mapping analyses, a comprehensive longlist of barriers was formulated under eight main categories, as detailed in **Table 2.1**. Concurrently, prospective enabling measures designed to directly neutralize each identified barrier were developed; these are presented in **Table 2.2**, along with measure descriptions and any national policies supporting the respective measure.

To systematically filter and prioritize the comprehensive longlist of constraints and interventions, the circular economy sectoral working group conducted a participatory screening and scoring exercise via an online structured questionnaire. Stakeholders evaluated each barrier's relative severity on technology diffusion using a five-tier qualitative hierarchy (Killer/Non-starter, Crucial, Important, Less important, or Insignificant), while simultaneously assessing the aligned enabling measures using a three-tier priority scale (High, Medium, or Low). These qualitative judgements were subsequently translated into discrete numerical values, assigning ordinal scores from 5 (Killer) to 1 (Insignificant) for barriers, and from 3 (High) to 1 (Low) for enablers. Following the summation of expert responses, a standard linear min-max normalization formula was applied to map the cumulative scores onto a standardized 0–100% relative index. Under this framework, the maximum aggregated score within the dataset was anchored at 100% and the minimum score was scaled to 0%, generating the normalized metrics presented in the rightmost column of the **Table 2.1 and 2.2**.

***Table 2.1*** *Identified Barriers to Multi-Stream Waste Separation.*

| Category | Specific Barrier | Description of the Barrier | Score (%) |
|---|---|---|---|
| **1. Economic & financial** | **High Upfront Capital Expenditure (CAPEX)** | Massive investment required for specialized multi-compartment collection vehicles and thousands of color-coded containers. | 82 |
| | **Artificially Low Waste Tariffs** | Artificially low municipal fees fail to cover basic operational costs (OPEX) for complex multi-stream logistics. | 64 |
| **2. Market conditions** | **Secondary Material Market Weakness** | Lack of mandatory recycled content standards makes recovered materials less competitive than cheaper virgin inputs. | 100 |
| | **Price Control / Power Imbalance** | A limited number of large industrial end-users can exert dominance to suppress the purchase prices of recovered plastic, paper, and glass. | 36 |
| | **Geographic Concentration** | Waste processing/recycling infrastructure is heavily centralized in Almaty, Astana and Shymkent, making the transport of low-value recyclables from remote regions economically unviable. | 27 |
| **3. Legal & regulatory** | **Weak Enforcement of Mandates** | Inadequate municipal inspection capacity and low financial penalties that fail to deter citizens from mixing waste streams. | 55 |
| **4. Institutional capacity** | **Digital Accounting/Monitoring Gaps** | Lack of real-time digital frameworks and IoT sensors to track waste flows and verify compliance across the service chain. | 55 |
| **5. Human skills** | **Lack of Specialized Technical Personnel** | Shortage of skilled workers trained in advanced sorting techniques and the maintenance of modern, compartmentalized vehicles. | 36 |
| **6. Social / Behavioral** | **Ingrained Disposal Habits** | Deep-seated public apathy and a long-standing habit of disposing of all waste in a single mixed stream. | 91 |
| **7. Information & awareness** | **Technical Awareness Deficit** | Lack of public understanding regarding specific technical protocols for 5–7 waste streams and the impact of cross-contamination on the success of sorting. | 64 |
| **8. Technical** | **Climatic Vulnerability** | Severe continental winter fluctuations in Kazakhstan can negatively impact mechanical sorting equipment and biological treatment of organics. | 18 |
| | **Urban Space/Architectural Constraints** | Dense residential layouts and narrow streets lack the physical footprint to accommodate 5-7 separate receptacles per site. | 0 |

***Table 2.2*** *Suggested measures grouped with the barriers to Multi-Stream Waste Separation.*

| Category | Specific Barrier | Description of the Possible Measure | Score (%) |
|---|---|---|---|
| **1. Economic & financial** | **High Upfront Capital Expenditure (CAPEX)** | Provide low-interest loans for the procurement of specialized vehicles and containers.<br>**National Policy:** The '*Zhasyl Damu*' has established a 3% preferential financing program through the Industrial Development Fund using EPR fees. The Ministry of Ecology and Natural Resources has allocated approximately USD 450 million for waste infrastructure for 2024–2030. | 100 |

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| | **Artificially Low Waste Tariffs** | Transition toward "Pay-As-You-Throw" (PAYT) systems to reward recycling and cover operational expenditures.<br>**National Policy:** Improving tariff structures is identified as a necessary step for financial sustainability by the recently adopted the "Concept for the Management of All Types of Waste 2026–2030", which proposes implementation of economically justified utility tariffs indexed to inflation every three years to attract private investment. | 60 |
| **2. Market conditions** | **Secondary Material Market Weakness** | Introduce mandatory recycled content usage standards for manufactured goods to increase the demand for secondary raw materials.<br>**National Policy:** The EcoQoldau program provides direct compensation to enterprises collecting and processing recyclable materials. | 60 |
| | **Price Control / Power Imbalance** | Diversifying the pool of industrial consumer base and supporting recycling SMEs limits the market dominance of large manufacturers, preventing monopolistic price-setting and market manipulation. | 100 |
| | **Geographic Concentration** | Establish regional waste hubs and secondary sorting facilities to reduce transport distances for low-value recyclables. | 40 |
| **3. Legal & regulatory** | **Weak Enforcement of Mandates** | Strengthen municipal inspection capacity and increase financial penalties for non-compliance with source-separation rules.<br>**National Policy:** The 2021 Environmental Code already prohibits landfilling recyclables (like paper, plastic, and glass) and organics. | 80 |
| **4. Institutional capacity** | **Digital Monitoring Gaps** | Deploy GPS tracking and IoT sensors for real-time monitoring of waste flows and fleet logistics.<br>**National Policy:** Implementation is driven by digitalization mandates from the recently established National Waste Management Centre. | 20 |
| **5. Human skills** | **Lack of Specialized Technical Personnel** | Implement vocational training and technical assistance for facility operators and maintenance crews. | 0 |
| **6. Social / Behavioral** | **Ingrained Disposal Habits** | Implement sustained, high-impact media campaigns and school-based outreach to foster consistent source-separation habits adults and school children.<br>**National Policy:** Behavioral change is a core objective of the national transition to a circular economy. | 80 |
| **7. Information & awareness** | **Technical Awareness Deficit** | Provide technical education to households and businesses regarding correct sorting protocols to reduce cross-contamination. | 100 |
| **8. Technical** | **Climatic Vulnerability** | Invest in climate-resilient specialized infrastructure, such as insulated compartmentalized trucks and sheltered bin sites. | 20 |
| | **Urban Space / Architectural Constraints** | Integrate space-optimized smart-bin systems and mandate recycling areas in new residential urban layouts.<br>**National Policy:** Regulations mandate multi-stream receptacles in new building and residential designs. | 80 |

### 2.1.4 Classification of barriers for Multi-Stream Waste Separation

The long list of barriers was screened to isolate the most critical constraints obstructing technology implementation and diffusion in Kazakhstan. Barriers scoring below 50% were classified as non-essential or minor obstacles, as they do not fundamentally halt the national deployment strategy. The remaining high-scoring barriers were listed below under two categories.

#### *2.1.4.1 Economic and financial barriers*

Economic and financial constraints present a severe structural bottleneck to scaling up source-segregated waste management systems.

- **High Upfront Capital Expenditure (Score: 82%):** Designated as a "Killer" barrier, the high upfront capital expenditure for specialized multi-compartment vehicles and durable, color-coded receptacles exceeds the budgetary capacity of regional municipalities, necessitating access to preferential financing or dedicated state infrastructure funds.
- **Artificially Low Waste Tariffs (64%):** Multi-stream logistics are inherently more capital and labor-intensive than mixed waste collection due to compartmentalized routing, higher collection frequencies, and increased container maintenance. Current utility tariffs, suppressed at USD 0.60–1.50 per citizen monthly will absolutely fail to reflect the true economic cost of multi-stream logistics. This systemic OPEX deficit prevents cost recovery, undermining the financial self-sufficiency of waste utilities and deterring private sector investment.

#### *2.1.4.2 Non-financial barriers*

The non-financial barriers represent deeply interconnected social, market, regulatory, and institutional bottlenecks that require targeted policy interventions and structural transformation.

- **Secondary Material Market Weakness (100%):** The lack of mandatory recycled content standards renders recovered materials uncompetitive against virgin inputs, undermining the entire supply chain's economic viability.
- **Ingrained Disposal Habits (91%):** Decades of reliance on unsegregated disposal systems have institutionalized public apathy, making the transition to source-separation physically and behaviorally difficult.
- **Technical Awareness Deficit (64%):** A lack of precise sorting knowledge among citizens leads to significant cross-contamination at the source, which degrades feedstock quality and reduces MRF processing efficiency.
- **Weak Enforcement of Mandates (55%):** Limited municipal inspection capacity and negligible administrative fines for non-compliance render landfill bans ineffective, keeping participation strictly voluntary.
- **Digital Accounting and Monitoring Gaps (55%):** The lack of integrated digital tracking systems prevents transparent volume accounting, hindering performance verification and effective oversight of waste management operations.

### 2.1.5 Measures for Multi-Stream Waste Separation

To ensure the successful diffusion of multi-stream waste separation across Kazakhstan's designated urban centers (Astana, Almaty, and Shymkent), the preliminary list of enabling options was evaluated and prioritized based on stakeholder feedback and normalized scoring. Measures corresponding to minor barriers that scored below the 50% threshold during the barrier screening phase were eliminated.

#### *2.1.5.1 Economic and financial measures*

To resolve the critical financial bottlenecks that act as non-starters for municipal waste utilities, the enabling framework establishes two precise economic instruments aimed at covering capital expenditures and ongoing operating expenditures.

- **Subsidized Capital Financing and Preferential Loans (100%):** This measure deploys a USD 450 million public capital allocation for the 2024–2030 fiscal period through the state operator "Zhasyl Damu," offering 3% preferential loans via the Industrial Development Fund. Derived from Extended Producer Responsibility (EPR) fees, these funds are strictly prioritized to finance the procurement of specialized multi-compartment collection vehicles and color-coded source containers for dense residential sectors.
- **Variable Tariff Restructuring and Inflation Indexation (60%):** This intervention phases out the suppressed flat-rate collection fees in favor of a "Pay-As-You-Throw" (PAYT) variable pricing model, which charges households based on residual waste volumes while keeping sorted streams free. In alignment with the "Concept for the Management of All Types of Waste 2026–2030," tariffs will be legally indexed to national inflation cycles every three years to guarantee full cost recovery for multi-stream logistics and incentivize private sector investment.

#### *2.1.5.2 Non-financial measures*

The non-financial enabling architecture addresses regulatory gaps, market imbalances, public awareness deficits, and behavioral resistance through institutional adjustments and legislative enforcement.

- **Mandatory Industrial Recycled Content Standards and Performance Subsidies (60%):** This measure introduces minimum recycled content mandates for manufacturers and utilizes the EcoQoldau program to provide tonnage-based financial compensation to recyclers. To diversifying the industrial consumer base, supporting recycling SMEs should be prioritized.
- **Administrative Enforcement Reform and Enhanced Municipal Inspectorates (80%):** Local *akimats* will expand environmental inspectorates and increase administrative fines to enforce the 2021 Environmental Code's landfill bans on recyclables and organics. Regular multi-point audits of collection sites will transform voluntary separation into an obligatory municipal standard.
- **Sustained Mass Media Campaigns and Circular Curricula (80%):** The state will fund permanent public media campaigns across national television, digital channels, and mobile networks to normalize daily sorting routines. Concurrently, the Ministry of Education will embed practical circular economy and source-separation protocols into primary school curricula.
- **Targeted Technical Sorting Education and Contamination Protocols (100%):** Local *akimats* and waste operators will distribute neighborhood-level granular sorting instructions, such as packaging rinsing and resin code identification. This targeted education addresses the contamination bottleneck at the source to preserve feedstock value for MRFs.
- **Space-Optimized Smart-Bin Systems and New Residential Layout Mandates (80%):** To proactively prevent urban density bottlenecks, this measure mandates space-optimized smart-bin systems in high-density sectors. Additionally, new construction regulations will require dedicated, built-in multi-stream recycling areas in all upcoming residential urban layouts in Astana, Almaty, and Shymkent. Note that although the barrier corresponding to this measure was previously eliminated, the measure itself has been retained due to its high stakeholder score and specific stakeholder feedback.

### 2.1.6 Grouping complementary measures for Multi-Stream Waste Separation

In most cases, individual enabling measures cannot successfully accelerate technology diffusion if executed in isolation, which is even more relevant in the case of multi-stream waste separation. Establishing a source-separated, multi-stream source separation framework is highly complex; beyond overcoming technical and financial barriers, its success relies heavily on public awareness and active participation. To address this, the seven prioritized enabling measures have been organized into three cross-cutting strategic packages (programs) to form a cohesive framework addressing hardware (specialized vehicles, containers, smart bins), software (technical know-how, public sorting protocols), and orgware (tariffs, legislative mandates, institutional enforcement mechanisms) components:

- **Program 1.) Integrated Municipal Waste Financing and Tariff Reform Framework (Financial & Economic Package):** This package directly pairs *Subsidized Capital Financing and Preferential Loans (Score: 100%)* with *Variable Tariff Restructuring and Inflation Indexation (60%)*. It links the state infrastructure allocation (3% preferential loans via Zhasyl Damu) to cover upfront CAPEX with volume-based Pay-As-You-Throw (PAYT) utility pricing and a mandatory three-year inflation indexation loop. This synchronization guarantees full OPEX cost recovery for complex multi-stream logistics, secures the long-term self-sufficiency of public investments, and mitigates risks for private public-private partnership (PPP) concessionaires. Ultimately, this program focuses on operationalizing existing statutory regulations and fully utilizing established state funding mechanisms rather than creating new legislative infrastructure.

  A counterfactual alternative to this proposed program is employing a purely market-driven approach relying on private sector equity and punitive landfill taxes. In that case, the state would withhold the concessional loan facility, forcing private operators to fully self-finance sorting infrastructure to evade disposal penalties. However, given the baseline of heavily suppressed municipal tariffs, forcing private entities to absorb high upfront capital expenditures without state backing would most likely trigger an operational collapse of waste collection services, particularly in lower-income regions.

