Ukraine

TECHNOLOGY NEEDS ASSESSMENT REPORT MITIGATION TECHNOLOGY BARRIER ANALYSIS AND ENABLING FRAMEWORK

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MITIGATION TECHNOLOGY
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National Consultants:

Dr. Mykola Shlapak Agriculture Sector
Dr. Yuri Matveev Waste Sector
Dr. Sergii Shmarin Waste Sector

National TNA Coordinator (Team Leader):

Mr. Anatolii Shmurak Senior Expert of Climate Policy and Reporting Division of the Climate Change and Ozone Layer Protection Department of the Ministry of Ecology and Natural Resources of Ukraine

Dr. Yevheniia Anpilova Assistant of Team Leader

TNA Global Project Coordinator

Dr. Sara Lærke Meltofte Trærup UNEP DTU Partnership

TNA Regional Consultants:

Dr. Debbie Sparks University of Cape Town
Dr. Jiska De Groot University of Cape Town
Dr. Ala Druta Moldova

Foreword

Ukraine plays an active role in international climate change cooperation processes. Being a Party of United Nations Framework Convention on Climate Change and Paris Agreement our country puts significant efforts through its policies and measures to contribute to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change.

Ukraine has submitted its 1st NDC in 2015. Also, Ukraine has developed its Low Emission Development Strategy up to 2050 in 2017, identifying core policies and measures, which implementation would lead to deep decarbonization of national economy.

However, low carbon development of Ukraine's economy could be obtained only due to wide diffusion and dissemination of modern highly efficient technologies, in particular, for Agriculture, Waste and Water sectors.

For us, the ongoing Technology Needs Assessment project in Ukraine is an excellent opportunity to accelerate environmentally friendly technology transfer that should become the basis for Ukraine to reach the ambitious GHG emission reduction targets and promote low carbon and climate-resilient development of the country. Wherein, Barrier Analysis and Enabling Framework project's phase will recognize in detail the concrete needs in modern technologies to reach ambitious national low carbon development targets for Agriculture, Waste and Water sectors.

Iryna Stavchuk

Deputy Minister of Energy and Environment Protection of Ukraine

Preface

Ukraine has been playing an active role in the cooperation processes of international climate change as an Annex I Party to the United Nations Framework Convention on Climate Change since 1997 and Annex B Party to Kyoto Protocol since 2004.

In 2016, Ukraine was one of the first countries to ratify the Paris Agreement. Being committed to achieve Paris Agreement’s goals and being guided by national priorities, Ukraine will ensure in doing its best to achieve by 2050 the indicative greenhouse gases emission target of up to 31-34% of the emission level in 1990. This target is ambitious and fair in the context of Ukraine’s participation in the global response to the threat of climate change.

Ukraine has also climate related obligations determined in accordance to EU-Ukraine Association Agreement, which became the part of National Legislation in 2014, envisioned the gradual approximation of Ukraine's legislation to EU Laws and policies in energy efficiency, renewable energy, energy products taxation, waste treatment, and climate change, including implementation of GHG allowances trading scheme in accordance to Directive 2003/87/EU.

According to Decision 3/CP.5 adopted at the 5th session of the United Nations Framework Convention on Climate Change Conference of Parties, Ukraine annually submits its National Greenhouse Gas Inventory, which includes the detailed and complete information for the entire time series in accordance with the guidelines of the UNFCCC. Also in accordance with articles 4 and 12, under UNFCCC the country periodically develops its National Communication. The latest one has been submitted in 2013.

In accordance with article 4, para. 12 under the Paris Agreement, Ukraine periodically submits its Nationally Determined Contribution. The latest one has been submitted in 2016 planning to be revised in 2020.

In accordance with article 4, para. 19 under Paris Agreement, Ukraine has already prepared and submitted in 2018 its Low Emission Development Strategy up to 2050, being focused mostly at Energy and Industrial sectors.

The Paris Agreement, in enhancing the implementation of the United Nations Framework Convention on Climate Change, aims to strengthen the global response to the threat of climate change, in the context of sustainable development and efforts to eradicate poverty, including by:

- «Holding the increase in the global average temperature to well below 2°C above preindustrial levels and pursuing efforts to limit the increase in temperature to 1.5°C above preindustrial levels, recognizing that this would significantly reduce the risks and impacts of climate change;
- Increasing the ability to adapt to the adverse impacts of climate change and to foster climate resilience and low greenhouse gas emissions development, in a manner that does not threaten food production;
- Making finance flows consistent with a pathway towards the low greenhouse gas emissions and the climate-resilient development».

In Ukraine, the achievement of optimum interrelationship (synergy) of Paris Agreement’s goals with the Ukraine's national priorities will make it possible to:

- Enhance the role of technological modernization of economy on the basis of sustainable development;
- Implement the renewable energy and material sources on a broader and more sound basis;
- Ensure the interlink of the State policy in climate change with the strategies, policies, plans and programs of economic and social development;

- Implement new economic instruments to ensure the optimum way for Ukraine to make its nationally determined contribution into Paris Agreement;
- Establish grounds to attract the climate investments into the Ukraine's economy;
- Strengthen the Ukraine's role in the international climate change with combatting efforts.

Ukraine is actively involved in Technology Needs Assessment. National policies on climate change mitigation are aimed at promoting the energy efficiency and the renewable energy sources in all sectors of the national economy, systematic afforestation activities and rational land management, promoting innovative approaches and environmentally friendly technologies and exploring the carbon financing mechanisms.

The Nationally Determined Contribution, the Low Emission Development Strategy up to 2050 and the Technology Needs Assessment to ensure the adequate technological assistance and create a favorable environment for technology development and transfer, as well as establishing the institutional mechanisms to overcome barriers for the introduction of innovative technologies for climate change mitigation and adaptation, including the strengthening of the system for the legal protection of intellectual property rights.

Executive Summary

The project for Technology Needs Assessment provides a great opportunity for Ukraine to perform the country-driven technology assessment to identify environmentally sound technologies that might be implemented with a substantial contribution in addressing climate change mitigation needs of the country.

The aim for the Technology Needs Assessment project is to support developing countries and countries with economies in transition to meet their obligations under the United Nations Convention on Climate Change, bringing contribution to the following:

- The priority of technology needs, which can be used in an environmentally safe technology package;
- To facilitate an access to and transfer of environmentally sound technologies;
- To identify the transmission-initiated projects and programs;
- To facilitate the implementation of paragraph 4.5 of the United Nations Convention on Climate Change on the know-how access;
- To define and prioritize the technologies, processes and techniques that are consistent with the mitigation of climate change and adaptation in the participating countries are consistent with the goals and priorities of the national development;
- To identify barriers that prevent the primary / preferred acquisition, implementation and dissemination of technology;
- To develop Technology Action Plan to overcome barriers, which will define the scope of activities and a favorable environment that will facilitate the transfer for the adoption of technology and the dissemination of the participating countries.

Technology Needs Assessment for climate change mitigation in Ukraine is focused on Agriculture and Waste sectors. These two sectors were responsible for 16% of total greenhouse gases emissions in 2016 and do not demonstrate downward trends during the last decade against the Energy and Industry Sectors.

The agriculture sector demonstrates the upward trend with greenhouse gases emissions, having increased by 30.6% during the last reporting decade. The intensification of agricultural production could lead to further significant growth of GHG emissions both in the Agriculture sector and Land Use, Change in Land Use and Forestry sector due to the intensive application of fertilizers and soil mineralization.

The waste sector is the only one, where greenhouse gases emissions increased since 1990 and have remained at a constant level during the last decade. The growing volumes of waste generation and the lack of developed practices for waste management pose a risk for further growth of greenhouse gases emissions.

The technology barrier analysis and enabling framework (BAEF) is a second step (after technology's prioritization) in the framework of technological transfer, which also includes technological information, enabling environment, capacity building and understanding the mechanisms for technological transfer. The technology barrier analysis and enabling framework are implemented by applying the methodology proposed by the United Nations Convention on Climate Change and the team for Technology Needs Assessment.

This report aims to outline the analysis of existing barriers and an enabling framework for prioritized technologies in Ukraine. The document was elaborated based on being developed by UNEP DTU Partnership, the Second Edition of Overcoming Barriers to the Transfer and Diffusion of Climate Technologies guidebook (Nygaard, I. & Hansen, U. E., 2015). It has two objectives: to identify barriers and understand addressing barriers to the transfer and diffusion of each selected technology, and based on these findings to establish an enabling framework for technologies of the same sector. Based on the provided TNA methodology and Multi-criteria analysis (MCA) approach (MCA, 2009), applied in the first report "Technology Needs Assessment", the following technologies (comprising consumer and capital goods, public provided and other market goods) received the highest values and were prioritized and selected for further examination of barriers and enabling framework:

Agriculture sector:

- The use of information and telecommunication technologies for GHG emission reductions in agriculture;
- Conservation tillage technologies (low-till, no-till, strip-till, etc.);
- Biogas production from animal waste;
- Organic agriculture;
- The production and use of solid biofuels from agricultural residues

Waste sector:

- Methane capture at landfills and waste dumps for energy production;
- Waste sorting (sorting of valuable components of municipal solid waste with subsequent treatment of waste residual by other technologies);
- The closure of old waste dumps with methane destruction (flaring, bio-covers, passive vent etc.)
- The aerobic biological treatment (composting) of food and green residuals;
- The mechanical-biological treatment of waste with biogas and energy production (the anaerobic digestion of organic fraction of municipal solid waste)
- The mechanical biological treatment of waste with the alternative fuel production for cement industry.

Project activities were implemented in consultation with stakeholders, representatives from the Ministry of Development of Communities and Territories of Ukraine, the Ministry of Energy and Environmental Protection of Ukraine, the Ministry for Development of Economy, Trade and Agriculture of Ukraine, Research Institutions, Business, International Organizations, NGOs, etc. National consultants have applied a participatory approach for barrier analysis and identification of enabling measures in respective sectors.

The process started with the analysis of the barrier hampering the priorities of development and climate change mitigation in Ukraine, followed by an overview and investigation of the specific sub-sectoral objectives, which are necessary to meet the national targets.

Afterwards, in order to identify the main motives and details why the discussed technology is not widely used at the moment, and why neither the private nor the public sector have invested seriously in this as a first step in the process of barrier analysis, the desk study of policy documents and other relevant documents were implemented. Further, the process of consultation was conducted with stakeholders through direct interviews and discussions.

Market mapping techniques were used in the initial stages of the barrier analysis process which involved several consultations between the concerned parties. The developed market maps continued to improve during the consultations, and they were served as a main input in the detailed categorization of the barriers and the subsequent identification of cross-technological relations (see Annex I), as well as for MSW management system individually in fig. 2.6 and 2.7.

In order to understand the fundamental problems in technology transfer, the working group of each sector has applied Logical Problem Analysis (LPA). The cause effect relations were prepared in Problem tree, having the main problem, it was put as a starter problem, causes at the bottom of the tree and their effects in the upper part of the diagram. Using LPA, the working groups were able to bring together the key features of problems, to apply logical analysis of interconnected elements, and to identify linkages between problem components and external factors. Thus, the Problem trees were used for understanding the causal relations of barriers and their linkages (see Annex II).

After compiling a long list of barriers, screening of barriers and grouping them under different categories were organized (information, social, technological, capacity building, economic and financial, policy and regulatory, etc.). For the identification of most important barriers, a modest method was applied in grouping them into basic and non-basic barriers and criteria such as starter, crucial, important, less important and insignificant barriers. Barriers related to technology implementation have been identified in ten categories (see Table 1).

The next step of the Project was the identification of measures supporting technology transfer as actions that could be taken to enhance technology transfer. The process of identification and description of measures to overcome barriers was done for two sectors (Agriculture [5 technologies, see Table 2] and Waste [6 technologies, see Tables 3a, 3b]) in the same context as barrier analysis, applying the LPA. Gender aspects where also provided in tables 2, 3a and 3b in form of individual type of barriers and corresponding group of measures to overcome it.

The experts have considered the situations and set objectives for each technology, organizing them into the Objective tree. Proposed measures were discussed according to their financial and economic profile and encouragements used (see Annex III).

Table 1. – Identified barriers' categories related to technologies implementation for Agriculture and Waste sectors

Barriers	Agriculture sector	Waste sector
Economic	Yes	Yes
Financial	Yes	Yes
Legal and regulatory	Yes	Yes
Network	Yes	Yes
Institutional and organizational capacity	Yes	Yes
Human resources	Yes	Yes
Social, cultural and behavioural	Yes	Yes
Information and awareness	Yes	Yes
Technical	Yes	Yes
Other	May occur	May occur

Afterwards, meetings and direct information exchange with stakeholders were organized to present the Market maps, Problem trees and Objective trees, discuss and familiarize with the short-list of the barriers and measures to overcome barriers pre-selected and pre-analyzed by working group, sector experts, expert team leaders and project coordinator.

Another important result of the meetings and consultations is the formation of common understanding among the involved experts that diffusion of modern waste treatment and agriculture technologies would contribute to gender equality by creating new environmentally friendly market niches and high qualified jobs in public utility sector, energy, industry, agriculture sector, monitoring services and related areas in Ukraine.

All above-mentioned prioritized technologies are described in the First Report "Technology Needs Assessment". Moreover, all the discussed technologies are available for possible financing. Next steps in the TNA process will be the preparation of TAP.

Table 2. Identified barriers and proposed measures to overcome barriers to technology transfer in the Agriculture Sector

Technology Barriers and measures		Use of information and telecommunication technologies for GHGs emission reductions in agriculture	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	Biogas production from animal waste	Organic agriculture	The production and use of solid biofuels from agricultural residues
Economic and financial	Barriers	High capital expenditures required.	High capital expenditures required.	High capital expenditures required.	Export barriers due to additional controls/ requirements on products to be imported from Ukraine to the EU. Increased competition on key export markets. Low internal demand for organic products.	High capital expenditures required.
	Measures	Subsidies for the purchase of machinery, equipment and tools.	Subsidies for the purchase of machinery, equipment and tools. Subsidies for the land area under conservation tillage for the conversion period.	Renewable heat incentives. Biomethane incentives. Carbon tax reform.	Subsidies for the land area under organic practices for the conversion period. Subsidies to cover certification expenses.	Renewable heat incentives. Carbon tax reform.
Legal and regulatory	Barriers	Lack of the approved and enforceable legislative framework on land protection and nutrients management.	The introduction of land market and risk to lose control over land plots.	Lack of environmental control over the use of organic waste. Lack of legal definition of biomethane and relevant specific policy measures.	Lack of fully operationalized regulatory base for organic agriculture development.	Lack of a specific action plan and underlying policy measures to achieve the goals of the National Energy Strategy for the period up to 2035 Lack of quality standards for biomass fuels.

Technology Barriers and measures		Use of information and telecommunication technologies for GHGs emission reductions in agriculture	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	Biogas production from animal waste	Organic agriculture	The production and use of solid biofuels from agricultural residues
	Measures	Development, adoption and enforcement the regulatory framework to ensure the effective use of nitrogen fertilizers.	Supporting the development of project-based carbon crediting mechanism. Regulatory framework for effective soil quality monitoring system. Preferential rights of lease holders to purchase land plots after the launch of land market.	Development, adoption and enforcement the regulatory framework to ensure effective use of nitrogen fertilizers. New regulatory framework on industrial emissions control.	Supporting the development of project-based carbon crediting mechanism. The incorporation of organic products into green procurement schemes. Operationalizing the Law of Ukraine On Organic Production.	-
Network	Barriers	-	-	-	-	Lack of developed biomass supply chains.
	Measures	Foster cooperation of industry players and informal industry networks.	Foster cooperation of industry players and informal industry networks.	-	-	-
Institutional and organizational capacity	Barriers	-	-	-	-	Lack of established biomass fuel market.
	Measures	-	-	-	-	Introduction of digital biomass trading platform.
Human resources	Barriers	Capacity barrier due to the need of new types of knowledge and skills for farmers.	Limited number of professionals with practical experience.	Capacity barrier due to not sufficient number of qualified managers and operational personnel.	Capacity barrier due to the lack of sufficient knowledge and lack of specialists with practical experience.	Capacity barriers include lack of sufficient expertise in setting up and servicing of equipment.
	Measures	Capacity building through the dedicated training in educational institutions Capacity building via farm advisory services.	Capacity building through the dedicated training in educational institutions Capacity building via farm advisory services.	Capacity building through the dedicated training in educational institutions Other capacity building activities.	Capacity building via farm advisory services.	-
Social, cultural and behavioral	Barriers	-	Cultural barrier (farmers got used to traditional tillage practices).		-	-

Technology Barriers and measures		Use of information and telecommunication technologies for GHGs emission reductions in agriculture	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	Biogas production from animal waste	Organic agriculture	The production and use of solid biofuels from agricultural residues
	Measures	-	-	-	-	-
Information and awareness	Barriers	Insufficient publicly available information on cost and benefits of the ICT application in agriculture. Available data on soil quality and land use do not meet industry requirements.	Lack of reliable information on soil quality, incl. soil organic carbon content.	-	Low awareness about the benefits of organic products and organic products labelling.	Information barriers.
	Measures	The provision of reliable statistical data on soil quality and land use Information policies Supporting the development of publicly available decision support tools.	The provision of reliable statistical data on soil quality and land use. Information policies.	-	The provision of reliable statistical data on soil quality and land use Information policies.	The provision of reliable statistical data on soil quality and land use Information policies.
Technical	Barriers	Not sufficient coverage of RTK and GSM networks in rural areas Low availability of agro-meteorological stations Technological problems during operation and low level of servicing Lack of interoperability standards.	Technological barrier related to the region- and plant-specific requirements for the application of conservation tillage.	Technological barrier related to the complicated technological processes Insufficient availability of equipment servicing providers.	-	Technological barrier related to the specific agro-biomass fuels characteristics and the limited availability of specialized equipment suitable for agricultural biomass combustion.
	Measures	-	-	-	-	-
Other	Barriers	-	-	-	-	Environmental barrier due to soil degradation risk Environmental barrier due to air pollution during biomass combustion.
	Measures	General improvement of digital education especially in rural areas.	-	-	Mitigation of export barriers via negotiations with international partners.	Emission limits requirements for biomass capacities.

Technology Barriers and measures		Use of information and telecommunication technologies for GHGs emission reductions in agriculture	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	Biogas production from animal waste	Organic agriculture	The production and use of solid biofuels from agricultural residues
Gender aspects	Barriers	Women in rural areas of Ukraine face gender related challenges (e.g. lack of social infrastructure, limited employment possibilities, non-attractive working conditions and lack of opportunities to receive professional education). There is a significant gap in employment and wages levels between men and women in agriculture sector.	Women in rural areas of Ukraine face gender related challenges (e.g. lack of social infrastructure, limited employment possibilities, non-attractive working conditions and lack of opportunities to receive professional education). There is a significant gap in employment and wages levels between men and women in agriculture sector.	Women in rural areas of Ukraine face gender related challenges (e.g. lack of social infrastructure, limited employment possibilities, non-attractive working conditions and lack of opportunities to receive professional education). There is a significant gap in employment and wages levels between men and women in agriculture sector.	Women in rural areas of Ukraine face gender related challenges (e.g. lack of social infrastructure, limited employment possibilities, non-attractive working conditions and lack of opportunities to receive professional education). There is a significant gap in employment and wages levels between men and women in agriculture sector.	Women in rural areas of Ukraine face gender related challenges (e.g. lack of social infrastructure, limited employment possibilities, non-attractive working conditions and lack of opportunities to receive professional education). There is a significant gap in employment and wages levels between men and women in agriculture sector.
	Measures	Inclusive approach in capacity building activities Requirements on vacancies should be gender neutral both for government and business.	Inclusive approach in capacity building activities Requirements on vacancies should be gender neutral both for government and business.	Inclusive approach in capacity building activities Requirements on vacancies should be gender neutral both for government and business.	Inclusive approach in capacity building activities Requirements on vacancies should be gender neutral both for government and business.	Inclusive approach in capacity building activities Requirements on vacancies should be gender neutral both for government and business.

Table 3a. Identified main barriers and proposed measures to overcome barriers to technology transfer in the Waste Sector

Technology Barriers and measures		Methane capture at landfills and waste dumps for energy production	Waste (MSW) sorting	The closure of old waste dumps with methane destruction
Economic and financial	Barriers	Possible low feasibility of the projects in case of achieved less than expected efficiency of LFG recovery. High cost of finance.	Low tariffs on MSW management for population and other waste generators. Absence of economic incentives to process and recycle MSW. Absence of producer responsibility on the generated waste.	Low tariffs on MSW disposal (tariffs do not include costs for closure, care and aftercare monitoring). Disincentives to foreign investment. Absence of waste producer responsibility The improper use of environmental protection fund.
	Measures	The creation of economic and financial conditions for modern regional landfill construction program. The creation of economic and financial conditions for old waste dumps closure. The introduction of high gate fee/ tax for organic waste disposal. The creation of conditions for LFG use for heat and biomethane production. Adequate access to financial resources; Incentives to foreign investment.	The introduction of the tariffs for waste management sufficient to cover associated expenses. Implementation of “Pay as you throw” principle. Implementation of “Extended producer responsibility” principle.	The introduction of tariffs on waste disposal, which will cover all expenditures including environmental and operational, as well as related to landfill closure and re-cultivation. The implementation of “Extended producer responsibility” principle. Increase in environmental tax on waste disposal. Repeated increase in penalties for the violation of legislation in waste disposal issues.
Legal and regulatory	Barriers	Lack of comprehensive and strategic energy policy implementation. Insufficient institutional framework. Over-bureaucratic procedures. Lack of control for unofficial landfilling and activities.	Insufficient institutional framework. Lack of comprehensive and strategic waste management policy. Lack of stimulus for MSW treatment and utulisation.	Low requirements on landfill operation. Inadequately low responsibility for violation of legislation in waste treatment system, especially waste disposal procedures. Landfill operators have no responsibility for landfill post-operational period on practice. Issue of secondary raw materials extraction/ mining from the closed or old landfills is not regulated.

Technology Barriers and measures		Methane capture at landfills and waste dumps for energy production	Waste (MSW) sorting	The closure of old waste dumps with methane destruction
	Measures	The alignment of landfill operation procedures in Ukraine with the requirements of Directive 1999/31/ EC. The responsibility of landfill operators for the post-operational period of landfills (closure and monitoring). The legalization and regulation of landfill mining activity.	The introduction of new Law On waste unified with EU legislation. The implementation and use of cost-effective tools to encourage the creation of infrastructure on waste treatment facilities.	The alignment of landfill operation procedures in Ukraine with the requirements of Directive 1999/31/ EC. The implementation of national waste classification. Increase of responsibility for violation of legislation in waste disposal procedures. Increased responsibility of landfill operators for the post-operational period of landfills. Legalization and regulation of landfill mining activity.
Network	Barriers	Lack of inter-municipal cooperation.	Existing MSW treatment system does not permit to collect the significant amount of MSW valuable components.	Local authorities, communities and MSW collecting companies have no alternatives to waste disposal.
	Measures	The expansion of inter-municipal cooperation. Ensuring that at least 50 new sanitary regional landfills would be put into operation by 2030.	Ensuring that new waste reception/collection centres, centres for collecting MSW materials with the purpose of reuse, MSW sorting lines, additional containers and collection vehicles, as well as MSW reloading stations would be put into operation by 2030.	Ensuring that new sanitary regional landfills, new waste reception/collection centres, centres for collecting MSW materials with the purpose of reuse, MSW sorting lines, additional containers and collection vehicles, as well as MSW reloading stations would be put into operation by 2030.
Institutional and organizational capacity	Barriers	Responsibilities in waste management system are over-dispersed between a number of central and local authorities.	Responsibilities in waste management system are over-dispersed between a number of central and local authorities. Informal sector has negative influence on institutional and organizational capacity.	Responsibilities in waste management system are over-dispersed between a number of central and local authorities. Informal sector has negative influence on institutional and organizational capacity.
	Measures	The creation of a new central authority responsible for waste management state policy implementation in Ukraine. The introduction of inter-municipal cooperation. Levelling an influence of informal sector.	The creation of a new central authority responsible for waste management state policy implementation in Ukraine. The introduction of inter-municipal cooperation. Levelling an influence of informal sector. The creation of an interagency coordination board for research on waste reuse, processing and utilisation.	The creation of a new central authority responsible for waste management state policy implementation in Ukraine. The introduction of inter-municipal cooperation. Levelling an influence of informal sector. The creation of an interagency coordination board for research on waste reuse, processing and utilisation.

Technology Barriers and measures		Methane capture at landfills and waste dumps for energy production	Waste (MSW) sorting	The closure of old waste dumps with methane destruction
Human resources	Barriers	Lack of specialists in sustainable waste management.	Lack of specialists in sustainable waste management.	Lack of specialists in MSW disposal sites closure technologies. Absence of experience on environmental friendly post-operational management of the landfills, monitoring and integration of landfills areas in the sustainable regional development plans.
	Measures	Support on new specialties on sustainable waste management at the universities. The consideration of waste management issues when developing high education standards. The creation of guidelines in modern waste management opportunities for the municipalities.	Support on new jobs in the innovative sector of waste management system. The creation of guidelines on modern waste management opportunities for municipalities. The support of new specialties on sustainable waste management in universities.	Support on new specialties on sustainable waste management at the universities. The consideration of waste management issues when developing higher education standards. The creation of guidelines in modern waste management opportunities for municipalities.
Social, cultural and behavioural	Barriers	Landfill closure will lead to loss of jobs for the poor people involved in the grey sector of economy.	Lack of economic stimulus for population to contribute to MSW separate collection.	Landfill closure will lead to loss of jobs for the poor people involved in grey sector of economy.
	Measures	The creation of alternative legal jobs for the poor people from communities, located nearby landfills that are planned to be closed.	The provision of support by local authorities to carry out awareness companies for local communities.	The creation of alternative legal jobs for the poor people from communities, located nearby landfills that are planned to be closed.
Information and awareness	Barriers	Limited awareness of the modern technology used in developed countries. Lack of available information, poor population knowledge and involvement. Missing feedback among interested parties.	Lack of knowledge and awareness of population on the importance of MSW separation. Lack of knowledge about the health risks related with waste burning. Lack of training courses and programs focused on MSW sustainable treatment for school.	Lack of knowledge and awareness by local communities about negative effect on environment, local business activity end their life quality caused by MSW landfills and dumps. People do not know the alternatives to waste disposal and how to organize their lifestyle to prevent such a practice.
	Measures	National awareness campaign on sustainable waste management as an alternative to MSW disposal. Waste management awareness activities in school and pre-school institutions.	National awareness campaign on sustainable waste management. Product labeling. The implementation of MSW management awards. Waste management awareness activities in school and pre-school institutions.	Carrying out national awareness campaign on sustainable waste management as an alternative to MSW disposal. Carrying out waste management awareness activities in school and pre-school institutions.

Technology Barriers and measures		Methane capture at landfills and waste dumps for energy production	Waste (MSW) sorting	The closure of old waste dumps with methane destruction
Technical	Barriers	Low technical standards of landfill operation, lack of information regarding waste content. Lack of historical data regarding waste delivery, operation practice, landfilling events, etc.	Population is limited in modern MSW treatment technology accessibility.	Population is limited in alternatives to waste disposal practice and mainly do not have an influence on MSW collecting companies regarding the future waste processing procedures on the waste generated by these people.
	Measures	Ensuring the availability of MSW collecting companies to transfer cargo to modern MSW processing facilities and new sanitary regional landfills, where needed.	Ensuring the availability of MSW collecting companies to transfer cargo to modern MSW processing facilities and establishing control over the separate collection infrastructure accessibility.	Ensuring the availability of MSW collecting companies to transfer cargo to modern MSW processing facilities and new sanitary regional landfills, where needed.
Gender aspects	Barriers	Workers should be able to operate in difficult physical and sanitary conditions. Men are used to have higher average salaries at the similar positions and higher chances for carrier paths.	Workers should be able to operate in difficult physical and sanitary conditions. Men are used to have higher average salaries at the similar positions and higher chances for carrier paths.	Workers should be able to operate in difficult physical and sanitary conditions. Men are used to have higher average salaries at the similar positions and higher chances for carrier paths.
	Measures	Introduction of innovative technologies and modern practice. Requirements on vacancies should be gender neutral both for government and business. Implementation of awards focused on promoting women to be involved in waste management issues. Encouraging business and governmental institutions to engage women in leadership positions.	Introduction of innovative technologies and modern practice. Requirements on vacancies should be gender neutral both for government and business. Implementation of awards focused on promoting women to be involved in waste management issues. Implementation of supporting mechanisms stimulating migration of hired workers in waste management from informal sector to legal business. Encouraging business and governmental institutions to engage women in leadership positions.	Introduction of innovative technologies and modern practice. Requirements on vacancies should be gender neutral both for government and business. Implementation of awards focused on promoting women to be involved in waste management issues. Implementation of supporting mechanisms stimulating migration of hired workers in waste management from informal sector to legal business. Encouraging business and governmental institutions to engage women in leadership positions.

Table 3b. Identified barriers and Proposed measures to overcome barriers to technology transfer in the Waste Sector

Technology Barriers and measures		The aerobic biological treatment (composting) of food and green residuals	The mechanical-biological treatment of waste with biogas and energy production (AD)	The mechanical-biological treatment of waste with SRF production for cement industry
Economic and financial	Barriers	Low tariffs for waste collection, treatment and landfilling. Waste disposal is still the cheapest option of MSW management. High cost of finance. Low population income and difficulties to pay communal bills.	Low feasibility or unprofitability (low IRR, NPV, long payback period) of MBT projects. Low tariffs for waste landfilling and treatment. Low population income and difficulties to pay communal bills. High cost of capital. High cost of finance. Lack of local suppliers.	Low feasibility or unprofitability (low IRR, NPV, long payback period) of MBT projects. Low tariffs for waste landfilling and treatment. Low population income and difficulties to pay communal bills. High cost of capital. High cost of finance. Lack of local suppliers.
	Measures	The creation of conditions for separate collection of food and garden waste. The creation of conditions including preferential taxation, for the development of the municipal organic waste composting industry. The creation of conditions for modern home composting. Development of a detailed composting algorithm for individual types of waste, including domestic waste. The development of the program for compost use as soil improver and organic fertilizer. Adequate access to financial resources, reduction of the cost of finance.	The introduction of high gate fee/ tax for organic waste disposal. The creation of conditions for MBT with biogas and energy production. To create condition for biogas use as heat and biomethane production source. The development of the program for MBT projects implementation. Adequate access to financial resources; Reduction of the cost of finance.	The introduction of high gate fee/ tax for waste disposal. The creation of conditions for MBT with RDF/SRF for cement industry production. To create condition for RDF/SRF use as natural gas and other conventional fuels substitution. The development of the program for MBT projects implementation. Adequate access to financial resources. Reduction in the cost of finance.
Legal and regulatory	Barriers	Lack of comprehensive and strategic energy policy implementation. Insufficient institutional framework. Over-bureaucratic procedures (land plot allotment, introduction of changes in the project, etc.). Lack of control for unofficial landfilling and activities. No incentives for organic waste separate treatment.	Lack of comprehensive and strategic energy policy implementation. Insufficient institutional framework. Over-bureaucratic procedures (land plot allotment, introduction of changes in the project, etc.). Lack of control for unofficial landfilling and activities. No incentives for organic waste separate treatment.	Lack of comprehensive and strategic energy policy implementation. Insufficient institutional framework. Over-bureaucratic procedures (land plot allotment, introduction of changes in the project, etc.). Lack of control for unofficial landfilling and activities.