- **Program 2.) Regulatory Enforcement and Circular Market Pull Optimization Program (Institutional & Regulatory Package):** This program combines *Administrative Enforcement Reform and Enhanced Municipal Inspectorates (80%)*, *Mandatory Industrial Recycled Content Standards and Performance Subsidies (60%)*, and *Space-Optimized Smart-Bin Systems and New Residential Layout Mandates (80%)*. It expands regional inspection budgets to strictly enforce the 2021 Environmental Code landfill bans, utilizing smart-bin systems and spatial building codes to prevent urban density bottlenecks. To absorb the recovered waste, mandatory industrial recycling thresholds force off-take demand, directly supported by EcoQoldau performance subsidies to bridge the price gap with virgin feedstock and stabilize the domestic secondary market. The transformation shall be mandated in stages; first, public buildings, campuses, educational institutions, hospitals, airports, commercial buildings, and organized industrial zones will switch to the multi-stream in the cities of Astana, Almaty and Shymkent before residential buildings in these cities. This proposed phased framework, which targets highly controlled institutional and commercial zones first, secures a reliable, high-purity initial volume of feedstock, allowing MRFs to steadily scale up operational capacities before absorbing the complex logistical demands of the residential sector.

The alternatives to this program's approach include a purely voluntary incentive scheme and a simultaneous blanket nationwide rollout. However, it is considered that a voluntary mechanism would fail to overcome deep-seated civic apathy, while an immediate nationwide implementation would instantly overwhelm the collection services and sorting facilities.

- **Program 3.) Socio-behavioral Transformation and Source-Purity Education Campaign (Social & Informational Package):** This human-centric package integrates *Sustained Mass Media Campaigns and Circular Curricula (80%)* with *Targeted Technical Sorting Education and Contamination Protocols (100%)*. It coordinates broad cultural conditioning by utilizing national mass media and school textbooks to eliminate civic apathy. This program will run in parallel with Program 2, initiating the gradual adaptation of new sorting habits within schools and workplaces. Citizen commitment to source separation will strengthen as individuals witness the reliable utilization of sorted waste, confirming that their efforts result in genuine recycling rather than disposal in mixed-waste landfills. Consequently, these enablers are aimed to transform public behavior into a reliable sorting mechanism, delivering low-contamination, high-purity feedstock to minimize downstream operational processing costs at MRFs.

### 2.1.7 Assessment of measures for inclusion in the TAP

The prioritized programs for Multi-Stream Waste Separation technology have been assessed to determine their viability for inclusion in the Technology Action Plan (TAP) and described below (**Table 2.3**).

***Program 1: Integrated Municipal Waste Financing and Tariff Reform Framework***

- **Impact:** Eliminates financial bottlenecks by mobilizing public capital for immediate infrastructure acquisition and transitioning to volume-based utility fees to erase persistent operational deficits. A predictable three-year inflation indexation framework provides long-term commercial visibility, successfully attracting private concessionaires into public-private partnership (PPP) frameworks.
- **Societal Benefits:** Replaces flat-rate pricing with a progressive, variable system that enhances social equity by directly lowering service bills for citizens who minimize waste. It establishes a financially self-sufficient waste sector that reduces the fiscal burden on regional municipal budgets, freeing public funds for primary social services.
- **Cost:** Initial capital requirements are prohibitively high but features low long-term operational costs as ongoing OPEX can be fully shifted to the waste producers through volume-based charges.
- **Feasibility:** High, as the program utilizes existing financial pathways like the 3% preferential loan mechanism managed by the Industrial Development Fund using Extended Producer Responsibility (EPR) funds held by JSC Zhasyl Damu. The main regulatory hurdle involves the passing of municipal tariff resolutions by regional legislative bodies (*maslikhats*), which is fully supported by the strategic mandates of the Concept for the Management of All Types of Waste 2026–2030.

***Program 2: Regulatory Enforcement and Circular Market Pull Optimization Program***

- **Impact:** Drives waste value chain efficiency by expanding municipal inspectorate capacity to prevent illegal waste diversion, thereby securing steady feedstock for MRFs. Simultaneously, mandatory industrial recycled content standards create reliable domestic off-take demand for

processed polymers, paper, and glass, while space-optimized smart bins provide the physical infrastructure necessary to comply with these rules.

- **Societal Benefits:** Eliminates illegal dumping to reduce spontaneous landfill fires and protect urban groundwater tables from toxic contamination. The optimization of secondary raw material markets drives domestic industrial modernization, creating safe, formal green tech employment.
- **Cost:** Moderate administrative setup and enforcement costs, requiring targeted budget allocations for municipal inspection staff and smart monitoring infrastructure, which are directly balanced by the operational design of the EcoQoldau program that provides performance subsidies directly to recycling enterprises to offset sorting costs.
- **Feasibility:** Moderate to high, supported by the statutory landfill bans of the 2021 Environmental Code. Success depends on inter-agency coordination between regional municipal administrations (*akimats*) and national environmental enforcement bodies, though stakeholder feedback confirms that space-optimized smart bins effectively prevent high urban density from stalling long-term enforcement goals.

***Program 3: Socio-Behavioral Transformation and Source-Purity Education Campaign***

- **Impact:** Targets the root causes of public resistance, transforming household disposal routines to provide low-contamination, high-purity feedstock. Sustained media campaigns establish source separation as a daily civic routine, while targeted neighborhood education minimizes cross-contamination at the source to maximize downstream processing efficiency and preserve secondary material value at MRFs.
- **Societal Benefits:** Integrates circular economy principles into primary education curricula to foster an institutional culture of ecological responsibility among younger generations, building strong community ownership over local environmental conditions.
- **Cost:** Low financial requirements restricted to public mass media allocations, digital outreach campaigns, and the modification of educational materials by the Ministry of Education, requiring minimal capital infrastructure outlays.
- **Feasibility:** Exceptionally high, as public information campaigns and educational updates fall within the standard operational mandates of the Ministry of Education and regional *akimat* press offices. These initiatives require no complex structural or legislative overhauls and can be deployed rapidly to prepare urban populations for incoming infrastructure upgrades.

***Table 2.3*** *Summary Assessment Matrix for TAP Inclusion: Multi-Stream Waste Separation*

| Program | Strategic Focus | Estimated Cost | Implementation Feasibility | Recommended TAP Action |
|---|---|---|---|---|
| **Program 1:** Financing and Tariff Reform | Hardware & Orgware Sustainability; Concessional Capital Mobilization | **CAPEX:** €57.5M<br>**OPEX:** €83.5M·year$^{-1}$ | **High** (Utilizes IDF & EPR pathways for CAPEX; and PAYT tariffs cover OPEX) ***Total amortized unit cost*:*** €44.4 ·t$^{-1}$(20-year lifetime) | Include as Core Financial and Infrastructure Action to eliminate upfront capital bottlenecks. |
| **Program 2:** Enforcement & Market Pull | Supply Chain Stabilization, Telematics Orgware, and | **CAPEX:** €1.98M<br>**OPEX:** €1.32M·year$^{-1}$ | **Moderate-High** (Requires *Akimat* coordination) | Include as Core Regulatory Action to secure steady feedstock. |

| | | | | |
|---|---|---|---|---|
| | Value Chain Optimization | | ***Total amortized unit cost:*** €1.70 $\cdot t^{-1}$ (20-year lifetime) | |
| **Program 3:** Behavioral Transformation | Software, Public Awareness, Staff Training & Source Purity | **CAPEX:** €5.5M<br><br>**OPEX:** €0.88M$\cdot year^{-1}$ (€0.45 $\cdot t^{-1}$) | **Very High** (Operationalize existing mandates) | Include as Immediate Support Action to rapidly prepare urban populations. |

**Methodology of Cost Estimations:** The multi-stream waste separation framework across Astana, Almaty, and Shymkent is evaluated using a parametric cost model based on a footprint of 5.32 million citizens generating 1.0 kg$\cdot capita^{-1} \cdot day^{-1}$ of municipal waste. Capital procurement under Program 1 targets 110,000 new specialized containers and 200 new multi-stream collection vehicles. Capital and operational outlays for Program 2 scale according to unit-based telemetry deployment and connectivity fees for 1,250 vehicle transponders and 20,000 smart-bin node sensors, combined with dedicated payroll for 60 environmental inspectors. Finally, Program 3 incorporates standalone capital and operating budgets for public mass media campaigns, collection point auditing, and school curricula updates to minimize downstream contamination.

## 2.2 Anaerobic Digestion of Sewage Sludge

### 2.2.1 General description and target for Anaerobic Digestion of Sewage Sludge

Anaerobic Digestion (AD) of sewage sludge optimizes wastewater utility circularity by transforming putrescible organic residuals into high-purity biogas and stabilized digestate. This technology serves as a cornerstone for fulfilling Kazakhstan's strategic climate milestones, including the 17% greenhouse gas emission reduction commitment by 2035 under the updated Nationally Determined Contributions (MENR, 2025) and the net-zero pathway outlined in the Strategy for Achieving Carbon Neutrality by 2060 (Republic of Kazakhstan, 2023). Furthermore, it supports the Concept for the Transition to a Green Economy, which mandates 100% urban wastewater treatment coverage by 2030 (Republic of Kazakhstan, 2013). Additionally, Kazakhstan aims to increase the treatment of anthropogenic wastewater to 45% by 2030, 65% by 2040, and achieve 100% treatment by 2050 (Republic of Kazakhstan, 2024).

Nationwide, the government is systematically upgrading wastewater treatment infrastructure through the ongoing WWTP Modernization Program, which targets the upgrade of 68 facilities (EBRD, 2025). Shymkent WWTP is operating the country's only AD unit, generating 4.38 GWh of electricity and 7.35 GWh of heat annually, and new large-scale projects involving biogas production via AD systems are underway in cities like Karaganda and Aktobe.

Almaty and Astana represent the highest potential for immediate AD replication, significantly outperforming Shymkent (flow rate =43 million $m^3 \cdot year^{-1}$) due to their highly centralized infrastructure. Based on 2025 statistics, Almaty City processes wastewater through a single biological treatment facility with a flow rate of 154 million $m^3 \cdot year^{-1}$, while Astana City is also served by a single biological treatment facility with a flow rate of 119 million $m^3 \cdot year^{-1}$ (BNS, 2026). Unlike regions where

wastewater is fragmented across numerous small, inefficient plants, these two large WWTPs offer the economies of scale necessary to maximize methane recovery and justify intensive capital investment.

**Preliminary Deployment Target:** Installation of high-efficiency Anaerobic Digestion systems (Estimated sewage sludge generation =23.9 kt dry solid·year$^{-1}$ for Almaty; 18.4 kt dry solid·year$^{-1}$ for Astana) equipped with biogas capture and Combined Heat and Power (CHP) units (installed electricity generation capacity =3.30 MW for Almaty; 2.55 MW for Astana) at the municipal wastewater treatment plants in Almaty City and Astana City by **2035**. This strategy aims to leverage the centralization of these facilities to expand upon the Shymkent baseline, supported by localized technical capacity building and modernized digestate quality certification networks.

### 2.2.2 Identification of barriers and possible enabling measures for Anaerobic Digestion of Sewage Sludge

The structural analysis of the technology reveals that the critically low deployment rate of this technology is driven by a compounding mix of heavy financial burdens, climatic vulnerabilities, and missing commercial regulations (**Figure A2.4**). The problem tree highlights that high upfront capital expenditures (CAPEX) are exacerbated by artificially low utility tariffs and extreme winter temperatures that threaten biological reactor stability. Furthermore, because AD functions as a Publicly Provided Good within a municipal service chain, the market mapping (**Figure A2.6**) isolates two fundamental bottlenecks preventing financial self-sufficiency: the lack of technical codes for supplying biogas-generated electricity from WWTP to the energy grid (weakening the utility-to-grid link) and the lack of national quality standards to certify digestate as an agricultural fertilizer (breaking the sludge-to-agribusiness link). Consequently, the solution tree (**Figure A2.5**) demonstrates that merely mobilizing preferential capital financing is insufficient; it must be coupled with the establishment of clear regulatory frameworks that allow operators to monetize biogas and digestate byproducts, ultimately transforming municipal wastewater plants from energy-intensive cost centers into resilient renewable energy hubs.

### 2.2.3 Screening of barriers and possible enabling measures for Anaerobic Digestion of Sewage Sludge

The long list of identified barriers and corresponding enabling measures were given in **Table 2.4** and **Table 2.5**, respectively, along with their scores (*see* **2.1.3** for scoring methodology).

***Table 2.4*** *Identified Barriers to Anaerobic Digestion of Sewage Sludge.*

| Category | Specific Barrier | Description of the Barrier | Score (%) |
|---|---|---|---|
| **1. Economic & financial** | **High Upfront Capital Expenditure (CAPEX)** | Massive initial investment is needed for digesters, gas storage, and combined heat and power (CHP) units. | 89 |
| | **Long Payback Periods** | Low municipal wastewater treatment tariffs and low energy prices and a lack of specific green power (electricity and heat) feed-in tariffs make the return on investment (ROI) slow for municipal operators. | 33 |
| **2. Market conditions** | **Lack of Fertilizer Market Standards** | Lack of mandatory quality standards prevents the sale of digestate as certified organic fertilizer to the agricultural sector. | 89 |

| | | | |
|---|---|---|---|
| **3. Legal & regulatory** | **Grid-connection Constraints** | Regulatory uncertainty regarding supplying biogas-generated electricity into the national electricity grid. | 56 |
| **4. Institutional capacity** | **Weak Inter-agency Coordination** | Fragmented oversight between municipal water utilities (*Vodokanals*), ministries, and environmental agencies. | 78 |
| **5. Human skills** | **Specialized O&M Gap** | Shortage of local technical personnel trained in the complex biological management of anaerobic reactors and biogas safety. | 11 |
| **6. Social / Behavioral** | **None** | - - | - - |
| **7. Information & awareness** | **Limited Performance Data** | Lack of local reference projects and performance data for AD technology operating in extreme cold climates of the Northern Kazakhstan. | 56 |
| **8. Technical** | **Severe Climatic Sensitivity** | Harsh continental winters can freeze pipes and significantly reduce the efficiency of biological methane production. The infrastructure must be heavily insulated and climate controlled. | 0 |
| | **Poor State of Existing WWTPs** | Many existing treatment plants are too old or mechanically decrepit to integrate modern AD technology without total reconstruction. | 100 |

***Table 2.5*** *Suggested measures grouped with the barriers to Anaerobic Digestion of Sewage Sludge.*

| Category | Specific Barrier | Description of the Possible Measure | **Score (%)** |
|---|---|---|---|
| **1. Economic & financial** | **High Upfront Capital Expenditure (CAPEX)** | Leverage government-backed preferential financing to mitigate high initial costs. **Government Program:** Modernization of wastewater infrastructure is primarily driven by the 2019 WWTPs Modernization Program, which aims to upgrade 68 facilities nationwide. Funding is channeled through this program and often involves international financial institutions such as the EBRD, which recently provided $105 million for sludge treatment and biogas recovery projects in Aktobe. | 88 |
| | **Long Payback Periods** | Increase municipal wastewater treatment tariffs and implement guaranteed feed-in tariffs for biogas-generated electricity and heat to ensure long-term profitability. | 88 |
| **2. Market conditions** | **Lack of Fertilizer Market Standards** | Develop and adopt national quality specifications and mandatory standards for the use of digestate in agriculture. **National Policy:** The government aims to transition toward a circular economy by mandating the use of recovered materials. | 50 |
| **3. Legal & regulatory** | **Grid-connection Constraints** | Establish clear regulatory frameworks and technical codes for supplying biogas-generated electricity from a WWTP into national electricity grid. | 100 |
| **4. Institutional capacity** | **Weak Inter-agency Coordination** | Create a joint commission to oversee anaerobic digester projects and facilitate coordination between municipal water utilities and relevant ministries (e.g., Water Resources, Energy, and Ecology). This body will resolve policy conflicts, such as aligning sludge reduction goals with national renewable energy targets, and streamline procurement mechanisms for biogas and biogas-generated heat and electricity. | 38 |
| **5. Human skills** | **Specialized O&M Gap** | Establish specialized vocational training programs for the technical management and safety of anaerobic reactors. | 0 |
| **6. Social / behavioral** | **None** | - - | - - |
| **7. Information & awareness** | **Limited Performance Data** | Launch R&D initiatives and pilot projects to gather data on AD performance in Kazakhstan's climate in the Northern Regions. | 38 |
| **8. Technical** | **Severe Climatic Sensitivity** | Mandate high-efficiency insulation and climate-control standards for all new anaerobic digestion infrastructure. | 38 |
| | **Poor State of Existing WWTPs** | Integrate AD technology into a broader national program for the modernization of municipal wastewater treatment plants. | 63 |

### 2.2.4 Classification of barriers for Anaerobic Digestion of Sewage Sludge

The barriers deemed significant were classified into financial and non-financial categories below (see **2.1.4** for screening methodology).

#### *2.2.4.1 Economic and financial barriers*

Economic constraints present a major hurdle for municipal water utilities (*Vodokanals*) attempting to transition from conventional sludge drying to advanced biological energy recovery.

- **High Upfront Capital Expenditure (CAPEX) (Score: 89%):** Implementing modern hermetically sealed digesters, biogas storage infrastructure, and CHP units require massive initial public investments that far exceed current municipal budget capacities.

#### *2.2.4.2 Non-financial barriers*

The non-financial barriers represent a complex web of outdated physical infrastructure, missing commercial regulations, and fragmented institutional oversight that paralyze project development.

- **Poor State of Existing WWTPs (100%):** The vast majority of legacy municipal wastewater treatment plants are mechanically decrepit and require complete baseline reconstruction before advanced anaerobic technologies can be safely integrated.
- **Lack of Fertilizer Market Standards (89%):** A lack of mandatory national agricultural quality standards prevents municipal operators from legally certifying and selling the nutrient-rich digestate by-product, cutting off a vital revenue stream.
- **Weak Inter-agency Coordination (78%):** Systemic fragmentation and poor communication between municipal water utilities, environmental regulators, and national energy ministries severely delay complex project approvals.
- **Grid-connection Constraints (56%):** The lack of clear regulatory codes and commercial mechanisms hinders supplying green electricity produced from sewage sludge-derived biogas into national power grid.
- **Limited Performance Data (56%):** A critical shortage of local reference projects successfully operating in the extreme cold climates of Northern Kazakhstan creates technical uncertainty and deters institutional backing.

### 2.2.5 Measures for Anaerobic Digestion of Sewage Sludge

#### *2.2.5.1 Economic and financial measures*

- **Preferential Infrastructure Financing (Score: 88%):** Leverage government-backed, low-interest capital through the "WWTPs Modernization Program" and international financial institutions (e.g., EBRD) to offset the high CAPEX of modern digesters and CHP units.
- **Feed-in Tariffs and Tariff Reform (88%):** Increase municipal wastewater treatment tariffs and implement guaranteed feed-in tariffs for biogas-generated energy to shorten project payback periods and attract private operators.

#### *2.2.5.2 Non-financial measures*

- **Regulatory Framework for Supplying the Electricity Grid (100%):** Establish standardized technical codes for supplying biogas-generated electricity into national electricity grids. While the country's regulatory framework formally recognizes biogas as a renewable energy source (RES) and contains legal mechanisms to facilitate its integration into the unified electric power system, actual field injection most likely requires the WWTP administration to complete licensing procedures and register formally as an RES producer. Alternatively, a more practical operational approach is utilizing all generated electricity directly on-site within the WWTP; although this configuration does not generate external commercial revenue, it achieves significant operational cost reductions through internal energy savings.

- **National Fertilizer Certification Standards (50%):** Develop and adopt mandatory quality specifications to certify nutrient-rich digestate as an accredited agricultural biofertilizer, opening a commercial revenue stream.
- I**ntegrated WWTP Modernization Program (63%):** Integrate AD technology as a prioritized component within the broader national program for upgrading mechanically decrepit municipal wastewater treatment plants serving large urban centers (population >200,000). AD implementation is reserved for the large-scale facilities, where the organic loading and operational capacity are sufficient to ensure economic and technical feasibility of this technology.
- **Public and Institutional Awareness Campaign (Added via Stakeholder Feedback):** Launch dedicated outreach initiatives to demonstrate the safety and circular economy benefits of sewage sludge digestion to governing bodies and the general public, building the necessary social license for infrastructure siting.

### 2.2.6 Grouping complementary measures for Anaerobic Digestion of Sewage Sludge

The identified enabling measures for anaerobic digestion have been consolidated into two synergistic programs. These programs ensure that infrastructure deployment is supported by both the necessary regulatory "orgware" and commercial "software," preventing the risk of isolated measures (such as building hardware without the legal ability to sell energy or fertilizer).

**Program 1.) Infrastructure Modernization and Financial Sustainability Framework (Economic & Technical Package):** This program creates the physical and economic foundation for AD by linking capital intensive asset renewal with guaranteed operational revenue streams. It integrates the following complementary measures: Preferential Infrastructure Financing (Score: 88%), Feed-in Tariffs and Tariff Reform (88%), and Integrated WWTP Modernization Program (63%). By packaging the modernization of aging WWTP assets with low-interest preferential financing, this program lowers the prohibitive upfront capital barrier. Crucially, it links these long-term investments to a viable operational revenue model. The introduction of guaranteed feed-in tariffs for biogas-derived electricity and heat ensures that water utilities (*Vodokanals*) can bridge the gap between high operational maintenance costs and current suppressed service tariffs, converting them from electricity consumers into renewable energy producers.

**Program 2.) Regulatory Standardization and Market-Pull Framework (Institutional & Regulatory Package):** This program addresses the institutional and market-related barriers that currently restrict the commercialization of biogas and digestate. It combines the following measures: Regulatory Framework for WWTPs to supply energy to the grid (100%), National Fertilizer Certification Standards (50%) and Public and Institutional Awareness Campaign (Added via Feedback). Even if AD infrastructure is deployed, it cannot achieve financial self-sufficiency or climate mitigation goals if the byproducts are treated as waste rather than commodities This package removes legal and market "lock-in" by establishing standardized grid connection codes to monetize electricity production, while fertilizer certification unlocks agricultural value chains to provide essential secondary revenue. Furthermore, the inclusion of dedicated awareness campaigns secures the "social license to operate" by demonstrating the technology’s circular economy and public health benefits. Ultimately, this approach bridges the gap between hardware deployment and the development of resilient commercial markets for AD outputs.

### 2.2.7 Assessment of measures for inclusion in the TAP

The prioritized programs have been assessed to determine their viability for inclusion in the Technology Action Plan (TAP) (**Table 2.6**). This evaluation weighs the technical mitigation potential against the socioeconomic and institutional requirements for successful scaling in Kazakhstan's municipal wastewater sector.

***Program 1: Infrastructure Modernization and Financial Sustainability Framework***

This program addresses the capital-intensive nature of AD by bundling infrastructure upgrades with sustainable revenue mechanisms.

- **Impact:** This program provides the necessary hardware (digesters, CHP units) and fiscal conditions (feed-in tariffs) to transition wastewater plants from energy-consumers to renewable-energy producers. It directly mitigates methane emissions from sludge beds while significantly offsetting the grid-electricity procurement costs of municipal *Vodokanals*.
- **Societal Benefits:** Enhances public health by eliminating odor and groundwater contamination associated with raw sludge storage, while simultaneously improving the energy resilience of critical municipal infrastructure.
- **Cost:** High initial CAPEX is required, though this is mitigated through international concessional financing (e.g., EBRD) and national modernization funds. The long-term profitability is supported by feed-in tariffs, reducing the fiscal burden on the state over the asset lifecycle.
- **Feasibility:** High, as this aligns with ongoing national mandates for wastewater treatment modernization (e.g., "Wastewater Treatment Plants Reconstruction and Construction Program" backed by ADB and EBRD). The successful deployment in cities like Shymkent serves as a proven pilot for nationwide replication.

***Program 2: Regulatory Standardization and Market-Pull Framework***

This program focuses on creating the commercial "orgware" necessary to monetize AD by-products and ensure consistent project delivery.

- **Impact:** By removing regulatory uncertainty regarding grid injection and digestate certification, this program unlocks the commercial value of biogas and organic fertilizers. This stabilizes the business case for operators, ensuring that investments are backed by predictable legal frameworks for energy and resource sales.
- **Societal Benefits:** Promotes a circular economy by returning essential nutrients (phosphorus, nitrogen) to agricultural soils, thereby supporting regional food security and reducing reliance on synthetic, carbon-intensive fertilizers.
- **Cost:** Low-to-moderate administrative costs primarily associated with establishing technical standards, legal frameworks, and national certification schemes.
- **Feasibility:** Moderate. While establishing technical codes for grid injection and fertilizer standards requires significant cross-ministerial coordination (Water, Energy, and Agriculture), these are standard regulatory tasks that can be integrated into the ongoing 2026–2030 Waste Management Concept roadmap.

***Table 2.6*** *Summary Assessment Matrix for TAP Inclusion: Anaerobic Digestion of Sewage Sludge*

| Program | Strategic Focus | Estimated Cost | Implementation Feasibility | Recommended TAP Action |
|---|---|---|---|---|
| **Program 1:** Infrastructure & Finance | Construction of AD Plant & Installation of CHP Units | **CAPEX:** €118.5M (Total CHP Sizing:8.5 MW installed)<br><br>**OPEX:** €5.61M·year$^{-1}$ (sludge loop operations, polymer dosing, and CHP O&M); Corresponding to €0.0205·m$^{-3}$ treated wastewater, or €132.6·t$^{-1}$ raw dry solids | **High** (Can leverage international concessional loans and national modernization programs; supported by electricity savings)<br><br>***Savings for not using grid electricity:*** €1.67M·year$^{-1}$<br><br>***Net amortized life-cycle cost*:*** €186.5·t$^{-1}$ raw dry solids | Include as Core Financial and Infrastructure Action |
| **Program 2:** Regulatory & Market-Pull | Grid Connection Code Harmonization, National Digestate Fertilizer Certification Framework, and Institutional Capacity Building | **CAPEX:** €5.5M (assumed as a one-time expenditure) | **Moderate** (Requires cross-ministerial alignment) | Include as Core Regulatory and Institutional Action to secure long-term system circularity |

***:** Total amortized lifecycle cost per unit of dry sludge processes the combined capital assets linearly across a 30-year infrastructure lifecycle boundary condition.

Both programs are recommended for immediate inclusion in the TAP. Program 1 provides the essential physical and fiscal "backbone" required for the technology to function, while Program 2 provides the necessary regulatory environment to ensure economic sustainability. Together, they establish a robust enabling framework to transition AD technology into a standardized climate mitigation tool for all major municipal wastewater treatment plants across Kazakhstan.

**Methodology of Cost Estimations:** The biological sludge management infrastructure for Almaty and Astana is evaluated using a parametric cost model scaled to physical loading, combined with a sequential thermodynamic mass-to-energy balance. Reference parameters were drawn from the Shymkent sludge digestion unit, where influent flow is 43 million m³·year$^{-1}$ and annual output is 4.38 GWh of electricity and 7.35 GWh of heat; from these figures, a sludge yield of 0.155 kg total solids per m³ of wastewater was back-calculated. Applying this yield, projected annual dry solids loading is estimated at 23.9 kt·year$^{-1}$ for Almaty and 18.4 kt·year$^{-1}$ for Astana, with corresponding annual methane output of $4.13\times10^6$ m³·year$^{-1}$ in Almaty and $3.19\times10^6$ m³·year$^{-1}$ in Astana. Based on the projected annual solids loadings, the sludge line equipment (gravity belt thickeners, anaerobic digesters, and dewatering centrifuges) and CHP units were sized to estimate capital costs. Electricity generated by the CHP units is assumed to partially offset total plant electrical demand, valued at a grid displacement saving of €0.06 per kWh, while recovered thermal energy is assumed to fully cover digester heating requirements, including during severe winter conditions in Astana.

## 2.3 Sanitary Landfills with Methane Recovery

### 2.3.1 General description and target for Sanitary Landfills with Methane Recovery

Sanitary landfills with methane recovery involve modern engineering facilities designed to transition solid waste disposal away from traditional open dumping toward controlled, environmentally secure management. These facilities utilize advanced bottom liners, leachate collection networks, and active extraction wells to capture methane-rich landfill gas (LFG) generated during anaerobic decomposition, converting it into renewable electricity or heat via internal combustion engines, turbines, or flaring systems. Retrofitting existing landfills by installing methane recovery systems can also be considered. The primary objective is to mitigate the climate impact of the municipal solid waste (MSW) sector while preventing soil and groundwater contamination. Implementation of this technology directly aligns with Kazakhstan's updated Nationally Determined Contributions' (MENR, 2025) target of a 17% greenhouse gas reduction by 2035, the Strategy for Achieving Carbon Neutrality by 2060 (Republic of Kazakhstan, 2023), and the Concept for Transition to a Green Economy (Republic of Kazakhstan, 2013), which mandates that 95% of landfills comply with sanitary standards by 2030 and reach 100% compliance by 2050.