Technology Barriers and measures		The aerobic biological treatment (composting) of food and green residuals	The mechanical-biological treatment of waste with biogas and energy production (AD)	The mechanical-biological treatment of waste with SRF production for cement industry
	Measures	The introduction of national waste classification based on European practice. The implementation and use of cost-effective tools to encourage the creation of waste management facilities infrastructure. The introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of recycling/ composting practice. The introduction of a mechanism for providing subsidies for the collection and transportation of green waste suitable for compost production.	The introduction of national waste classification based on European practice. The implementation and use of cost-effective tools to encourage the creation of advance waste treatment facilities infrastructure. Introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of biological waste treatment practice. The introduction of a mechanism for providing subsidies for the collection and transportation of green waste suitable for biogas production.	The introduction of national waste classification based on European practice. The implementation and use of cost-effective tools to encourage the creation of advance waste treatment facilities infrastructure. The introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of MBT waste treatment practice. The introduction of a mechanism for providing subsidies for the collection and transportation of waste suitable for RDF/SRF production.
Network	Barriers	Underdeveloped inter-municipal cooperation.	Underdeveloped inter-municipal cooperation.	Underdeveloped inter-municipal cooperation.
	Measures	The development and implementation of waste management plans at regional level and at the level of all administrative entities. The implementation of the principle "Community is the owner of the waste and responsible entity for its processing in accordance with the regional waste management plan". The expansion of inter-municipal cooperation. Ensuring that Waste Reception/Collection and Compost Centres in cities with a population above 20,000.	The development and implementation of waste management plans at regional level and at the level of all administrative entities. The implementation of the principle "Community is the owner of the waste and responsible entity for its processing in accordance with the regional waste management plan". The expansion of inter-municipal cooperation. Ensuring the implementation of MBT Centres in territorial clusters with total population above 200,000.	The development and implementation of waste management plans at regional level and at the level of all administrative entities. The implementation of the principle "Community is the owner of the waste and responsible entity for its processing in accordance with the regional waste management plan". The expansion of inter-municipal cooperation. Ensuring the implementation of MBT Centres in territorial clusters with total population above 200,000.
Institutional and organizational capacity	Barriers	Responsibilities in waste management system are over-dispersed in between a number of central and local authorities.	Responsibilities in waste management system are over-dispersed in between a number of central and local authorities.	Responsibilities in waste management system are over-dispersed in between a number of central and local authorities.

Technology Barriers and measures		The aerobic biological treatment (composting) of food and green residuals	The mechanical-biological treatment of waste with biogas and energy production (AD)	The mechanical-biological treatment of waste with SRF production for cement industry
	Measures	The creation of a new central authority responsible for waste management state policy implementation in Ukraine. Introduction of inter-municipal cooperation as a legal mechanism supported by the Government. Levelling an influence of informal sector, giving it an opportunity to work within the framework of acting legislation.	The creation of a new central authority responsible for waste management state policy implementation in Ukraine. The introduction of inter-municipal cooperation as a legal mechanism is supported by the Government. Levelling an influence of informal sector, giving it an opportunity to work within the framework of acting legislation, wherein it's acceptable.	The creation of a new central authority responsible for waste management state policy implementation in Ukraine. The introduction of inter-municipal cooperation as a legal mechanism is supported by the Government. Levelling an influence of informal sector, giving it an opportunity to work within the framework of acting legislation, wherein it's acceptable.
Human resources	Barriers	Lack of specialists in sustainable waste management.	Lack of specialists in sustainable waste management.	Lack of specialists in sustainable waste management.
	Measures	Support on new specialties on sustainable waste management in universities. Launching of targeted programs at high school. The consideration of waste management issues when developing higher education standards. Support of new specialties on sustainable waste management in universities. The creation of guidelines in modern waste management opportunities for municipalities.	Support on new specialties on sustainable waste management in universities. Launching of targeted programs at high school. The consideration of waste management issues when developing higher education standards. Support of new specialties on sustainable waste management in universities. The creation of guidelines in modern waste management opportunities for municipalities.	Support on new specialties on sustainable waste management in universities. Launching of targeted programs at high school. The consideration of waste management issues when developing higher education standards. Support of new specialties on sustainable waste management in universities. The creation of guidelines in modern waste management opportunities for municipalities.
Social, cultural and behavioural	Barriers	No developed culture of home composting in suburban and rural areas.	-	-
	Measures	The introduction of home composting in suburban and rural areas.	-	-
Information and awareness	Barriers	Limited awareness of the modern technology used in developed countries. Lack of available information, poor population knowledge and involvement. Missing feedback among interested parties.	Limited awareness of the modern technology used in developed countries. Lack of available information. Missing feedback among interested parties.	Limited awareness of the modern technology used in developed countries including cement industry. Lack of available information. Missing feedback among interested parties.
	Measures	National awareness campaign on sustainable waste management as an alternative to MSW disposal. Waste management awareness activities in school and pre-school institutions.	National awareness campaign on sustainable waste management as an alternative to MSW disposal. Waste management awareness activities in school and pre-school institutions.	National awareness campaign on sustainable waste management as an alternative to MSW disposal. Waste management awareness activities in school and pre-school institutions.

Technology Barriers and measures		The aerobic biological treatment (composting) of food and green residuals	The mechanical-biological treatment of waste with biogas and energy production (AD)	The mechanical-biological treatment of waste with SRF production for cement industry
Technical	Barriers	Low collecting efficiency of the high-quality organic waste. Lack of separate food and green waste collection.	Low technical standards of waste management. Lack of information regarding waste content and amount.	Low technical standards of waste management. Lack of information regarding waste content and amount.
	Measures	The introduction of separate collection and sorting activities. The development of the program for compost use as soil improver and organic fertilizer. The development of the program for composting.	The introduction of separate collection and sorting activities. The development of the program for MBT projects implementation.	The introduction of separate collection and sorting activities. The development of the program for MBT projects implementation.
Gender aspects	Barriers	Men are used to have higher average salaries at the similar positions and higher chances for carrier paths.	Men are used to have higher average salaries at the similar positions and higher chances for carrier paths.	Men are used to have higher average salaries at the similar positions and higher chances for carrier paths.
	Measures	Introduction of innovative technologies and modern practice. Requirements on vacancies should be gender neutral both for government and business. Implementation of awards focused on promoting women to be involved in waste management issues. Encouraging business and governmental institutions to engage women in leadership positions.	Introduction of innovative technologies and modern practice. Requirements on vacancies should be gender neutral both for government and business. Implementation of awards focused on promoting women to be involved in waste management issues. Encouraging business and governmental institutions to engage women in leadership positions.	Introduction of innovative technologies and modern practice. Requirements on vacancies should be gender neutral both for government and business. Implementation of awards focused on promoting women to be involved in waste management issues. Encouraging business and governmental institutions to engage women in leadership positions.

Contents

Acronyms

AD	Anaerobic Digestion
BA&EF	Barrier Analysis and Enabling Framework
CAPEX	Capital Expenditures
CHP	Combined Heat and Power
CLO	Compost-Like-Output
COP	Conference of the Parties
DH(S)	District Heating (Systems)
DTU	Technical University of Denmark
EPR	Extended Producer Responsibility
EST	Environmentally Sound Technology
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
LEDS	Low Emission Development Strategy
LFG	Landfill Gas
LPA	Logical Problem Analysis
LULUCF	Land Use, Land-Use Change and Forestry
MBT	The Mechanical Biological Treatment of waste
MCA	Multi Criteria Analysis
MRF	Material Recovery Facility
MSW	Municipal Solid Waste
NC	National Communication
NDC	Nationally Determined Contribution
OPEX	Operational Expenditures
PET	Polyethylene terephthalate
PPP	Purchasing Power Parity
RES	Renewable Energy Sources
RDF	Refused Derived Fuel
SAEE	State Agency on Energy Efficiency and Energy Saving
SRF	Solid Recovered Fuel
TAP	Technology Action Plan
TNA	Technology Needs Assessment
TPEC	Total Primary Energy Consumption
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VAT	Value Added Tax
WSL	Waste Sorting Line
WWTP	Waste Water Treatment Plant

Units of measurement

ºC	Degrees Celsius
CO_2-eq.	Carbon Dioxide equivalent
GWh	Gigawatt-hour
ha	hectare
EUR	Euro (€)
kt	thousand tons
ktoe	thousand tons of oil equivalent
kWh	kilowatt-hour
Mt	Millions of tons
Mtoe	Millions tons of oil equivalent
MW	Megawatt
MWh	Megawatt-hour
toe	tons of oil equivalent
USD	United States Dollar

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Chapter 1 Agriculture Sector

1.1 Preliminary targets for technology transfer and diffusion in Agriculture sector

Under the Paris Agreement, adopted in 2015, countries agreed to strengthen the global response to the threat of climate change, including by holding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change. Each country has an obligation to prepare, communicate and maintain successive nationally determined contributions (NDC) to the global response to climate change, including the description of domestic mitigation measures, that it intends to achieve (PA, 2016). Ukraine has prepared and communicated a nationally determined contribution with the level of GHG emissions not exceeding 60% of 1990 GHG emissions level in 2030 (NDC, 2016). This target is also reflected in the Concept of state's policy implementation in the area of climate change for the period till 2030 (CSPIACC, 2016). However, Ukraine's NDC is planned to be updated in 2020 and the results of the TNA project is being considered as one of inputs in developing the new and more ambitious economy-wide emission reduction target.

Greenhouse gases emissions from Agriculture sector

Agriculture related activities influence greenhouse gases emissions flows in the two categories reported in the national inventory: emissions in Agriculture sector and emissions associated with cropland sub-sector in Land Use, Land Use Change, and Forestry sector.

In 2017, emissions from the Agriculture sector in Ukraine amounted 38.9 Mt CO_2-eq. and the main sources included agricultural soils (70.0%), enteric fermentation (22.1%) and manure management (4.9%). Emissions in the cropland sub-sector amounted to 39.6 Mt CO_2-eq. and stem from soil organic carbon losses due to more intense agricultural practices and decline in the use of organic fertilizers. The loss of soil organic carbon is caused by a negative balance between the inflow of nitrogen and carbon in the form of humification of dead organic matter and organic fertilizers on one side and the removal of nitrogen and carbon with main products (harvest), by-products and crop residues as a result of soil humus mineralization process on the other side (NIR, 2019). During the last 5 years, emissions from Agriculture sector remained relatively stable in the range of 37-40 Mt CO_2-eq. per year, while emissions in cropland sub-sector demonstrated broader variation in the range of 40-47 Mt CO_2-eq. per year (TNA, 2019).

Policy context

Low Emissions Development Strategy (LEDS, 2017) foresees the indicative GHG emissions target of 31-34% by 2050, compared to 1990 level, and covers aspects related to agriculture in all three main objectives:

- Objective I: Transition to energy system which envisions the use of energy sources with low carbon content and the development of the sources for clean electricity and heat energy;
- Objective II: Increase in the volumes of carbon absorption and uptake with the help of best climate change mitigation practices in agriculture and forestry;
- Objective III: Reduction in GHG emissions such as methane gas and nitrogen oxide predominantly associated with fossil fuel production, agriculture and waste.

The LEDS also includes several policy options for climate mitigation in the agriculture sector: drafting nationally acceptable recommendations on the improvement of animal feeding practice (feed energy content increase, the use of specific natural or synthetic additives to improve digestibility, etc.); promoting the implementation of improved manure management technologies; enhancing the efficiency in the use of fertilizers; and incentivizing more efficient use of water.

The Law of Ukraine On the Main Grounds of the State Environmental Policy of Ukraine for the Period till 2030 was adopted in 2019 and entered into force starting from the 1st January, 2020 (LU SEPU, 2019). One of the five goals of state environmental policy (Goal 3. Ensuring the integration of environmental policy in the decision-making process with respect to the social and economic development of Ukraine) includes such tasks as climate change mitigation and adaptation, as well as the sustainable low carbon development of all areas of the Ukrainian economy.

In 2019, the President of Ukraine approved an order On Sustainable Development Goals for Ukraine for the period till 2030, which declared Ukraine's support for the achievement of 17 sustainable development goals and introduced them as indicators for developing national policy documents (PU, 2019). The order supports UN's Sustainable Development Goals approved by the Resolution 70/1 "Transforming our world: the 2030

Agenda for Sustainable Development” and adopted by the General Assembly on the 25th September 2015, which was adapted to account the national circumstances as reflected in the National Report “Sustainable Development Goals: Ukraine” (MEDTU, 2017).

According to the Food and Agriculture Organization of the United Nations, climate-smart agriculture (CSA) can support the achievement of all 17 Sustainable Development Goals. The CSA approach comprises three pillars or objectives: (1) sustainably to increase agricultural productivity and incomes; (2) to adapt and build resilience to climate change; and (3) to reduce/remove GHG emissions. Reduction of GHGs emissions could be achieved by increasing resource use efficiency, retaining and sequestering carbon in agro-ecosystems, and replacing fossil fuel-based energy with renewable energy. There are strong synergies of mitigation activities with actions aimed at increasing productivity, as many GHGs reduction measures will also reduce expenditure on inputs, increase resource efficiency or contribute to income diversification for farmers, as well as with actions aimed at climate change adaptation, as many mitigation technologies have adaptation co-benefits (e.g. practices that increase soil organic carbon content also improve soil structure, thereby reducing susceptibility to erosion, drought and floods) and vice versa (e.g. agroforestry practices enhance the sequestration of carbon in soils and plant biomass). Potential trade-offs, such as competition between food production and use of arable land to produce biomass for bioenergy, should be considered (FAO, 2019 A).

The Strategy of Agrarian Sector Development for the period till 2020 includes a strategic goal of the rational use of agricultural lands and reduction in the technogenic pressure of agriculture sector on the environment. Priority actions to achieve the strategic goals include environmental protection measures, such as the support of organic agriculture, ensuring the effective use of natural resources through the implementation of monitoring and quality control system for agricultural lands, creating conditions for the soil conservation, as well as the renovation of irrigation systems (CMU, 2013).

Overall, the agriculture sector is reflected in the existing strategic documents related to national climate policy but there is insufficient coverage of climate change mitigation activities in sector-specific policy documents and lack of policy tools which promote climate technologies in the agriculture sector. Developing policy tools to address existing barriers for prioritized mitigation technologies will support the achievement of national development goals.

Prioritized climate mitigation technologies

Within the first stage of the TNA project, the following mitigation technologies have been identified taking into account agriculture sector’s development priorities, climate, energy and environmental policy goals:

1) Organic agriculture;
2) Biogas production from animal waste;
3) Conservation tillage technologies (low-till, no-till, strip-till, etc.);
4) The production and use of solid biofuels from agricultural residues;
5) The use of information and telecommunication technologies in agriculture for the reduction of GHGs emission in agriculture.

All technologies listed above are already available in Ukraine, however the level of penetration is far beyond their technological and economic potential. Specific policy tools to support further dissemination of prioritized technologies should be developed taking into account the long-term effects of the technologies and based on the broad stakeholder engagement.

All five prioritized technologies could be categorized as capital goods technologies, since they are used to produce other goods (i.e. agricultural crops) and purchased by private companies, as well as they have relatively large CAPEX and simpler market chains. However, depending on the specifics of the technology to be implemented by a particular farmer for the use of information and telecommunication tools in agriculture and organic farming, the technology could also be classified as consumer goods technologies, since they can involve smaller investment and the use of separate pieces of equipment or materials with relatively low prices and large supply chains. For the purpose of the TNA project, the focus is on the complex introduction of prioritized technologies and therefore, all of them are treated as capital goods technologies.

Table 1-1. Summary of prioritized agriculture mitigation technologies

Technology	Hardware	Software	Orgware
Organic agriculture – consumer goods / capital goods category*	Equipment (standard agricultural machinery, organic fertilizer spreader machines, etc.) and materials (organic fertilizers)	Know-how on organic agricultural practices (manuals, guidance, recommendations, skills, etc.) Farm management practices (crops rotation, organic fertilizers use, etc.)	Diffusion of the technology depend on effective collaboration of the farmers, material suppliers, and product distributors Legislation and regulatory base on organic agriculture
Biogas production from animal waste – capital goods category	Equipment (methane tanks, CHP units, auxiliary equipment)	Know-how on biogas production project development and operation of biogas units	Owners of the hardware and farmers Legislation and regulatory base on biogas production and animal manure management
Conservation tillage technologies (low-till, no-till, strip-till, etc.) – capital goods category	Equipment (special agricultural machinery)	Know-how on conservation tillage practices (manuals, guidance, recommendations, skills, etc.) Farm management practices	Owners of the hardware Legislation and regulatory base on conservation tillage
The production and use of solid biofuels from agricultural residues – capital goods category	Equipment (balers, transportation machinery, CHP units, boilers, auxiliary equipment)	Know-how on solid biofuels production project's development and operation of biomass boiler houses or CHP units	Owners of the hardware Legislation and regulatory base on biomass fuel use
The use of information and telecommunication technologies in agriculture for the reductions of greenhouse gases emission in agriculture – consumer goods / capital goods category*	Equipment (drones, specialized agricultural machinery with on-board IT systems, equipment for differentiated fertilizers input, etc.)	Know-how on the use of information and telecommunication technologies in agriculture	The diffusion of the technology depends on the effective collaboration of farmers and service providers

** depending on the specific elements of the technology to be implemented in each particular case and the size of the investment required (e.g. investment in drones and IT systems/services vs investment to renew the park of machinery to be able to use ICT)*

Stakeholder consultations

Key stakeholders that are expected to be involved in the development of enabling framework for further dissemination of prioritized mitigation technologies in the agriculture sector include:

- central state authorities, including the Ministry of Economic Development, the Trade and Agriculture of Ukraine, the Ministry of Environmental Protection and Energy of Ukraine, State Energy Savings and Energy Efficiency Agency of Ukraine;

- regional and local state authorities, including regional state administrations and local communities;
- business associations and private companies;
- scientific institutions; and
- non-governmental organizations.

Information on the identified barriers for climate mitigation technologies and proposed policy measure to support the diffusion of climate technologies will be distributed among the key stakeholders.

Stakeholder's engagement process within the second stage of the TNA project included the following activities:

- in person interviews with the experts specialized in prioritized mitigation technologies;
- the review of position papers and other communications presented by institutions, private companies and business associations;
- participation in key agricultural exhibitions and conferences and following the presentations of sector representatives on the developments of prioritized technologies (e.g. Agro 2019, Agroport Kherson 2019, Biomass for Energy 2019, AgroComplex 2019, Netherland-Ukrainian Agro-IT Forum 2020, Organic Ukraine 2020, etc.);
- online discussions using social media and email communication.

Taking into account potential adaptation co-benefits of identified technologies, development of climate policies for agriculture sector should cover both mitigation and adaptation aspects.

As a result of the limited land availability and growing food demand on the global scale, new technologies will be playing key roles in the future development of agriculture sector.

<u>Gender equality and equal opportunities</u>

Gender equality is an important aspect of supporting the diffusion of climate mitigation technologies, since women could often be more vulnerable to the effects of climate change.

Women in rural areas of Ukraine face both gender related and residence related challenges, in particular lack of social infrastructure (e.g. kindergartens, medical services, public transportation, etc.), limited employment possibilities (both for women and men, since employment of men from the families also brings benefits to women in terms of higher welfare), non-attractive working conditions (long hours, wage levels, etc.), and lack of opportunities to receive professional education and strengthen skills (digital technologies, soft skills, etc.) (NECU, 2015).

Gender aspects are getting greater attention and in 2020 a business community WE AGRI (Women Entrepreneurs Agri) has been established to unite female leaders in the agricultural industry. Environmental protection and climate protection were mentioned among the key priorities of WE AGRI.

Both men and women can equally take advantage of prioritized climate mitigation technologies, if gender aspects are considered during all stages of supportive policies development. Taking into account existing inequalities, climate technologies should be deployed considering the women's access to technology value chains, dedicated trainings on climate technologies for women, the participation of women in stakeholder consultations and decision-making process to ensure that women can benefit from the diffusion of new technologies.

Information on gender aspects in the agricultural sector is annually published by the State Statistics Service of Ukraine (SSSU) in its Statistical herald "Labour of Ukraine" (LU, 2019; LU, 2018; LU, 2017; LU, 2016; LU, 2015).

Between 2014 and 2018, the official employment in the agricultural sector decreased by 11.2%, which is in line with the overall tendency for official employment decrease of 12.6% caused by economic decline, labor immigration and other factors. Figure 1.1 shows the dynamics of men and women employed in the agricultural sector of Ukraine during recent years, demonstrating a significant gap between the number of men and women employed in the sector and also larger decrease in employment of women (-14.8% compared to -9.3% for men) during recent years.

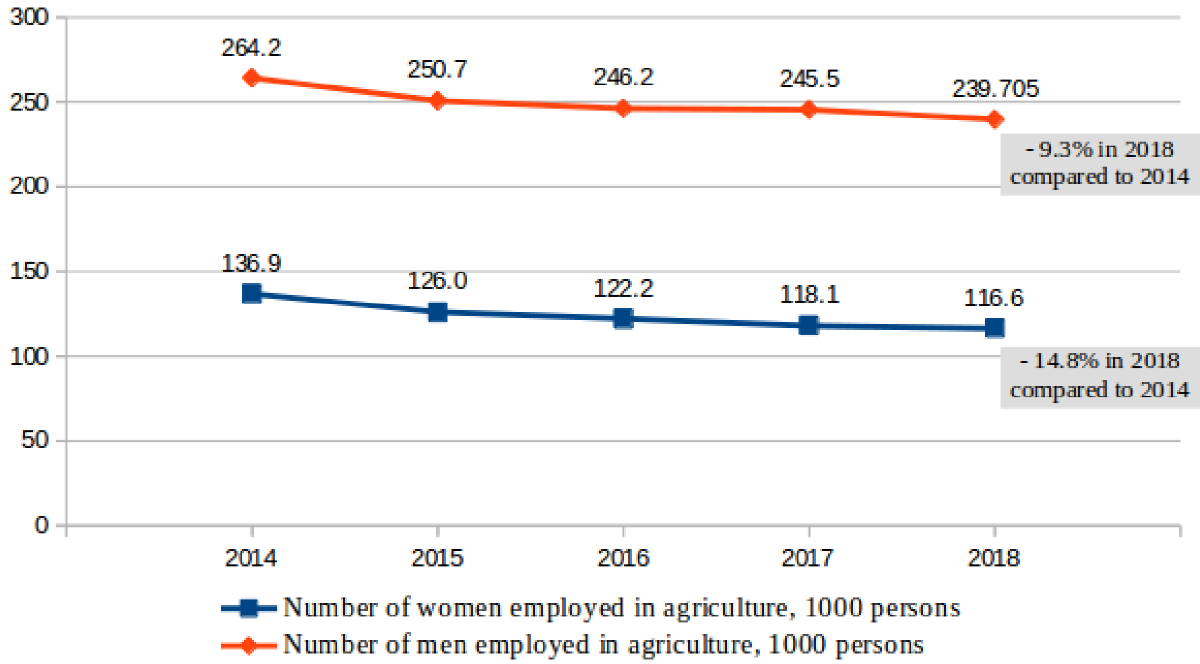


Figure 1.1. – Employment in the agricultural sector of Ukraine in 2014-2018

Figure 1.2 illustrates that more than half of reported employed workers in Ukraine are women, however in the agricultural sector, there is a gender gap, as only every third reported worker is a woman. There was also a small decline in the share of women employed in agriculture from 34.1% in 2014 to 32.7% in 2018, while on the economy-wide level, the women's share is relatively constant at 56%.

The diffusion of climate mitigation technologies in the agricultural sector would create new job opportunities, as, for instance, organic agriculture is more labor intensive than traditional farming practices. Some mitigation technologies would, however, have negative impact on employment as the automation of agricultural machinery and using ICT tools will reduce the labour demand. It is important that the state's support measures that introduced to promote the diffusion of climate technologies, take into account gender aspects (support of women owned farms, women access to capacity building programs, etc.).

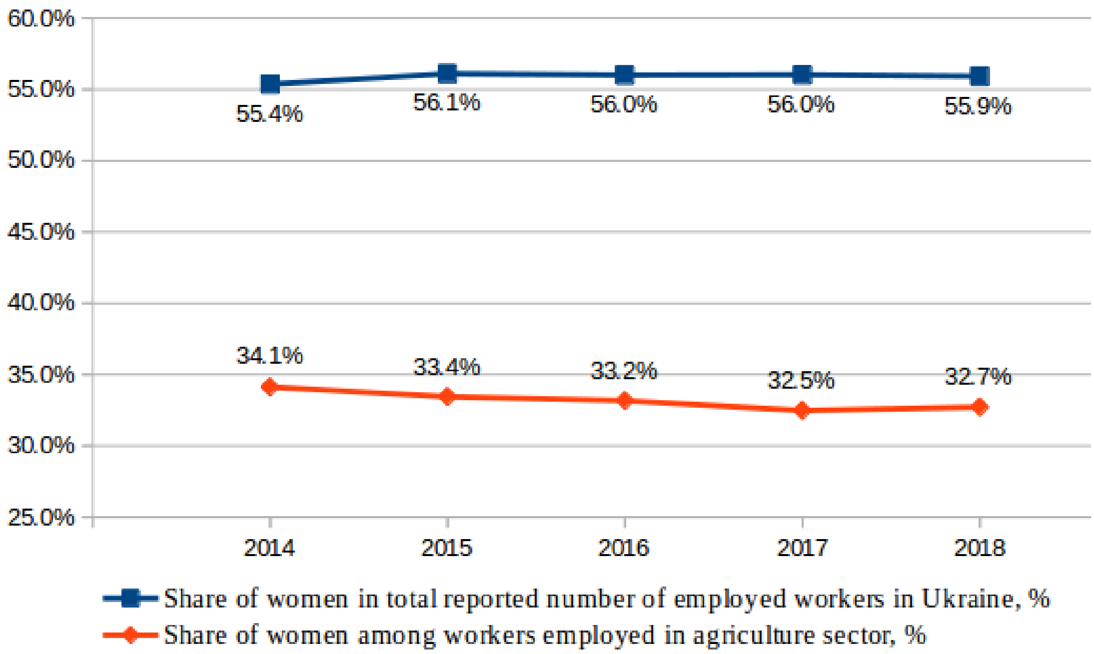


Figure 1.2. –The share of women employed economy-wide and in the agricultural sector of Ukraine in 2014-2018

The gap in salaries between men and women in agriculture is lower compared to the economy-wide gap (19.4% vs 22.3% in 2018). However, there was a tendency for gender gap growth from 14% in 2014 to 19.4% in 2018. Therefore, policy measures that would be introduced to promote the diffusion of climate technologies should also take into account the equality aspects in establishing salaries for men and women.

Table 1.2 Information on salaries in Ukraine in 2014-2018

Data	2014	2015	2016	2017	2018
Average monthly salary in Ukraine, UAH	3,480	4,195	5,183	7,104	8,865
Average monthly salary in Ukraine for women, UAH	3,037	3,631	4,480	6,321	7,830
Average monthly salary in Ukraine for men, UAH	3,979	4,848	6,001	8,021	10,083
Gap between the salaries for men and women, %	23.7%	25.1%	25.3%	21.2%	22.3%
Average monthly salary in agriculture, UAH	2,476	3,140	3,916	5,761	7,166
Average monthly salary in agriculture for women, UAH	2,226	2,767	3,455	5,040	6,142
Average monthly salary in agriculture for men, UAH	2,589	3,307	4,121	6,077	7,618
Gap between the salaries for men and women in agriculture, %	14.0%	16.3%	16.2%	17.1%	19.4%

1.2 Barrier analysis and possible enabling measures for Technology A1 "Use of information and telecommunication technologies for GHGs emission reductions in agriculture"

1.2.1 The general description of technology A1 "The use of information and telecommunication technologies for GHGs emission reductions in agriculture"

Information and telecommunication technologies that have emerged in recent years provide various benefits to farmers in terms of cost saving, resource efficiency, labour optimization, and could also support climate mitigation activities in the agricultural sector, in particular, in the following ways:

- reduction in nitrous oxide emissions due to more efficient differentiated use of mineral fertilizers and associated reduction in CO_2 emissions from fossil fuel combustion during fertilizers production process;
- reduction in CO_2 emissions from fossil fuel combustion due to more efficient use of diesel fuel for agricultural processes;
- indirect impact on the GHGs emissions from the land use sector due to control over land use's practices and change in land use.

Examples of ICT use in agriculture include the following:

- the use of auto pilots at agricultural machinery for more efficient operation;
- the use of drones for the aerial monitoring of agricultural lands with photo and video fixation, as well as applying different sensors and multispectral cameras; drones are used for the development of fertilizers input maps, as well as Normalized Difference Vegetation Index (NDVI) maps, humidity maps and other maps characterizing soil quality;
- the use of satellite images to analyze the land productivity and other characteristics by reviewing historical satellite images and producing maps of average land productivity and NDVI indexes (e.g. Sentinel 2 satellite providing high-resolution (10 m) multispectral reflectance measurements);
- the use of tractor mounted sensors for generation of vegetation index maps;
- the use of specialized applications and software, including cloud-based systems, for fertilizers input management, irrigation, crop protection, etc.

Emissions from fertilizer's application

The Agricultural sector is the largest source of nitrous oxide emissions in Ukraine (100.49 kt or 86.3% of total nitrous oxide emissions in 2016). The emission of nitrous oxide from soils occurs naturally as a result of the microbial processes of ammonification, nitrification and denitrification, but the application of nitrogenous fertilizers increases significantly the amount of N_2O emitted from the soils. Emissions from inorganic N fertilizers directly depend on the volumes of synthetic fertilizers (sodium nitrate, calcium nitrate, ammonium nitrate, ammonium chloride and others) applied by the agricultural companies. The application of inorganic N fertilizers resulted in emissions of 19.59 kt of N_2O or 5,538 kt CO_2-eq. in 2016 (TNA, 2019). Besides, nitrogen input with mineral fertilizers also contributes to the emissions of greenhouse gases reported under atmospheric deposition and nitrogen leaching and run-off categories of the national inventory.

According to the data from the State Statistical Service of Ukraine, the volumes of synthetic fertilizers applied in Ukraine have been continuously growing during recent years both due to increasing application rate and the expanding area of agricultural land, where synthetic fertilizers are applied. The average N input per hectare of land where synthetic fertilizers were applied (16.5 million ha) has increased to 82.7 kg N per ha in 2017 (SSU, 2019). There is a potential for further growth of N fertilizer's application both due to increasing rates and application area.

In Europe, fertilizers containing an average of 11.5 million tons of nitrogen were applied to 133.8 million hectares of farmland, leading to an average application rate of 86 kg N per ha. Nitrogen application demonstrates a slight decreasing trend over the last years and its application is expected to be decreased to 11 million tonnes by the 2028/2029 season. One of the reasons for the declining trend is higher emphasis on environmental issues (water quality, climate change, or air quality) in European regulatory context (FE, 2019).

Multispectral and hyper-spectral aerial and satellite imagery helps in creating NDVI maps, which can differentiate soil from grass or forest, detect plants under stress, and differentiate between crops and crop stages. NDVI data, in combination with other indexes such as the Crop-Water Stress Index (CWSI) and the Canopy-Chlorophyll Content Index (CCCI) in agricultural mapping tools can provide valuable insights into crop health (FAO, 2018 A). Data collected with drones are also combined with other information's sources like soil testing (ground-based verification), weather data and satellite images to generate nitrogen's input maps.

Apart from the information on nitrogen demand, two other key technologies are required to use such data (FAO, 2019 B):

- guidance systems that can be used on all kinds of equipment (e.g. tractors, sprayers, planters, etc.) and allows the precise positioning and movement of a machine with the support of a Global Navigation Satellite System (GNSS), which could be based on GPS or more precise real-time kinematic (RTK) positioning;
- variable rate technology (VRT) that focuses on the automated application of materials (fertilizers, chemicals, seeds and water) to a given landscape.