National infrastructure relies heavily on land disposal (~75% of MSW generated nationwide on average between 2005 and 2025), with total accumulated landfill volumes reaching 52 million tons by the end of 2025 in registered landfills (BNS, 2026). The current disposal landscape is severely constrained; of approximately 3,000 registered landfills, only about 20% meet environmental and sanitary standards stipulated in the 2021 Environmental Code (CAREC, 2025). None of these facilities feature landfill gas collection systems or energy recovery installations. In order to improve landfill compliance with national standards and enhance greenhouse gas emission mitigation, the TNA team considers urban centers with populations exceeding 100,000 suitable to be served by engineered sanitary landfills equipped with energy recovery systems. In Kazakhstan, there are 18 such urban centers (core city settlements, excluding their broader administrative areas) with populations over 100,000, along with 3 cities of republican significance, housing a total population of 10.65 million (as of April 1$^{st}$, 2026): Almaty City, Astana City, and Shymkent City (cities of republican significance); and Aktobe, Karaganda, Taraz, Ust-Kamenogorsk, Pavlodar, Atyrau, Semey, Aktau, Kyzylorda, Kostanay, Uralsk, Turkestan, Petropavlovsk, Kokshetau, Taldykorgan, Temirtau, Ekibastuz, and Rudny (BNS, 2026). The concentrated waste flows from these urban centers can provide the reliable feedstock necessary to achieve economies of scale for active gas extraction and justify the capital investment. While the landfilling of organic waste has been legally prohibited since 2021, implementation remains inadequate. Upstream multi-stream waste separation (*see* **2.1**) in the future would facilitate more organic matter diversion from landfills, reducing methane generation.

**Preliminary Deployment Target:** Implement and fully scale engineered sanitary landfill infrastructure equipped with active methane collection and energy recovery systems in 21 Kazakh cities with populations over 100,000 with high methane recovery potential by **2032**. This strategy aims to systematically close and remediate hazardous open dumps, replacing them with centralized sanitary facilities supported by real-time IoT digital monitoring of methane destruction levels, localized technical operations and maintenance (O&M) capacity building, and modernized regional waste logistics networks.

### 2.3.2 Identification of barriers and possible enabling measures for Sanitary Landfills with Methane Recovery

The logical problem analysis conducted via the problem tree framework demonstrates that the slow development and poor operational sustainability of modern landfill infrastructure in Kazakhstan are driven by high capital costs, artificially suppressed waste collection tariffs, and severe continental freezing cycles that cause structural or biological system failures (**Figure A2.7**). To systematically counteract these root causes, the corresponding solution tree maps out a cohesive path of enabling interventions, establishing that long-term system uptime and greenhouse gas reduction depend directly on adopting climate-resilient engineering standards, restructuring municipal gate fees to capture actual operating expenditures (OPEX), and upgrading enforcement to legally channel waste streams to sanitary sites (**Figure A2.8**). Finally, by integrating these insights into a broader context, the market mapping framework presents this technology as a critical Publicly Provided Good (or a Public-Private Partnership capital good) and maps a multi-layered service delivery chain that is currently broken by structural linkage weaknesses (**Figure A2.9**). Specifically, because gate fees at fully engineered facilities are inherently higher than at substandard open dumps, transportation fleets are economically incentivized to bypass authorized zones in favor of illegal dumping. This operational leakage must be resolved by introducing real-time digital tracking via the National Waste Management Centre and establishing standardized grid codes to allow operators to economically deliver recovered landfill gas energy back into regional power distribution grids.

### 2.3.3 Screening of barriers and possible enabling measures for Sanitary Landfills with Methane Recovery

The long list of identified barriers and corresponding enabling measures were given in **Table 2.7** and **Table 2.8**, respectively, along with their scores (*see* **2.1.3** for scoring methodology).

***Table 2.7*** *Identified Barriers to Sanitary Landfills with Methane Recovery.*

| Category | Specific Barrier | Description of the Barrier | **Score (%)** |
|---|---|---|---|
| **1. Economic & financial** | **High Upfront Capital Expenditure (CAPEX)** | Massive investment is required for specialized engineering, bottom liners, leachate treatment plants, and gas extraction wells. | 100 |
| | **Artificially Low Waste Tariffs** | Current municipal collection fees are insufficient to cover the high operational costs (OPEX) of an engineered sanitary site. | 57 |
| **2. Market conditions** | **Energy Price Competition** | Recovered landfill gas for electricity or heat must compete against heavily subsidized and cheap domestic coal and natural gas. | 52 |
| | **Geographic and Logistical Constraints** | The vast distances in Kazakhstan make transporting waste from remote locations to regional sanitary facilities economically unviable. | 33 |
| **3. Legal & regulatory** | **Uneven Environmental Enforcement** | It remains more economical for some actors to pay low fines for illegal dumping than to pay the "gate fees" at an authorized sanitary landfill. | 19 |
| **4. Institutional capacity** | **Digital Monitoring Gaps** | A lack of integrated frameworks for real-time digital accounting of waste flows and verified methane destruction levels. | 33 |
| **5. Human skills** | **O&M Technical Deficit** | Shortage of local expertise in managing complex leachate treatment systems and optimizing gas collection efficiency. | 29 |
| **6. Social / Behavioral** | **Public Resistance** | Possibly strong community resistance to the placement of new landfills near urban residential areas due to perceived environmental risks. | 0 |
| **7. Information & awareness** | **None** | - - | - - |
| **8. Technical** | **Harsh Climatic Conditions** | Severe winter temperatures (-40 to -52 °C) can freeze leachate pipes and negatively impact the biological activity required for consistent methane generation. | 10 |

***Table 2.8*** *Suggested measures grouped with the barriers to Sanitary Landfills with Methane Recovery.*

| Category | Specific Barrier | Description of the Possible Measure | Score (%) |
|---|---|---|---|
| **1. Economic & financial** | **High Upfront Capital Expenditure (CAPEX)** | Utilize government-backed preferential loans to finance high-cost engineering and gas recovery systems. **National Policy:** The '*Zhasyl Damu*' has established a 3% preferential financing program through the Industrial Development Fund using EPR fees. The Ministry of Ecology and Natural Resources has allocated approximately USD 450 million for waste infrastructure for 2024–2030. | 100 |
| | **Artificially Low Waste Tariffs** | Implement a phased increase in municipal waste collection fees and transition toward "Pay-As-You-Throw" systems to ensure long-term financial sustainability. **National Policy:** Improving tariff structures is identified as a necessary step for financial sustainability by the recently adopted the "Concept for the Management of All Types of Waste 2026–2030". Implementation of economically justified utility tariffs indexed to inflation every three years to attract private investment. | 78 |
| **2. Market conditions** | **Energy Price Competition** | Establish feed-in tariffs for electricity or direct subsidies to help landfill-gas-to-energy projects compete with cheaper fossil fuels. | 33 |
| | **Geographical and Logistical Constraints** | Establish regional waste hubs and optimize transport routes using digital data analytics to reduce the cost of moving waste to centralized sanitary sites. | 78 |
| **3. Legal & regulatory** | **Uneven Environmental Enforcement** | Increase administrative fines for illegal dumping and strengthen municipal oversight to ensure waste is diverted to authorized sanitary sites. **National Policy:** The updated Nationally Determined Contribution (NDC 3.0) sets a specific target of a 42% reduction in fugitive methane emissions across the energy and waste sectors by 2035 under its conditional mitigation pathway enabled by international partnerships and investment. | 44 |
| **4. Institutional capacity** | **Digital Monitoring Gaps** | Mandate GPS-based vehicle tracking and IoT fill-level sensors to ensure transparency and prevent illegal waste diversion. **National Policy:** Digitalization is a priority driven by mandates from the National Waste Management Centre. | 56 |
| **5. Human skills** | **O&M Technical Deficit** | Launch specialized vocational programs and technical assistance for the operation and maintenance of gas collection and leachate treatment systems. | 0 |
| **6. Social / Behavioral** | **Public Resistance** | Conduct public awareness campaigns and community consultations to demonstrate the environmental safety of engineered landfills compared to open dumps. | 11 |
| **7. Information & awareness** | **None** | - - | - - |
| **8. Technical** | **Harsh Climatic Conditions** | Design climate-resilient infrastructure, including insulated piping for leachate and gas collection, specifically adapted for Kazakhstan's severe winters. | 22 |

### 2.3.4 Classification of barriers for Sanitary Landfills with Methane Recovery

Following the screening step (see **2.1.4** for screening methodology), the remaining essential barriers have been classified into financial and non-financial frameworks below.

#### 2.3.4.1 *Economic and financial barriers*

Economic constraints remain the most definitive bottleneck obstructing the transition from substandard open dumps to environmentally sound containment assets across Kazakhstan's urban municipalities.

- **High Upfront Capital Expenditure (CAPEX) (Score: 100%):** Developing a fully compliant sanitary site demands a massive initial capital mobilization to fund advanced multi-layer impervious bottom liners, localized leachate treatment facilities, and complex active gas extraction piping networks.
- **Artificially Low Waste Tariffs (57%):** Heavily regulated municipal flat-rate disposal fees are socially suppressed and completely fail to provide the cost-recovery levels required to fund the intensive, continuous operating expenditures (OPEX) of engineered sanitary landfill cells.

#### 2.3.4.2 *Non-financial barriers*

The non-financial enabling environment is bottlenecked by macro-market energy price competition that limits the commercial viability of resource recovery systems.

- **Energy Price Competition (52%):** Recovered landfill gas destined for local thermal, or electricity grids cannot easily establish commercial viability due to direct competition against heavily subsidized and cheap domestic coal and natural gas inputs across Kazakhstan’s power markets.

### 2.3.5 Measures for Sanitary Landfills with Methane Recovery

The prioritized enablers retained following the screening process are listed below under financial and non-financial categories.

#### 2.3.5.1 *Economic and financial measures*

- **Preferential Capital Financing (100%):** This measure leverages the financial pathways of "Zhasyl Damu" to provide 3% preferential loans through the Industrial Development Fund using accrued EPR utilization fees. These government-backed funds are strictly designated to offset the high capital expenditures (CAPEX) required for installing multi-layer impervious bottom liners, localized leachate treatment plants, and methane gas extraction networks.
- **Cost-Reflective and Fair Tariff Reform (78%):** This intervention structures a phased transition toward unit-based "Pay-As-You-Throw" pricing models to secure sustainable operating expenditures (OPEX) for engineered disposal assets. In direct response to stakeholder feedback highlighting the lack of standardized methodology, this measure mandates the formulation of a transparent legal framework to calculate a "fair" tariff for the population that fully captures collection, transport, sorting, and landfilling costs while balancing social equity.

#### 2.3.5.2 *Non-financial measures*

- **Regional Waste Hubs and Inter-District Site Integration (78%):** This logistical measure optimizes transport networks through digital data analytics to make waste hauling from low-density urban centers economically viable. Integrating specific stakeholder feedback, the operational scope is expanded to mandate the formal creation of regional waste management systems, including the establishment of interconnected inter-district integrated waste transfer stations (bulk aggregation/hauling points) and regional sanitary disposal sites.
- **Digital Logistics Monitoring and Fleet Auditing (56%):** Driven by structural digitalization mandates from the National Waste Management Centre, this measure enforces real-time GPS tracking and

IoT storage fill-level sensors across waste handling chains. This automated framework provides full transparency over material flows, ensures verified reporting of methane destruction levels, and structurally prevents operators from illegally bypassing authorized gates.

- **Enforcement Activation and Interconnected Legal Framework (44%, retained via Stakeholder Feedback):** Although this measure scored below the baseline threshold, the TNA sectoral team re-included it to address widespread implementation gaps within the 2021 Environmental Code voiced by stakeholders. To bridge this enforcement deficit, the intervention introduces a substantial increase in administrative fines for illegal dumping alongside a cohesive package of logically interconnected regulatory legal acts designed to eliminate systemic enforcement loopholes.

### 2.3.6 Grouping complementary measures for Sanitary Landfills with Methane Recovery

The five prioritized significant measures have been organized into two interactive, cross-cutting strategic programs. Together, these enabling packages align the hardware (engineered liners, piping, monitoring sensors), software (fair unit-based tariff methodologies, digital fleet data analytics), and orgware (inter-district regulatory legal acts, activated enforcement penalties) of the solid waste disposal sub-sector into a cohesive national enabling framework.

**Program 1.) Integrated Capital Financing and Cost-Reflective Waste Tariff Framework (Financial & Economic Package):** This program creates a self-sustaining economic foundation for advanced waste containment by combining targeted state public capital with long-term operational cost-recovery tools. It directly integrates Preferential Capital Financing (100%) and Cost-Reflective and Fair Tariff Reform (78%). Packaging the allocation of long-term capital from the Ministry of Ecology and Natural Resources and 3% preferential Industrial Development Fund loans via Extended Producer Responsibility funds systematically addresses the prohibitive upfront capital barrier for multi-layer liners and gas networks. Crucially, it links these capital investments to a viable operational revenue model. Transitioning toward unit-based "Pay-As-You-Throw" pricing and indexed cost-reflective tariff methodologies ensures that operators have access to reliable operational expenditure (OPEX) streams, compressing project payback periods and reducing performance risks for public-private partnerships.

**Program 2.) Inter-District Logistical Consolidation and Automated Legal Enforcement Program (Institutional, Regulatory & Logistical Package):** This program creates a standardized, legally protected supply chain that secures stable waste throughput at authorized sanitary facilities while eliminating illegal dumping leakages. It combines Regional Waste Hubs and Inter-District Site Integration (78%), Digital Logistics Monitoring and Fleet Auditing (56%), and Enforcement Activation and Interconnected Legal Framework (44%). Even if advanced landfill infrastructure is deployed, it cannot achieve performance optimization or methane capture goals if waste streams bypass authorized sites. This package removes field-level operational barriers by enacting interconnected regulatory acts to establish regional waste management systems and inter-district integrated hubs, creating necessary regional scale economies. To ensure transportation fleets route waste to these centralized hubs rather than bypassing higher gate fees, the program mandates real-time GPS vehicle tracking and IoT container sensors overseen by the National Waste Management Centre. This transparent digital auditing is reinforced by an aggressive increase in administrative fines for non-compliance, converting strict enforcement loops into an automated municipal standard that secures the critical mass of feedstock required to sustain methane recovery.

### 2.3.7 Assessment of measures for inclusion in the TAP

The two prioritized strategic packages designed for Sanitary Landfills with Methane Recovery were evaluated across four criteria (i.e., impact, benefits, cost, and feasibility) to determine their readiness for the Technology Action Plan (TAP). Both programs demonstrate strong alignment with national climate policies and are recommended for immediate inclusion (**Table 2.9**).

**Program 1: Integrated Capital Financing and Cost-Reflective Waste Tariff Framework (Financial & Economic Package)**

This program combines targeted public capital with a structural overhaul of municipal solid waste (MSW) utility pricing to transition disposal assets toward long-term operational cost-recovery.

- **Impact:** It directly removes the financial barriers stalling modern landfill development. Securing upfront capital allows municipal authorities and private concessionaires to implement engineered containment systems (such as thick high-density polyethylene bottom liners and active gas extraction wells) that would otherwise be unviable due to high commercial credit constraints. This capital mobilization is sustained by volume-based waste disposal fees calculated via a standardized "fair" tariff methodology, ensuring continuous revenue to fund intensive daily operating expenditures (OPEX), compressing project payback periods, and unlocking private public-private partnership (PPP) funding streams.
- **Societal Benefits:** Restructuring waste tariffs creates a transparent utility framework where costs are directly aligned with actual waste generation, incentivizing household-level reduction and upstream sorting while relieving depleted municipal tax budgets. Furthermore, establishing financially viable landfill operators ensures the continuous maintenance of active safety cells, directly reducing the risk of spontaneous landfill fires that frequently threaten air quality near Kazakhstan's major cities.
- **Cost:** Initial infrastructure deployment costs are high, requiring the strategic utilization of the waste infrastructure fund allocated by the Ministry of Ecology and Natural Resources (MENR) for the 2024–2030 period. However, long-term costs to the public sector are low, as the program transitions ongoing OPEX entirely to a self-sustaining user-pays model (i.e., a breakeven gate fee). Favorable electricity feed-in tariffs are also available for renewable energy produced from captured landfill gas. The regulatory and economic framework for supporting renewable energy production was strengthened through the 2021 Environmental Code and corresponding amendments to the "*Law on Supporting the Use of Renewable Energy Sources*" (Orazbekov, 2025). The legislation guarantees that electricity generated by renewable energy utilities will be purchased by the Financial Settlement Centre for Renewable Energy Support at auction-determined prices. For example, under this scheme, Kazakhstan held its inaugural centralized auction for MSW incineration projects in July 2021, allocating a total capacity of 100.8 MW at a tariff of 172.71 KZT (equivalent to 0.343 EUR in July 2021) per kWh (MENR et al., 2022).
- **Feasibility:** High. The program directly leverages the established 3% preferential financing mechanism managed by the Industrial Development Fund (IDF) using Extended Producer Responsibility (EPR) utilization fees handled by "Zhasyl Damu". The primary implementation challenge lies in passing localized tariff modifications through regional legislative bodies (maslikhats), a process supported by the state mandates outlined in the Concept for the Management of All Types of Waste 2026–2030.

**Program 2: Inter-District Logistical Consolidation and Automated Legal Enforcement Program (Institutional, Regulatory & Logistical Package)**

This program combines regional waste hub optimization with automated digital monitoring and activated legal penalties to secure stable feedstock streams and stop illegal environmental leakages.

- **Impact:** It resolves value chain fragmentation by connecting decentralized municipal nodes into integrated inter-district sanitary disposal hubs, rendering advanced methane capture infrastructure economically viable through enhanced economies of scale. Enacting a coordinated package of regulatory legal acts closes enforcement loopholes and ensures that private transport fleets face strict financial penalties for non-compliance. This regulatory push is optimized by mandatory real-time GPS vehicle tracking and IoT cell sensors overseen by the National Waste Management Centre, eliminating information gaps and structurally preventing fleets from bypassing authorized gates to avoid tipping fees.
- **Societal Benefits:** Legally channeling mixed municipal residuals into engineered sanitary facilities ensures the immediate protection of regional groundwater tables from toxic leachate seepage and alleviates uncontrolled atmospheric methane venting. This directly supports the NDC 3.0 target of reducing in fugitive methane emissions by 2035. Additionally, shutting down substandard open dumps significantly improves public health and restores land assets for surrounding suburban communities.
- **Cost:** Implementation costs are moderate, requiring targeted administrative budget allocations across regional administrations (*akimats*) to expand municipal environmental inspectorates and deploy digital monitoring infrastructure. Logistical optimization costs are minimized by using automated data analytics to optimize haulage routes.
- **Feasibility:** Moderate to High. While the structural alignment of inter-district waste hubs requires close cross-jurisdictional coordination between national environmental ministries and distinct regional *akimats*, the legal foundation is already anchored within the 2021 Environmental Code. Stakeholder feedback confirms that activating these latent legislative mechanisms via an interconnected package of regulatory updates is highly practical and urgently required to turn voluntary compliance into an automated municipal standard.

***Table 2.9*** *Summary Assessment Matrix for TAP Inclusion: Sanitary Landfills with Methane Recovery*

| Program | Strategic Focus | Estimated Cost | Implementation Feasibility | Recommended TAP Action |
|---|---|---|---|---|
| **Program 1:** Capital Financing & Tariff Reform | Phased Infrastructure Development and Self-Sustaining Operations | **Initial CAPEX:** €130.5M *(Year 0)* **LFGtE CAPEX:** €38M *(Year 11, 21.1 MW installed)* **OPEX:** €42M·year$^{-1}$ *(collection/transfer, landfilling/LFGtE O&M and leachate treatment)* | **High** (Leverages 3% preferential financing via the IDF, gate fees and LFGtE revenues) ***Discounted payback period:*** 21.5 years ***Breakeven gate fee:*** €28.3·t$^{-1}$ (covering all costs w/ electricity revenue) ***Baseline OPEX:*** €24.5·t$^{-1}$ (logistics and landfilling only) | Include as Core Financial and Infrastructure Action |
| **Program 2:** Logistical Consolidation & Enforcement | Supply Chain Stabilization, Telematics Orgware, and Illegal Dumping Prevention | **CAPEX:** €2.87M **OPEX:** €2.13M·year$^{-1}$ | **Moderate to High** (Requires *Akimat* alignment) ***Total amortized unit cost:*** €1.97· t$^{-1}$ (20-year lifetime) | Include as Core Regulatory and Institutional Action to secure the long-term system integrity |

**Methodology of Cost Estimations:** The financial viability of the municipal solid waste infrastructure is evaluated using a multi-phase discounted cash flow model calibrated to 2026 economic baselines, spanning a two-year construction phase, a 20-year landfilling period, and an overlapping 20-year energy recovery period. Operating across 21 urban centers, the model processes a constant throughput of 2,530 kt·year$^{-1}$ of waste, based on the assumption that 65% of generated MSW is routed to sanitary landfill. Long-term landfill gas production kinetics are simulated using the IPCC First-Order Decay framework (IPCC, 2006; 2019), mapping the generation of 48.7 Mt CO2-eq of GHG emission reduction and fuel 21.1 MW of installed modular gas engines from Year 12 onward. Financial metrics utilize a 3% preferential interest rate, an 8% real discount hurdle, and a highly favorable feed-in tariff of 172.71 KZT·kWh$^{-1}$ (€0.31·kWh$^{-1}$ based on an exchange rate of 566 KZT/€) to numerically solve for the minimum breakeven gate fee required to secure a 10% project Internal Rate of Return. Concurrently, Program 2 capital and operational costs are scaled parametrically to provide telematic hardware, cellular network data subscriptions, and a dedicated 100-inspector payroll to monitor 2,100 collection vehicles and 35,000 dual-stream municipal collection nodes.

## 2.4 Common barriers and measures in Urban/Circular Economy Sector

After reviewing the prioritized technologies for the Republic of Kazakhstan (Multi-Stream Waste Separation, Anaerobic Digestion of Sewage Sludge, and Sanitary Landfills with Methane Recovery), several systemic bottlenecks and synergistic solutions emerge. Different prioritized technologies in the sector share critical structural vulnerabilities. Addressing these through common programmatic measures creates economies of scale and improves the overall effectiveness of the national transition toward a circular economy.

### 2.4.1 Identification of common barriers in Urban/Circular Economy Sector

The barrier analysis reveals four primary constraints that crosscut the prioritized mitigation technologies, fundamentally stalling infrastructure deployment and operational sustainability.

- **High Upfront Capital Expenditure (CAPEX):** The implementation of advanced circular economy infrastructure demands massive initial capital mobilization. Municipal budgets are deeply constrained and lack the fiscal capacity to independently procure specialized multi-compartment collection vehicles, complex biological digesters and combined heat and power units, or multi-layer impervious bottom liners for sanitary landfills.
- **Artificially Suppressed Utility Tariffs (OPEX Deficits):** Across the sector, heavily regulated municipal flat-rate fees fail to capture the true operational costs of modern waste and wastewater management. This systemic operational expenditure deficit prevents cost recovery, undermines the financial self-sufficiency of local utilities, and actively deters private sector investment.
- **Lack of Secondary Market Standards and Regulatory Codes:** Recovered resources cannot compete against cheaper virgin or fossil-based alternatives due to missing commercial regulations. The sector is paralyzed by a lack of mandatory industrial recycled content standards, a lack of agricultural certification protocols for organic digestate, and undefined technical codes for injecting waste-derived biogas and electricity into national energy grids.
- **Weak Enforcement and Digital Monitoring Gaps:** Regulatory fragmentation and inadequate municipal inspection capacities render environmental mandates ineffective. A widespread lack of integrated digital tracking (such as IoT sensors and GPS fleet monitoring) prevents transparent volume accounting, allowing high rates of illegal waste diversion and cross-contamination to persist without financial penalty.

### 2.4.2 Common measures in Urban/Circular Economy Sector

To systematically dismantle the identified bottlenecks, the following crosscutting enabling measures form a sector-wide framework that supports the deployment of all relevant circular economy technologies.

- **Centralized Preferential Financing Facilities:** To overcome prohibitive CAPEX barriers, the sector must aggressively leverage government-backed preferential financing. Channeling Extended Producer Responsibility funds through entities like "Zhasyl Damu" to provide low-interest loans (e.g., 3% via the Industrial Development Fund), alongside mobilizing international concessional finance for wastewater modernization, will secure the hardware necessary for the entire sector.
- **Structural Tariff Reform and Volume-Based Pricing:** Ensuring long-term financial viability requires transitioning from suppressed flat rates to cost-reflective utility pricing across both solid waste and wastewater domains. Implementing unit-based "Pay-As-You-Throw" models for municipal solid waste, indexing tariffs to inflation, and establishing guaranteed feed-in tariffs for biogas-generated energy will guarantee the continuous operational revenue required to sustain complex logistics and advanced engineering operations.
- **Standardization of Secondary Markets and Grid Integration:** To pull recovered resources into the formal economy, national regulatory bodies must enact standardized commercial frameworks. This includes establishing mandatory recycled content thresholds for industrial manufacturers, defining accredited agricultural quality specifications for digestate biofertilizers, and codifying strict

technical rules for purifying and injecting landfill and sludge-derived biogas into national utility grids.

- **Integrated Digitalization and Automated Enforcement:** A sector-wide modernization of municipal oversight is required to secure supply chains. Deploying comprehensive GPS tracking and IoT fill-level sensors under the National Waste Management Centre will provide real-time transparency. Pairing this digital auditing with significantly increased administrative fines and expanded municipal inspectorates will eliminate illegal dumping leakages, ensure compliance with source-separation mandates, and guarantee a stable volume of feedstock for sorting, digestion, and methane recovery facilities.

To support the structural transition of the waste management infrastructure in Astana, Almaty, and Shymkent, a staged implementation timeline has been established based on technological complexity and market readiness. To maximize capital efficiency and operational viability across these three cities of republican significance, deployment targets for the prioritized technologies are structured sequentially rather than uniformly. First, sanitary landfills with methane recovery are targeted for full deployment by 2032, as these engineering facilities can be constructed rapidly to increase landfill compliance rates, protect critical local groundwater resources, and mitigate immediate fugitive methane emissions. This critical baseline is followed by the implementation of high-efficiency anaerobic digestion of sewage sludge by 2035, leveraging the highly centralized biological wastewater infrastructure and existing economies of scale in these major metropolitan centers. Finally, the full deployment of a granular multi-stream waste separation scheme is established for 2038. This extended timeline ensures that the necessary expansion of specialized collection fleets is closely mirrored by the development of a mature, vibrant domestic secondary raw material market capable of sustainably absorbing high-purity recycled feedstocks. In the interim, source-sorting efficiencies will be steadily optimized within the existing dual-stream framework, allowing public participation and behavioral habits to mature alongside the off-take infrastructure. Ultimately, because these three technologies are targeted for the same dense urban centers, their successful integration will serve as a high-performance circular economy blueprint to transform the rest of the country in the future.

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## Annex 1: Problem/Solution Trees and Market Maps – Energy Sector