The use of information and telecommunication technologies allows differentiated fertilizer's input using guidance systems for agricultural machinery and variable rate application technologies leading to fertilizers savings. The savings could reach as much as 20% of fertilizers without productivity losses. Potential savings of fertilizers depend significantly on the characteristics of specific fields. On the fields with relatively equal soil characteristics savings would be limited (e.g. 2-3% or lower) and variable rate application technologies would not be feasible. On the contrary, on the fields with significant differences in soil characteristics and soil types across different sections, the savings would be the highest (e.g. 12-20%). The maximum potential in the reduction of GHGs emission due to lower N_2O emissions is estimated at the level of 1.2 Mt of CO_2-eq.

The additional reduction of GHG emissions could be achieved due to the reduced use of fossil fuel for fertilizers manufacturing. According to the National Emission Inventory of Ukraine (GHGI, 2018), ammonia production in 2016 constituted 2.044 Mt and caused 2.663 Mt of CO_2 emissions, which result in the average emission factor of 1.3 tons of CO_2 per ton of ammonia or 1.6 tons CO_2 per ton of nitrogen content. The maximum potential for the reduction in GHG emissions due to lower CO_2 emissions in chemical industry is estimated at the level of 0.4 Mt of CO_2-eq. (20% or 273 kt reduction of N fertilizers use multiplied by the emission factor of 1.6 tons CO_2 per ton of nitrogen content).

Total maximum potential for the reduction of GHGs emission is 1.6 Mt of CO_2-eq. The actual potential could be limited by further extension of land area, where the synthetic fertilizers are applied.

Emissions from fuel consumption

The agricultural sector is a significant source of GHGs emissions related to diesel fuel combustion in transport. The use of ICT in agriculture could reduce fuel consumption per hectare of land and lead to GHGs emission reductions.

Potential of GHG emission's savings could be roughly estimated from the publicly available data of one of the large agricultural holdings producing crops at acreage of about 0.5 million ha. According to Kernel's annual report, the company achieved the lowest ever energy use per ton of grain grown in 2019, decreasing energy consumption from 854 MJ per ton in 2015 to 546 MJ per ton (36% improvement per tonne of grain grown or approximately 16% improvement per ha of harvested area). This is partly explained by higher crop's yields and the use of more powerful and larger size vehicles providing lower specific consumption of fuel. However, the improvement of operation efficiency due to the use of GPS trackers, remote monitoring of actual fuel consumption and running machinery in auto-pilot mode also contributed to lower fuel intensity (Kernel, 2019).

Apart from the use of auto-pilots, fuel savings could also be achieved by the replacement of standard machinery with drones for the spot-specific application of crops protection agents and fertilizers. Such technologies are not yet widespread in Ukraine, but there are some pilot projects being implemented by agricultural companies.

Even assuming fuel savings due to ICT at a level of 5-7%, reduction in potential GHGs emission could reach approximately 0.2 Mt CO_2-eq. at the area of 10 million ha.

Emissions because of land use changes

ICT and, in particular, satellite and aerial images analysis could be an important tool for control of land use practices and identification of land use changes that lead to increased GHGs emissions.

ICT tools also allow farmers to use their land bank more efficiently by identifying excessive unused land areas (e.g. field entry and exit points). According to the estimates of experts, approximately 2-4% of land areas could be added to harvesting area due to the use of ICT. However, agricultural companies could also violate land use requirements by using the land plots that are located in water protection zones, nature protected areas or on slopes.

A recent study prepared by NGO Ecoaction, revealed that the satellite imagery analysis and machine learning techniques could provide valuable information on the practices of land use. In particular, the analysis of satellite images of three different areas in two regions of Ukraine with the total area of about 140,000 ha identified arable land within the territories of natural protected areas, water protection zones, forest areas, and on the slopes. Satellite data allows the identification of the year, when a particular land plot has been tilled. Recent conversion of land plots to cropland category indicated lack of state's control over the requirements of land use on the local level. The algorithms of machine learning also allows the identification of specific crop's varieties and control over crop's rotation practices (Ecoaction, 2020). Experts consulted within the stakeholder's consultation process suggested that similar violations are typical for other regions of Ukraine as well (e.g. agricultural land use on the protected areas in Mykolaiv and Sumy regions). ICT could provide effective tools for the identification of such violations and contribute to land conservation efforts.

Technology diffusion potential

The technology could be broadly applied in all regions of Ukraine, as there is developed IT infrastructure (e.g. high mobile network coverage, internet access rate, smart-phone adoption rate) and there are both local and international service providers available in the market allowing extension of technology application in a short-term period. Wider adoption of the technology would however lead to the collection and transmission of large datasets and would require additional investment in broadband internet connections in rural areas.

According to InVenture, only about 10% of Ukrainian agricultural companies use innovative technologies. At the same time, there are about 70 Ukrainian AgriTech-startups as well as leading international developers operating in the market in Ukraine. The products available in the market include software and hardware developers of farm management solutions, drone-based and remote sensing solutions and precision farming solutions. Big Ukrainian agro-holdings, including UkrLandFarming, Kernel, MHP and Astarta-Kiev, are also developing innovative in-house products, launching accelerators and cooperating with local and foreign start-ups (Agritech Unit).

The implementation of the technology could support job creation in IT sector of Ukraine. However, the demand of agricultural workers could be reduced. More efficient use of fertilizers will also contribute to health protection due to lower nitrates content in agricultural products and reduced soils and water pollution. The implementation of the technology could reduce the operational cost of agricultural enterprises due to savings on fertilizers and improving the economic efficiency of their operations. The efficient use of fertilizers ensures additional environmental co-benefits in addition to climate change mitigation, in particular, the reduction of water pollution, improving soil quality and reduction of air emission associated with fossil fuel combustion during fertilizers manufacturing.

The extensive diffusion of ICT in agriculture could trigger total GHG emission reductions at the level of 2 Mt of CO_2-eq. per year. The effectiveness of the technology will be increasing with time due to both new technology developments and accumulation of data on soil characteristics, agricultural practices and yields.

The development of the proposed mitigation technology could have synergies with the development of an agrometeorological early warning system, which is defined as a priority adaptation technology within the TNA project.

1.2.2 The identification of barriers for technology A1 "The use of information and tele-communication technologies in agriculture for GHGs emission reductions in agriculture"

1.2.2.1 Economic and financial barriers

Economic and financial barriers relate to the capital expenditures required for the implementation of ICT in agriculture.

Direct capital costs for the implementation of the ICT tools are moderate and could be applicable in case of establishing own divisions for ICT application as an alternative to use specialized service providers (starting from USD 20,000). However, potential capital expenditures are mainly related to indirect costs for the investment in the machinery and equipment, which will allow the practical application of recommendations, developed using ICT tools (tractors with computer-based guidance systems, specialized software, machinery for differentiated fertilizers input, and other variable rate technologies). These indirect costs could be quite significant and pose a financial barrier, but could not be totally attributed to the implementation of the technology, as many farmers invest in such machinery for other efficiency reasons (e.g. the extension of the operation period during the night time, lower labour requirements). For small and medium farms economic and financial barriers could be applicable even for smaller investments such as the purchase of drones and software.

In case of differentiated fertilizers input technologies, the economic barrier could be significant, as economic benefits from fertilizers savings could be limited (not accounting for the economic cost of greenhouse gases emissions). Several studies demonstrated that there was no statistically significant economic advantage of sensor-based fertilizer application as profitability hardly covers the costs of application. Potential explanations are that the application rate is already near optimum. However, this is not a valid conclusion for all crops under all growing conditions. Digital technologies have strong economies of scale and scope, making a greater volume required to make them profitable and creating disadvantage for adoption and operation of ICT in a sustainable manner for small farmers (FAO, 2019 B).

Operational cost for the use of ICT tools varies significantly depending on specific applications and availability of in-house expertise. They could range from USD 3 per ha (recommendations for fertilizers input based on land monitoring with drones) and USD 10 per ha for satellite images used in irrigation planning to USD 100 per ha and more depending on the complex of technologies applied and additional soil monitoring tests required. For instance, Sentinel 2 satellite raw data are free to use but require additional processing to be converted into multispectral images, which could cause additional expenses. Application of crop protection or fertilizers brings efficiency benefits but require more workforce comparing to traditional methods.

The key economic and financial barriers relate to the capital access and financial feasibility of investment in agricultural equipment and machinery allowing the utilization of recommendations derived from digital technologies.

1.2.2.2 Non-financial barriers

Non-financial barriers for the implementation of the technology include technical, regulatory, information and capacity barriers.

Technological barriers

Technological barriers for the diffusion of ICT in agriculture include the insufficient coverage of RTK and GSM networks in rural areas, as well as the low availability of agricultural meteorological stations.

Besides, due to high priority on cost optimization, integrated technological solutions in some cases do not meet high quality requirements, which along with lack of service networks leads to technological problems during operation.

Lack of interoperability standards and of technical protocols that would allow communication between machinery and tools/instrument is considered as one of the main challenges associated with precision agriculture, which limits the exchange of data between systems, increase administrative burden and creates risks of farmers' dependency on a single technology provider. Technical compatibility between systems, as well as hardware and software components, on the contrary would allow the linking of information systems and use data from different systems for processing and analysis. Data interoperability includes different levels, such as technical (the use of data management systems that allows connection with other systems), semantic (the use of metadata and knowledge organisation systems for the description and organisation of data, based on existing standards) and legal (the use of appropriate licences that allow the exchange of data between different systems and providers). Interconnectivity would allow the proper management and sharing of data acquired by different sensors and from different sources independently of the software to be used and data formatting solutions (EP, 2017). Besides, a lack of standardization in the format and ownership of data could create disparities among large international companies, smaller enterprises and local farmers. The adoption of digital technologies is higher among major farmers, usually associated with multinational companies, but this is lower among small farmers, who must face additional problems of access to the infrastructure of communications (networks) and technology in general (FAO, 2019 B).

Acknowledging the importance of agricultural data generated by digital technologies, EU agricultural associations have signed the voluntary EU Code of conduct on agricultural data sharing by contractual agreement, which covers such aspects as the protection of sensitive information, control the use of data by data originators, data protection and transparency, privacy and security, etc. (COPA, 2018).

Regulatory barriers

Regulatory barrier relates to the lack of approved and enforceable legislative framework on land protection and nutrients management. The Cabinet of Ministers of Ukraine has approved standards on optimal crop rotation for different regions of Ukraine (CMU, 2010), however the control over compliance with such standards is not effective. Similarly, the Law of Ukraine On Land Protection defines general provisions on soil quality standards and prevention from soil contamination, however lacks effective enforcement measures (LoU, 2003). The provisions of EU's Nitrates Directive are not yet incorporated in the national legislation of Ukraine.

The additional regulatory gap, that needs to be addressed to promote the technology, relates to legislation on the use of drones in agriculture.

Capacity barriers

Capacity barrier relates to the lack of understanding of benefits related to the application of modern information and telecommunication technologies and experience in their implementation, especially in small and medium enterprises. The application of ICT requires the new types of knowledge and skills among the farmers from totally new areas of expertize (e.g. data and map processing, use of new software packages, etc.). This barrier relates both to the management, which should have a clear vision of benefits from the technology and support trials and experimentation, and to for workers on fields, that should be trained to use modern machinery and ICT tools. The training of the personnel and changing their mindsets takes time and lower capacity reduces the speed of technology diffusion.

Information barriers

Information barriers are associated with insufficient publicly available information on cost and benefits of the ICT application in agriculture, low quality of available data, as well as different data formats.

There is a growing community of AgriTech specialists from business sector and increasing number of specialized events and publications. However, environmental and climate benefits are not among priorities and receive low attention in the growing information coverage of ICT tools in agriculture. Institute of Agroecology and Natural Resources of NAS of Ukraine has developed guidance on the reduction of ammonia emissions from agricultural sources (IANR, 2016), however it does not contain any information on

ICT use and the differentiated input of fertilizers. The provision of reliable and up-to-date information is especially important, since digital technologies are constantly evolving at high speed. Besides, the knowledge about the climate mitigation effect of the technology and associated public benefits should be communicated to farmers.

Available data on soil quality and land use do not meet industry's requirements and businesses spent significant time to accumulate high-quality data improving their coverage from year to year.

1.2.3 Identified measures

1.2.3.1 Economic and financial measures

State Subsidies

In case of supporting the ICT use in agriculture, subsidies could be provided for the purchase of agricultural machinery and equipment that allows variable applications of fertilizers, even if the equipment is not produced locally. Taking into account the economy of scale of digital technologies in agriculture, a special focus should be paid to the financial support of small and medium agricultural enterprises. Additional conditions for state support provision could include requirements for data collection in order to guide the future policy development process.

For instance, according to the CAP legal requirements, each Member State has established an Integrated Administration and Control System (IACS), which includes a spatial component called Land Parcel Identification System (LPIS), that allows the identification and quantification of agricultural land (agricultural parcels) eligible for EU support through very detailed geo-spatial data. LPIS is used for cross-checking during the administrative control procedures and as a basis for on- the-spot checks by the paying agency. For the purpose of the CAP controls on cross-compliance and greening, the system collects data on agricultural practices beneficial for the climate and the environment, requirements related to environment, health, soil, animal welfare, food safety, climate change, and water protection policies. An application of digital monitoring systems collecting data from farmers could also bring additional benefit by facilitating the detection of land cover's changes and contribute to the development of GHGs emissions and removals monitoring on a national level (EP, 2017).

1.2.3.2 Non financial measures

Regulatory Framework on Nutrients Management

To foster the implementation of the technology, it is recommended to develop, adopt and enforce the regulatory framework to ensure the effective use of nitrogen fertilizers according to the requirements of the EU's Nitrates Directive (Nitrates Directive, 1991). The objective of the directive is to reduce water pollution caused or induced by nitrates from agricultural sources and preventing from further such pollution. The Directive requires the establishment of a code or codes of good agricultural practice, to be implemented by farmers on a voluntary basis, which should contain provisions covering at least the following items related to mineral fertilizer's application:

- periods when the land application of fertilizer is inappropriate;
- the land application of fertilizer to steeply sloping ground;
- the land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground;
- conditions for the land application of fertilizer near water courses;
- procedures for the land application, including rate and uniformity of spreading, of both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.

Member States may also include in their code(s) of good agricultural practices for the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use.

The example of UK's Code of Good Agricultural Practices (DEFRA, 2009) demonstrates how these requirements could be specified at the national level. The recommendations regarding more efficient nitrogen management include the following:

- controlling nitrogen application by carefully defining the amount of nitrogen fertilizer needed for each crop in each field (the crop nitrogen requirement) taking into account the soil nitrogen supply and not exceeding the defined requirement; where the soil nitrogen supply is high, soil analysis for mineral nitrogen can provide a more precise guide to fertilizer requirement;

- keeping accurate records of the amounts and dates of applications of manufactured nitrogen fertilizers, organic manures and other nitrogen containing materials that are used as nitrogen fertilizers (e.g. dredgings and soil from the processing of sugar beet) to help work out how much nitrogen fertilizer is needed for future crops;
- applying manufactured nitrogen fertilizer only at time when the crop can use the nitrogen; manufactured nitrogen fertilizer should not be applied to grass between 15 September and 15 January and to other crops between 1 September and 15 January, unless there is a specific crop requirement at this time;
- spreading manufactured nitrogen fertilizer as accurately as possible and at the right rate;
- taking special care when any manufactured nitrogen fertilizer is applied in fields, where there is a significant risk of run-off to surface water, taking into account in particular the slope of the land, weather conditions, ground cover, proximity to surface water, soil condition and the presence of land drains.

The Directive also prescribes setting up, where necessary, a programme, including the provision of training and information for farmers, promoting the application of the code(s) of good agricultural practice.

The Directive prescribed the identification of vulnerable zones as all known areas of land which drain into the water bodies and contribute to their pollution. Special action programmes and provisions to monitor their effectiveness should be established with respect to designated vulnerable zones. Such action programmes should cover all measures defined in the code(s) of good agricultural practices as well as additional measures, such as:

- periods when the land application of certain types of fertilizer is prohibited;
- the limitation of the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the vulnerable zone concerned, in particular: (a) soil conditions, soil type and slope; (b) climatic conditions, rainfall and irrigation; (c) land use and agricultural practices, including crop rotation systems.

Member States are exempt from the obligation to identify specific vulnerable zones, if they establish and apply such action programmes throughout their national territory (JRC, 2020).

Though the Directive does not specifically target the use of information and telecommunication technologies for GHGs emission reductions in agriculture, the application of this technology could ensure meeting many recommendations mentioned in the Directive and Codes of Good Agricultural Practices, in particular with respect to:

- the identification of physical field’s characteristics, which define the specific requirements of nitrogen fertilizer’s application (e.g. slopes, distance to water courses, etc.);
- defining the optimal nitrogen fertilizer’s application rate based on soil mapping techniques using drones, satellites images and other tools.

The adoption of EU’s Nitrates Directive has been also named as a number one agricultural sector of policy priority measure for the new Government of Ukraine by environmental non-governmental organization Ecoaction (Ecoaction, 2019).

<u>Capacity building policies</u>

Measures aimed at capacity building for the use of ICT in agriculture for reducing the emissions of greenhouse gas could include the following:

- the inclusion of the information about ICT in agriculture for reducing the emissions of greenhouse gases in the activities of farm advisory services;
- establishing and support of educational programs devoted to the technology in educational institutions teaching young professionals for agriculture sector.

Ukraine has an operational system of farm advisory services, which can provide advice and support to farmers regarding the use of ICT for more efficient application of nitrogen fertilizers and reducing greenhouse gases emissions.

The development of ICT in agriculture and climate mitigation should be included in national farm advisory services development program, national agriculture and rural development programs, and regional and local socio-economic development programs to be eligible for receiving finance for advisory services from national and local budgets.

Fostering of programs on ICT topics in the professional education programs of universities and other educational institutions is another important element of capacity building activities. Only several universities have specialized programs on the use of modern ICT tools in agriculture often developed in cooperation with businesses. Such pilot programs, including private educational programs (AgTech course at AgroKebeti program, AgriStart program, agro sector digitalization course at AgriFood MBA, etc.), could serve as a model for developing digital agriculture courses. Representatives from agricultural companies and AgriTech industry are interested in such cooperation, but the establishing of educational programs requires support from state authorities and management universities. There is a growing interest in establishing the research and development offices of international companies in Ukraine and in case of establishing cooperation among such companies, Ukrainian scientific institutions and universities, this could be potentially used as the valuable source of most up-to-date knowledge on ICT in agriculture.

Information Policies

The state authorities can support the dissemination of the technology by the following information policies:

- the dissemination of information on nitrogen management and ICT in agriculture for reducing the emissions of greenhouse gases among farmers; communication channels should be aligned with the preferences of local farmers and could include social media, messengers, electronic newsletters or specially developed dedicated mobile applications;
- to foster the cooperation of industry players and informal industry networks through the support of industry conferences, round-tables, accelerators, field days and other events; guiding the discussion and inclusion of climate change related topics in the agenda;
- the provision of reliable statistical data on soil quality and land use;
- supporting the development of publicly available decision support tools that optimize fertilizer application using ICT.

Information products prepared with the state support and in cooperation with industry players and experts could include the following:

- developing fertilizer recommendations covering such topics as fertilizer's impact on the emissions of greenhouse gases and climate change, crop nutrient requirements, recommendations on nitrogen fertilizers application for the most popular crops and minimization of nitrogen losses, etc. (see for instance Nutrient Management Guide (RB209) (AHDB, 2019);
- information on digital technologies, equipment and service providers available in the Ukrainian market that could contribute to more efficient application of fertilizers and reduced emissions of greenhouse gases (specification, cost, etc.);
- the preparation and publication of case studies on the application of ICT to reduce the emissions of greenhouse gases with the information on the cost of the technology and achieved results in terms of fertilizer's savings and the emissions reduction of greenhouse gases;
- information on funding sources and technical support available to promote ICT in agriculture.

There are also numerous private initiatives targeting the promotion of digital technologies in agriculture in Ukraine and public sector could play an important role in fostering such cooperation programs and integrating climate mitigation priorities in such programs. Examples of such private initiatives include AgriTech Unit, MHP Accelerator 2.0, #DigitalAgriBusiness project from Kernel, Syngenta Digital Innovation Lab, and others. Public sector could contribute to the discussion by the facilitated participation of international organizations and policy makers from different countries, bringing knowledge on environmental and social benefits of digital technologies, and also collecting industry views on policy development aimed at promoting ICT in agriculture.

The provision of reliable statistical data on soil quality and land use is another important element of the enabling framework for the diffusion of ICT in agriculture. High quality data will allow the development of analytical tools and scientific studies leading to the increased efficiency of the technology. All of them, farmers, scientists, technology providers and start-ups would benefit from the reliable statistical information.

An example of decision support tool is CropSat system available for farmers in Sweden, Denmark, and Norway. The system uses satellite imagery to visualize the crop variation within farmers' fields and new images are added, as soon as they become available during the growing season. CropSat allows farmers to find their fields, select land parcels by drawing a polygon on a map and easily create variation maps and prescription files that can be used to control fertilizer's application rates. Satellite images showing vegetation index for five different intervals are automatically downloaded for the land parcels of interest. The farmer can enter the desired N rate in kg/ha for each vegetation index interval and the system will generate a prescription file that can be downloaded in different formats. CropSat uses the modified soil-adjusted vegetation index (MSAVI2) calculated mainly from data obtained from satellites Sentinel-2 (ESA, EU) and DMC (DMCii Ltd, Guildford, UK). In Sweden, CropSAT is funded within a programme for the improved efficiency of nutrient use and reduced environmental impact (Focus-on-Nutrients) administered by the Swedish Board of Agriculture (Jordbruksverket, Jönköping, Sweden). In Denmark, it is funded by the central advisory organisation (Seges Landbrug & Fødevarer F.m.b.A., Aarhus, Denmark) (Söderström et al. 2017). The satellite images cannot be used during periods, when the fields of interest are covered by clouds. The practical experience is that cloud free vegetation index data for fields in Denmark and in south Sweden was obtained 1 to 2 times per month beginning from April to August. Even acknowledging the limitations of the data (e.g. lower accuracy comparing to ground vehicle mounted sensors, limited frequency), satellite sensed reflection data from crop foliage provide valuable data for farmers with good resolution (10 x 10 m) and free of cost (SEGES, 2017).

Digital education

The general improvement of ICT education especially in rural areas is also an important enabling factor for promoting the use of digital technologies in agriculture. Special attention should be paid to the gender aspects of digital education in rural areas to provide equal opportunities to both men and women to benefit from the evolving industry.

Digital education is one of the priority goals defined by the newly established Ministry of Digital Transformation of Ukraine. The Government realizes the economic benefits of digital education and plans to create infrastructure that will provide access to educational resources on digital skills. Such infrastructure will include the online educational platform and offline hubs in all regions of Ukraine and the Government plans that 6 million people will use the educational infrastructure (PGU, 2019 A).

It is very important to ensure an access to the digital education infrastructure for rural communities and youth in rural areas, as well as to provide not only education on general digital skills but also adapted basic knowledge about the application of digital technologies in different areas of economy, including ICT in agriculture.

Digital technologies and precision agriculture should be also widely incorporated into the educational programs of colleges and universities preparing workers for agricultural sector. Such knowledge is especially important for rural communities to provide foundations for further professional education and broaden available job opportunities.

Another Government's priority aimed at increasing the penetration of broadband internet in all settlements and along all international roads, that will support the availability of digital education tools in rural communities (PGU, 2019 B).

1.3 Barrier analysis and possible enabling measures for Technology A2 "Conservation tillage technologies (low-till, no-till, strip-till, etc.)"

1.3.1 The general description of technology A2 "Conservation tillage technologies (low-till, no-till, strip-till, etc.)"

Conservative agriculture reduces the disruption of soil structure by minimizing tillage. The technology allows raising soil carbon content by ensuring carbon dioxide sequestration. Additional mitigation benefits are achieved because of less intensive use of fossil fuels by agricultural machinery.

Land preparation for seeding or planting under no-till technology involves slashing or rolling the weeds, previous crop residues or cover crops; or spraying herbicides for weed control and seeding directly through the mulch. Crop residues are retained either completely or to a suitable amount to guarantee soil cover; fertilizer and amendments are either broadcast on the soil surface or applied during seeding (FAO, 2020 A).

The conservation tillage technology also includes such practices as cover crops and the use of mycorrhiza, which both increase soil carbon content and contribute to carbon sequestration. Mycorrhiza increases the total volume of root systems by 20-100 times improving the supply of water and nutrients.

The implementation of the technology has large scale potential in Ukraine. The areas of agricultural land under conservative tillage practices could be significantly extended in the medium-term perspective. The overall potential of conservation tillage in Ukraine is estimated at the level of up to 17 million ha (FAO, 2013). More conservative estimates provided by the experts of the working group Mitigation Technologies in Agriculture is in the range of 10-15 million ha.

Ukrainian agricultural companies actively experiment with no-till and other conservation tillage practices. Some companies operate almost exclusively applying no-till practice. Companies actively using conservation tillage practices, include Agrosoyuz, Kernel, Vinnytska Agro-Industrial Group, Agro Generation, I&U Group, KSG Agro, Agromino, UkrAgroCentr, Ukrlandfarming, etc.

Cover crops most typically used in Ukraine include winter rye, lupine, lean, and oilseed radish.

According to the latest available data from the FAO Aquastat database, the conservation of agricultural areas in Ukraine comprised of 700 000 ha (2.14% of all arable land area) (FAO, 2020 B) in 2013.

The application of the technology and potential limitations should be analysed on a case by case basis taking into account the types of crops produced and climatic conditions. Conservation tillage technologies are well suited for the plain relief, but more complicated to implement on hilly fields and mineralized soils. Mineralized soils are also not suitable for the application of mycorrhiza.

Conservation tillage contributes to the reduction of GHGs emission due to the reduced emissions of CO_2 from fossil fuel combustion by agricultural machinery, increased CO_2 sequestration and reduced soil mineralization.

Scientific literature provides carbon sequestration rates due to no-tillage application in the range of 270 – 500 kg of C per ha per year for US (Olson 2013) and 200 – 400 kg of C per ha per year for Europe (Smith et al. 2005), which correspond to GHGs emission reduction at the level of 0.7-1.8 tons CO_2 per ha per year.

Assuming the conservative estimate of carbon sequestration rate of 0.7 ton CO_2 per ha per year and potential for no-tillage technology application at the area of 10 million ha, total potential of reduction of GHG emissions are estimated at the level of 7 Mt CO_2-eq.

The implementation of the technology might be associated with some environmental and social risks related to the increased use of crop protection agents and pesticides, soil compaction, and the reduced labour demand in the agricultural sector. Such risks should be explored during technology implementation and appropriate mitigation measures should be implemented. The use of cover crops in combination with conservation tillage practices could reduce the application of crop protection agents lowering human health risks.

The implementation of technology supports national environmental priorities on the reduction of soil erosion and agricultural run-off minimization through keeping biomass residues in fields. Tillage is the main driver of soil erosion, which is a growing environmental problem in Ukraine. Conservation tillage improves the chemical, physical, and biological characteristics of the soil, as well as increases soil organic content. Cover crops also reduce the land degradation by protecting soil from wind erosion and water erosion. Conservation tillage also contributes to more efficient use of water resources because of the reduced evaporation and more efficient use of water by plants. Cover crops also improve the quality of soil by mobilizing phosphorus and micro-elements from soil increasing their availability for plants, as well as increasing nitrogen quantity in soils.

The implementation of the technology has significant adaptation co-benefits due to lower dependency on weather conditions and more efficient water resources use.

1.3.2 The identification of barriers for technology A2 “Conservation tillage technologies (low-till, no-till, strip-till, etc.)”

1.3.2.1 Economic and financial barriers

The implementation of technology allows to enhance the economic efficiency of agricultural production because of reduced operational expenses and crop’s yields similar to those achieved under conventional tillage practices. However, it requires significant capital investment in the procurement of specialized planters (direct seeders or modified seeders) as well as equipment for herbicides and fertilizers input. Therefore, the technology faces financial barrier due to the lack of affordable sources of financial resources to invest in the new machinery.

The scale of the required investment depends on the specific technology and equipment to be utilized and could be estimated in the range of USD 100 – 200 per ha. In the US-based study, the average machinery investment for no-till agriculture for the farm sizes of about 500-100 ha were reported to be about USD 200 per ha (Epplin, 2007). In examples from Paraguay and Kazakhstan, the cost of the new machinery was estimated in the range of USD 100 - 120 per ha (Derpsch; FAO, 2012). Experts of the working group for Mitigation Technologies in Agriculture estimated the capital expenditures required at the level of UAH 3 million per 1000 ha (USD 120 per ha). The specialized planters for no-till technology are at least 30% more expensive than standard planters.

The investment could be partially compensated from operational savings. In Kazakhstan, the overall savings due to no-till practices for wheat production was estimated at the level of USD 15 per ha (FAO, 2012). Conservation tillage practices allows the reduction of operational and maintenance cost for agricultural enterprises, in particular due to (Climate Wiki, 2019 A):

- less labour time is required because of fewer tillage trips and cultivation operations for seedbed preparation;
- fuel cost savings (reported savings ranges 26.5-43.7 litres per ha);
- lower machinery repair and maintenance costs;
- the reduced use of irrigation water compared with conventional practices.

Operational expenses for crop protection agents could be increased.

At the same time, there is a risk of the reduced economic efficiency due to lower yields after transition to conservation tillage practices, especially during the conversion period (3 to 5 years).

1.3.2.2 Non-financial barriers

Non-financial barriers include regulatory, technology, information, capacity, as well as cultural barriers.

<u>Regulatory barriers</u>

The introduction of land market and the possibility to trade agricultural land, which has been recently approved in Ukraine and is going to be enforced in coming years, pose a regulatory barrier for the diffusion of conservation tillage technology. The effectiveness of conservation tillage technology is increasing over time due to the gradual improvement of soil quality. Farmers, who have invested resources in conservation tillage, lease land plots from individual land owners. In case of land market launch, farmers risk to lose control over land plots, as land owners could be willing to sell their land to third parties.

<u>Technological barriers</u>

Conservation tillage has been used in Ukraine by some agricultural enterprises for many years. However, there is still a technological barrier related to the region- and plant-specific requirements for the application of conservation tillage. Technological barriers relate not only to the use of new planting and tillage equipment but also other technological aspects of seeds planting and different field operations.

The application of conservation tillage technology is associated with the high variability of local conditions and impact of tillage practices and other related practices on the soil quality and crop's yields. On initial stages, the introduction of the technology requires experimentation with different methods and practices and could take approximately 3-5 years to achieve stable positive results. Lack of site-specific advices poses a barrier for technology's implementation for farmers.

<u>Information barriers</u>

In Ukraine, there is limited information on soil quality. According to FAO's estimates, the area of degraded and unproductive arable land in Ukraine exceeds 20% (more than 6.5 million hectares) of the total arable land and the eroded area is estimated to have increased by 70,000 to 100,000 hectares per year during the last decade (FAO, 2018 B). The main cause of soil degradation is inappropriate farming technologies. Chernozems are vulnerable to mechanical deformation due to their low bulk density before tillage in the spring, and the influence of moisture also causes the low stability of swelling smectite minerals which predominates in their mineralogical composition (FAO, 2015).

The Institute of Soil Protection of Ukraine and its regional divisions conduct scientific studies on soil monitoring on agricultural land and its classification on the basis of ecological parameters. During 2011-2015, agro-chemical monitoring was conducted on the area of 19.8 million ha (47.7% of total agricultural land) with 1.9 million soil samples collected and 9.6 million laboratory tests executed. On the basis of analysis, agrochemical passports of land plots with recommendations on the efficiency improvement of land use were issued to land users. The weighted average humus content in soils was 3.16% comparing to 3.14% during the previous monitoring round in 2006-2010 and 3.19% in 1996-2000. The overall deficit of humus balance has decreased from 530 kg/ha in 2010 to 130 kg/ha in 2015. The situation depends on the region and positive balance of humus has been recorded in 6 regions, while the level of humus has decreased in 11 regions (ISPU, 2018).