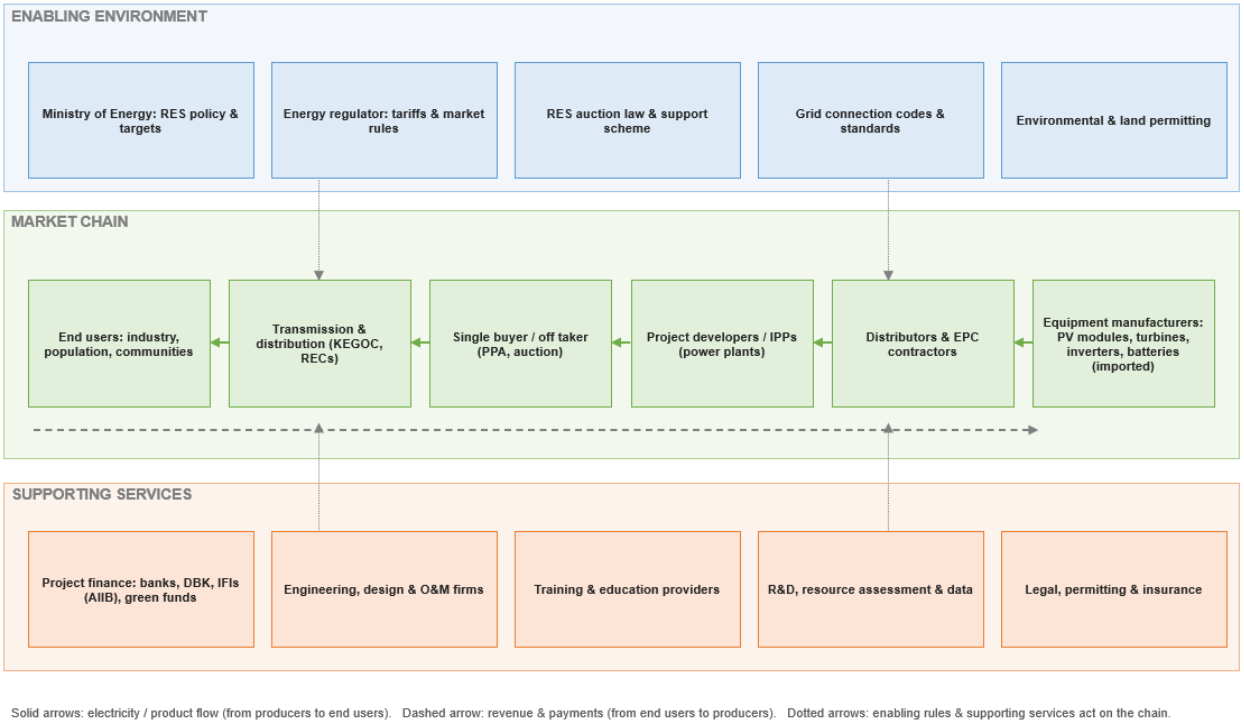



***Figure A1.1*** *Market map: large-scale grid-connected solar and wind power plants (0.1–1 GW)*

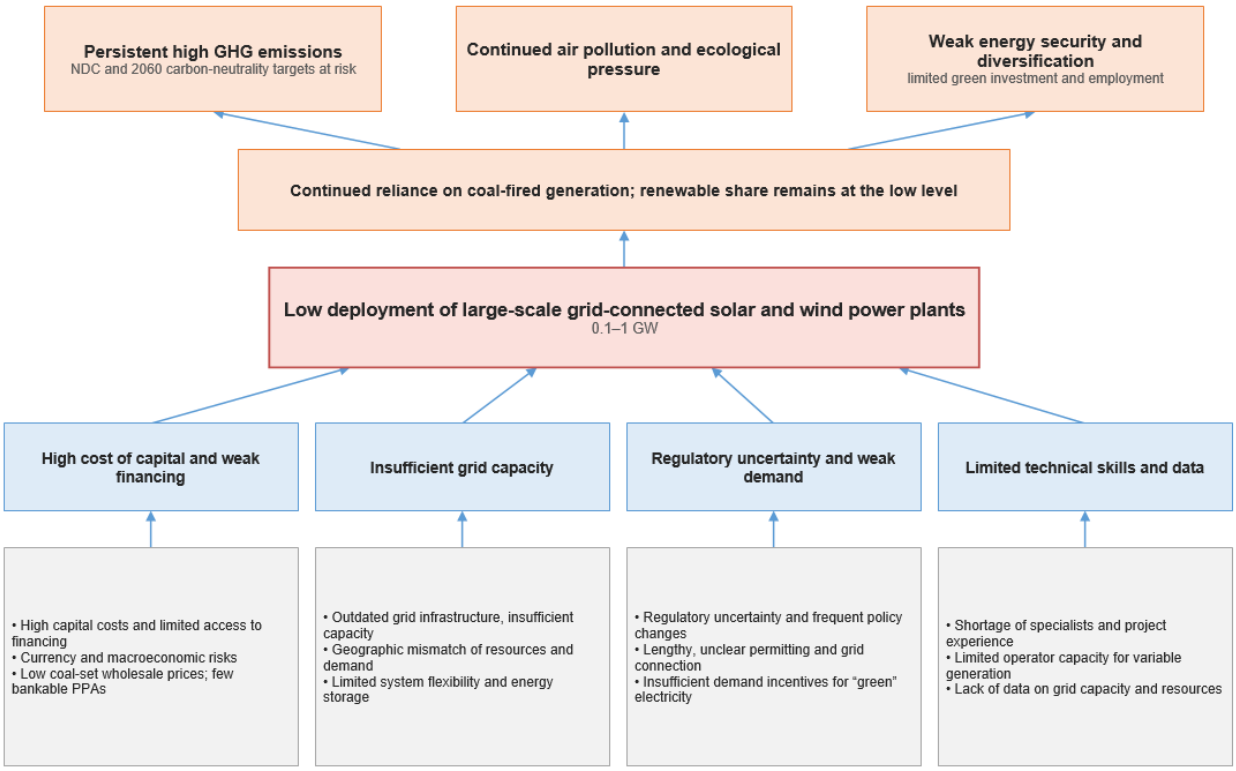



***Figure A1.2*** *Problem tree: large-scale grid-connected solar and wind power plants (0.1–1 GW)*

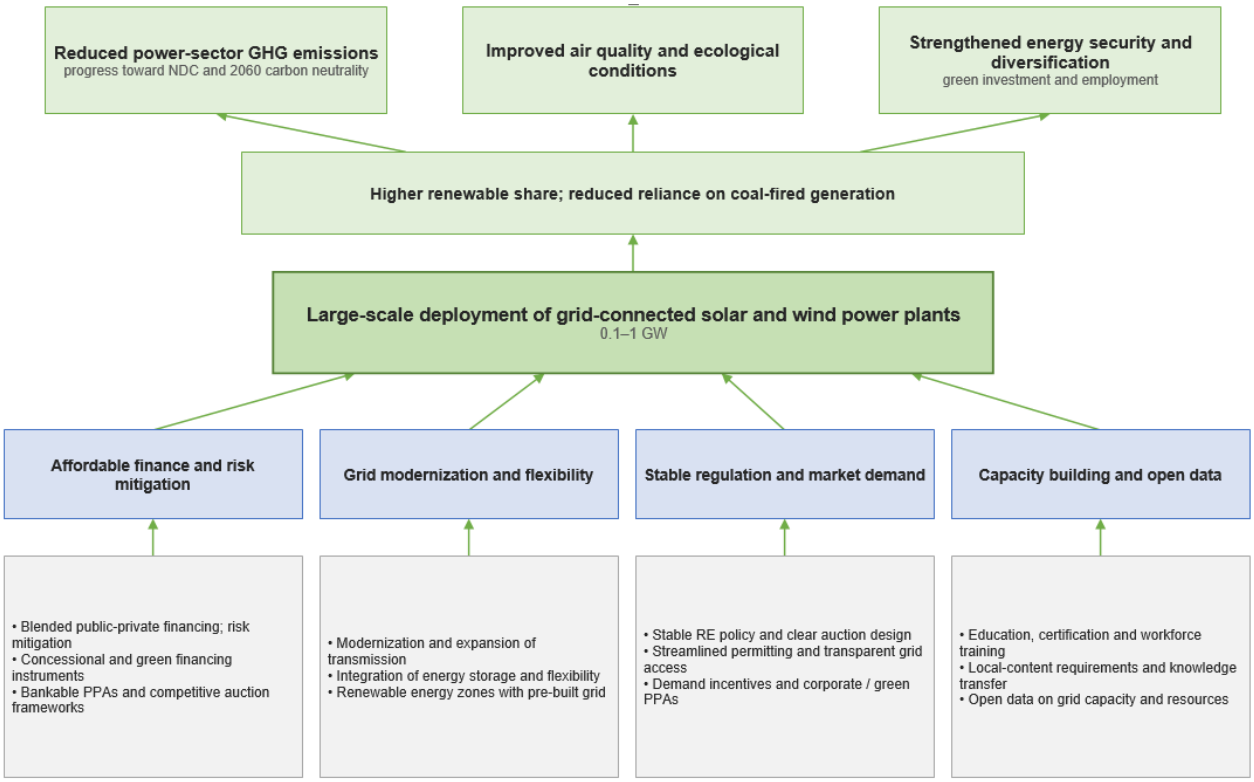



***Figure A1.3*** *Solution (objective) tree: large-scale grid-connected solar and wind power plants (0.1–1 GW)*

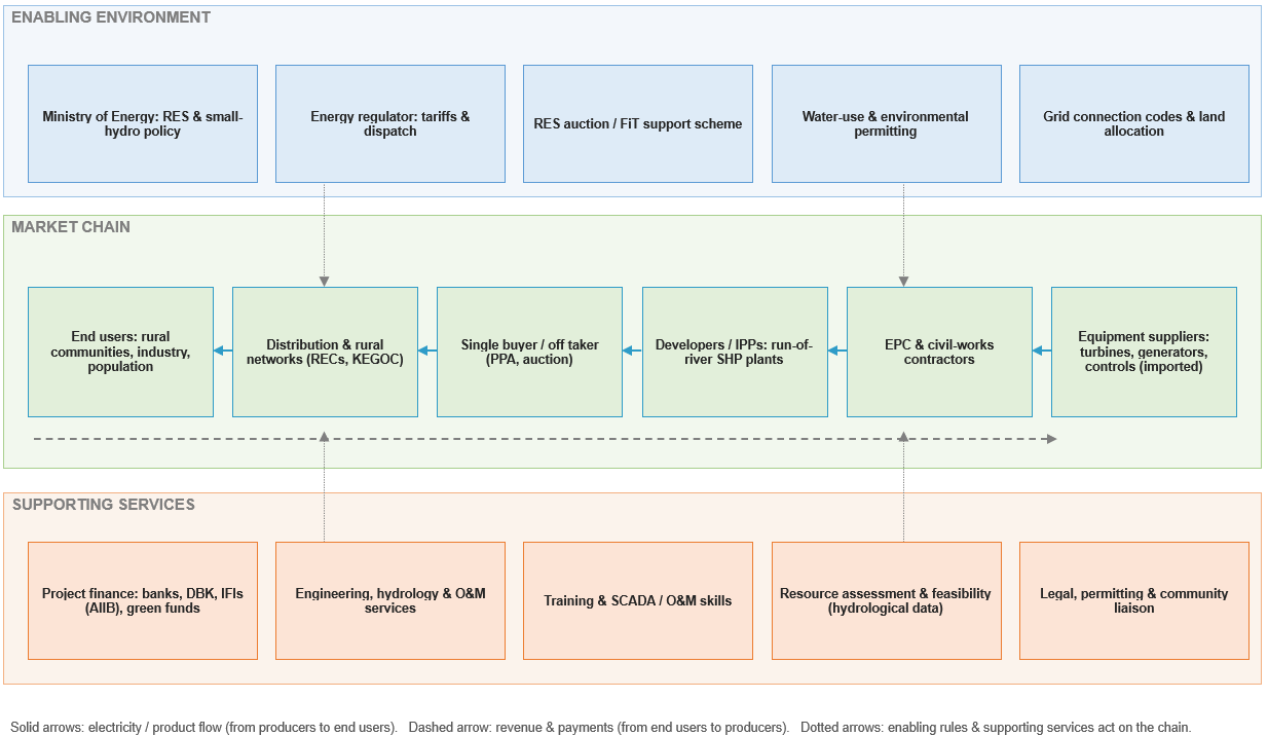



***Figure A1.4*** *Market map: small hydropower plants (<10 MW) in southern and north-eastern Kazakhstan*

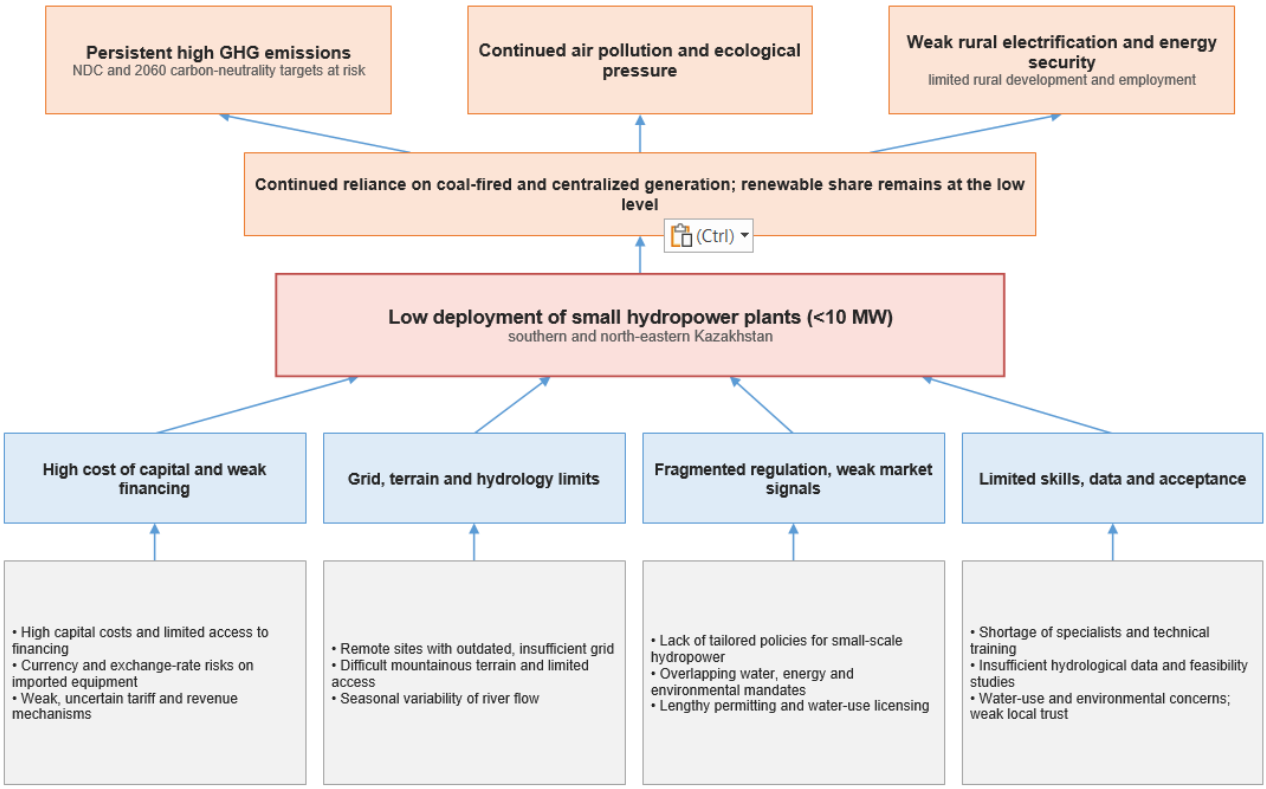



***Figure A1.5*** *Problem tree: small hydropower plants (<10 MW) in southern and north-eastern Kazakhstan*

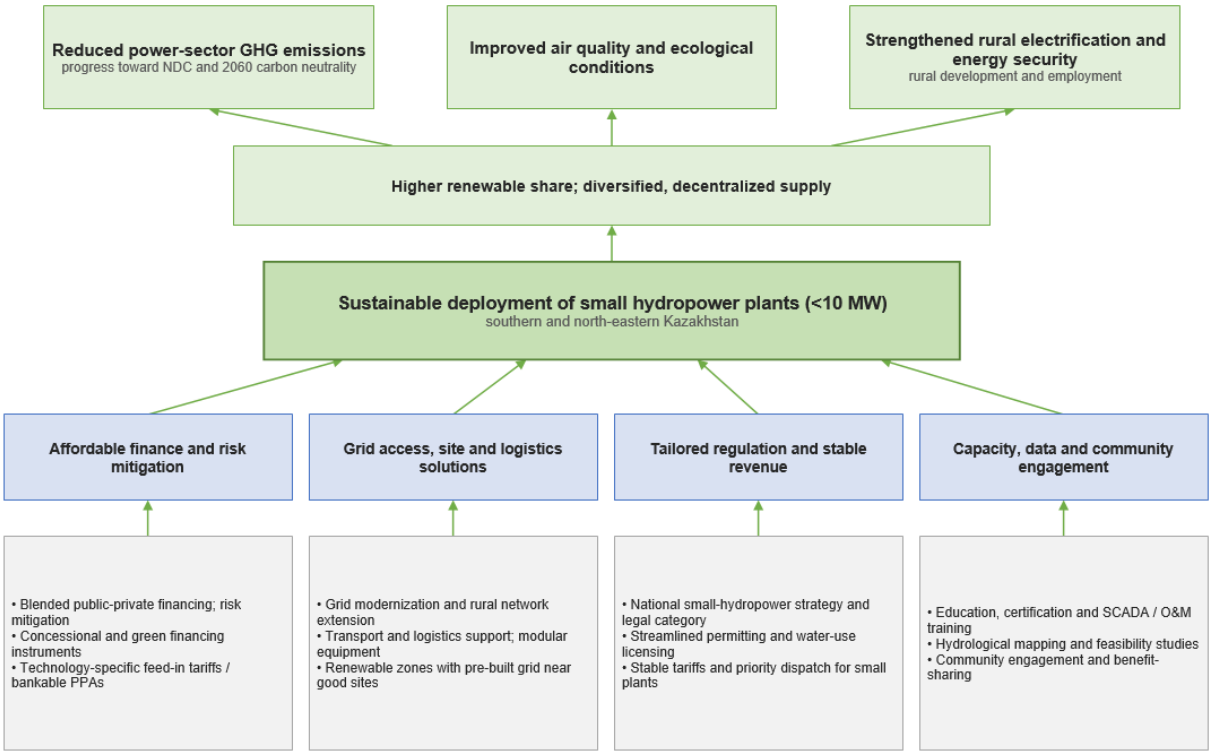