However, the data reliability of soil quality needs improvement as soil sampling and information based on actual soil tests is limited. Existing soil maps are based on the outdated information and have low resolution.

Moreover, there are no unified approaches for soil sampling and testing. There are different approaches for the identification of sampling locations, number of samples per hectare, and sample collection methods. Soil sampling locations and tests results are often not registered in information systems with GPS coordinates, which makes it impossible to analyze the dynamic of soil quality on land plots. As well, there are different methods of soil quality tests and different approaches for samples preparation before testing. Such situation leads to different test results for samples collected at one location, but analysed in different laboratories, which undermines the validity of soil quality data for farmers and other users.

As a result, there is no detailed and reliable information on soil carbon content in Ukraine. A national organic carbon stock map was developed within FAO's Global Soil Partnership (GSP) initiative. The data were collected by NSC "ISSAR named after O.N. Sokolovsky" and 15 other scientific and research institutions and they include data from existing databases (1121 test results from Ukrainian Soil Characteristics Database) and newly collected information from different organizations. Overall, 4137 test results were used for the development of the first national organic carbon stock map. The data in Ukrainian covers Soil Characteristics Database from the period of 1955-2012, however 60% of the records relate to soil tests conducted before 1990, 9% for soil tests conducted during 1990-2010 and the rest 31% for tests conducted after 2010 (Plisko, 2018). The final map (ISSAR, 2018 A) was built on the basis of the regression model algorithms and has the resolution of 1 km. The next revision of the map is expected to have a resolution of 250 m with potential further improvement to 100 m resolution (ISSAR, 2018 B). Assuming the low resolution and data quality limitations, there is a need to update the national map, which is planned to be performed under the support of FAO and coordination of the Ukrainian Soil Partnership.

The improved soil quality will provide reliable information for the assessment of conservation tillage technology impact on climate mitigation and for tracking the efficiency of other relevant policies.

Cultural barriers

There is a cultural barrier for the application of conservation tillage, as farmers get used to traditional tillage practices and it is hard to switch to new technologies especially taking into account efficiency risks during the conversion period. Having traditional tillage equipment, farmers sometimes can switch back to traditional practices, while conservation tillage requires time to achieve benefits stemming from the improved soil quality.

1.3.3 Identified measures

1.3.3.1 Economic and financial measures

State subsidies

Since capital expenditure for the specialized machinery and equipment is the main economic barrier for the dissemination of the technology, state support could be focused on providing subsidies for the purchase of such equipment. Currently, such subsidies already exist under the support of local producers of machinery and equipment for agriculture. During recent years, national producers developed own products for conservation tillage and farmers often give more preferences to national equipment than expensive imported alternatives.

Additional subsidies could be provided for the introduction of conservation tillage practices in a form of area-based payments during some limited conversion period. The introduction of such subsidies should be performed along with the development of control procedures, identification of non-compliance cases, and associated penalties. An example of such subsidies for minimum tillage practices exists under Ireland's Green, Low-Carbon Agri-Environment Scheme (GLAS) with the payment rate of Euro 40 per ha per year (DAFM, 2016).

1.3.3.2 Non-financial measures

Supporting the development of project-based carbon crediting mechanism

One of proposed measures is the creation of access to project-based carbon offset's generation activities related to land management practices and participation of Ukrainian agricultural companies in voluntary carbon markets.

In 2018, the volume of voluntary carbon market reached 98.4 million tonnes of CO_2-eq. traded with transaction volume equal to USD 295.7 million. The average price of voluntary emission's reduction units was at the level of about USD 3 per tonne of CO_2-eq., however the market is characterized by a large variance of prices. The market demonstrates significant growth during the last several years with 2018 trading volumes being nearly the highest volume of purely voluntary offsets ever tracked in a single year. The cumulative volume of voluntary emission's reductions tracked since 2006 has now exceeded 1.2 billion metric tons. Special popularity during recent years is gained by voluntary carbon projects, using natural climate solutions such as the improved management of forests, farms, and natural ecosystems (Ecosystem Marketplace, 2019 A). Market participants expect that the demand for voluntary carbon credits will be growing in future (Ecosystem Marketplace, 2019 B).

Voluntary carbon standards are evolving to incorporate other co-benefits apart from carbon emission's reductions. In the past two years, Verra (managing entity for the Voluntary Carbon Standard) and the Gold Standard both have introduced tools for quantifying impacts that various projects and activities have specific Sustainable Development Goals (SDGs) (Ecosystem Marketplace, 2019 C).

There are several methodologies for the quantification of emission's reduction stemming from sustainable land management's practices (for instance, Verra, 2020 A), and new protocols to quantify, monitor, report and verify the emission reduction of greenhouse gas on farms and carbon sequestration within soils are being developed (Indigo AG, 2020). For example, Methodology VM0017 Adoption of Sustainable Agricultural Land Management, v1.0 targets any practice that increases the carbon stocks in the land, including improved tillage practices, the use of cover corps, returning composted crop residuals to the field (Verra, 2020 B).

To participate in voluntary carbon markets, GHG emissions reduction projects should meet a number of eligibility requirements, including conditions related to the additionality of emission reduction, project types constraints, methodology-specific requirements, as well conditions related to the avoidance of double-counting. Although double-counting risk is reviewed on a case by case basis, it would most likely require certain state regulation of voluntary carbon projects. According to Gold Standard, double counting is a risk that occurs where a carbon credit is issued from a project in a host country that engages in emissions trading (domestically or internationally) and a benefit or value of an emission reduction unit could be used twice or more. This includes such examples as a potential use of voluntary emission reduction units along with AAUs in international carbon trading, along with carbon units in a domestic ETS or domestic carbon taxation scheme (i.e. project receiving the financial benefit of the VER as well as a reduced tax burden) (Gold Standard, 2015).

The following two aspects should be covered by national regulations to promote voluntary carbon projects:

- the notification of designated national authority and any relevant regulatory bodies concerning the voluntary activity/issuance of voluntary emissions reductions prior to project initiation and procedure for receiving feedback;
- possibility to permanently cancel national carbon units (AAUs, national ETS units, etc.) in lieu of voluntary carbon projects.

Though carbon offsetting projects could be initially driven by the voluntary market demand, the national government could also create additional incentives by either allowing the use of domestic voluntary carbon market credits to meet carbon tax obligations or by creating a special fund for purchasing such carbon credits. For example, in Australia, the governmental Emission Reduction Fund (ERF) manages a carbon offset certification scheme, under which agricultural producers can generate carbon credits, known as Australian carbon credit units (ACCUs), from activities that reduce agriculture-related emissions or increase removals on agricultural land. Australian Government voluntarily purchases ACCUs from eligible offset projects and as of February 2019, there were 550 registered agriculture-related ERF projects that had received 38 million ACCUs since 2012 (Agri Futures, 2019). Some countries allow the use of voluntary carbon credits from domestic carbon emission reduction projects under their national carbon taxation schemes. In Columbia carbon credits are voluntary cancelled by companies to cover their obligations under the national carbon tax, which is the main source of demand for voluntary carbon projects in the country with 21.6 million carbon credits used against the country's carbon tax (Carbon Pulse, 2019). In South Africa, the Carbon Tax Act adopted in 2019 also allows the use of carbon credits from voluntary emission reduction standards such as Gold Standard and VCS stemming from activities that are not subject to the carbon tax (Center for Environmental Rights, 2019).

Soil quality monitoring system

Since carbon sequestration is one of the most significant potential sources of GHG emissions reductions from agriculture, the information on carbon content in the soil is crucial for monitoring the efficiency of policy measures and progress with climate mitigation goals.

State land monitoring foresees the regular observation of land conditions and assessment of processes causing soil fertility changes (water and wind erosion, humus loss, salination, etc.) and soil contamination by pesticides, heavy metals, and other toxic substances (CMU, 1993). Soil monitoring on agricultural land is performed to monitor soil quality and introduce appropriate land management practices and agro-technologies. Monitoring foresees the development of information data bases on soil conditions on agricultural lands and analytical system to define soil preservation measures (MAPU, 2004).

However, existing soil quality monitoring system needs improvement to fulfil the above-mentioned tasks. The development of enhanced soil quality monitoring system would contribute to better understanding of soil properties and impact of conservation tillage practices on soil quality and carbon sequestration.

The improvement of soil quality monitoring system could include, in particular, the following measures:

- the synchronization of approaches, methods and standards for soil sampling and soil analysis;
- establishing data sharing arrangements with state authorities, scientific institutions, universities, local agencies and other parties on implementation of the monitoring, evaluation, and reporting process;
- the creation of public soil quality database.

The implementation of this policy measure could include actions foreseen in the National Action Plan to Combat Land Degradation and Drought, in particular the development and approval of the Law of Ukraine On Soil Protection and Preservation of Fertility and approval of soil quality standards (CMU, 2016).

Moreover, the proposed measure will contribute to the achievement of national voluntary targets on the stabilization of soil organic carbon content on agricultural land under United Nations Convention to Combat Desertification (UNCCD, 2020):

- by 2020, to achieve a stable level of the content of soil organic carbon (humus) in agricultural land (not lower than the baseline (2010: 3.14% on average in Ukraine, including Polissya − 2.24% Forest Steppe − 3.19% Steppe − 3.40%);
- by 2030, to increase the content of soil organic carbon (humus) in agricultural land by not less than 0.1% (Polissya - by 0.10–0.16%; Forest Steppe and Steppe − by 0.08–0.10%).

The improvement of soil quality monitoring systems could be performed in cooperation with international organizations and, in particular, Ukrainian Soil Partnership, which has been established under the support of FAO and united scientific institutions and state authorities to foster coordination and cooperation among different parties to develop soil quality monitoring system. Data collected by the monitoring system should enable to track the impact of conservation tillage on carbon sequestration and the emission reduction of greenhouse gases.

Regulatory changes

Regulatory support could include the preferential rights of lease holders to purchase land plots after the launch of land market.

Capacity building policies

Policies aimed at capacity building's activities and the promotion of conservation farming technologies could include the following measures:

- capacity building on region-specific and crop-specific aspects of conservation tillage technologies;

- the organization and support of training and educational activities on carbon sequestration potential of improved soil management practices and climate benefits of the technology;
- the incorporation of the promotion of climate mitigation technologies in the activities of farms advisory services in Ukraine.

Capacity building should target both the management of the farms and workers.

There are the established informal networks of no-till farmers, which effectively exchange knowledge and experience. Support of such networks and specialized events with the involvement of small and medium farmers from different regions could contribute to the diffusion of the technology in Ukraine. Field days and other site's visit events could be an effective tool for the promotion of the technology as practical cases, which often provide more valuable information and insights for farmers. Such farmer's networks could be used not only for knowledge exchange but also for the exchange of cover crops seeds or even the cooperative use of agricultural machinery.

Farm advisory services could be also an effective channel for the communication of knowledge and experience on conservation tillage. The involvement of private companies with practical experience in conservation tillage could be considered for the execution of advisory services.

Capacity building measures would allow the mitigation of both cultural barrier and information barriers related to conservation tillage technologies.

1.4 Barrier analysis and possible enabling measures for Technology A3 "Biogas production from animal waste"

1.4.1 The general description of technology A3 "Biogas production from animal waste"

Biogas is produced as a result of biochemical decomposition of macromolecular compounds of animal manure into methane (CH_4), carbon dioxide (CO_2), and ammonia (NH_4). The process is performed under anaerobic conditions. Animal waste could be used in combination with agricultural crops.

The produced biogas is typically used for heat energy and / or electricity generation. The produced biogas could also be cleaned into biomethane and used as a fuel in the transport sector or supplied to the natural gas grid. The key technological equipment used for biogas production include reactors for anaerobic fermentation with substrate mixing units and gas holders, biogas treatment units and co-generation units. The by-products of biogas production (i.e. processed substrate) are used as bio-fertilizers.

According to the estimate of Bioenergy Association of Ukraine, the total potential of biogas production from animal manure is almost 1 billion cubic meter per year. The potential includes 385.8 million m^3 of biogas from cattle manure, 160.3 million m^3 of biogas from swine manure, and 377.7 million m^3 of biogas from chicken manure (BAU, 2013). The potential of natural gas substitution is 0.5 billion of CH_4 (assuming 50% methane content). The Bioenergy Association of Ukraine estimates that 97% of the theoretical biogas potential for cattle manure, 30% for swine manure, and 68% for chicken manure are available for energy purposes, which is the equivalent of substituting 0.34 billion cubic meters of natural gas.

As of January, 2020, there are about 20 biogas units using agricultural biomass and supplying electricity to the national grid under green tariff mechanism with total electric capacity of about 58 MW (NCSREPU, 2019). There are biogas units working on biomass from agricultural crops (corn silo, sugar beet pulp, etc.), animal waste (swine, cattle, and chicken manure), and on combination of biomass from agricultural crops and animal waste. There are also additional biogas units at the construction stage and the total installed capacity could exceed to 100 MW in the nearest future.

Examples of biogas plants using animal waste include:

- Komertsbud-Plast LLC with 3.1 MW biogas unit using chicken manure;
- Goodvalley Ukraine LLC with 1.2 MW biogas unit using swine manure;
- Gorodyshche-Pustovarivska Agrariran Company LLC with the biogas plant of 0.3 MW capacity working on swine manure.

Examples of biogas plant using both agricultural crops biomass and animal waste include a biogas unit operated by PJSC Oril-Lider with the capacity of 5.69 MW and PJSC Ecoprod with the capacity of 1.5 MW.

The biogas power plant of Ukrainian Milk Company LLC with the capacity of 0.625 MW using cattle farm waste as a biomass source is connected to the Ukrainian grid, but it is not included in the list, as it was commissioned before the green tariff introduction for biogas plants.

There are also several biogas units at animal farms using biogas for own energy needs, including PE Sigma with the 150 kW biogas unit using swine manure and Terezyne with 250 kW biogas unit working on cattle manure.

Technology could be implemented in all regions of Ukraine near animal farms to ensure the stable centralized source of animal manure, as its transportation is not economically feasible. Limitation could include infrastructure constraints to organize export of electricity to the national grid or heat energy to the district heating system or other consumer. The location of biogas plants should also take into account environmental restrictions with respect to sanitary protection zones, water protection zones, etc.

The implementation of the technology leads to the reduction of GHG's emission due to the substitution of fossil fuel based energy with renewable energy and reduction methane emissions from animal manure management.

Assuming the potential for substituting 0.34 billion cubic meters of natural gas (emission factor is 55.95 tons CO_2 per TJ, density 0.708 kg/m^3, NCV - 48.75 GJ per ton or 34.52 GJ per 1000 m^3 as reported in GHGI, 2018), the reduction of GHGs emission would constitute to 0.7 Mt CO_2.

As animal manure is processed at the place of generation GHG's emissions associated with biomass collection, transportation and processing is not taken into account.

The actual reduction of emission would be higher as a part of the biogas would substitute electricity generated at coal fired power plants, but for the purpose of technology prioritization process, the conservative estimate mentioned above was applied.

The additional reduction in GHG emission is achieved due to the avoidance of animal manure decay in the lagoons or other storages. The potential for the reduction of GHG emissions from this source is estimated at the level of 1.1 Mt CO_2-eq. (50% of the GHGs emissions in Manure Management category).

Total potential of GHG's emission reduction for the technology is 1.8 Mt CO_2-eq.

The technology supports national environmental priorities due to the reduction of environmental pollution associated with animal manure management. The utilization of animal waste by anaerobic treatment reduces the surface and groundwater pollution with nitrates, organic substances and biological contamination. Bio-fertilizers, which are the by-products of biogas production process, contribute to soil improvement. The implementation of technology could be combined with natural-based solutions for wastewater treatment such as constructed wetlands further extending environmental benefits.

The implementation of technology also has social benefits, as it leads to job creation in the agricultural industry and reduce health risks related to environmental pollution by animal waste for the people living near farms. The diffusion of technology will also contribute to the economic development and energy security of Ukraine.

1.4.2 The identification of barriers for technology A3 “Biogas production from animal waste”

1.4.2.1 Economic and financial barriers

Economic and financial barriers for the technology diffusion include both general barriers related to the limited access to affordable financial resources, the high cost of capital, and risks for country, and specific risks related to the significant capital investment required for the implementation of biogas projects and lack of efficient mechanisms for supporting heat energy generation from biogas and biomethane production. According to the estimation of the experts from the working group Mitigation Technologies in Agriculture capital expenditures for biogas power plants varies in the range of EUR 2 to 5 million per MW of installed electric capacity with most of the estimates falling in the range of EUR 3 to 4 million per MW. The level of capital expenditures depends on the chosen technology and equipment. According to the estimation of experts from the working group for Mitigation Technologies in Agricultural annual operational expenditures for biogas power plants varies in the range of EUR 120,000 – 400,000 per MW of the installed electric capacity and usually are lower than operational expenses for biogas plats on crops biomass as animal manure has either low cost or free.

1.4.2.2 Non-financial barriers

The key non-financial implementation barriers for biogas technology in Ukraine include technological barriers, capacity barriers, and regulatory barriers.

Technological barriers

The technical barrier relates to complicated technological processes, various biomass sources used, and low capacity utilization factors of operational biogas plants in Ukraine. Technological equipment should be selected and adjusted by taking into account the specifics of biomass material that will be used for biogas production. For instance, in case of chicken, manure is used as a feedstock, the concentration of H_2S in biogas could be high and additional biogas purification unit would be required. However, in case of chicken manure, the quality of biogas could differ significantly depending on the type of chicken grown at the farm.

The significance of technological barriers could be demonstrated by the operation data of existing biogas plants. The average capacity utilization factor for biogas plants using agricultural sources of biomass is about 30%. Only few biogas power plants demonstrated a capacity utilization factor above 50%. The reason for this could be both the deficit of raw biomass, technological problems and non-effective set-up and maintenance of biogas production process.

The insufficient availability of equipment servicing providers, spare part suppliers and lack of supplier's guaranty also pose significant technological barriers for the technology.

Capacity barriers

The capacity barrier relates to insufficient number of qualified managers and operational personnel with the practical experience in biogas plants construction and biogas production. There are no professional training programs in Ukrainian universities preparing operators of biogas plants and other personnel specific to biogas production. There are a limited number of professionals who started their career in the industry 5 or more years ago and gain significant practical expertise in developing and operating biogas units. New biogas project developers have to cooperate with technology suppliers and send their personnel for training for operating biogas plants in Ukraine or abroad to gain the practical expertise.

According to industry's experts, the training of the personnel operating a biogas plant plays an important role in the efficiency of biogas production. For instance, the personnel of a biogas plant and a farm should have sufficient knowledge and skills on biomass source preparation starting from the shredding of straw used for animal bedding and control of straw quality and including operation of a biogas unit. Technological errors of the personnel often lead to decrease of biogas production and electricity generation. Trainings of the personnel during the set up works and initial period of operation should be included in the scope of equipment supply agreements, however state policy could also support capacity building activities.

Regulatory barriers

The regulatory barrier relates to the lack of environmental control over the use of organic waste and enforceable mitigation measures. According to national legislation, animal waste could be used for the production of organic fertilizers and soil additives, used for composting or biogas production, used as a fuel or for industrial processes. By-products of biogas production could also be used or marketed as organic fertilizers. Since, 2016 the number of options for animal manure management has been extended and obligatory sterilization under pressure has been cancelled. Animal manure could be applied to soils without preliminary processing (LoU, 2015). At the same time, animal manure management systems cause a number of environmental risks, including atmospheric air emissions, groundwater and surface water pollution, soil contamination, waste generation, and GHG emissions. Environmental monitoring and compliance control system, as well as financial fines for potential violations, are not sufficiently effective to limit negative environmental impact and foster business to introduce more efficient animal waste management systems.

With respect to biomethane production and use, the regulatory barrier exists due to lack of legal definition of biomethane and relevant specific policy measures to support biomethane production projects.

1.4.3 Identified measures

1.4.3.1 Economic and financial measures

Electricity tariffs

The Law of Ukraine On the Electricity Market introducing bilateral agreements, day-ahead, intra-day and balancing markets entered into force on the 11th June, 2017 and new markets started operation on the 1st July, 2019. Under the new law, the sale of electricity under green tariff is performed on the basis of bilateral agreement between power plant operator and Guaranteed Buyer, which is signed for the whole period of green tariff approval (till 01.01.2030). Electricity from renewable energy sources could also be sold under Bilateral Agreements, on Day-Ahead Market, Intra-day Market and Balancing Market.

The Law of Ukraine On Alternative Energy Types defines the provisions on renewable energy generation support through green tariff. The amounts of the fixed green tariffs are calculated through the multiplying of the size of the retail tariff for electricity for second-class consumers as of 01.01.2009 (584.60 UAH per MWh according to the Decision of National Commission on State Regulation of Energy Sector of Ukraine #1440 from 23.12.2008 (or EUR 53.85 per MWh)) onto the relevant coefficient approved by the Law of Ukraine On Alternative Energy Sources (article 9-1) for each kind of renewable energy source. The green tariff for biogas and biomass electricity is EUR 123.86 per MWh.

For the power plants commissioned by 31.12.2024 the level of green tariff could be increased by 5-10%, if the equipment manufactured in Ukraine exceeds to 30% or 50% of CAPEX respectfully.

For the power plants commissioned by 31.12.2024, the level of green tariff is also adjusted to fluctuations of national currency exchange rate to Euro. Every quarter, in its last meeting, National Commission on State Regulation of Energy and Utilities Sectors calculates the fixed green tariff in national currency, using the average official UAH/EUR exchange rate during last 30 days before the meeting. The green tariffs are to be applied till 01.01.2030.

The alternative option introduced in 2019 is participation in renewable energy capacity auctions, where for biomass power plants, the tariff could not be higher than the green tariff level, but the validity period could be extended beyond 2030 (CMU, 2019).

The existing mechanisms provide reasonable incentives for electricity generation using biomass, however future state policy should ensure the stability of payments and electricity market's operation, as well as the protection of investor's rights. The reliability of long-term legislative framework is an important factor for attracting investment. Besides, the legal definition of biomethane and introduction of green tariff for electricity generated from biomethane would support the diffusion of the technology. The relevant draft law introducing changes to the Law of Ukraine On Alternative Energy Types has been developed by Bioenergy Association of Ukraine.

Heat energy tariffs

As for now, heat energy from many biogas installations is mostly wasted due to lack of demand at the locations of biogas plants. Partially, heat energy could be used for heating the digestate and buildings of the farm. At the planning stage, many operators included in the project concept for construction of greenhouses to utilize the heat energy, however, such projects have been rarely implemented in practice.

Policy measures to increase heat energy utilization from biogas plants could include:

- The elimination of direct and indirect subsidies for natural gas and other fossil fuels;
- heat energy tariffs incentives for the amount of heat energy produced from biogas (fixed tariff or premium).

In case of heat energy tariff incentives, the payment could be limited in time (e.g. 10 to 15 years) and bound to additional eligibility conditions (e.g. proper environmental monitoring, efficiency requirements, etc.). Validity period for the support scheme as well as the level of support should be defined on the basis of additional investigations and stakeholder's consultations, taking into account the results of financial analysis of typical biomass to energy projects. Ireland's Support Scheme for Renewable Heat (SEAI, 2020) could serve as an illustrative example for the design of the policy tool.

The efficient use of heat energy from biogas plants is especially important in light with the expected adoption of the Law of Ukraine On Energy Efficiency (SAEE, 2019), which would incorporate the provisions of the EU's Energy Efficiency Directive into national legislation. The Directive, in particular, requires to adopt policies, which encourage the due taking into account at local and regional levels of the potential of using efficient heating and cooling systems, in particular those using high-efficiency cogeneration, as well as the development of local and regional heat markets (EED, 2012).

Biomethane incentives

Another option for promoting the diffusion of the technology is the introduction of incentives for biomethane production and its further use as a fuel in transport sector or biogas injection into natural gas grid. In latter case, special quality requirements and quality control procedures should be enforced.

Financial incentives for biomethane production could be established in a form of exemptions from carbon taxation, green tariffs for renewable gases, direct financial support for production and financial incentives for consumption, non-discriminatory network access, etc. (Matveev, 2019).

Such option could be interesting for farmers, since they can use biomethane to fuel agricultural machinery and reduce fossil fuel consumption.

Carbon Tax

The use of biomass and biogas for energy purposes should be excluded from the carbon tax (i.e. environmental tax for CO_2 emissions) or any other carbon pricing mechanisms that could be introduced in Ukraine in the near future (e.g. national emission trading scheme, energy tax based on carbon content). On the contrary, the carbon tax for fossil fuels should be increased from the current low level of UAH 10 per tonne to reflect environmental cost of GHG's emissions.

1.4.3.2 Non-financial measures

Regulatory Framework on Nutrients Management

One of the key goals of the technology is to reduce negative environmental impact associated with animal manure waste. To foster the implementation of the technology, it is recommended to develop, adopt and enforce the regulatory framework to ensure effective use of nitrogen fertilizers according to the requirements of the EU's Nitrates Directive (Nitrates Directive, 1991). The objective of the directive is to reduce water pollution caused or induced by nitrates from agricultural sources in order to prevent further such pollution. The Directive requires to establish a code or codes of good agricultural practice, to be implemented by farmers on a voluntary basis, which should contain provisions covering at least the following items related to fertilizers application and manure management:

- periods when the land application of fertilizer is inappropriate;
- the land application of fertilizer to steeply sloping ground;
- the land application of fertilizer to water-saturated, flooded, frozen or snow-covered ground;
- the conditions for land application of fertilizer near water courses;
- the capacity and construction of storage vessels for livestock manures, including measures to prevent water pollution by run-off and seepage into the groundwater and surface water of liquids containing livestock manures and effluents from stored plant materials such as silage;
- procedures for the land application, including rate and uniformity of spreading, for both chemical fertilizer and livestock manure, that will maintain nutrient losses to water at an acceptable level.

Code(s) of good agricultural practices may also include provisions on the establishment of fertilizer plans on a farm-by-farm basis and the keeping of records on fertilizer use.

The Directive prescribed the identification of vulnerable zones as all known areas of land which drain into the water bodies and contribute to their pollution. Special action programmes and provisions to monitor their effectiveness should be established with respect to designated vulnerable zones. Such action programmes should cover measures defined in the code(s) of good agricultural practices as well as additional measures, such as:

- periods when the land application of certain types of fertilizer is prohibited;
- the capacity of storage vessels for livestock manure; this capacity must exceed that required for storage throughout the longest period during which land application in the vulnerable zone is prohibited, except where it can be demonstrated to the competent authority that any quantity of manure in excess to the actual storage capacity will be disposed of in a manner which will not cause harm to the environment;

- the limitation of the land application of fertilizers, consistent with good agricultural practice and taking into account the characteristics of the concerned vulnerable zone, in particular: (a) soil conditions, soil type and slope; (b) climatic conditions, rainfall and irrigation; (c) land use and agricultural practices, including crop rotation systems.

Measures specified above will ensure that, for each farm or livestock unit, the amount of livestock manure applied to the land each year, including animals, shall not exceed to the amount of manure containing 170 kg N (up to 210 kg N for the first four years of the action programme. Different amounts may be justified on the basis of the objective criteria, such as long growing seasons, crops with high nitrogen uptake, high net precipitation in the vulnerable zone, and soils with exceptionally high denitrification capacity.

Member States are exempt from the obligation to identify specific vulnerable zones, if they establish and apply such action programmes throughout their national territory.

The introduction of the provision of EU's Nitrates Directive into national legislation will strengthen the requirement for animal manure management and create additional triggers for the diffusion of the technology.

<u>Manure and digestate management</u>

In addition to the aspect covered by EU's Nitrates Directive, the following topics could be addressed to foster more sustainable animal manure management and contribute to the development of biogas production:

- the requirements for animal manure and digestate storage time before land application (e.g. in Europe requirement for storage capacities for liquid slurry is frequently six months but there are variations according to the country and the environmental risks) (MANEV, 2015);
- the requirements for storage systems and management practices; currently, digestate is mostly either applied directly on fields or stored in open lagoons leading to the emissions of greenhouses gases and negative impact on air quality and water resources;
- quality restrictions and quality control requirements (sampling, testing, etc.) for animal manure and digestate both at the generation stage and delivery to the storage facility and before its application (e.g. nutrient composition, pathogenic organisms, heavy metals, etc.).

This policy measure will also support the development of organic agriculture, as farmers would have better quality of organic fertilizers to be used on fields.

<u>Industrial emissions control</u>

The EU's directive for industrial emissions lays down rules on the integrated prevention and control of pollution arising from industrial activities, as well as rules designed to prevent or, where that is not practicable, to reduce emissions into air, water and land and to prevent the generation of waste, in order to achieve a high level of protection of the environment taken as a whole (IPPC Directive, 2010).

The following activities related to biogas production from animal waste are subject to the requirements of the directive:

- anaerobic digestion plants with the capacity exceeding 100 t/day,
- the intensive rearing of poultry or pigs, if places for poultry exceed 40,000, for pigs over 30 kg exceeds 2,000 places and for sows 750 places (Systemic, 2019).

The provision of the directive, which are applicable and important for animal waste management facilities, include the following:

- integrated approach, which considers the whole environmental performance of the plant, covering e.g. emissions into air, water and land, generation of waste, the use of raw materials, energy efficiency, noise, prevention of accidents, and restoration of the site upon closure;
- permit conditions including emission limit values on the basis of the Best Available Techniques (BAT) with some flexibility to set less strict emission limit values in case of disproportionately higher costs with comparison to the environmental benefits due to the geographical location or the local environmental conditions or the technical characteristics of the installation;
- mandatory requirements on environmental inspections with site visits at least every 1 to 3 years, using risk-based criteria;

- public participation in the decision-making process and disclosure of information by having access to permit applications, permits and the results of the monitoring of release.

The incorporation of the provision of the directive in national legislation will promote the diffusion of the technology due to more strict environmental requirements for animal manure management and greater possibilities for compliance monitoring and enforcement. The draft Law of Ukraine On Industrial Pollution Prevention, Reduction and Control has been presented by the Ministry of Energy and Environmental Protection of Ukraine and approved by the Cabinet of Ministers of Ukraine (MoE, 2020). The enhanced environmental oversight will push farmers to implement modern manure management systems, including anaerobic digestion and biogas production.

Capacity building

Capacity building activities should target the training of professionals for biogas industry and also the dissemination of information and knowledge about the economic, environment and social benefits of anaerobic digestion of animal waste with biogas production. In particular, educational institutions should adjust their curriculum and train specialists that would meet current industry requirements. At the moment, there are no institutions training operators of biogas units and companies invest their own resources to train personnel on existing operational biogas units in Ukraine or abroad or at the facilities of equipment suppliers.

The topics to be covered by capacity building activities could include:

- technologies for animal manure management, biogas production and digestate management, including the examples of good practices;
- The concepts of heat use for biogas plants, including heating (district heating, greenhouses, etc.), drying (e.g. of agricultural products, digestate, etc.), or additional electricity production;
- The operational maintenance of biogas production plants to increase biogas generation efficiency;
- The monitoring of biogas and digestate quality parameters;
- The application of liquid and solid digestate as organic fertilizers;
- climate mitigation and adaptation benefits from the technology.

1.5 Barrier analysis and possible enabling measures for Technology A4 “Organic agriculture”

1.5.1 The general description of technology A4 “Organic agriculture”

Organic agriculture is a production system which avoids or largely excludes the use of synthetic fertilizers, pesticides and growth regulators and promotes the use of crop rotations, green manures, compost, biological pest control and mechanical cultivation for weed control. Natural materials such as potassium bicarbonate and mulches are also used to control diseases and weeds. The most effective techniques used by organic farmers are fertilisation by animal manure, by composted harvest residues and by leguminous plants such as (soil) cover and (nitrogen) catch crops. Introducing grass and clover into rotations for building up soil fertility, diversifying the sequences of crops and reducing the ploughing depth and frequency also augment soil fertility. All these techniques increase carbon sequestration rates in organic fields, whereas in conventional fields, soil organic matter is exposed to more tillage and consequent greater losses by mineralisation (ClimateTech Wiki, 2019 B).

The area of organic land in Ukraine as of 2017 was 289,000 ha (including 201,000 ha of fully converted area and 88,000 ha of conversion area). In 2018, the area of organic land increased to 309,100 ha (0.7% of total agricultural land) with 233,500 ha of fully converted area and 75,600 ha of conversion area. Organic land includes 133,440 ha under cereals, 52,020 ha under oilseeds, 14,450 ha under dry pulses, 5,780 ha under vegetables, 2,500 ha under temperate fruits. In 2018 there were 501 organic agricultural producers in Ukraine (FIBL, 2019; FIBL, 2020). Therefore, the area of organic land demonstrates a steady growth but still covers less than one percent of the total agricultural land in Ukraine.

The largest organic agricultural companies include Arnika (15,078 ha), Haleks Agro (8,800 ha), Agroecology (7,500 ha), Agroinvest – Natural Products (6,000 ha), UkrBioLand (5,600 ha), Etnoproduct (4,000 ha), Ritter Bio Agro (3,500 ha) (Baker Tilly, 2018). Detailed information on some major market players that were participating in BIOFACH 2020 is presented in Organic Ukraine Guidebook (Organic Ukraine, 2020).

The implementation of the technology could be scaled up significantly in the mid-term perspective. Ukraine has large potential for increasing the share of organic agriculture (Chygryn, 2017). According to the estimates of the experts of "Mitigation Technologies in Agriculture" for working group in the mid-term perspective, the share of organic land could be increased up to 10% of the total farmland similar to the leading European countries. For comparison, in 2018, the area of organic land in EU was 13.8 million ha or 7.7% of total farmland with leading countries having 20% share or more (e.g. Sweden – 19.9%, Estonia – 21.6%, Austria – 24.7%). The increase from previous year was 1 million ha or 7.6% (FIBL, 2020). The map of soil's most suitable for organic agriculture has been developed by the National Academy of Agrarian Science of Ukraine (see also Annex VI) (NAAS, 2019). However, the organic agriculture could be applied on all lands, including the restoration of degraded lands. Thus, potential for organic agriculture is estimated at the level of 4 million ha.

Organic agriculture has the potential of sequestering carbon into soils at the rate of 200 kg of C per ha per year for arable crops. By combining organic farming with reduced tillage, the sequestration rate can be increased to 500 kg of C per ha per year for arable crops with comparison to ploughed conventional cropping systems, but as the soil C dynamics reach a new equilibrium, these rates will decline in future (ClimateTech Wiki, 2019 B). Other studies report the similar average sequestration potential of about 200 to 400 kg C per ha per year for all croplands (Müller-lindenlauf 2009). This corresponds to the sequestration of 0.7-1.4 tons of CO_2-eq. per ha per year.

Besides, organic agriculture requires 28% to 32% less energy with comparison to conventional systems. Input costs for seed, fertilisers, pesticides, machinery and hired labour are approximately 20% lower in a rotation that includes a legume with comparison to a conventional rotation system (Nátr 2008). These lead to the additional reduction of emissions of greenhouse gases.

A diversified crop rotation with green manure in organic farming improves soil structure and diminishes the emissions of N_2O due to the ban on the use of mineral nitrogen, although the nitrogen provided by the green manure does contribute to N_2O emissions. Soils in organic farming are more aerated and have significantly lower mobile nitrogen concentrations, which reduces the emissions of N_2O (ClimateTech Wiki, 2019 C). The application of synthetic fertilizers leads to the emissions of 0.4 ton of CO_2-eq. per ha (5.8 Mt of CO_2-eq. emissions due to inorganic N fertilizers (GHGI, 2018) and 15.7 million ha of agricultural land with synthetic fertilizers applied according to the information of the State Statistical Service of Ukraine).

According to the Thünen Institute study, the comparison of the emissions of soil-based greenhouse gas from organic and conventional agriculture in temperate climates on the basis of empirical measurements shows positive effects from organic management with a cumulative climate protection performance of organic farming of 1.082 kg CO_2-eq. per ha per year (Thünen Report 65, 2019).

The conservative estimate is the potential for the reduction of GHG's emissions at a rate of 1 ton of CO_2-eq. per ha of land under organic agriculture practice. Total potential for reduction of GHG's emission is 4 Mt CO_2-eq.

The impact of the technology on job creation depends on the types of organic products produced and baseline situation in specific agricultural enterprises. The production of organic crops requires a lower amount of man hours per ha with comparison to the traditional agriculture because of more efficient machinery (FIBL, 2018).

The implementation of the technology will have positive impact on human health due to the avoidance of chemicals and higher quality of agricultural products.

Organic agriculture could contribute to the economic development by increasing the added gross value of agricultural sector. However, some crops with high nutrient demand could demonstrate lower yields, reducing the economic benefits of agricultural industry.

Organic agriculture increases soil's water retention capacity and contribute to climate adaptation, improves soil quality and soil organic content, as well as reduce agricultural runoff pollution. Co-benefits of the technology for climate adaption would be even more significant in case of simultaneous promotion of agroforestry practices, which have been identified as priority adaptation technology for the agricultural sector in Ukraine. Organic producers often use buffer zones between organic and inorganic fields, which can be used for agroforestry practices. Besides, organic agriculture also contributes to the achievement of sustainable development goals.

1.5.2 The identification of barriers for technology A4 “Organic agriculture”

1.5.2.1 Economic and financial barriers

There are various studies comparing the operational cost of organic and non-organic agriculture and examples of both higher and lower cost of organic crops production could be found in the literature. Even taking into account that the capital expenditures associated with organic agriculture are moderate, there are still important economic and financial barriers for the diffusion of technology in Ukraine. Organic products compete both with organic products from other countries on international market and with conventional products within the Ukrainian market. Besides, expenses for certification and annual inspections could be quite significant for smaller farms.

The following main economic barriers related to the development of organic farming in Ukraine were identified:

1) the economic barrier due to the additional controls or requirements on products imported from Ukraine to the EU;
2) the economic barrier due to the increased competition on key markets with suppliers from countries with extensive state subsidies for organic agriculture;
3) the economic barrier due to the low internal demand for organic products.

Export barriers

Although Ukrainian producers are entering new markets in North America and Asia during the recent years, the European Union remains a key market for Ukrainian organic products, as 83% of Ukrainian organic products export went to EU in 2018 (MAPU, 2019; Organic Info, 2019A). According to the EU legislation, the imported product to be sold as organic must conform to equivalent standards as EU produced goods. There are special procedures for importers of organic products to the EU, which depend on where the goods have originated. For Ukraine, additional controls have been established (i.e. the complete documentation check at point of entry and sampling and analysing for presence of pesticide residues). The complete documentation and verification covers certificates of inspection, documents of custom declaration, transport documents, as well as checks on operators and product traceability (i.e. the verification of names, addresses and valid certification of each operator involved, from farmer(s) to exporter and all operators in between, including traders and sub-contractors). At least 1 representative sample of each of incoming consignments of organic products from Ukraine is taken at the point of entry in the EU. The analysis of these samples for the presence of pesticide residues is conducted in a laboratory accredited to the analytical methods used, which should cover all the relevant pesticides, as defined by expert knowledge. When pesticide residues or other irregularities are detected, an investigation shall be started and a notification in the Commission's Organic Farming Information System (OFIS) shall be made (EC, 2020). Such measures lead to higher costs and impact competitiveness.

International competition

The EU sources organic agri-food from 115 countries with China having 12.5% share (mainly oilcakes, soybeans and other oil seeds), Ecuador (mainly tropical fruits), the Dominican Republic (tropical fruits, nuts, spices, and cocoa beans), Ukraine (mainly cereals, soybeans and other oil seeds) and Turkey (mainly cereals, oilseeds, fruits and vegetables) having 8% share (FIBL, 2020). Therefore, producers from China and Turkey along with EU’s producers are key competitors for Ukrainian companies. In EU, there are different forms of state support for organic farmers and most of the countries provide area conversion and/or maintenance payments. In Turkey, there has been an Environmentally Based Agricultural Land Protection Scheme since 2009, under which support payments, on the basis of land area, are made annually for three years for agricultural practices with minimum soil tillage (to conserve soil and water structure and prevent erosion) and environmentally friendly agricultural techniques (water and fertiliser savings, and organic agriculture) (OECD, 2019). In 2013, payments for organic agriculture amounted to around EUR 200 Euros per hectare for fruits and vegetables, and EUR 40 per hectare for field crops (IFOAM, 2017). Therefore, there is a competitive advantage of foreign producers with comparison to Ukrainian organic farmers.

Undeveloped domestic market

With some exceptions, organic products are typically more expensive than conventional alternatives. Relatively low average income of Ukrainian consumers along with insufficient awareness on the environmental impact of food products and, agriculture and benefits of organic products limit the volume of internal organic market. According to the different estimates the export of organic products from Ukraine reached 104-133 million Euro in 2018 (Organic Info, 2019A; FIBL, 2020), while retail sales were at the level of 33 million Euro (FIBL, 2020) or 590 million UAH (18 million Euro) without the imported products sales (Organic Info, 2019B). Per person consumption of organic products is less than 1 Euro, while in Germany every person spends on average 132 Euro and in Poland 7 Euro per year on organic products (FIBL, 2020). The main channels for sales in the domestic market are supermarkets and specialty shops in big cities. The assortment of organic products is not full, but they include dairy, meat products, groats, eggs, flour, macaroni products, vegetable oils, beverages, chocolate, honey, spices, some vegetables, fruits, snacks, etc. (Organic Info, 2020). Most of organic raw products are being exported, while final organic products are consumed mostly in the internal market. The share of final organic products in total organic production is relatively low. Since external markets are becoming more and more competitive, national market could become a significant driver of organic farming diffusion in Ukraine.

1.5.2.2 Non-financial barriers

The non-financial barriers for the implementation of the technology include the following:

1) the capacity barrier due to the lack of sufficient knowledge about the organic agriculture and lack of specialists with practical experience;
2) the regulatory barriers due to the lack of fully operationalized regulatory base for organic agriculture development;
3) the information barrier due to low awareness about the benefits of organic products and organic products labelling;
4) the technological barrier due to the lack of seeds and planting material.

1.5.3 Identified measures

1.5.3.1 Economic and financial measures

<u>State subsidies</u>

Organic farming provides environmental (e.g. water conservation, climate change adaptation and mitigation, etc.) and social benefits (e.g. job creation in rural areas, health protection, etc.) but at the same time farmers could bear additional costs due to the loss of income, especially during the conversion period. In the EU, the yields under organic production for wheat could be in the range of 40% (Germany) and 85% (Italy) of conventional yields, and for grain maize, the gap is lower and yields reach 60% to 95% of conventional yields. The yield’s gap strongly differs depending on factors such as location, agricultural practice’s management or type of crop and could be close to the conventional yields. Lower yields are partly compensated by higher producer prices (EC, 2019 A). Still, the high variability of potential yields require state support to incentivise farmers for conversion to organic practices.

State subsidies in a form of direct payments would compensate farmers for the environmental and societal benefits they provide and also for potential economic losses.

In the EU, state support is provided for organic farmers under the following schemes (EC, 2019 B):

- direct payments under common agricultural policy as organic practices complies with the greening requirements introduced in 2013;
- support dedicated to organic farming production and conversion to organic farming under rural development policies.

State support through direct payments or other financial measures could be coupled with additional requirements for the farmers. For example, in pursuant to the EU legislation for governing organic farming, a holding may only partially convert to organic farming under certain circumstances. At the same time, in Germany the conversion of the entire holding is a prerequisite for support with public funds. The Act on a Joint Task for the Improvement of Agricultural Structure and Coastal Protection (GAK Act – GAKG) forms the national legal basis for the financial participation of the federal government in support measures. The introduction and maintenance of organic farming are supported with public funds from the EU, the federal government and the Länder. The introduction of payments per hectare constitutes EUR 250 for arable land and grassland, EUR 590 for vegetable growing and EUR 950 for land under permanent crops or nursery crops. Payments for maintenance per hectare constitute EUR 210 for arable land and grassland, EUR 360 for vegetable growing and EUR 750 for land under permanent crops or nursery crops. The Länder may increase or lower the amounts mentioned above up to 30% on the basis of political priorities and the available Land budget funds (FMFA, 2019).

In Ukraine, the support for organic farming is provided by regional authorities, but mainly in the form of compensation of expenses for the certification process and audits.

The Law of Ukraine On Main Principles and Requirements for Organic Production (hereafter Law On Organic Production) that was adopted in 2018 and enforced in August 2019 (LoU, 2018). Article 8 of the Law defines that state support for organic market's operator could be provided within national and regional programs by using the funds of budgetary programs for the support of agricultural producers development.

The introduction of dedicated funds at national level for the conversion and maintenance periods could provide significant support to organic farms and increase the share of land converted to organic practices. The level of support should be defined on the basis of additional assessments and consultations with the industry's stakeholders, as well as taking into account the availability of public finances. The indicative level of support could be in the range of EUR 50 – 100 per ha, which reflects carbon mitigation benefits of the technology and the price of carbon required to trigger significant carbon emission's reductions. Due to the limited availability of state funds, direct budgetary support initially could be implemented with a set of limiting factors, such as:

- limiting state's support to conversion period only;
- limiting the total land area for which the support is provided or limiting the total sum of direct payments per single farm;
- the introduction of additional conditions for the provision of direct payments, which will allow to secure environmental and social benefits (carbon sequestration monitoring requirements, job creation, etc.).

<u>Green procurement schemes</u>

State authorities could foster the internal market development by the inclusion of organic products in procurement schemes for schools, kindergartens, and hospitals. Such support measures could be introduced through the non-financial criteria for public procurement. Amendments to the Law of Ukraine On public procurement approved in 2019 (entering into force in April 2020) foresees lifecycle costs as one of options for the evaluation of tendering proposals. In this case, the purchaser, while evaluating tendering bids, could include additional costs related to the lifecycle of the product, including cost caused by external environmental factors during product's lifecycle, including GHG's emissions (LoU, 2019). The introduction of incentives for organic product's procurement would require an additional regulatory and legislative changes. Products purchased under such schemes should be certified according to the applicable legislation on organic products.

<u>Supporting the development of project on the basis of carbon crediting mechanism</u>

An access to project-based carbon offsets generation activities related to land management practices and participation of Ukrainian agricultural companies in voluntary carbon markets as described in section 1.3.1 is also applicable for promotion of organic agriculture technology.

1.5.3.2 Non-financial measures

<u>The mitigation of export barriers and operationalizing the Law of Ukraine On Organic Production</u>

Export barriers in a form of additional document's checks and product's quality control could be mitigated by the full implementation of the provisions of the Law On Organic Production, as well as subsequent negotiations between the Ukrainian national authorities and the EU.

Regulation (EC) No 1235/2008 defines that agricultural products and foods from non-EU countries may only be freely marketed as organic products in the EU, if these countries have compliant or equivalent regulations regarding both production's rules and inspection measures.

For instance, there is a state-supervised private inspection system in place in Germany. The Länder authorities (federal lands authorities) are responsible for the supervision of the 17 private inspection bodies that have been publicly approved by the Federal Office of Agriculture and Food (BLE). Detailed criteria for the accreditation of private inspection bodies are approved by the Ordinance on the Accreditation of Inspection Bodies pursuant to the Act Concerning Organic Farming (ÖLG-Kontrollstellen-Zulassungsverordnung). Organic agricultural producers are controlled once a year or more frequently, if it is necessary, and inspections usually focus on procedural aspects, while elements of final product inspection are conducted in special cases only. Soil and plant samples are also taken and residue analyses are carried out on a random basis and in all cases where there are reasonable grounds for suspicion (FMFA, 2019).

The Law of Ukraine On Organic Production defines rights and obligations of organic products market participants, certification bodies, and relevant state authorities. In particular, certification bodies have a right to collect soil and products sample for conducting laboratory studies, as well as conduct annual certification on the basis of certification agreement and cancel certification in case of violations. The State Service of Ukraine on Food Safety and Consumer Protection has rights to conduct state control over compliance with the legislation organic production, distribution and labelling, as well as submit requests to the Ministry for Development of Economy, Trade and Agriculture of Ukraine to cancel the registration of certification bodies or market operators from relevant registries.

To operationalize the Law On Organic Production, a number of secondary legislative acts have been approved, including:

- detailed rules on organic goods production and organic products distribution (approved on 23/10/2019, entering into force on 06/06/2020) (CMU, 2019 B);
- on approval of national organic product logo (MAPU, 2019 B);
- rules for the examination of inspectors on organic production and organic products (MAPU, 2019 C);
- procedures for the management of state registries of organic certification bodies, operators of organic market, and organic seeds (CMU, 2020).

However, additional regulations are needed to be adopted, including the procedures for the certification of organic production and / or organic products distribution; the list of substances that are allowed for use for organic production; as well as reporting requirements for certification's bodies and market operators. Besides, measures foreseen in the regulations should be implemented.

The efficient operation of national certification system, inspection checks and reporting will ensure the increased transparency of Ukrainian organic market and create prerequisites for the elimination of export barriers. Relevant state's authorities should establish procedures for the monitoring of organic market development, collect statistical information and conduct risk-oriented inspections. In case of any violations, there should be effective national procedures for investigations to ensure strict compliance with legislation on organic agriculture. The developments of EU regulations on organic farming should be followed and relevant amendments into national legislation developed in order to ensure in compliance with the EU's requirements for organic product's import and avoid similar export barriers in future.

The elimination of export barriers is one of the priorities of the Government of Ukraine and agriculture and food products are listed among the priority products for barriers mitigation (PGU, 2019 C).

Following the elimination of additional check during organic products export from Ukraine, export's support measures could include the participation of state authorities in trade missions and key exhibitions, negotiations with key potential partners, the advisory support of organic farmers on entering foreign markets and other measures.

Information policies

Information policies focusing on the promotion of organic farming could also positively contribute to the dissemination of the technology. Utilizing the improved statistical data that would collect according to the provisions of the Law On Organic Production, the responsible state's authorities could promote organic agriculture focusing on the following key aspects:

- sharing information on successful case studies in conversion from traditional farming to organic farming;
- the inclusion of the information on organic farming and the support that could be provided for organic farms into the priorities of farm advisory system;
- the publication of statistical information on organic farming, including the information on average yields with comparison to yields in traditional agricultural systems.

Most of the organic products grown and manufactured in Ukraine are exported with the EU being the major destination. The internal market of organic products is currently limited.

Policy measures that could promote internal market development could include, for instance, the following:

- the promotion of environmental, climate and health benefits of organic product through information campaigns, including those developed in cooperation with businesses and civil society;
- the support of small organic farmers and cooperatives of organic farmers to foster their access to internal market (e.g. super market chains);
- support for the organization of local organic product fairs in cooperation with local state's authorities.

In Germany, most of organic farms have joined associations, including the largest and oldest organic associations, such as Bioland and Demeter, and smaller associations such as Naturland, Biokreis, Bundesverband Ökologischer Weinbau (Federation for Organic Viticulture, ECOVIN), Gäa, Ecoland, Biopark and Verbund Ökohöfe (FMFA, 2019). Associations of organic farmers have better position to advocate for further development of state regulations related to the organic sector as well as promote their products on the market. State's support could target capacity building, the marketing of organic products, collaboration between market players and other measures in cooperation with key national associations.

Information support should target not only the promotion of organic products, but also the relevant requirements for organic farming and labeling requirements. Consumers should have reliable information on the benefits of organic products and distinguish them from other products that could use environmental or biological related terms in their naming and marketing materials.

Soil quality regulations

The improved quality of soil monitoring and soil quality information would allow the demonstration of the benefits of organic agriculture. Details of the proposed measure are provided in section 1.3.3.2.

1.6 Barrier analysis and possible enabling measures for Technology A5 "The production and use of solid biofuels from agricultural residues"

1.6.1 The general description of technology A5 "The production and use of solid biofuels from agricultural residues"

The technology foresees the direct combustion of biomass residues or combustion of biofuels produced from biomass residues (e.g. pellets, briquettes) to produce heat and/or electricity. Co-firing of biomass fuels with coal at the thermal power stations is also possible. Solid biofuels from agricultural residues could be used either locally of exported to European market. Besides, the technology could also include biochar production from agricultural residues using pyrolysis process (thermochemical conversion under low oxygen level), which result in generation of both soil additives (called charcoal or biochar) and energy source (pyrolysis gas or syngas). Pellets production allows extending the area of solid biofuel use due to high density and energy content, as well standardization of quality parameters.

According to the National Action Plan on Renewable Energy till 2020, the capacity of solid biomass plants is expected to be increased to 660 MW and the electricity production from biomass is expected to reach 2,950 GWh (NREAP, 2014). Besides, the Concept of State Policy Implementation in the Area of Heat Supply aims to achieve the 30% share of renewable sources in heat generation by 2025 and 40% share by 2035 (CSPIHS, 2017).

According to the Energy Strategy of Ukraine for the period till 2035 "Security, Energy Efficiency, Competitiveness" the share of biomass in heat and power generation will be increasing. Biomass and solid municipal waste would cover 11 Mtoe of total primary energy supply already in 2035. The share of biomass and solid municipal waste in total primary energy supply will be increased from 3.1% in 2016 to 11.5% in 2035.

Main agricultural residues, which could be used for energy generation, include straw, sunflower seed's husk, as well as corn and sunflower stalks and other residues. The availability of biomass residues depends on the yield's volumes in a particular year, but the overall trend in Ukraine is the increasing yields and increasing biomass volumes that could be used for energy purposes.

Ukraine is one of the major producers of cereals in the region with cereals and legumes growing area of 15 million ha and production volumes at the level of 60-70 Mt per year. The production of grain corn ranged between 23-36 Mt during last 5 years, while the production of other cereals (mainly wheat and to a lower extent's barley) is more stable and was in the range of 34-38 Mt during 2014-2018.

According to the World Energy Council, straw is usually produced at a ratio of about 0.6-0.8 tonnes of straw per ton of grain yield (WEC, 2016). The national data provide higher estimates of straw generation potential with the ratio of 1 ton of straw per ton of grain for wheat, 0.8 for barley, 1.3 for rye, and 1 for oat (Методика, 2013). Biomass residues should partly remain in fields to ensure soil protection from erosion, compensating organic content loss and reducing evaporation. For Ukraine, it is recommended that 30%-40% of cereal's straw could be used for energy purposes (Renewable Energy Agency, 2018; IFC, 2013). The percentage of crop residues that could be removed from each particular farm should be defined on a case by case basis, taking into account the full range of local conditions (crop yield, the level of development of local animal husbandry, soil condition, the application of mineral and organic fertilizer, etc.). The Bioenergy Association of Ukraine estimates cereals straw potential for the energy use at the level of 3.65 Mtoe or 10.68 Mt for 2017 (BAU, 2019). More conservative estimate with lower straw generation ratio of 0.8 ton of straw per ton of grain would result in straw potential at the level of 8.6 Mt (2.9 Mtoe) for the average cereals yields.

The production of sunflower increased six-fold during the last 20 years with the simultaneous increase in processing volumes and the generation of sunflower seed's husk. Total generation of sunflower seed's husk is estimated at the level of 1.8 Mt, however about 50% is already used for direct combustion in oil processing plants or nearby enterprises (STC Biomass, 2016). Another 50% are mostly used for pelleting with further use for heat energy's generation either in Ukraine or abroad, but will be increasingly used for electricity generation due to the announced plans of CHP unit's construction by major oil extraction plants. According to the Bioenergy Association of Ukraine, the energy potential of sunflower seed's husk is 0.99 Mtoe.

The Bioenergy Association of Ukraine estimates energy as the potential of grain corn (stalks, cobs) and sunflower (stalks, heads) harvesting by-products at the level of 40% from generation volumes, which is the equivalent to 2.45 and 1.33 Mtoe respectively for the year 2017. In addition, energy potential of rape straw is estimated at the level of 0.54 Mtoe for 2017.

Total energy potential of agricultural biomass is in the range of 8-9 Mtoe with about 1 Mtoe being already in use (mostly sunflower seed husk and partly straw).

In 2017 biofuel ensured 3.4% (3,046 ktoe) of total primary energy supply and 3.8% of final energy consumption (1,892 ktoe) in Ukrainian energy balance. Most of the biomass is consumed by residential sector for heating and cooking purposes.

The most dynamically developing segment of the use of biomass for energy purposes is the generation of heat energy. Heat energy generation, using alternative types of fuel and renewable energy sources is growing and it is one of the key performance's indicators for regional development (MRDCUSU, 2019). However, the use of agricultural biomass is quite rare and the main fuels include raw wood, unprocessed wood waste (sawdust, wood chips) and wood pellets. Grain corn (stalks, cobs) and sunflower (stalks, heads) harvesting by-products are not currently used for energy purposes.

There are also 15 biomass CHP's supplying electricity to the national grid, utilizing green tariff support mechanism. Total biomass-based power generation capacity is equal to 84 MW, including 31 MW added in 2019. Most of the biomass CHP's use for wood biomass and four of them (APK Evgroil LLC, Kropyvnytskyi OEM PJSC, Singa Energies LLC, and Ajaks Energo LLC) use sunflower seed husk as a fuel. Total annual generation of biomass power is about 162 GWh.

However, there are new projects being developed in different regions, foreseeing the use of agricultural biomass, including sunflower seed's husks and straw. For instance, Khmelnytskyi Biomass Power Plant will have the electric capacity of 46 MW and the capacity of heat energy with 130 MW. The plant will consume 270 000 tons of straw (14 GJ per ton) per year and produce 368 GWh of electricity (MoE, 2018).

The key limitations for the technology are associated with infrastructural requirements (e.g. power substations for electricity's export, district heating infrastructure or nearby heat energy' consumer for heat energy's supply, road infrastructure for organizing biomass residues logistics, etc.).

The use of agricultural biomass residues for energy generation leads to the reduction of GHG's emission due to the substitution of fossil fuels.

Assuming the additional energy potential of agricultural biomass at the level of 7 Mtoe (293 million GJ) and a conservative assumption of substituting natural gas as the fossil fuel (emission factor is 55.95 tons CO_2 per GJ), as well lower efficiency of energy conversion from biomass with comparison to natural gas (80% vs 90%), the potential reduction of GHG's emissions from fossil fuel substitution would constitute of 14.6 Mt CO_2.

GHG's emissions associated with biomass residues collection, transportation and processing should be considered during the estimation of potential for the reduction of GHG's emission. Assuming the required reduction of greenhouse gas emissions set by the EU's sustainability criteria at the level of 70% for electricity, heating and cooling production from biomass fuels used in installations starting operation from the 1 January 2021, the potential reduction of GHG's emission from technology implementation is estimated at the level of 10.2 Mt CO_2-eq.

In case of biochar production, the additional GHG's emission reduction could be achieved due to carbon sequestration in agricultural soils.

The promotion of the technology could support rural development due to diversification of revenue streams for agricultural enterprises and, creation of local job opportunities in biomass logistics and heat energy generation sectors, and supporting economic development in rural areas. In case of agricultural enterprises with more than 5,000 ha in operation complex bioenergy projects could be considered based on available biomass streams, including covering own energy demand from renewable energy sources, pellets production and energy supply to the national grid and/or district heating systems. The technology would contribute to the economic development of Ukraine by fostering the development of renewable energy sector. Environmental impact and mitigation measures in order to reduce air emissions from biomass combustion should be analysed on a case by case basis. Competing the use of agricultural crops residues (as organic fertilizers substitutes, feed for livestock, etc.) should be considered in estimating technology's application potential.

1.6.2 The identification of barriers for technology A5 "The production and use of solid biofuels from agricultural residues"

1.6.2.1 Economic and financial barriers

The economic and financial barriers for the diffusion of the technology stem from high capital investment requirements for biomass to energy projects, the high cost of capital and limited access to financial resources, as well as significant operational expenditures.

Capital expenditures

Significant capital expenditures required for biomass to energy projects pose a financial barrier for their implementation in Ukraine.

According to the estimations of the experts from the working group, Mitigation Technologies in Agricultural capital expenditures for biomass boiler's houses varies in the range of EUR 0.1-0.3 million per MW of installed heat capacity with most of the estimates falling in the range of EUR 0.15-0.25 million per MW.

IRENA's report "Cost-competitive renewable power's generation: Potential across South East Europe" estimates the average investment costs for solid biomass incineration plant (CHP) is EUR 3487.5 per kW (IRENA, 2017). The capital expenditures could be reduced due to construction/material's localization. According to the estimations of the experts from the working group Mitigation Technologies in Agricultural capital expenditures for biomass CHP could be in the range of EUR 2.5 – 3.5 million per MW.

Operational expenditures

Main operational costs are related to the biomass fuel cost (the market price of biomass residues or biomass residues collection and logistics cost). The price of biomass fuel from agricultural residues could vary from 20 Euro per ton in case of straw to as much as 100 EUR per ton or more in case of agricultural pellets. Due to the lack of the developed biomass market, the price of biomass fuel is characterized by very high fluctuation rates. High volatility of biomass prices during the heating season and in medium-term perspective creates additional risks for the feasibility of biomass to energy projects.

The economic value of biomass residues as a substitute for mineral fertilizers

Farmers are often reluctant to use straw and other crop's residues for energy purposes due to nutrient (N, K_2O, P_2O_5) level contained in the residues and compare their value with the relevant cost of mineral fertilizers.

1.6.2.2 Non-financial barriers

The detailed analysis of barriers for the use of agricultural biomass for energy purposes was performed by the Bioenergy Association of Ukraine (BAU, 2019), while the specific barriers for biomass use in district heating systems were also reviewed within KeepWarm Horizon 2020 project (KeepWarm, 2020).

Technological barrier

Technological barriers relate to the specific characteristics of agro-biomass fuels and the limited availability of specialized equipment suitable for agricultural biomass combustion, as well as lack of the specialized machinery for the harvesting of crop production by-products (e.g. balers, loading and unloading equipment, transportation equipment). Straw combustion, in particular, is accompanied by the emissions of carbon monooxide, particular matters, hydrogen chloride, and other polluting substances. It is important to follow the operational requirements for the equipment and ensure appropriate maintenance and operation control procedures, including fuel quality control and air emission's control. In case of biomass residues collection, there is growing experience for cereals straw collection, transportation and storage, however for corn and sunflower residues, the technological solutions are much less known and only initial technical and economic feasibility studies are being performed in Ukraine. Technological barriers are also applicable for high-quality pellets production, since this is a complicated technological process, where the quality of raw materials, equipment and final products requirements should be taken into account. Significant number of national pellets producers use equipment and technologies designed for animal feed production, which leads to low quality of pellets and high energy consumption.

Besides, more specific technological barriers for the use of biomass in district heating systems could include the following:

- lack of sufficient territory and street infrastructure limitations for the organization of biomass supply and storage; this is especially important for the straw use, as it has relatively low density (0.12-0.14 tonnes per m^3 for baled straw) and requires larger storage facilities;
- limited capacity for the power grid connection for the implementation of combined heat and power projects;
- need to ensure compliance with air quality standards for the exhaust gases from biomass installations.

Most of the technological barriers could be mitigated at project level by a mixture of such measures as proper site selection criteria, the exchange of experience, involvement of technology and equipment providers in trainings and capacity building, the inclusion of requirements for air quality according to the terms of references for project design documentation and tender's documentation, environmental monitoring, as well as cooperation with scientific institutions.