***Figure A1.6*** *Solution (objective) tree: small hydropower plants (<10 MW) in southern and north-eastern Kazakhstan*

## Annex 2: Problem/Solution Trees and Market Maps – Urban/Circular Economy Sector

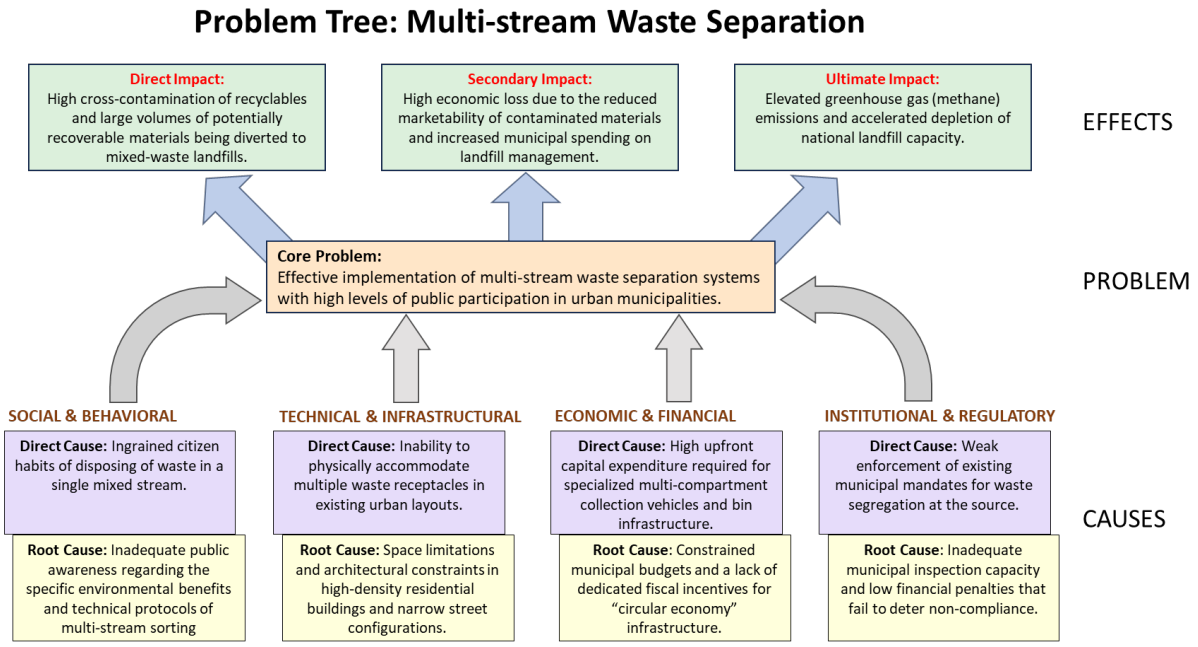



***Figure A2.1*** *Problem tree: Multi-Stream Waste Separation in Urban Areas*

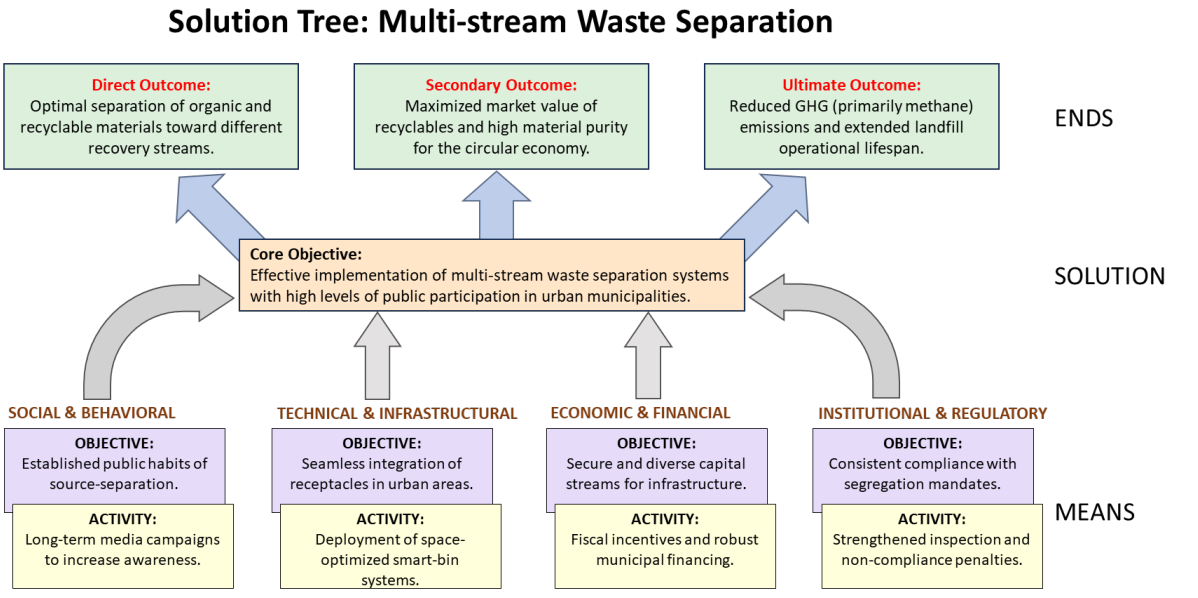



***Figure A2.2*** *Solution tree: Multi-Stream Waste Separation in Urban Areas*

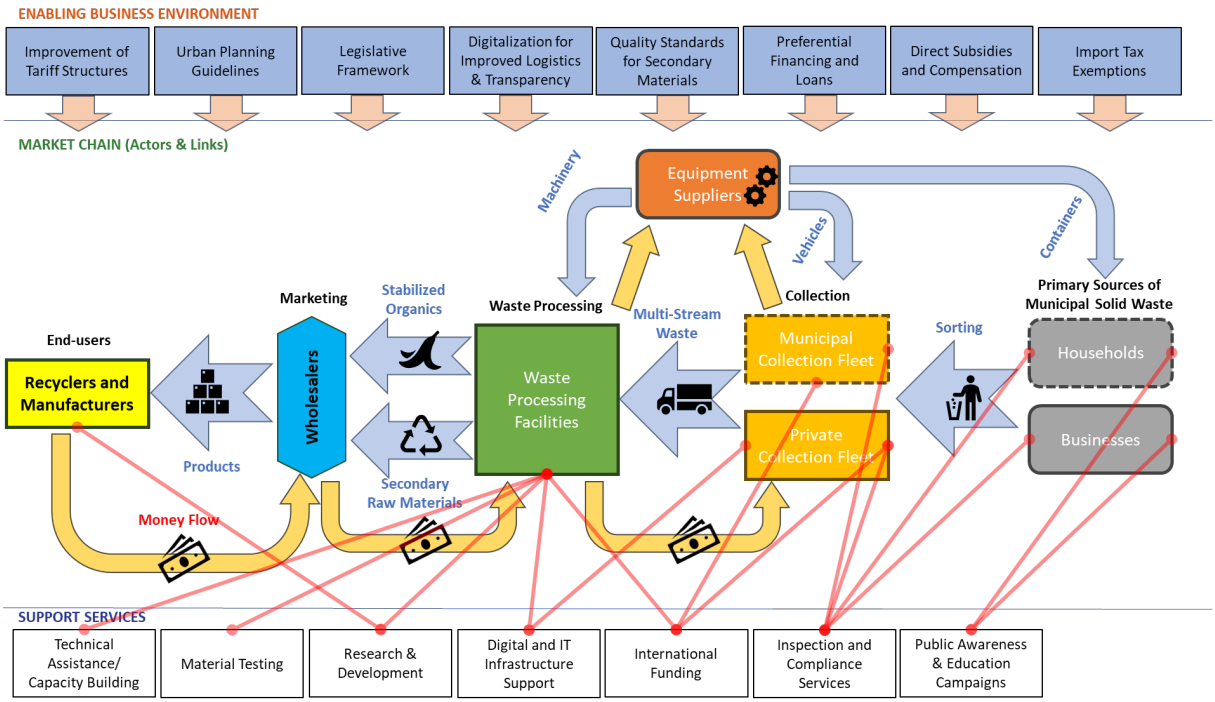



***Figure A2.3*** *Market Map: Multi-Stream Waste Separation in Urban Areas*

***Note:*** *The direction of material flow is from right to left. Linkages between support services and market actors are illustrated by red lines.*