Lack of developed supply chains

Barriers related to biomass supply chain relate to the complexity of organizing stable supply chain of biomass and reliable biomass logistic system for energy generation.

The development of supply chains for agro-biomass covers the following aspects:

- the evaluation of agro-biomass resource base in the region of potential biomass to the execution of energy project; due to high transportation costs, the availability of biomass is evaluated at close proximity to the project site (in the radius of up to 100 km maximum); pelleted biomass has water content of 8-12% and the density is increased almost by a factor of 10 (1-1.2 tonnes per m^3), allowing transportation on large distances, but also has significantly higher costs;
- the evaluation of technical feasibility and economic efficiency of logistical operations (baling, transportation, storage, etc.);
- the sourcing of biomass resources and concluding agreements with specific biomass suppliers;
- arranging biomass logistics: transportation, loading and unloading operations, biomass storage.

The experience in the development of reliable and economically sustainable supply chains is limited in Ukraine and would require investment in equipment and infrastructure, as well as capacity building, information sharing and organizational innovations.

Lack of established biomass fuel market

Currently, biomass market is characterized by the high volatility of prices and seasonality of both the biomass supply and demand. Biomass production from agricultural residues could start after the beginning of the harvesting period and last for a limited period of time depending on available storage capacities and arrangements with suppliers. The prices could be changing significantly each month or even weeks and there are examples of twofold increase in the price of biomass during one-year period or even the heating season.

Usually, the prices are relatively lower after the end of the heating season starting from March, and grow before the start of the next heating season due to increasing demand.

National biomass trading industry is at the early stage of development with limited number of players, lack of biomass standards, constantly evolving market and mainly short-term contracts for the supply of specific volumes of biomass. It is complicated to sign supply's contracts for the duration of the heating period or longer periods with pre-defined supply schedule and fixed prices. For instance, in case of straw pellet's production, potential production volumes are defined and production planning is performed on the basis of secured straw resources after the end of the cereals harvesting period. At the same time, some producers of biomass fuel prefer to work with consumers, who can purchase pellets or wood chips throughout the year and not only during or before the heating season. All these factors make the challenging building of reliable supply chain of biomass for energy production' projects.

Environmental barrier due to soil degradation risk

Environmental barriers for the diffusion of the technology include barrier due to risks for the deterioration of soil quality associated with the removal of crop residues from fields. The excessive removal of biomass residues could contribute to reduction of soil organic content and soil fertility, while leaving biomass residues in the field will contribute to carbon sequestration as an alternative to carbon emission's reduction due to the substitution of fossil fuels with biomass. The amount of biomass residues that could be removed from fields without affecting soil quality is characterized by the sustainable residue removal rate.

The level of sustainable removal rates would depend on which of the many important roles residues play in the agronomic system (e.g. soil erosion from wind and water; soil organic carbon; plant nutrient balances; soil, water, and temperature dynamics; soil compaction; and off-site environmental impacts) are taken into account (Muth et al. 2013). Assuming climate change mitigation priorities, the most relevant environmental limitation is the loss of soil organic carbon (SOC). In this case, the sustainable residue removal rate is defined by the quantity of residue that must be left in the field to maintain the levels of existing soil organic matter (SOM). Existing levels of SOM in the plough layer is characterized by percentage in soil composition or mass units per hectare. On average, microbes decompose (mineralize) existing soil organic matter at a rate of about 2–2.5% and biomass residues should compensate for the respective amounts of SOM loss. The formation rate of soil organic matter (i.e., the rate of residue transformation to SOM) ranges between 10% and 20%, with an average of 15%. Increase in grain yield will result higher biomass residues availability for removal. Certain crop management practices, such as the use of cover crops with prolific rooting systems and vegetative growth in rotations, adding animal and/or green manure or compost to field crops, and adding soil amendments that can increase both the active and heavy fractions of SOM could also increase sustainable residue removal rate (Kludze et al. 2013).

A review of studies of crop residue management impact on soil organic carbon revealed that in temperate climates the average SOC content was 12% lower in soils in which crop residues were removed with comparison to soils in which crop residues were retained. However, the studies also demonstrated the high variation of the results, which is explained the by site dependency (e.g. soil type and texture, soil C initial status, climatic factors, such as temperature and rainfall, land use and management) of the crop residues management impact on the content of soil organic carbon. In SOC-depleted soils, large crop residue application can be a valuable practice to increase the SOC concentration, while the partial removal of residue can be considered in temperate climates, when soils are well-endowed in SOC (Warren Raffa et al. 2015). Climate change and increase in temperature leads to the reduction in the content of soil profile carbon due to greater microbial activity and subsequently increased SOC decomposition rate in the periods with higher temperature (Bentsen et al. 2019).

The rate of optimal crop removal will also depend on carbon to nitrogen ratio of the soil and biomass residues. The carbon to nitrogen ratio (C/N ratio) is a key parameter characterizing the quality of soil organic matter, which depends on the application of different chemical or organic fertilizers, the use of crop residues and crop rotations, as well as climatic conditions (temperature, precipitation). A low C/N ratio (<20:1) will promote net N mineralization and a higher C/N ratio (>30:1) will lead to transient competition for N between soil microorganisms and crops and increase soil N immobilization (Qiu et al. 2016).

Therefore, definition of the sustainable residue removal rate requires detailed information on soil characteristics, including the content of soil organic matter in the top layer and amount of soil organic matter in the field, mineralization rate, rate of biomass residue's generation and the formation rate of soil organic matter. Both aboveground biomass and belowground biomass, as well as different crop varieties included in crop rotation systems should be taken into account.

Environmental barrier due to air pollution during biomass combustion

Combustion of biomass leads to atmospheric air emissions, which include PM, CO, NO_x, SO_x and other substances. The level of emissions depends on the air quality control systems installed (e.g. cyclones, bag filters, electric filters, etc.), operation mode of the equipment, and the quality of biomass. In case of biomass combustion with high content of water, the level of emissions increases significantly.

Examples of biomass to energy installations without the appropriate flue gas treatment systems, insufficient fuel quality control procedures and not optimal operation modest resulted in the decreased acceptance of the technology among some local state authorities and general public. There were a number of cases, when residents complained about air emissions from biomass installations, which lead to public protests and negative publications in the local media.

Control over air emissions from biomass to energy projects could be performed at the pre-construction stage for large scale projects during the environmental impact assessment procedure as well as during the operation phase through regular environmental monitoring activities and audits.

Regulatory barriers

Regulatory barriers relate to the lack of a specific action plan and underlying policy measures to achieve the goals of the National Energy Strategy for the period up to 2035 as well as lack of quality standards for biomass fuels.

Information barriers

Informational barriers include the following:

- lack of sufficient information about the energy potential of agricultural residues and available bioenergy technologies, especially at the local level;
- the poor dissemination of information about successful projects on energy production from agrobiomass;
- lack of specialized educational programs for bioenergy specialists;
- undeveloped cooperation between farmers and other small and medium enterprises on the establishment of biomass fuel supply chains.

Capacity barriers

Capacity barriers include lack of sufficient expertise in setting up and servicing of equipment, which is being installed within the biomass to energy or district heating modernization projects (e.g., operation of cogeneration units on biomass and biomass boilers), as well as pellets production lines. There are no dedicated programs in educational institutions, preparing a broad range of specialists required for biomass to energy projects.

1.6.3 Identified measures

1.6.3.1 Economic and financial measures

Electricity tariff

Policy aspects related to electricity tariffs for the promotion of technology would be similar to the measures described in section 1.4.3.1.

Heat tariff

The Law of Ukraine On Heat Supply governs the operation of the heat energy market and heat tariffs establishment mechanisms. In 2017, the Parliament of Ukraine introduced amendments to provide tariff incentives for the heat energy generation using renewable sources. The tariffs for heat energy for the companies, which generate heat energy using the alternative sources of energy, including CHPs, power plants and cogeneration units, for the needs of organizations and institutions financed through state or local budgets, as well for the needs of residential sector, are defined at the level of 90% of the current tariff established for the company for the heat energy, being generated using natural gas for the needs of the respective customer category. If the company does not have an established tariff for the heat energy being generated using natural gas, the tariff for heat energy being generated using alternative energy sources is defined at the level of 90% of the weighted average tariff for natural gas-based heat energy for the relevant customer's category.

The calculation of the weighted average tariff for natural gas-based heat energy is performed for each region of Ukraine by State Energy Efficiency and Energy Saving Agency on a quarterly basis. The calculation of the weighted average tariff for natural gas-based heat energy transportation and supply is performed for the whole territory of Ukraine. On the basis of the information on weighted average tariffs, each company calculates the tariff for biomass-based heat energy generation according to the provisions of the Law of Ukraine On Heat Supply and submits application for tariff approval to the authorized state authorities.

Such mechanisms aimed at the promotion of the use of biomass for heat energy generation, however, subsidized natural gas prices and later decrease of the market price for natural gas along with the growing biomass prices lead to a situation, when the tariff for heat energy from biomass calculated on the basis of the natural gas heat tariff does not cover the cost of biomass purchase and the generation of heat energy.

Therefore, alternative options for the promotion of heat energy generation from biomass should be considered. Such support measures could include both the elimination of direct and indirect subsidies for natural gas and additional heat energy tariffs incentives for biomass heat (fixed tariff or premium).

In case of heat energy tariff incentives, payments could be limited in time (e.g. 10 to 15 years) and bound to additional eligibility conditions (e.g. proper environmental monitoring, efficiency requirements, etc.). Validity period for the support scheme as well as the level of support should be defined on the basis of additional investigations and stakeholder's consultations, taking into account the results of financial analysis of typical biomass to energy projects. Ireland's Support Scheme for Renewable Heat (SEAI, 2020) could serve as an illustrative example for the design of the policy tool.

The development of competitive heat energy market with ensuring the access of independent heat energy producers to the district heating networks would also contribute to the competitiveness of heat tariff and could foster the use of biomass for the generation of heat energy.

Carbon Tax

The use of biomass and biogas for energy purposes should be excluded from the carbon tax (i.e. environmental tax for CO_2 emissions) or any other carbon pricing mechanisms that could be introduced in Ukraine in the near future (e.g. national emission trading scheme, energy tax based on carbon content). On the contrary, the carbon tax for fossil fuels should be increased from the current low level of UAH 10 per tonne to reflect environmental cost of GHG's emissions. Increase in tax level could also be applicable for other environmental taxes such as payments for polluting substances emissions into atmospheric air (PM, NO_x, SO_x).

1.6.3.2 Non-financial measures

Biomass trading platform

An introduction of a digital biomass trading platform would create transparent and competitive biomass market and contribute to price stability.

According to the information of Bioenergy Association of Ukraine, the introduction of biomass trading platform will require the approval of the following regulatory documents:

- the rules of conducting electronic trading of biofuels (access to electronic trading platform, trading rules, typical agreement, dispute settling procedures, etc.);
- the requirements for the quality of biofuel traded at the platform;
- the procedure for the selection of operator of the electronic trading platform (documents required for the application, composition of the selection committee, requirements for the operator, cost of services, etc.);
- the reporting requirements for the participants of electronic trading platform and operator of the platform.

The concept of biomass trading platform includes mechanism for ensuring the initial biomass supply and demand. In particular, state and municipal enterprises would be obliged to sell the part of the biofuel produced on the electronic platform. On the other side, biofuel consumers who receives state support in a form of green tariff for electricity or tariff incentives for heat energy would be also obliged to purchase biofuel through the electronic platform.

The introduction of the electronic biofuel trading platform will ensure the increased transparency of the marker and possibility for consumers to purchase fuel on the basis of competitive procedures.

The relevant draft law has been developed and is being actively discussed by relevant stakeholders, including central state authorities (MCTDU, 2019).

Environmental policies

The Law of Ukraine On Environmental Impact Assessment and the draft Law of Ukraine On Industrial Pollution Prevention, Reduction and Control targets energy installations with the heat energy capacity of more than 50 MW.

Environmental regulations should establish the requirements of clear and justified emission's limits for biomass capacities with the capacity below 50 MW.

Soil quality monitoring system

The development of a soil quality monitoring system as described in section 1.3.3.2 would also contribute to the diffusion of the technology by mitigating environmental barrier related to soil degradation risks.

Information policies

Information policies to support the diffusion of the technology should cover the following aspects:

- the exchange of knowledge about building biomass residues supply chains to ensure biofuel production for energy purposes;
- sharing best practices on the use of agricultural biomass residues in district heating systems;
- information on the impact of the use of biomass residues for energy purposes on soil nutrients management.

Due to high variability and site specifics of biomass residues sustainable removal rates dedicated scientific studies should be done for major crop rotation systems, soil types and regions in Ukraine. Such studies should aim to take into account not only high-level regional differences but specific field characteristics and provide estimation with high spatial resolution for better and more informed decision making at national, regional, local, and farm levels. The information about the availability of biomass residues should move from the estimation of high-level theoretical (total above ground biomass residues production) and technical (residues that could be collected taking into account existing equipment and management practices) potentials to the estimation of regional and local sustainable potentials, which take into account environmental limitations such as maintaining soil organic content level in the fields.

Other area of scientific focus could be the optimization of combustion process for local renewable biofuels, taking into account their chemical and physical properties, as well as combustion conditions. Such scientific studies could be done by state scientific institutions and universities in cooperation with European and other international partners (e.g. within the framework of Horizon Europe program). They could be also performed in cooperation with business entities interested in the development of biomass for energy projects in Ukraine, since the information the availability of resource is crucial for the identification of the most feasible project sites. There are already some examples of bioenergy educational programs (Laboratory of Bioenergy and Energy Efficiency at Zhytomyr National Agroecological University of Ukraine) and research projects (AgroBioHeat project under Horizon 2020 program), which should be supported and extended.

1.7 Linkages of the barriers identified

There are barriers that are not specific to any sector of the economy, including agriculture, such as country's risks associated with political stability and military conflicts, high cost of capital and access to finance, judicial system, etc. They impact the diffusion of climate mitigation technologies, but they are not analyzed in details, since they are not amenable by sector-specific policy actions.

Identified barriers for the diffusion of prioritized mitigation technologies in agriculture sector could be grouped in the following categories:

1. economic and financial barriers;
2. technological barriers;
3. regulatory barriers;
4. capacity barriers;
5. information and awareness barriers;

6. capacity barriers;
7. organizational barriers;
8. environmental barriers;
9. cultural barriers.

Barriers were analyzed by building the problem's trees for each technology and elaborating causes/effects relations and the linkages between barrier's elements. Some of the identified barriers impact several or even all prioritized technologies. For instance, financial and economic barriers related to high capital expenditure and high cost of capital, as well as technological barriers are applicable for all technologies related to the use of new expensive machinery or equipment (use of ICT in agriculture, conservative tillage, biogas production from animal waste and the use of biomass residues for energy purposes). Furthermore, since most of the technologies are not yet widespread in Ukraine, there are common barriers related to awareness about the specifics of technologies and capacity building. Regulatory barriers are also applicable for all technologies with some legislative gaps impacting several technologies (e.g. nutrients management, soil quality monitoring), while others are specific to a particular technology (e.g. regulations on organic farming and organic products).

There are also some specific barriers, which are applicable only for certain technologies, for instance:

- export barriers, international competition and undeveloped domestic market applicable for organic farming technology;
- lack of developed supply chains, lack of established biomass fuel market, and environmental barriers due to soil degradation risk and air pollution from biomass combustion applicable for the production and use of solid biofuels from agricultural residues;
- cultural barriers related to conservation tillage technologies.

Market map for the Agriculture sector is presented in Annex I. Problem trees based on the prioritized mitigation technologies in the agriculture sector are presented in Annex II.

Common barriers allow for focusing on policy measures that would contribute to the mitigation of most important obstacles and trigger further diffusion of different technologies.

1.8 Enabling framework for overcoming the barriers in Agriculture sector

On the basis of similarities in barriers described in section 1.7 above, the common policy measures could be introduced to streamline the diffusion of climate technologies. The enabling framework for supporting the diffusion of climate mitigation technologies in the agricultural sector in Ukraine could include the following components:

- introducing environmental and climate related conditions for the state subsidies provision in agriculture;
- strengthening and improving regulatory requirements;
- capacity building policies;
- information policies;
- supporting the development of project-based carbon crediting mechanisms.

<u>Environmental and climate related conditions for the state subsidies</u>

New technologies are always associated with the adoption costs for farmers, which could be the cost of equipment and machinery or the costs of learning how to use a new technology. Thus, subsidies either for the equipment and machinery or land area will enhance the diffusion of climate mitigation technologies in agriculture.

Ukraine has a state support scheme for agricultural enterprises and farmers, which in 2019 included the following main tools (AU, 2020 C):

- the partial compensation of interest rates for loans taken in national currency by agricultural and livestock industry enterprises;
- the partial compensation of the cost of seeds supplied by local producers;

- the partial compensation of the cost of agricultural equipment and machinery produced in Ukraine (MAPU, 2019 D);
- direct payments (per ha) to the newly established farms and existing farms;
- the partial compensation of expenses for the construction and modernization of new livestock farms;
- direct payments for growing cows and calves;
- the partial compensation of expenses for the construction of grain storage facilities;
- financing of advisory services.

For 2020, the state budget foresees UAH 4 billion (EUR 150 million) for the financial support of agricultural enterprises (LoU, 2020). The priority areas are the support of small and medium enterprises in light with the expected launch of land market, as well as measures aimed at economic development and job creation. Targeted sub-sectors include livestock industry, horticulture, processing industry, and the partial compensation of the cost of agricultural machinery and equipment (MEDTA, 2020).

The current procedure for receiving state support for the purchase of agricultural machinery and equipment is approved by the Cabinet of Ministers of Ukraine (CMU, 2017) and the list of eligible machinery and equipment is formed by a special commission established under the Ministry of Economic Development, Trade and Agriculture. Apart from being incorporated in Ukraine, manufacturers of the equipment and machinery have to meet some other eligibility requirements such as minimum share of personnel costs at the level of 8% from the cost of the equipment, the availability of registered intellectual property rights or design documentation, the provision of warranty services, etc.

Environmental protection and climate related conditions are not covered by the eligibility conditions of any state support programs for the agricultural sector in Ukraine. The incorporation of such conditions would create significant incentives for reducing negative environmental impact of agriculture and is in accordance with the experience of many other countries.

There is an increased number of countries linking subsidies design with the reduction of environmental pressure from agriculture and supporting the transition towards more environmentally friendly production systems. For instance, the EU's common agricultural policy has incorporated greening requirements and is moving towards a more results-based performance assessment and payments for environmental services, such as the quality of soil, biodiversity conservation, and greenhouse gases emission reduction. Another example is Brazil's Low-Carbon Agriculture Plan, which provides low-interest loans for sustainable agricultural practices, including no-till agriculture, biological nitrogen fixation, and treatment of animal wastes (Chatham House, 2019).

<u>Strengthening regulatory requirements</u>

Regulatory measures that would contribute to the diffusion of climate mitigation technologies in the agricultural sector should address the following aspects:

- requirements for nutrient's management in accordance with the requirements of the EU's Nitrates Directive;
- strengthening land protection and land use control requirements;
- developing soil quality monitoring system;
- introduction of EU's requirements on industrial emission control;
- approving and execution of regulatory documents on organic products market development and development of green procurement schemes for organic products;
- creating a legal base for the operation of biomass trading platform;
- improving financial incentives for the use of biomass and biogas for energy purposes in electricity, heat energy and transport fuel production;
- reforming carbon tax mechanism as a climate mitigation policy tool;
- supporting the development of project-based carbon crediting mechanism.

Capacity building policies

The incorporation of climate mitigation topics into the operation of farm advisory services is one of the most straightforward ways for launching capacity building programs on climate mitigation technologies for farmers.

Farm advisory services are regulated by the Law of Ukraine On Agricultural Advisory Activities (LoU, 2004). The keys tasks of advisory services include the provision of support on the aspects related to technologies and environmental protection, as well as the dissemination and introduction of modern technologies and innovations. Advisory services could be financed by state's and local budgets, own funds of the agricultural companies, as well as grants, international technical support funds, and other sources not prohibited by law. Up to 90% of the cost of advisory services but not more than UAH 10,000 could be compensated within the state's support program (AU, 2020 A). The state fund could be used for the financing of training seminars, demonstration of new operation methods, dissemination of printed materials, etc. (CMU, 2007). The development of farm advisory systems in Ukraine is included in the EU-Ukraine Association Agreement (article 404) (AU, 2020 B). As of 2019, there were about 700 registered agricultural advisors and about 800 experts providing part-time advisory services in Ukraine, as well as a National Association of Agricultural Advisory Services of Ukraine (dorada.org.ua).

According to the WorldBank's study, more educated farmers adopt new technologies earlier and get more profit out of them. Modern agricultural technologies are likely to be increasingly management- and skill-intensive, which will require continually upgrading the formal schooling levels of the farm workforce. The government can also strengthen the operation and management of agricultural advisory services by the following steps:

- encouraging pluralistic delivery systems, involving both public sector and other actors (private companies and NGOs possessing specialized skills and local capacities);
- reforming governance structures to increase accountability and responsiveness to needs of farmers and other clients, for instance, by involving local governments and broader stakeholder consultations during program set-up stage;
- investing in new skills and capacities to respond to evolving technical knowledge and consumer demands;
- maintaining strong links among research, extension, and farmers.

Moreover, the effectiveness of public investments in agricultural extension services is strongly impacted by the quality of the innovation system (e.g. research institutions, universities) that is producing well-adapted and profitable new technologies and practices for farmers. Linking agricultural advisory services more closely with research and other sources of knowledge generation could increase their effectiveness and make them more responsive to diverse needs of farmers (WorldBank, 2020).

Therefore, it is important to ensure an effective cooperation between the scientific and research institutions and farm advisory service providers.

Specific research priorities that could support the diffusion of climate mitigation technologies in agriculture and could be included in the program on scientific research of the National Academy of Science and other scientific and research institutions include the following:

- the improvement of methods for monitoring and assessment of soil organic carbon sequestration and CO_2 emissions from croplands;
- the optimization of local biomass fuel combustion and / or gasification technologies;
- the evaluation of sustainable biomass residues removal rates for different regions and crop management practices.

Information policies

Information policies are important to disseminate the most recent knowledge on climate mitigation technologies and successful case studies on their development in Ukraine. Information policies would also create data sources that would guide farmers within the process of new climate technologies adoption.

The choice of communication channels should be based on the preferences of the targeted audience, but existing informal and formal networks and field demonstration of the technologies could be among the most effective ways to reach farmers and demonstrate the benefits of new technologies.

Technology specific elements of the enabling framework include the following measures:

- the support of general digital education, especially in rural areas, to contribute to the diffusion of ICT in agriculture;
- the development of manure and digestate management requirements to contribute to the diffusion of biogas production from animal manure;
- the mitigation of export barriers for the development of organic farming;
- biomass trading platform development to contribute to the diffusion of production and use of solid biofuels from agricultural residues.

Market map for the Agriculture sector is presented in Annex I. Objective trees based for the prioritized mitigation technologies in agriculture are presented in Annex III.

Due to many interlinkages among supportive policy measures for different climate mitigation technologies, it is recommended to develop policy packages that would aim at the increased diffusion of both mitigation and adaptation technologies in agriculture.

The development of climate technologies in the agricultural sector would also benefit from overall improvement of legal and economic environment in Ukraine, including the strengthening of judicial system, lowering the cost of capital and country's risks impacting the access to capital, ensuring stability of political system and policy measures, as well as increased safety. However, enabling framework for overcoming barriers not specific for the agricultural sector was not covered by the TNA project, since they are not amenable by sector-specific policy actions.

The diffusion of climate mitigation technologies will have a positive impact not only on the reduction of GHG'ss emissions, but also for economic development, job creation, environmental protection and human health. Therefore, public costs related to the introduction of supportive policies should be assessed by taking into account non-economic benefits, too. Besides, proposed policies are in accordance with the state priorities in the areas of climate change mitigation and adaptation, environmental protection, as well as agricultural and rural area's development.

Chapter 2 Waste Sector

2.1 Preliminary targets for technology transfer and diffusion in Waste sector

Waste management system. Waste management is one of the most conservative types of economic activity in Ukraine. Despite numerous governmental and non-governmental incentives over the past decades, no principal changes in national waste management parameters have occurred. In particular, the share of landfilled municipal solid waste (MSW) fluctuated from 93.3 % to 95.8 % from officially collected amount for the period of 2014-2018. Changes were mostly influenced by the operational conditions of acting waste incineration plant in Kyiv. Nevertheless, certain successful results have been achieved due to the flexible economy mechanism under Kyoto Protocol and introduction of green tariffs for electricity on the basis of renewable energy sources since 2013. Thus, about 9.7 % of methane generated at MSW landfills in 2016 was flared or used for the energy's generation (GHGI, 2018).

In general terms, the MSW management system in 2018 was as follows. The amount of generated (physically collected) MSW was 10.1 Mt; 78 % of the population were covered by the centralized MSW collection system. The reported share of landfilling is 93.8 % of generated MSW. The rest (6.2 %) was reused, recycled or incinerated, in particular 2.0 % was incinerated and 4.2 % was collected at secondary raw materials procurement points and treated at waste processing facilities (MSWTS, 2019).

The acting legislation for waste management is partly out-of-date. Presently, it is based on the Law "On Waste" (LW, 1998), which is planned to be replaced. The draft law No. 2207-1 from 16.10.2019 "On Waste management" (on implementation of EU requirements in waste treatment system (DLW, 2017)", which involves the implementation of waste hierarchy principles, extended producer's responsibility, electronic licensing system, and also implying changes in waste classification and accounting system is still at the stage of approval procedures.

In general, the waste management system, in particular the municipal, in accordance with the draft Law of Ukraine "On waste management" should look like it is shown in fig. 2.1, including various methods of energy utilization, as shown in the last row of the diagram.

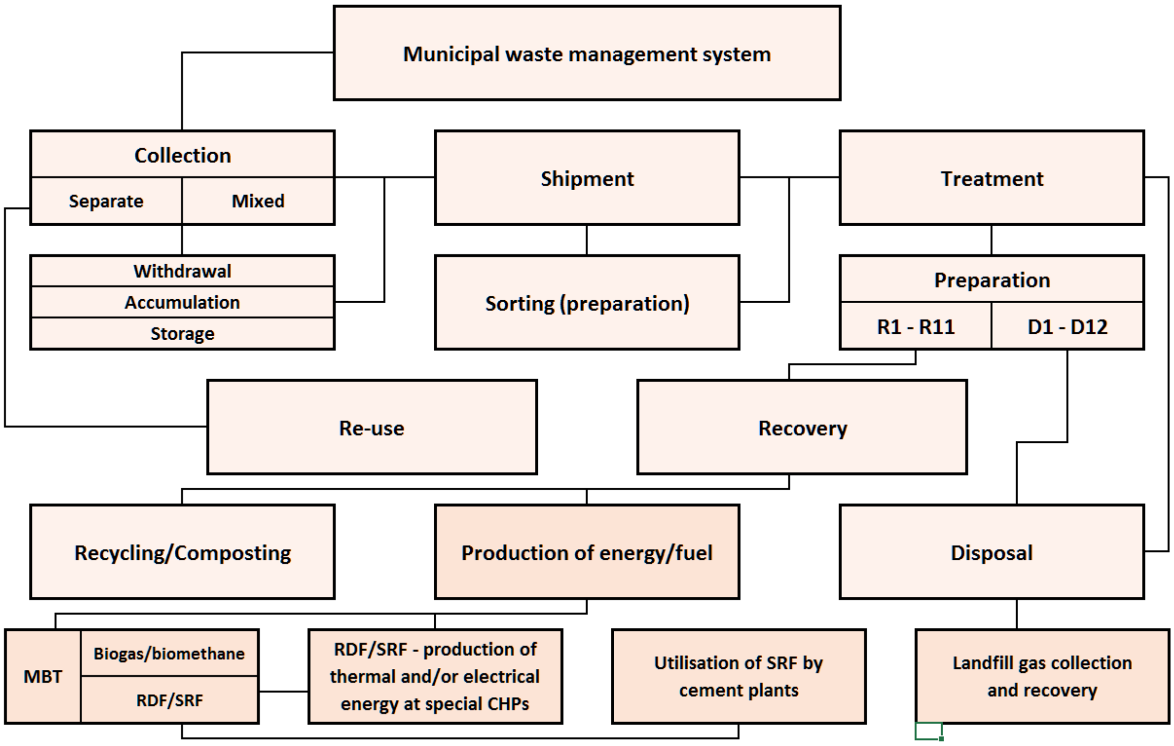


Figure 2.1 – Waste management system in Ukraine

D1-D12 – waste disposal operations (Annex 1 of the Law "On waste management"), R1-R11 – waste recovery operations (Annex 2 of the Law)

Landfilling (disposal) of waste in specially equipped places/objects that meet environmental standards should only be done, if it is not possible to involve the highest levels of the hierarchy.

To facilitate transformation processes on the basis of EU principles and practices, the National Waste Management Strategy up to 2030 was approved by the Cabinet of Ministers of Ukraine in 2017 (NWMS, 2017) as well as National Waste Management Plan up to 2030 was also approved in 2019 (NWMP, 2019). This document will support the successful implementation of the Waste Management Strategy. Initially, National Waste Management Strategy up to 2030 included three phases:

- Phase I (2017-2018) is a preparatory stage, which provides the development of a basis for the modern waste management system in Ukraine.
- Phase II (2019-2023) provides the implementation of the policy measures prepared in phase I.
- Phase III (2024-2030) provides an implementation of new MSW management policy fully harmonized with EU legislation and achievement.

Table 2.1 below shows intermediate and final targets to be achieved by 2030 (for more details see Technology Needs Assessment Report. Mitigation. Ukraine (TNA, 2019).

Table 2.1. –Targets set up in the National Waste Management Strategy up to 2030 (NWMS, 2017), in %

Indicator for MSW	Base value, 2016	Target			Statistics (MSWTS, 2019)
		2017-2018	2019-2023	2024-2030	2018
Reuse	5	7	8	10	4.2
Processing (recycling and composting)	3.04	5	15	50	
Incineration	2.37	5	7	10	2.0
Disposal/landfilling	95	80	50	30	93.8
Total (estimated)	105.41	97	80	100	100.0

Based on the data in table 2.1 it can be concluded that:

1. National Waste Management Strategy up to 2030 identifies the ambitious target for the decreasing of MSW disposal share from 95 % in 2016 to 30 % in 2030 during the period of 15 years.
2. The internal inconsistency of the preliminary targets shows that they were set up by political decisions without solid preliminary study.
3. Internal inconsistency for basic 2016 year shows that policy makers have not sufficient statistical picture regarding MSW treatment system in Ukraine.
4. Two years later, after entering into force in 2017, none of MSW management targets were achieved. Thus, the share of MSW landfilling was equal to 93.8 % in 2018 with comparison to the set-up target of 80 %; incineration – 2.0 % instead of 5.0 %; sum of reuse, recycling and composting – 4.2 % instead of 12 %.

The next annual report on MSW management system in Ukraine for 2019 is planned to be published by the Ministry of Community and Territorial Development of Ukraine in March, 2020. It should indicate the trend on achievement the targets of Waste Management Strategy up to 2030.

Historical GHG's emissions. According to Ukraine's GHG's Inventory (GHGI, 2018), GHG's emissions in the Waste sector amounted to 12.37 Mt CO2-eq. in 2016 that is equal to 3.65 % of total national emissions (excluding LULUCF). Nevertheless, it's the only sector where the GHG's emission upward trend has been observed since 1990 increasing by 3.70 % in 2016 compared to 1990.

Such overall sectorial trend was caused by two main factors: the rapid increasing of landfilled MSW since 1997 and the gradual reduction of wastewater generation in industrial and household sectors, especially since global economy crisis in 2008.

More than 65 % of GHG's emissions in the Waste sector are caused by MSW landfilling, and it's expected that this share will increase constantly in future, if significant changes do not take place in MSW's management practice. Approximately 33 % of emissions correspond to the wastewater treatment, the rest 0.3 % and 0.1 % belongs to solid waste biological treatment and incineration respectively. GHG's emissions from waste incineration (without energy recovery) and biological treatment are minor because these types of waste treatment technologies are limited in Ukraine.

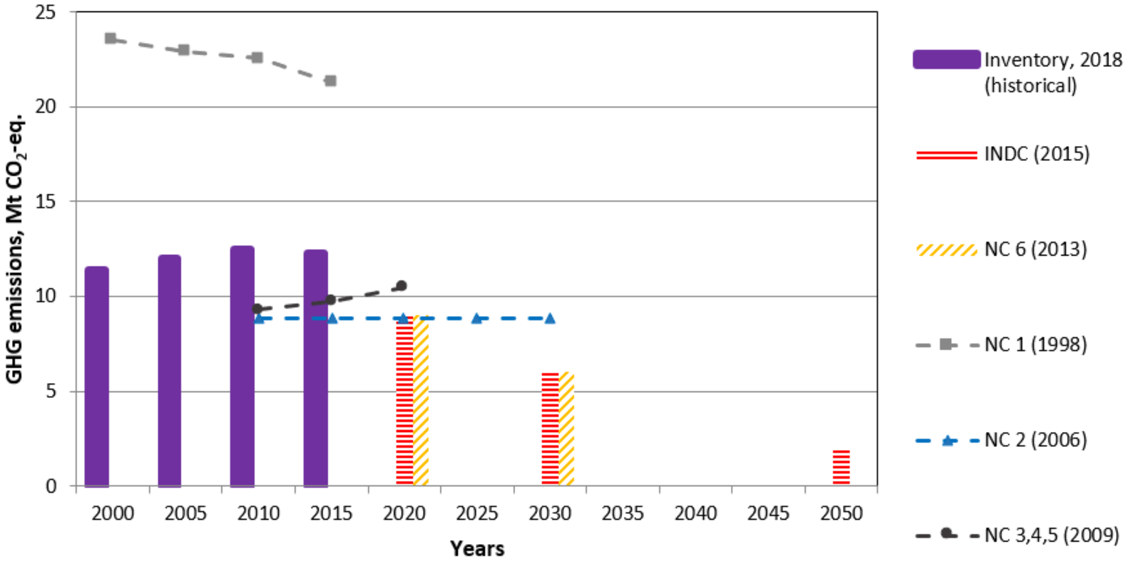
GHG's emission projections. According to acting Ukraine's obligations under UNFCCC, GHG's emissions in 2030 should not exceed to 60% of 1990 GHG's emission level (NDC, 2016). Nationally Determined Contribution (NDC) was approved on the basis of scientifically justifying documentation on the Intended Nationally Determined Contribution of Ukraine to a New Global Climate Agreement (INDC).

Issues related to the prediction of the GHG's emissions in Ukraine were considered in a number of documents (NC1, 1998; NC2, 2006; NC3-5, 2009; NC6, 2013; INDC, 2015; LEDS, 2017). Ukraine's Sixth National Communication on Climate Change (NC6) and justifying documentation on INDC are the latest Ukraine's officially approved documents which include GHG's emission forecasts for all the UNFCCC sectors, namely: Energy, Industry, Agriculture, LULUCF and Waste up to 2030 and vision up to 2050.

Nevertheless, most of the published reports on Ukraine's GHG's emission projections, including NC6 and INDC, are out-of-date and they do not reflect modern strategic as well as socio-economical processes in the country. The most reasonable research in this field is published in Ukraine's 2050 Low Emission Development Strategy (LEDS), which was focused mostly on Energy and Industry sectors without conducting the deep analysis in Waste sector.

To update Ukraine's NDC, "Support to the Government of Ukraine on updating its Nationally Determined Contribution" project under the support of EBRD has been launched in November 2018. The project is expected to be completed by the end of 2020. Its results will include the detailed information on GHG's emission forecasts up to 2030 and vision by 2050 for all the sectors of UNFCCC reporting format, e.g. Waste sector.

Systematized data on GHG's emission projections for the Waste sector in Ukraine are shown in the figure 2.2. It demonstrates that the existing GHG's emission trend in the Waste sector will exceed to the planned intermediate sectoral targets with a high probability. Thus, GHG's emissions in the Waste sector for 2015 were equal to 12.3 Mt CO_2-eq. with comparison to set-up intermediate target of 9 Mt CO_2-eq. If no extra efforts are taken to reduce GHG's emissions in the Waste sector, certain risks exist not to fulfil national commitment on the reduction of GHG's emissions by 2030, which, in its turn, may indirectly lead to reducing the investment attractiveness of national economy.



Source: GHGI, 2018; NC1, 1998; NC2, 2006; NC3-5, 2009; NC6, 2013; INDC, 2015

Figure 2.2 – GHG emission projections in the Waste sector of Ukraine
(Inventory – Ukraine's GHG Inventory, 1990-2016)

Technology Needs Assessment in Ukraine. Technology's prioritization for the Waste sector was carried out in the previous phase of the Technology Needs Assessment for climate change mitigation in Ukraine (TNA, 2019).

The technology's prioritization has been conducted through the following activities: the preliminary overview of options and resources; institutional arrangements and stakeholder's engagement; establishing decision's context; the assortment of priority sectors; establishing the criteria for selecting mitigation measures for priorities; selecting priority measures; detailed analyses, assessment and stakeholder's consultation; the selection of actions for high priority for further development and implementation. Mitigation technologies for waste sector were assesses based on their economic, climate related, political (waste management), technological, social and environmental benefits.

The results of technology's prioritization for the Waste sector as a relative average value were developed on the basis of activity of waste working group, composed of representatives from business, science, government, non-governmental organizations and international donors. The maximal scores were obtained for technologies:

- Methane capture at landfills and waste dumps for energy production (LFG-to-E);
- Waste sorting – the sorting of valuable components of MSW with subsequent treatment of waste residual by other technologies (Sorting);

The following technologies were also positively evaluated:

- The closure of old waste dumps with methane destruction, e.g. flaring, bio-covers, passive vent etc. (Closure);
- The aerobic biological treatment (composting) of food and green residuals (Composting);
- The mechanical-biological treatment of waste with biogas and energy production – anaerobic digestion of organic fraction of MSW (MBT-AD);
- The mechanical-biological treatment of waste with the alternative fuel (SRF) production for cement industry (MBT-Cement).

The rest technologies were evaluated with less than average scores:

- The construction of new regional sanitary MSW landfills (Construction);
- The mechanical-biological treatment of waste with alternative fuel (RDF/SRF) for district heating and/or electricity production (MBT-DH);
- The biological stabilization of municipal solid waste (Bio-stabilization);
- The combustion of residual municipal solid waste for district heating and/or electricity production (combustion);
- The gasification/pyrolysis of MSW for large-scale electricity/heat applications (Gasification).

Thus, the dissemination of technologies on methane capture at landfills and waste dumps for energy production, waste sorting, closure of old waste dumps with methane destruction, composting, mechanical-biological treatment of waste with biogas and energy production, with the alternative fuel (SRF) production for cement industry and anaerobic digestion of sewage sludge is a consensus between the wide range of stakeholders to implement climate friendly technologies in the Waste sector of Ukraine.

Table 2.2 below provides an information on hardware, software and orgware needs for prioritized waste mitigation technologies.

Some of technologies listed are already present in Ukraine, however the level of their penetration is far beyond their technological potential. Specific policy tools to support further dissemination of prioritized technologies should be developed, taking into account long-term effects of the technologies and on the basis of the stakeholder's engagement.

Table 2.2. – The summary of prioritized waste mitigation technologies

Technology	Hardware	Software	Orgware
Methane capture at landfills and waste dumps for energy production/ *capital goods category*	LFG recovery system including wells, gas collection points, intermediate and main gas pipelines, gas extraction with drainage and purification equipment, and CHP units for energy production	Landfill operation and management practice, landfill gas monitoring systems, LFG knowhow (manuals, guidance, recommendations, skills, etc.)	Legislation and regulatory base on landfill gas recovery including Ukrainian technical standard DBN V.2.4-2-2005 "Solid waste landfills”
Waste sorting/ *capital goods category*	Containers, vehicles, collection centers, reloading stations and sorting lines, valuable material treatment facilities	Knowledge on logistics (software, human capacity, statistics, monitoring), secondary resources market infrastructure (trade floors, good demand), awareness and behavior of population	Legislation and regulatory base for waste sorting, population involvement, collaboration of waste sorting companies and industry, waste producer’s responsibility legislation
The closure of old waste dumps with methane destruction/ *publicly provided goods category*	LFG recovery system with flaring and monitoring equipment, technical, landfill covering systems, changes in infrastructure (roads, waste water treatment, etc.)	Knowledge on logistics (software, human capacity, statistics), knowledge on environmental monitoring (soils, water resources, atmosphere, natural ecosystems etc.)	Legislation and regulatory base for closure of MSW dumps, increased taxes on waste disposal, population involvement, local authority incentives, green funding, regional waste management plans, etc.
The aerobic biological treatment (composting) of food and green residuals / *capital/ consumers goods category*	Main composting techniques as windrow, aerated static pile, vessels. Supporting techniques as sorting, screening and curing units	Know-how on composting project development and operation of composting sites, knowledge on logistics (software, human capacity, statistics), know-how for home composting	Legislation and regulatory base on municipal solid waste management and treatment including food and green residuals
The mechanical-biological treatment of waste with biogas and energy production – AD of organic fraction of MSW / *capital goods category*	Mechanical treatment units (separation with sieves, drums, magnets, etc.) and biological treatment units (anaerobic digestion), CHP unit for energy production	Know-how on biogas production project development and operation of biogas units, knowledge on logistics (software, human capacity, statistics)	Legislation and regulatory base on municipal solid waste management and treatment including biogas production with energy utilization
The mechanical-biological treatment of waste with SRF production for cement industry / *capital goods category*	Mechanical treatment units (separation with sieves, drums, magnets, etc.) and biological treatment units (drying), cement plants	Know-how on SRF production project development and operation of MBT plants, knowledge on logistics (software, human capacity, statistics)	Legislation and regulatory base on SRF management and use including Ukrainian standard "Solid recovered fuels - Specification and classes",
The anaerobic treatment (digestion) of sewage sludge / *capital goods category*	AD plants and CHP units for energy production	Know-how on biogas production project development and operation of biogas units based on sewage sludge	Legislation and regulatory base on sewage sludge treatment including biogas production with energy utilization

Six of seven prioritized technologies could mostly be categorized as capital goods technologies, since they are used to produce other goods (i.e. energy, fuel) and could be purchased by private companies, as well as have relatively large CAPEX and simple market chains. However, depending on the specifics of the technology to be implemented by a particular inhabitant, the use of aerobic biological treatment (composting) technology could also be classified as consumer goods technologies, since it can involve smaller investment and the use of separate pieces of equipment or materials with relatively low prices.

The closure of old waste dumps with methane destruction could be categorized as private goods category. However, for the purpose of the TNA project, the focus is on the complex introduction of prioritized technologies and therefore, they are all treated as capital goods technologies.

Key stakeholders that are expected to be involved in the development of enabling framework for further dissemination of prioritized mitigation technologies in waste sector include:

- Central state authorities, including the Ministry of Community and Territorial Development of Ukraine,
- The Ministry of Environmental Protection and Energy of Ukraine, the Ministry of Health of Ukraine, State Energy Savings and Energy Efficiency Agency of Ukraine, the Ministry of Economic Development, Trade and Agriculture of Ukraine, the Ministry of Education and Science of Ukraine;
- Regional and local state authorities, including regional state administrations and local communities;
- Business associations and private companies;
- Scientific institutions;
- Non-governmental organizations.

The engagement process of stakeholder within the second stage of the TNA project included the following activities:

- in personal interviews with the experts specialized in prioritized mitigation technologies;
- the review of position papers and other communications presented by institutions, private companies and business associations;
- participation in the key sector's exhibitions and conferences and following the presentations of sectoral representatives on the developments of prioritized technologies (Biomass for Energy 2019, Waste Forum Kyiv 2019, Waste Management 2019, etc.);
- discussions using social media and email communication.

Despite the fact, that above listed technologies should be widely disseminated in Ukraine due to the consensus of the local experts, there are barriers for this development, in particular among them are:

1) economic and financial barriers;
2) market conditions barriers;
3) legal and regulatory and legislation barriers;
4) technological barriers;
5) information barriers and others.

All these barriers have to be deeply analysed, as well as the reasons, why they do occur. Efficient measures on how to overcome such barriers should be developed.

Gender equality and equal opportunities. Publicly available information on gender aspects in waste management system is annually published by the State Statistics Service of Ukraine (SSSU) in its Statistical herald "Labour of Ukraine" (LU, 2019; LU, 2018; LU, 2017; LU, 2016; LU, 2015).

The most disaggregated level for waste management statistics is included in type of economy activity E "Water supply, sewerage and waste management". This information corresponds to gender labour statistics for waste management. Nevertheless, certain influence of water supply sector in it also takes place.

Figure 2.3 shows that the quantity of employed women in waste management sector has decreased by 11.3 % during past 5 years, with comparison to 11.5 % of decrease for men. It was aassuming that labor statistics in MSW treatment system corresponds to the overall statistics for type of economy activity E "Water supply, sewerage and waste management". Both figures are insignificantly lower than the average decrease of working places in Ukraine amounted as 12.6 % for the above-mentioned period, which was caused by the crisis in industrial sector, transition to new markets, automatization and digitalization, as well as labor immigration.

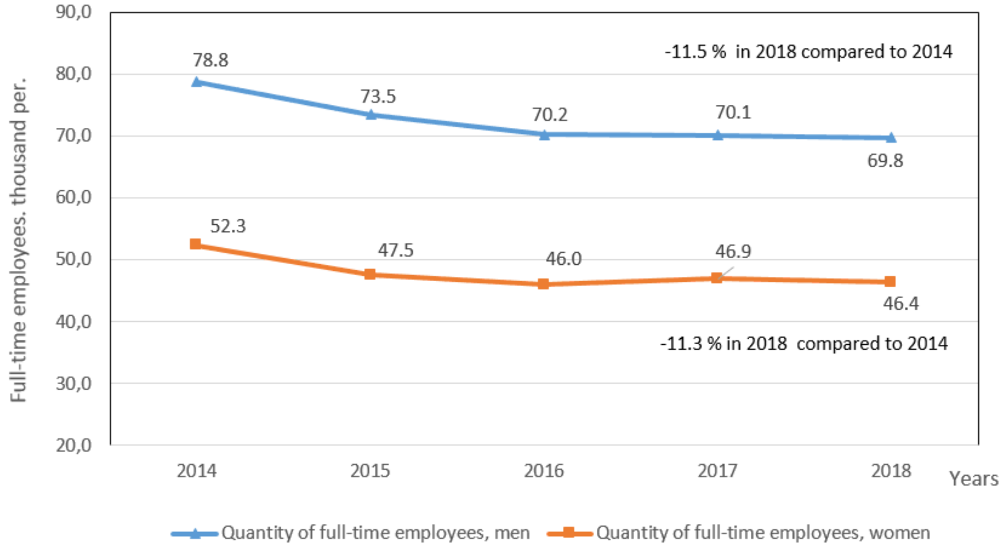


Figure 2.3 – Employment in water supply, sewerage and waste management in Ukraine, 2014-2018

Figure 2.4 illustrates the gender structure for full-time employees in Ukraine. Women employment in waste management system was almost constant in 2014-2018 being close to 40 % that is much lower than the average figures equal to 56 % all over Ukraine. Such gender quantitative inequality could be explained by the existing demand of physically hard-working positions in waste management with high sanitary risks: landfill workers, drivers of collecting vehicles, bulldozers and excavators. It’s expected that the diffusion of modern environmentally friendly technologies will significantly change the situation of gender quantitative inequality in waste management creating new “women” friendly positions in related areas of science, logistics, secondary raw material markets as well as monitoring and general management.

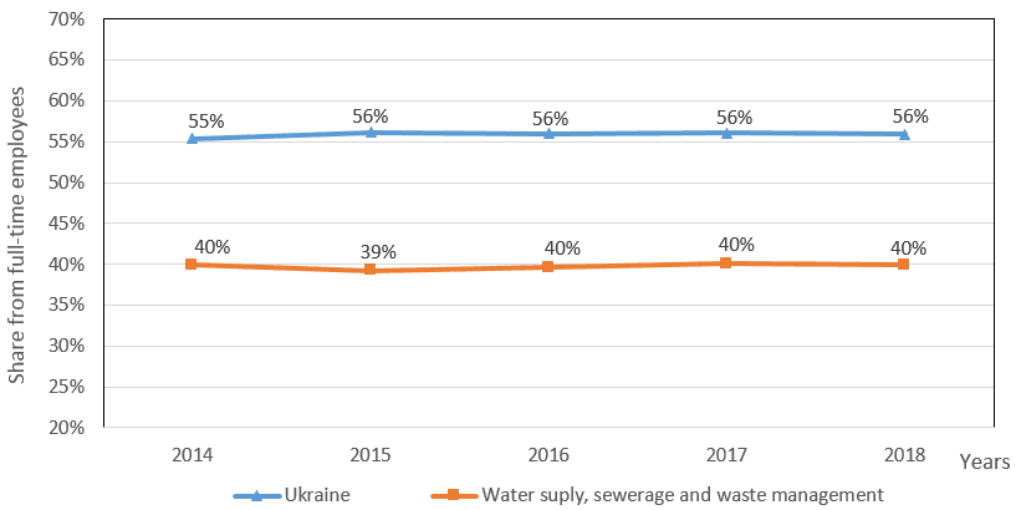


Figure 2.4 – Share of women among full-time employees in Ukraine, 2014-2018

Figure 2.5 illustrates a ratio between average salaries of men and women for the period of 2014-2018. Women’s average salaries in water supply, sewerage and waste management systems fluctuate within the range of 85-91 % with comparison to men, that is much higher, than average in Ukraine 75-79 %. Partly, it can be explained by the hidden gender inequality for the salaries on the positions with similar professional experience needs, because most of the low-quality positions in waste management system are men employee. It means that men still have higher salaries at the similar positions with comparison to women.

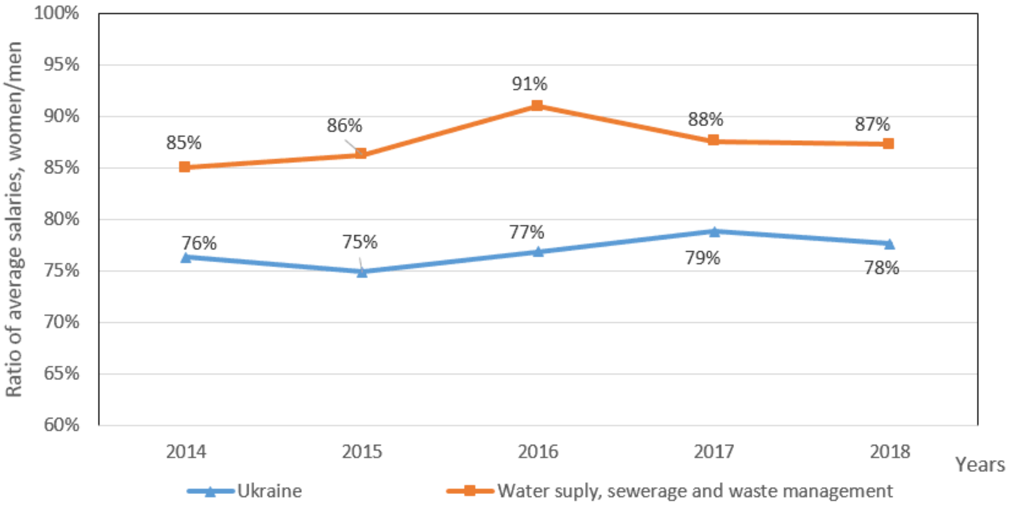


Figure 2.5 – The ratio of women salaries with comparison to men in Ukraine, 2014-2018

Some gender trends also take place in waste informal collection and sorting sectors. Currently, the scale of the informal sector in Ukraine is quite substantially involving tens of thousands of people. The gender situation is quite different in urban and rural areas. Men are mostly involved in illegal waste management in urban areas, the share of women is evaluated as 5-10 %. In rural areas, the share of women involvement is evaluated to be 20-30 %.

Summarizing, transfer of modern waste treatment technologies will facilitate gender equality in Ukraine, wherein the woman's role will increase in MSW management system due to the substitution of low skilled hard work needed workplaces by the position with high professional requirements. In this case, the average salary will increase for both men and women. Technology transfer and diffusion will also level the role of informal sector, creating new comfortable jobs, which will provide good opportunities for women, currently involved in informal sector in rural areas.

2.2 General Barrier analysis and possible enabling measures for MSW management system in Ukraine

2.2.1 The general description of expected MSW management system structure in a mid-term perspective

Currently, the National Waste Management Strategy up to 2030 (NWMS, 2017) and National Waste Management Plan up to 2030 (NWMP, 2019) are acting regulations in the MSW management system of Ukraine. A new version of framework law "On waste management" should be implemented in the nearest future as a part of the national obligations under the EU association agreement. This new framework law will be harmonized with the EU's directives on waste, namely 1999/31EU, 2008/98/EU, 94/62EU, 2012/19/EU and 2006/66/EU regulating all aspects of waste management including waste treatment and disposal, packaging waste, electronic waste, waste batteries and accumulators, etc.

Thus, a new regulation on waste management in Ukraine would be formed in a relatively short-time perspective, wherein the core issue is to ensure wide diffusion of modern technologies, which should be stimulated by market mechanisms.

General scheme for market mapping on MSW management system in Ukraine expected to be acting in a mid-term perspective, including: waste management market actors, market actor interconnections, regulatory environment, services ensuring efficient interconnections, available MSW treatment technologies and waste flows by components (fractions) is shown in the figure 2.6 as well as legend for it in figure 2.7.

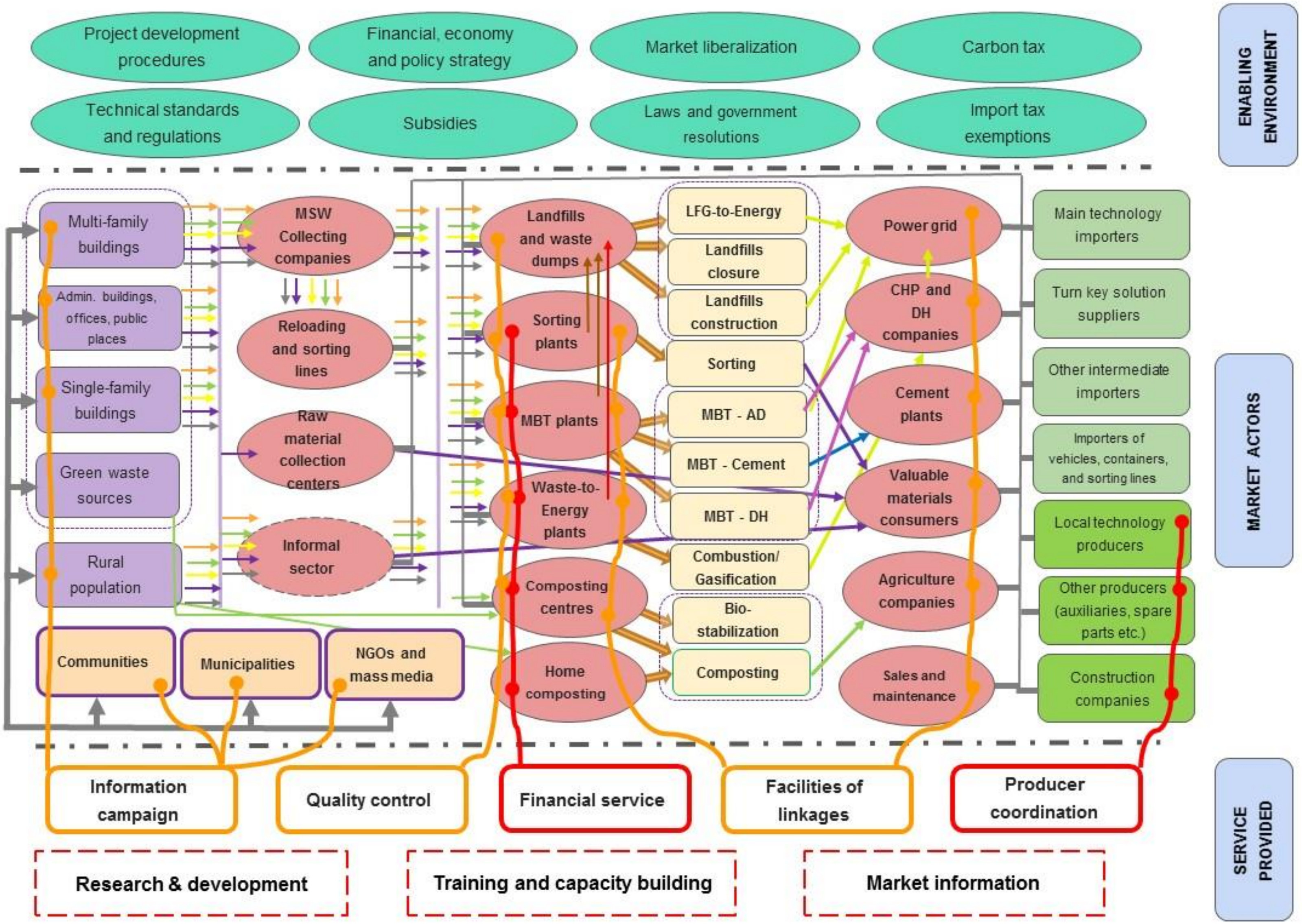


Figure 2.6 – Market mapping on MSW management system in Ukraine (expected in a mid-term perspective)

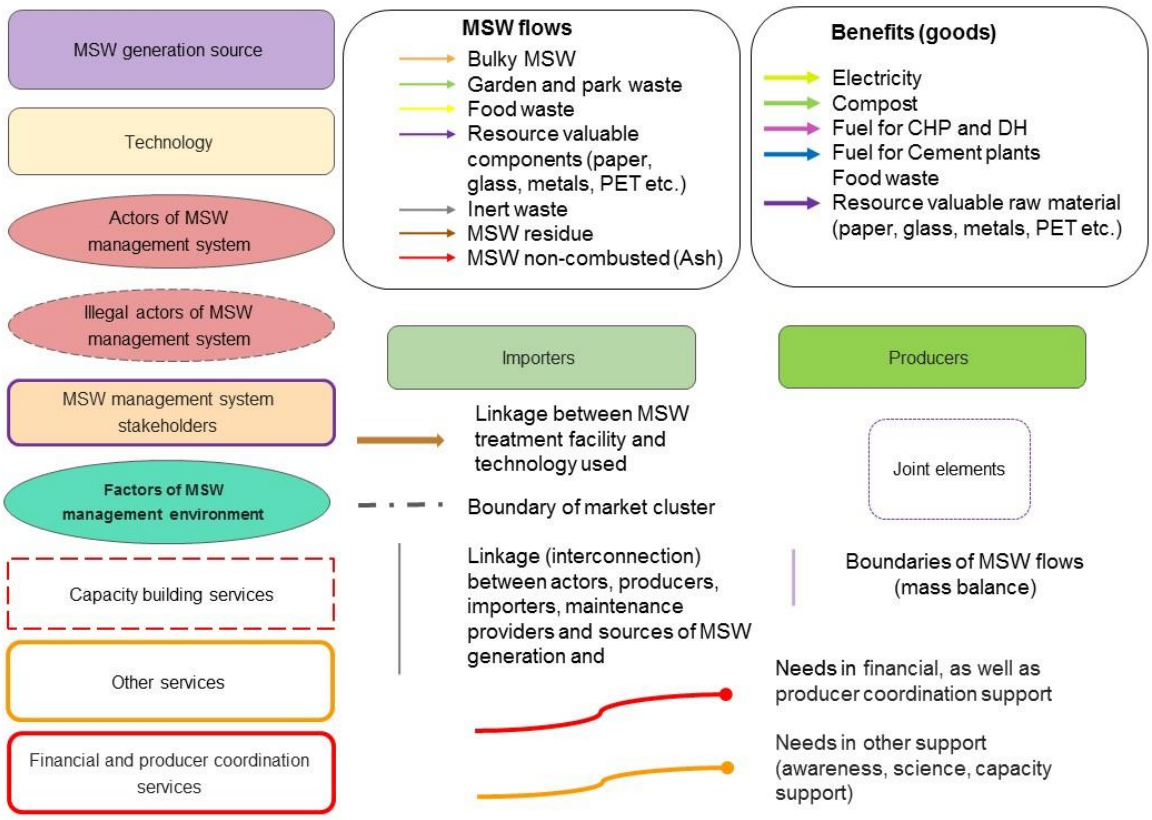


Figure 2.7 – Legend for market mapping on MSW management system in Ukraine

MSW management market could be divided into three main parts: regulatory environment, market actors and services needed to be provided. MSW management market has complex structure, wherein different technologies are alternatives to each other from the one hand, and the integrated part of other technologies from the other hand. Moreover, technology integrity is limited by the volume of generated MSW, its composition, quality and available industry facilities. Moreover, MSW management market has strong feedback from the population generating MSW.

Market actors can be divided by direct waste operators, importers, producers, communities and local authorities as well as MSW generating sources by types of population and place of generation. *MSW generating sources* are represented by the urban population (multi-family, single-family and administrative buildings, offices, public places, green waste sources (cleaning of park and yard areas)) and rural population. They generate different types of MSW flows depending on local collecting system including food waste, valuable components like paper, glass, metals, PET etc., bulky waste, garden and park waste, and inert waste.

Generated waste can be collected or directly transferred to *primary collectors* – waste collecting companies and raw material collection centers. Food and green waste from the rural population can be composted in home. Green waste generated at park and yard areas should be transported directly to composting centers.

MSW collecting companies can directly transfer the waste to operators of MSW treatment facilities, or through the reloading and sorting lines. Raw material collection centers directly sell resource valuable components to valuable material's treatment facilities.

The informal sector may play an important role at this stage spontaneously or in an organized manner. Spontaneous waste pickers withdraw valuable components from containers and other primary storage places. "Organized" informal sector operates with larger MSW flows at the area of landfills and waste dumps, which have been already collected by transportation companies. Informal sector sells valuable components to materials treatment facilities.

MSW treatment and management facilities (operators) may include landfills and waste dumps, sorting facilities, MBT plants, waste-to-energy plants, cement plants and composting centers. All of these facilities use specific technology to manage MSW or its separate components: landfilling, landfill gas recovery and utilization, waste sorting technologies; biogas production from biodegradable waste, composting, RDF production and combustion with cement, thermal and electrical energy production. MSW treatment facilities (within an exemption of certain landfill types and bio-stabilization) generate goods that can be transferred or sold out to industrial supplies.

Industrial supplies of goods produced from MSW components are power distribution companies (power grid) – buy electricity produced by LFG-to-Energy, landfill construction or MBT-AD technology; CHP and DH companies – buy fuel produced from MSW treatment at MBT-AD or MBT-DH; cement plants – buy fuel produced from MSW treatment at MBT-Cement; valuable materials consumers – buy valuable MSW components from sorting technologies, informal sector and raw material collection centers; agriculture companies may use compost from composting centers.

Other important players of MSW management market are companies that provide maintenance and sales supporting services.

In general, *producers* are represented by local technology's producers, construction companies and other producers (spare parts, auxiliaries etc.), *importers* – main technology's importers, turnkey solutions supplies, importers of vehicles, containers and sorting lines, and other intermediate importers.