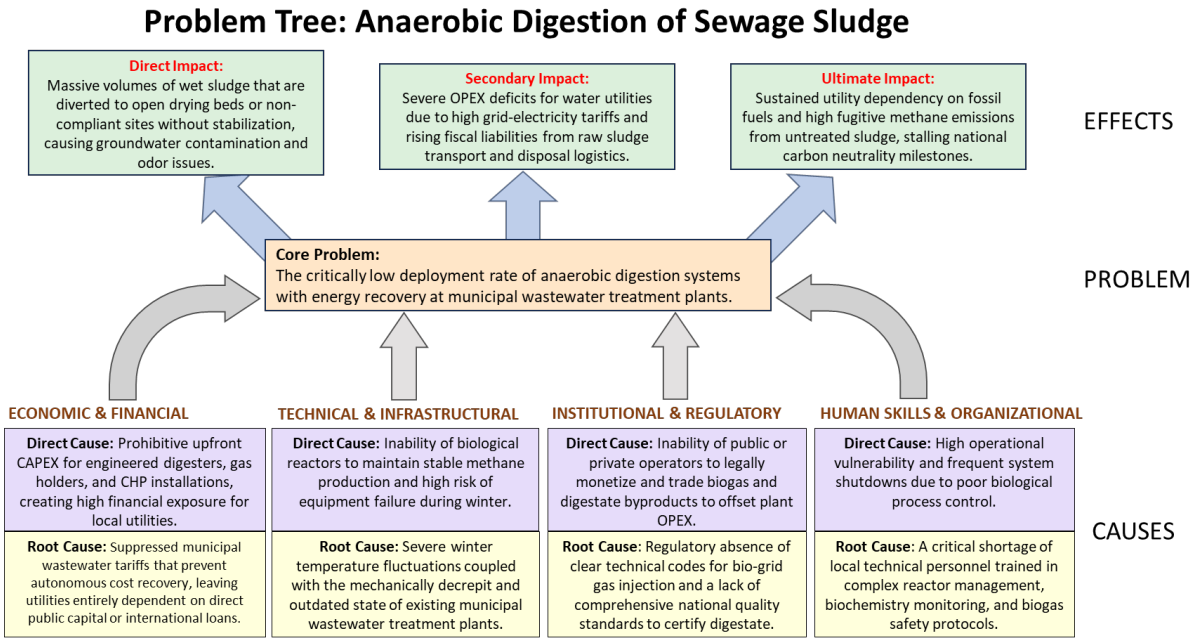



***Figure A2.4*** *Problem tree: Anaerobic Digestion of Sewage Sludge*

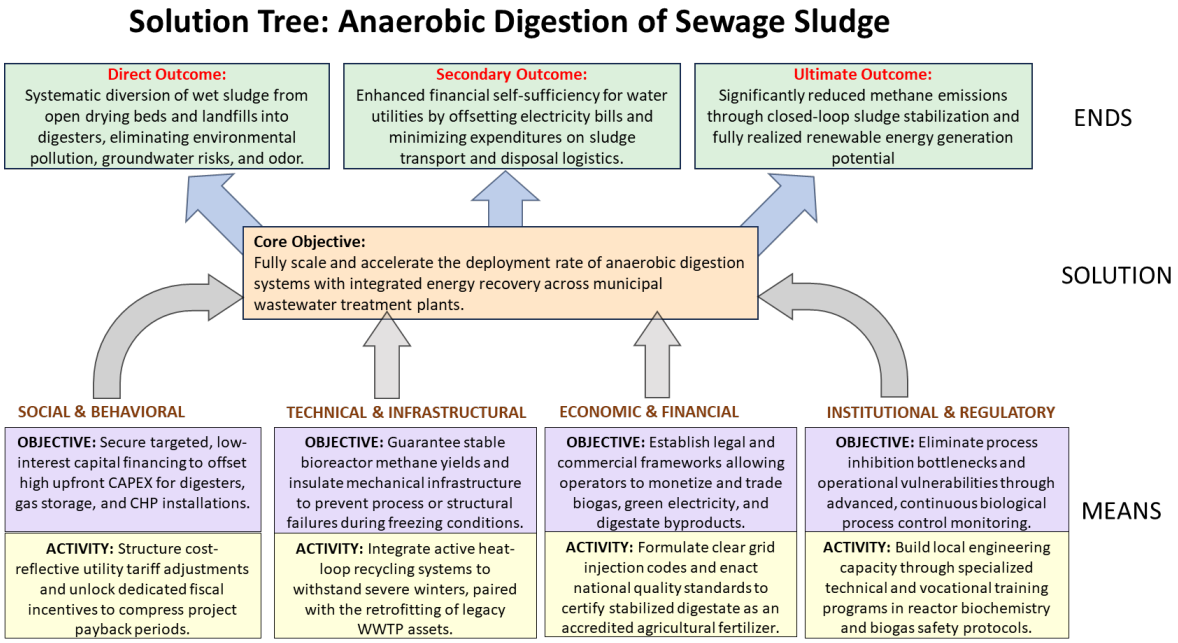



***Figure A2.5*** *Solution tree: Anaerobic Digestion of Sewage Sludge*

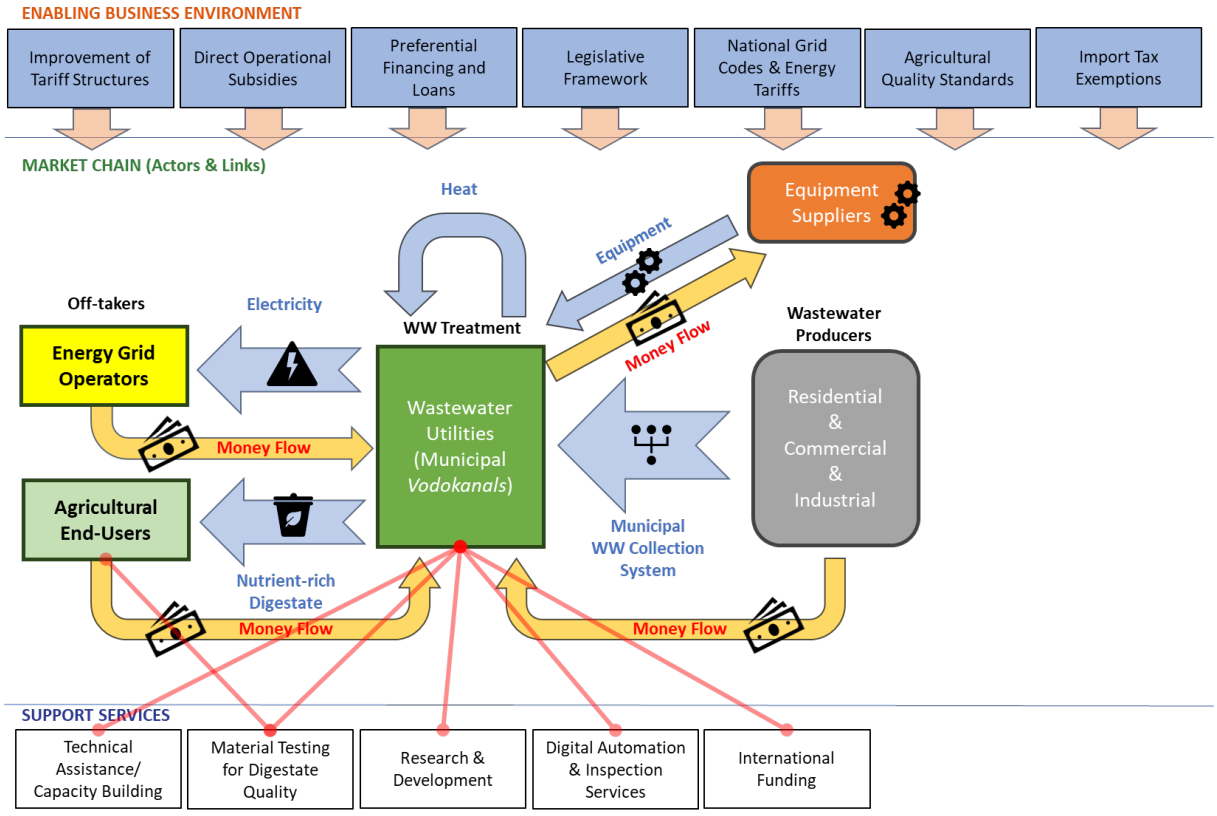



***Figure A2.6*** *Market Map: Anaerobic Digestion of Sewage Sludge*

***Note:*** *The direction of material flow is from right to left. Linkages between support services and market actors are illustrated by red lines.*

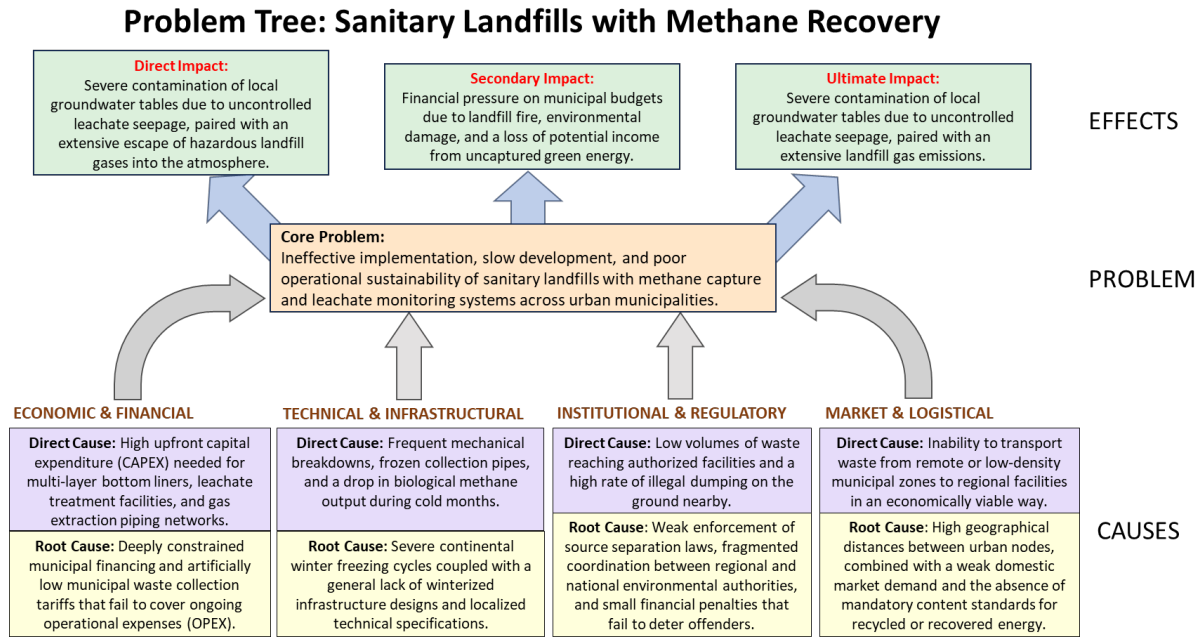



***Figure A2.7*** *Problem tree: Sanitary Landfills with Methane Recovery*

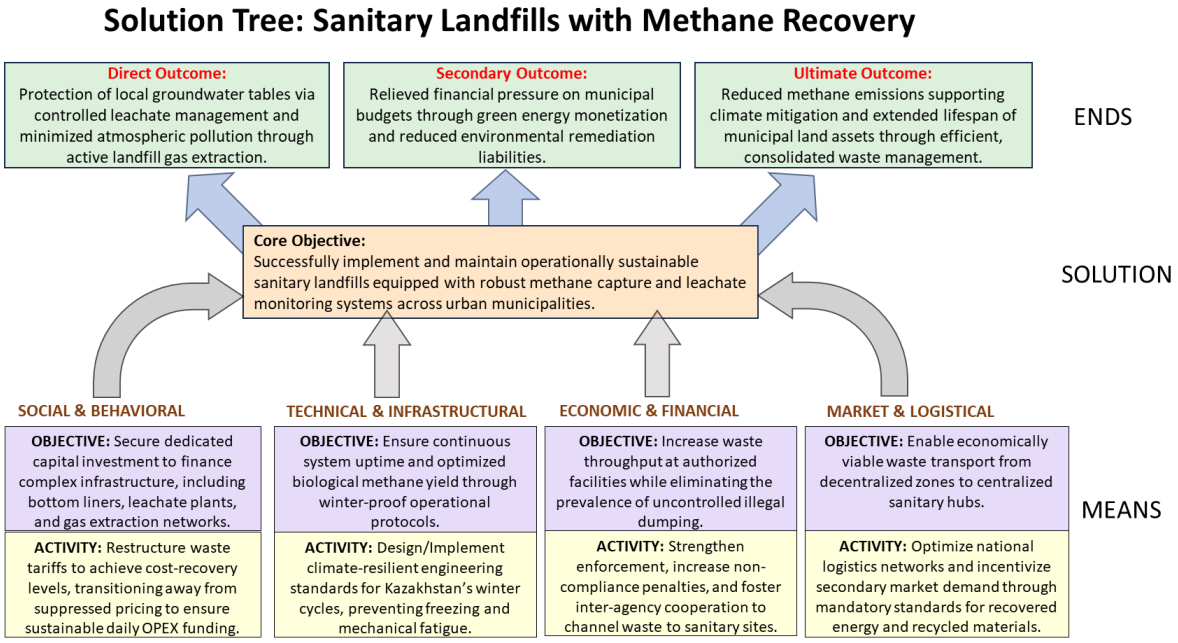



***Figure A2.8*** *Solution tree: Sanitary Landfills with Methane Recovery*

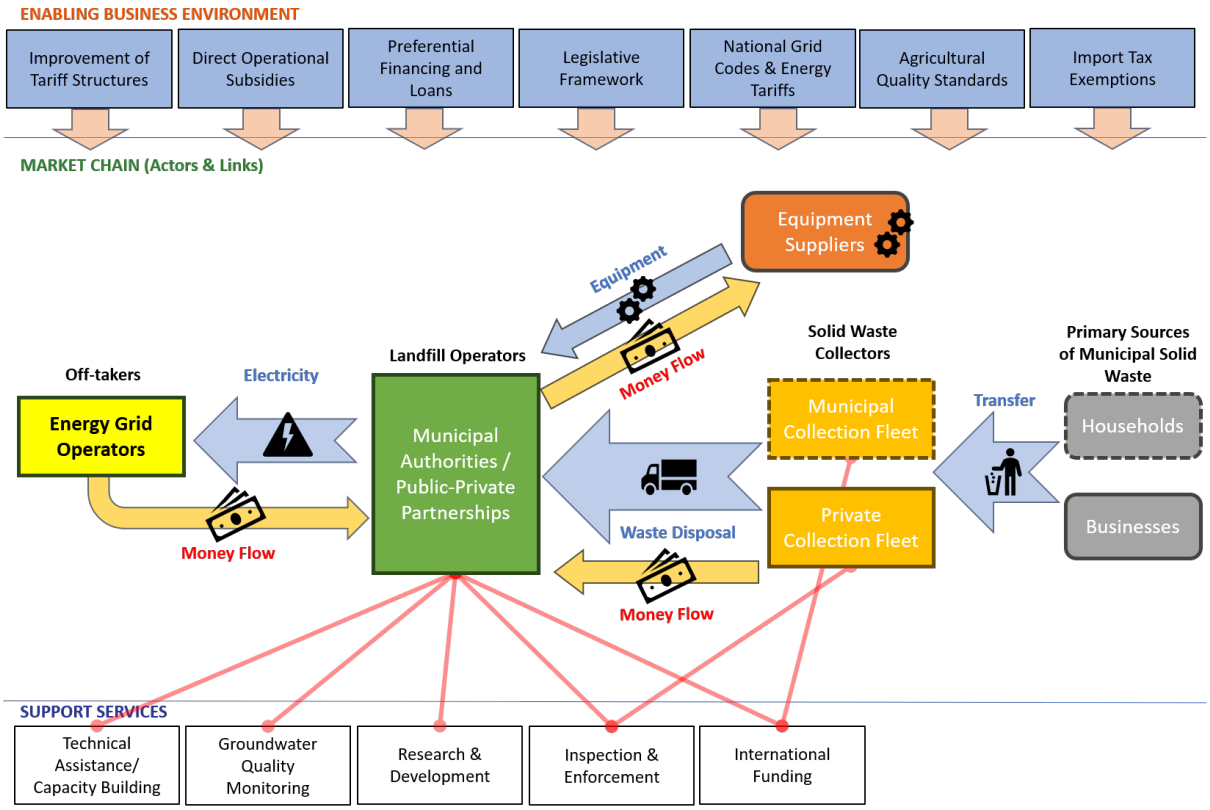



***Figure A2.9*** *Map: Sanitary Landfills with Methane Recovery*

***Note:*** *The direction of material and output flow is from right to left. Linkages between support services and market actors are illustrated by red lines.*

## Annex 3: List of stakeholders involved - Energy Sector

***Table A3.1*** *List of stakeholders involved in Energy Sector*

| Name | Affiliation (Ministry, Department, Company, etc.) | Form of consultation |
|---|---|---|
| **Kaipberdi Daurzhan** | Senior Expert, Electric Power Development Department, Ministry of Energy of the Republic of Kazakhstan | Questionnaire |
| **Meruyert Nizamutdinova** | Lead Power Systems Engineer, Kazakhstan Nuclear Power Plants LLP | |
| **Aida Maksut** | Board Member of the “Qazaq Green” RES Association and Director, LLP “SSDC” | |
| **Aydyn Bakdolotov** | Climate Policy Analyst, UNDP Kazakhstan | |
| **Nurgali Rakhmanov** | Director, Public Foundation “Digital Society” | |
| **Nicholas Pomeroy** | Founder and Director, AngloKazakh Limited | |
| **Rustam Nasirkhan** | Director, Department of Modeling, Analysis, and Forecasting (DMAF), “Zhasyl Damu” JSC | |
| **Kazbek Rysbekov** | Deputy Director, Department of Green Technologies at IGTIC | |
| **Alexander Cherednichenko** | Senior Manager, Sectoral Competence Department 1 (SCD-1), “Zhasyl Damu” JSC | |
| **Ainura Baydalina** | Manager, Sectoral Competence Department 1 (SCD-1), “Zhasyl Damu” JSC | |
| **Aislu Dossanova** | Director of the Environmental Regulation Department, KAZENERGY Association | |
| **Anton Merkulov** | Candidate of Technical Sciences. Senior member IEEE | |

## Annex 4: List of stakeholders involved - Urban/Circular Economy Sector

***Table A4.1*** *List of stakeholders involved in Urban/Circular Economy Sector*

| Name | Affiliation (Ministry, Department, Company, etc.) | Form of consultation |
|---|---|---|
| **Dana Agybayeva** | Senior Expert of the Industrial Waste Management Division, Waste Management Department, Ministry of Ecology and Natural Resources of the Republic of Kazakhstan | Questionnaire |
| **Adilbek Baltabekov** | Senior Manager, Best Available Techniques (BAT) Reference Division, IGTIC | |
| **Gulnaz Kasymbayeva** | Senior Manager, Best Available Techniques (BAT) Reference Division, IGTIC | |
| **Lyudmila Kuznetsova** | Expert in Solid Waste, Engineer-Economist, General Director, LLP “GeoData Plus” | |
| **Vadim Litvinov** | Industrial Waste Expert, Environmental Designer, LLP “Project-Environmental Bureau” | |
| **Saida Abdrakhim** | Senior Manager, Sectoral Competence Department 2 (SCD-2), “Zhasyl Damu” JSC | |
| **Olzhas Alshagirov** | Senior Manager, Department of Modeling, Analysis, and Forecasting (DMAF), “Zhasyl Damu” JSC | |
| **Anatoly Pinigin** | General Director, LLP “Ekom” | |
| **Aida Alimbekova** | Master of Environmental Sustainability, Climate Action and Circular Economy Expert | |
| **Zulpat Aziyeva** | CEO at the Association for Promoting the infrastructure and innovation development on Just energy transition programs | |