All market actors can directly or indirectly cooperate with each other: *primary collectors, MSW treatment facilities providing goods through specific technologies, industrial supplies, maintenance and sales supporting providers, importers and exporters.*

Communities, municipalities, NGOs and mass media form the *society and local authority's* group of market actors. This group of actors is focused on work with population and other entities responsible for waste generation. The government is responsible for enabling business environment in MSW management system through the establishing taxes (landfill tax, import tax exemption, carbon tax), market liberalization, laws and government resolutions, financial, economy and policy strategy, subsidies, tariffs, project development procedures, technical standards and regulations, etc.

Services provided though market actors could operate efficiently, applying modern waste treatment practices and interconnect without barriers. Such services are research & development, training and capacity building, market information's distribution, information's campaigns, quality control, finance service, and producer coordination. Research & development, training and capacity building as well as market's information services should be provided to all market's players; information's campaign services – to population and entities generating MSW, communities, municipalities, NGOs and mass media; quality control services – to MSW treatment facilities; facilities of linkages services – to MSW treatment facilities and industrial supplies; coordination services – to producers.

Detailed information on the role of each MSW treatment technology and market actors is presented in chapters 2.3-2.8.

2.2.2 The identification of barriers for MSW management system

2.2.2.1 Common economic and financial barriers

Common economic and financial barriers for the dissemination of modern MSW treatment technologies in Ukraine are:

- Low feasibility or even unprofitability (low IRR, NPV, long payback period) for most of technologies;
- Low tariffs on MSW management for population and other waste generators;
- Low tariffs on MSW disposal (tariffs do not include costs for closure, care and aftercare monitoring);
- Inadequate access to financial resources;
- High cost of finance;
- Disincentives to foreign investment;
- The absence of economy incentives to process and recycle MSW;
- The absence of producer responsibility on the generated waste.
- Low population income.

2.2.2.2 Common non-financial barriers

Common non-financial barriers for dissemination of modern MSW treatment technologies in Ukraine are:

Regulation/legislation barriers:

- Lack of comprehensive and strategic waste management policy implementation;
- Insufficient institutional framework;
- Lack of legislation development, for example, in some cases unclear ownership of MSW;
- Lack of non-financial stimulus for MSW treatment;
- The absence of producer's responsibility for the potentially generated waste;
- The poor stimulation of specific waste components separate collection, such as glass, packaging, batteries accumulators, etc;
- Lack of control for unofficial landfilling and other activities.

Market conditions barriers:

- Over-bureaucratic procedures and corruption;
- No possibility to sigh long-term contract;
- No possibility to sigh direct contracts between local governments and waste processing companies;
- Involvement of informal sector;

Technological barriers:

- Few local equipment and service suppliers and local references;
- Bad quality of mixed waste;
- Insufficient skilled manpower for O&M.

Information barriers:

- Limited awareness of technology used in the developed countries;
- Lack of available information, pure population knowledge and involvement in waste treatment issues;
- Missing feedback among interested parties.

Existing waste management system does not give equal gender opportunities, wherein the barriers that lead to such an inequality, could be conditionally divided into two groups: passive and active. **Passive gender barriers** reduce attractiveness of jobs for women due to specific human resource needs in the acting system, namely hired workers should be able to operate in difficult physical and sanitary conditions, as well as the system itself is conservative and is not flexible itself. **Active gender barriers** are reflected in the fact that men are used to have higher average salaries at the similar positions and have higher chances for carrier paths in this field.

2.2.3 Identified measures for MSW management system

2.2.3.1. Common economic and financial measures

Common measures to overcome economic and financial barriers for waste treatment technologies have could be identified as follows:

- The development and implementation of waste management plans at regional level and at the level of all administrative entities;
- The implementation of the principle "Community is the owner of the waste and responsible entity for its processing in accordance with the regional waste management plan"
- The introduction of tariffs for waste management sufficient to cover associated expenses for project life time (20 years);
- The implementation of "Pay as you throw" principle;
- The implementation of "Extended producer responsibility" principle;
- The introduction of "circular economy" principles in the activity of economic entities;
- The introduction of economic incentives for the production of domestic equipment for the dissemination of modern waste processing technologies;
- Temporary VAT exemption for reuse services;

- Temporary VAT exemption for recyclable materials and products.
- VAT exemption for RDF and SRF use.

2.2.3.2 Common non-financial measures

Common measures to overcome non-financial barriers for waste treatment technologies could be identified as follows:

- The creation of general conditions for modern regional landfill construction program and old waste dumps closure
- The creation of general conditions for modern waste treatment technology development;
- The creation of a new central authority responsible for waste management state policy implementation in Ukraine;
- The implementation of national waste list (classification) on the basis of European practice;
- The creation of guidelines on sustainable green public procurement;
- The implementation and use of cost-effective tools in order to encourage the creation of infrastructure on waste treatment facilities;
- The introduction of economic incentives for the dissemination of environmentally friendly production technologies and the expansion of recycling practice;
- The introduction of inter-municipal cooperation as a legal mechanism supported by the Government;
- Levelling an influence of informal sector;
- The creation of an interagency coordination board for waste reuse, processing and utilisation;
- Support on new jobs in waste management sector;
- Support on new specialties on sustainable waste management at the universities;
- The consideration of waste management issues when developing mid and higher education standards;
- The support of new specialties on sustainable waste management at the universities;
- The creation of guidelines in modern waste management opportunities for the municipalities;
- The creation of working platforms on dissemination best practices in Ukraine;
- Carrying out of national awareness company on sustainable waste management;
- The implementation of MSW management awards;
- Waste management awareness activities in school and pre-school institutions.

The implementation of new model on waste management system in Ukraine, which should be based on wide modern waste treatment technology dissemination, fair and transparent market rules and mechanisms of control, as well as good governing in the whole will lead to overcoming the passive gender barriers in waste management system of Ukraine.

To overcome active gender barriers, which are salary and carrier paths inequality, additional specific measures have to be implemented in waste management system, which are:

- The implementation of quotas for woman representativeness in central and local authority bodies;
- requirements on vacancies should be gender neutral both for government and business;
- the implementation of awards focused on promoting women to be involved in waste management issues;
- ensuring social guaranties for pregnant women and women with children;
- the implementation of supporting mechanisms stimulating migration of hired workers in waste management from informal sector to legal business.

2.3 Barrier analysis and possible enabling measures for technology W1 "Methane capture at landfills and waste dumps for energy production" (LFG-to-E")

2.3.1 The general description of technology W1 (LFG-to-E)

MSW disposal at the landfills and waste dumps remains the main method for waste management in Ukraine. The waste management strategy by 2030 envisages the transition from simple disposal to integrated treatment of waste. In particular, the strategy foresees the introduction of separate waste collection and sorting, the gradual increase of the share of reuse and recycling as well as the construction of at least 100...150 modern regional landfills using the principle of interregional cooperation. Thus, the role of landfill will remain significant in Ukraine for at least several decades.

During the waste disposal and accumulation, the landfill body is created, and as a result, the bulk of the waste appears in anaerobic conditions. Lack of oxygen, high humidity and elevated temperature in the range of 30...60 Celsius degrees are necessary and sufficient conditions for the start of the processes of organic fraction decomposition with generation of landfill gas (LFG). LFG is the mixture of methane, carbon dioxide and water with minor addition of nitrogen, hydrogen sulfide and organic volatile compounds.

Ukrainian technical standard DBN V.2.4-2-2005 "Solid waste landfills" includes such main provision as the utilization of LFG formed by anaerobic decomposition of the organic component of solid waste. LFG could be used as a fuel for power plants (boiler units, industrial furnaces, stationary generators) or for refueling in fuel tanks. The method of LFG's utilization is determined during the technical specification development for the design of LFG recovery system. In case of no economical reason to use LFG defined by appropriate feasibility study, a special high-temperature flare should be used at the landfill site.

LFG recovery system includes wells, gas collection points, intermediate and main gas pipelines, gas extraction system and unit for gas treatment with drainage and purification equipment.

Landfill gas volume is determined by MSW content and disposal schedule. On average, methane generation potential of Ukrainian MSW is 60...75 m^3/t. The rate of decay is also determined by MSW content and physical conditions in the landfill body, mainly water content and temperature. In turn, the internal conditions depend on climate, mainly on the amount of precipitation. The process of decomposition of organic fraction of solid waste is realized according to exponential law, the half-life of decay in Ukrainian conditions (corresponds to 50% of LFG production) is 10...12 years.

It is considered that recovery and energy's utilization of LFG makes sense with average thickness of waste layer at least 10 meters and one million tons of accumulated solid waste. The great importance has time of accumulation of required amount of waste. Typically, these conditions are met at the landfills that accept waste from the settlements with total population of 200 thousand inhabitants or more.

There are the following basic possibilities for the use of LFG:

1. The installation of gas combustion engines (in some cases, gas turbines) at the landfill with electricity supply to the grid without thermal energy utilization;
2. LFG pipeline to the nearest boiler house, sale of heat to district heating system;
3. Combined electricity and heat (for example, installing of CHP module on the basis of an internal combustion engine in a boiler house or supply of thermal energy to domestic or industrial consumers in close proximity to the landfill);
4. The upgrading of LFG to the quality of natural gas, followed by biomethane use as motor fuel or delivery into natural gas distribution/main grids (this option has not been widely used in the world on MSW landfills).

LFG recovery at the landfills and waste dumps is an effective environmental measure. As a result of LFG combustion (in power unit or by flare), GHG's emission is reduced, organic volatile compounds responsible for unpleasant odors are destroyed, the probability of fire events is reduced or eliminated. In addition, LFG is local and renewable energy source that can substitute any kind of fossil fuel like coal, oil, and natural gas.

The combustion of LFG for the production of energy contributes to the reduction of GHG's emission in two ways. LFG capture prevents the release of methane into the atmosphere (as GHG methane is 25 times as powerful as CO_2) and the electricity subsequently produced by LFG combustion produces less CO_2 emission than conventional fossil fuel combustion.

If we take into account that the share of the population of Ukraine living in cities with a population of more than 200 thousand inhabitants is 40%, the total annual potential of biogas collection in Ukraine is 60 $Mnm^3(CH_4)$ = 2.1 MGJ = 580 GWh. It corresponds to 1.05 Mt CO_2-eq./yr by methane avoiding and 0.64 Mt

CO_2-eq./yr by fossil electricity substitution. Total potential for the reduction of GHG emission is 1.7 Mt CO_2-eq./yr.

The technology is under development in Ukraine. The first Ukrainian biogas collection plants were implemented within joint implementation (JI) projects in 2008...2012 during the first period of Kyoto Protocol. Almost all recovered LFG was burned on flares.

There were 20 LFG-to-Energy projects at 01.01.19 with 18.4 MW_{el} of total installed capacity at the landfills and waste dumps. The corresponding figures for 1.01.20 are 27 projects and 26 MW_{el}.

The diffusion of LFG technologies will contribute to gender equality by creating new environmentally friendly market niches and high qualified jobs in energy, monitoring services and related areas. These jobs will need rather modern knowledge in software and measuring apparatus than physical strength and ability to work in extreme sanitary conditions.

2.3.2 The identification of barriers for technology W1 (LFG-to-E)

2.3.2.1 Economic and financial barriers

At present, the expediency of LFG's recovery in Ukraine is determined by the possibility of electricity selling, using so called "green" tariff (0.1239 EUR/kWh without VAT). Therefore, after the first period of Kyoto Protocol, starting from 2012, the main objective of LFG's recovery in Ukraine was not GHG emission's reduction, but the production of electricity with sales at green tariff. Currently, all active LFG projects are producing electricity in the country by gas engines with an efficiency of 35...42%. Produced heat is not used.

Inputs to estimate required investments for LFG recovery system with the production of electric and/or thermal energy can be the assessment of LFG generation rate, as a consequence, the potential of installed electric power, as well as landfill area (area of LFG collection system in the event of partial landfill coverage).

Capital expenditures on LFG recovery and the construction of utilization system in landfills and solid waste dumps depend on physical conditions formed during exploitation process. The specific cost of project, which involves the production of electricity from LFG, usually ranges from 1500 to 2500 €/kW_{el} of installed electrical capacity. The lower value is more associated with controlled landfills, the upper one with waste dumps. There are at least two reasons for that. At uncontrolled waste dumps, it is possible to collect less LFG per unit of accumulated waste. In addition, the construction of recovery system at waste dumps involves additional costs due to complex geometry of the waste body and the need to form the upper airtight layer covering the waste.

The investor must be aware that, at relatively small capital costs, dumpsite projects are associated with an increased risk because of uncertainty in the baseline conditions and the inability to reliably predict LFG generation rate. The payback period of the project will depend on actual LFG amount and the efficiency of its recovery. At present, green tariff for electricity sale and achieved efficiency of LFG recovery 50%, projects can pay off in 2-3 years, with possible recovery efficiency of 20% in 6-8 years or even longer.

The introduction of green tariff led to the fact that a significant part of the energy potential of LFG in Ukraine has already been implemented.

Existing economic and financial barriers are associated with:

- The possible low feasibility of projects, in case, achieved less than expected efficiency of LFG recovery;
- Inadequate access to financial resources;
- The high cost of finance.

2.3.2.2 Non-financial barriers

The amount of collected LFG is determined by collection's efficiency, mainly depends on technical reasons and landfill operation's practice. Important factors are the area of the "active" zone of the landfill, the presence/quality of the upper layer with low gas permeability, the degree of waste compaction, the presence of leachate, possible fire events and their category during whole life of the landfill. It is considered that the efficiency of LFG collection in the managed landfills is about 50%. Due to the low technical standards of operation and maintenance for Ukrainian waste disposal sites, this value can be considered as upper limit, more suitable values could be 25...30% or even lower.

The analysis of operational data for electricity production from LFG in 2017...2019 shows that the utilization rate of installed capacity is only 30…50% (60% for the most successful projects), which may be due to excessive expectations regarding gas generation rate and optimistic evaluations of LFG recovery efficiency on project preparation stage.

Therefore, technological barriers are important for this technology, in particular:

- Low technical standards of landfill operation;
- Lack of information regarding waste content;
- Lack of historical data regarding waste delivery, operation practice, landfilling events, etc.;

Market conditions barriers:

- Few local equipment and service suppliers;
- Disincentives to foreign investment.

Regulation/legislation barriers:

- Lack of comprehensive and strategic energy policy implementation;
- Insufficient institutional framework;
- Over-bureaucratic procedures (land plot allotment, introduction of changes in the project, etc.);
- Lack of control for unofficial landfilling and activities.

Information barriers:

- Limited awareness of technology;
- Lack of available information, pure population knowledge and involvement;
- Missing feedback among interested parties.

2.3.3 Identified measures for technology W1 (LFG-to-E)

In spite of the fact that in future, the technologies of mechanical biological treatment of waste with biogas production will probably be developed in specialized reactors, a certain part of the potential may be related to the construction of regional sanitary landfills in the framework of waste management strategy by 2030. The role of landfilling will remain significant in Ukraine for at least several decades. The concentration of waste resources on large scale and strict compliance with operation rules for sanitary landfills would allow recovering up to 75...85% of the generated landfill gas.

2.3.3.1 Economic and financial measures

The measures to overcome economic and financial barriers for methane capture for energy production have been identified as follows:

- The creation of economic and financial conditions for modern regional landfill construction program;
- The creation economic and financial conditions for old waste dumps closure;
- The introduction of high gate fee/ tax for waste disposal;
- Creation of economic and financial condition for the use of LFG not only for electricity, but also for heat and biomethane production;
- Adequate access to financial resources;
- Incentives to foreign investment.

These measures will support the construction of regional landfills with LFG recovery system, the closure of old waste dumps with LFG flaring equipment, the extensive use of LFG for electricity, heat and biomethane production.

2.3.3.2 Non-financial measures

Measures to overcome non-financial barriers for methane capture for energy production were identified as follows.

- The improvement of legislation and regulatory system
- Capacity building activities

Legal and regulatory. A new Law “On Waste Management” and following Law “On landfilling” should be entered into force. Wherein, at least following issues have to be regulated:

- The alignment of landfill operation procedures in Ukraine with the requirements of Directive 1999/31/ EC on the waste disposal (D. 1999/31/EC, 1999);
- The responsibility of landfill operators for the post-operational period of landfills (closure and monitoring);
- The legalization and regulation of landfill mining activity (Burlakovs J., et al., 2013).

Network. The expansion of inter-municipal cooperation. Ensuring that at least 50 new sanitary regional landfills would be put into operation by 2030.

Institutional and organizational capacity. The creation of a new central authority specified on waste management in Ukraine. The introduction of inter-municipal cooperation as a legal mechanism supported by the Government. Levelling an influence of informal sector, giving it an opportunity to work within the framework of acting legislation, where it’s acceptable.

Human resources:

- Support on new specialties on sustainable waste management in universities;
- The consideration of waste management issues when developing higher education standards;
- The support of new specialties on sustainable waste management in universities;
- The creation of guidelines in modern waste management opportunities for municipalities.

Social, cultural and behavioural. The creation of alternative legal jobs for the poor people from communities, located nearby the landfills that are planned to be closed.

Information and awareness should include activity on:

- National awareness company on sustainable waste management as an alternative to MSW disposal;
- Waste management awareness activities in school and pre-school institutions.

Technical. Ensuring the availability of MSW collecting companies to transfer cargo to modern MSW processing facilities and new sanitary regional landfills, where needed.

2.4 Barrier analysis and possible enabling measures for technology W2 (Sorting)

2.4.1 The general description of technology W2 (Sorting)

Waste sorting technology is an integral part of sustainable MSW treatment system. MSW sorting practice may play different role from country to country depending on the state’s waste management policy, which is based on the country’s specific aspects, such as: the level of economic development, number of population and its density, climate conditions, location of MSW generating sources, development level and structure of industry sector, needs in energy and biomass resources, cultural aspects, tourism attraction and so on.

Waste sorting technology is a complex of closely interconnected hardware, software and orgware components, whose main goals are to ensure preventive measures to minimize the negative impact of generated MSW on environment in future, as well as to provide economically viable raw material for industry and fuel for energy sector. In terms of sustainable waste management system planning, MSW sorting practice covers treatment procedures from the moment of MSW generation up to the transportation of MSW components or residue to industry, biological facilities, stabilization facilities, incineration plants or disposal sites.

The hardware components of MSW sorting technologies include: containers, collection vehicles (preferably equipped by GPS sensors), equipped sites for separate collection (including households), infrastructure and logistics programs, sorting lines, reloading stations, reception and collection centres.

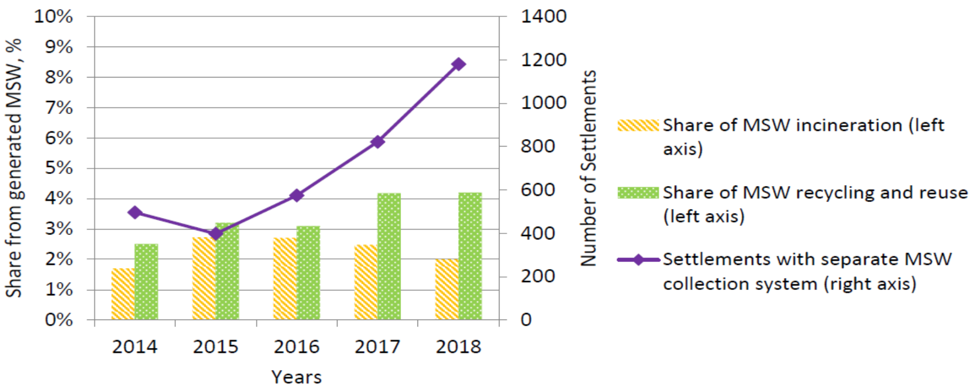
Software components include knowledge on how to use logistics software and optimize MSW flows, how to prepare economically competitive secondary raw materials and the clear understanding of current and projected prices for it, cooperation background between waste sorting companies and industry sector etc.

Orgware components include cooperation between state institutions, business and society, waste generation and sorting legislation (focused on different MSW components as well), tariffs, taxes and penalties, population involvement in waste sorting process and so on.

According to the Law "On Waste" it's prohibited in Ukraine to dispose non-treated (unprocessed) MSW since the 1st January, 2018, as well as to mix or dispose waste, for which there an appropriate processing technology does occur (LW, 1998). Thus, separate collection of MSW components is a mandatory element of MSW treatment system in Ukraine.

MSW sorting infrastructure of Ukraine included the following elements in 2018: 26 sorting lines in operation, approximately 4,000 specially equipped vehicles with 17,500 involved employees. Along with it, MSW separate collection systems was developed by being implemented only in 53 settlements in 2010 and in 1181 settlements in 2018 (MSWTS, 2019).

Nevertheless, the existing trend of local separate collection system's development does not provide the desired effect on MSW treatment system in Ukraine. Despite the fact that the amount of local MSW separate collection systems increased by 44 % in 2018 with comparison to 2017, the share of MSW recycling was stable, being equal to 4.2 %. Moreover, the share of MSW incineration continued to decrease, see details in figure 2.8.



Source: MSWTS, 2019

Figure 2.8 – MSW incineration, recycling, reuse and a number of settlements with implemented separate collecting system in Ukraine, 2014-2018

National Waste Management Strategy up to 2030 sets the target to achieve the 60 % share of reused, recycled or composted waste by 2030, which seems to be hardly achieved taking into account existing trends and efforts. Statistical data indicates that there are a number of barriers to implement efficient MSW separate collection system in Ukraine, among which are economic and financial, as well as non-financial ones.

The diffusion of waste sorting technologies will contribute to gender equality by creating new environmentally friendly market's niches and high qualified jobs in logistics, science, monitoring services and related areas. These jobs will need modern knowledge in software, logistics and secondary raw material market conditions unlike bulky MSW disposal.

2.4.2 The identification of barriers for technology W2 (Sorting)

2.4.2.1 Economic and financial barriers

Direct and indirect capital cost needed for waste sorting technologies introduction as well as benefits from its implementation depend on country and are regionally specific. Direct capital cost and operational cost needs for waste sorting technologies are significant. To ensure the achievement of targets regarding MSW sorting technologies, which have been set in the Waste Management Strategy up to 2030, particularly the share of reuse equal to 10 % and the share of processing (recycling and composting) equal to 50 %, the following waste sorting infrastructure should be implemented (EBRD, 2017):

- The development of 271 new waste reception/collection centres – 40.65 M€.
- Increasing of coverage of population by centralized collection system – 38 M€.
- Increasing of coverage of population by separate collection system, ensuring primary separation of "dry" fractions – 79 M€.
- The creation of 50 centres for collecting MSW materials with the purpose of reuse – 7.5 M€.
- The construction of additional 91 MSW sorting lines – 255 M€.
- The purchase of approximately 92,000 additional containers and approximately 630 additional collection vehicles – 79 M€.
- The construction of 200 MSW reloading stations (as integral part of new regional sanitary landfills) – 183 M€.

Thus, estimated capital cost needs for the wide introduction of waste sorting technologies in Ukraine by 2030 are close to 700 M€.

Operational cost needs for MSW collection, reloading stations and collecting centres up to 2030 are close to 3000 M€, or 52 % from total operational cost needs for MSW management system of Ukraine, which would correspond to the targets of Waste Management Strategy up to 2030. Estimation does not include direct operational expenditures for separate collection and sorting of MSW, because it's expected, that they would be compensated by secondary raw material selling and extended producer responsibility system

Regarding recycling market conditions, there are many recycling facilities in Ukraine. Currently, there are approximately 40 secondary polymer processing companies, about 20 PET container processing companies, as well as 15-17 paper, metal and glass processing plants. Processing capacities are fairly evenly distributed throughout Ukraine. The capacity use of these enterprises fluctuates with the range of 20–80 % only. At the same time, about 85% of the raw materials do not go to processing facilities to be landfilled.

The following main economic and financial barriers for waste sorting technologies exist in Ukraine:

- Low tariffs on MSW disposal (do not include costs for closure, monitoring and re-cultivation);
- Low costs on secondary raw materials;
- Inadequate access to financial resources;
- High cost of capital;
- Disincentives to foreign investment;
- Limited raw material base;
- The absence of economy incentives to process and recycle MSW;
- The absence of producer responsibility on the generated waste.

2.4.2.2 Non-financial barriers

Non-financial barriers include legal and regulatory, network, institutional and organizational capacity, human skills; social, cultural and behavioural, information and awareness, technical and others.

Legal and regulatory. The state regulatory policy was changed for the last five years. However, this is a fairly conditional improvement, as a number of changes to the legislation on meeting the requirements of the EU's directives on waste management and the environment is still expected. Thus, the following issues are still insufficiently regulated:

- Unclear definition on generated MSW ownership;
- Lack of stimulation of MSW recycling;
- The absence of producer responsibility for the potentially generated waste;
- Lack of stimulus and involvement of population in the MSW sorting activities;
- The poor stimulation of specific waste components separate collection, such as glass, packaging, batteries accumulators etc.

Network. Existing MSW management system does not allow the collection of significant amounts of MSW components due to a limited number of containers, sorting lines, reception/collection centres, reloading stations, vehicles, road infrastructure and trading floors on secondary raw materials.

Institutional and organizational capacity. Responsibilities in waste management system, and in particular, sorting issues, are over-dispersed among a number of central and local authorities, that lead to the potential conflict of interest among them, among different local authorities and communities, as well as business. Moreover, an informal sector has a significant negative influence on institutional and organizational capacity, especially in issues related to harvesting of recyclables.

Human resources. There's a lack of specialists in sustainable waste management in Ukraine due to following issues: high education institutions and technical schools are not ready to produce high quality's specialists in this field of technical science, in its turn, young specialists can't find an attractive job due to a limited number of innovative facilities in operation.

Social, cultural and behavioural. This barrier plays a significant role in inefficiency of modern technology diffusion, being a country specific aspect of Ukraine. Thrifty attitude to resource conservation and product reuse is often associated with the Soviet Union times, the times of communist propaganda and total shortage of household products. Mainly, it relates to elderly and rural population.

Information and awareness. Lack of knowledge and awareness of the population on the importance of MSW separation at the stage of generation. Moreover, people have no enough knowledge about the health risks related to green waste residue, plastics and glossy paper open burning. Moreover, there are not enough training courses and programs focused on MSW sustainable treatment for schoolchildren and other representatives from young generation.

Technical. Population is limited in modern MSW treatment technology accessibility. Often, in rural area, private sector and apartment houses, population has not an access to MSW separate collection infrastructure.

2.4.3 Identified measures for technology W2 (Sorting)

2.4.3.1 Economic and financial measures

The measures to overcome economic and financial barriers for waste sorting technologies have been identified as follows:

- Increasing of tariffs on waste removal;
- Implementation of "Pay as you throw" principle. The idea is to pay depending on the type of waste (MSW component) and its amount, which was transferred to the third parties (collecting companies);
- Implementation of "Extended producer responsibility" principle. The idea is that producers' responsibility for reducing environmental impact and managing their products extends over the entire product life cycle, from the selection of materials and design to the end of its life cycle;
- Temporary VAT exemption for reuse services;
- Temporary VAT exemption for waste recycling equipment;
- Temporary VAT exemption for recyclable materials and products;
- Subsidizing communities with low population density or living in highland areas.

2.4.3.2 Non-financial measures

Measures to overcome non-financial barriers for waste sorting technologies were identified as follows.

Legal and regulatory. A new Law "On Waste Management" should be entered into force. Wherein, following issues have to be regulated:

- The introduction of national waste classification based on European practice;
- The development of guidelines on sustainable green public procurement;
- The implementation and use of cost-effective tools to encourage the creation of waste management facilities infrastructure;
- The introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of recycling practice;

- The introduction of a mechanism for providing subsidies for the collection and transportation of vegetable waste suitable for the production of animal feed.

Network. It is ensured that at least 271 new waste reception/collection centres, 50 centres for collecting valuable components for reuse, 91 MSW sorting lines, approximately 92,000 additional containers and 630 additional collection vehicles, as well as 200 reloading stations would be put into operation by 2030. Support by the government on road infrastructure and business access to trading markets.

Institutional and organizational capacity. The creation of a new central authority was specified on waste management in Ukraine. An introduction of inter-municipal cooperation as a legal mechanism is supported by the Government. Levelling an influence of informal sector, giving it an opportunity to work within the framework of acting legislation, wherein it's acceptable. There is a creation of an interagency coordination board for research on waste reuse, processing and recycling.

Human resources:

- support on new jobs in the innovative sector of waste management system;
- support on new specialties on sustainable waste management in universities;
- the consideration of waste management issues when developing higher education standards;
- the creation of guidelines on modern waste management opportunities for municipalities;
- the establishment of a voluntary certification system for businesses engaged in MSW collection, exportation, sorting and processing;
- the creation of working platforms on the dissemination of best practices in Ukraine.

Social, cultural and behavioural. Provision of support by local authorities to carry out awareness companies for local communities, which would be focused on the benefits from resource conservation and sustainable waste management as a modern trend currently occurring in successful countries.

Information and awareness should include activity on:

- national awareness company on sustainable waste management;
- the implementation of MSW management awards;
- waste management awareness activities in school and pre-school institutions.

Technical. The availability of MSW collecting companies is ensured to transfer cargo to modern MSW processing facilities and to establish control over infrastructure accessibility for the separate collection.

2.5 Barrier analysis and possible enabling measures for technology W3 "The closure of old waste dumps with methane destruction (Closure)"

2.5.1 The general description of technology W3 (Closure)

Waste disposal is a trailing treatment practice of MSW management system, being the most inefficient method in terms of resource conservation, energy efficiency and environmental impact. In essence, these types of technologies are a final stage of a product's life cycle.

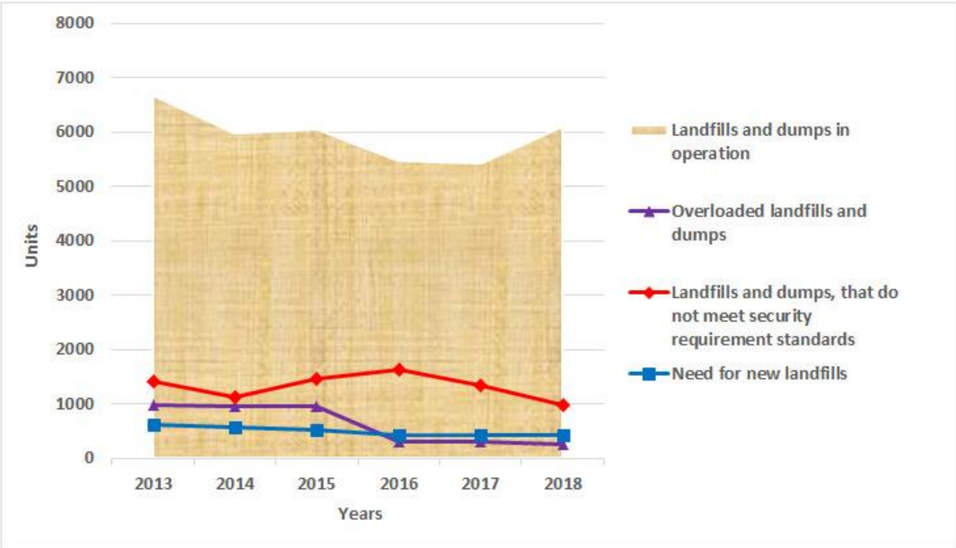
Transition from dominating MSW disposal practice to other modern MSW treatment methods is an integral part to create sustainable MSW management system. Accordingly, the modernization of Ukraine's MSW management system implies the widespread use of landfill and dump closure technologies. Landfill closure procedures may include the stabilization of closed landfill, that takes from 1–10 years depending on the climate conditions and the planned activity in the territory in future; and re-cultivation takes up to 4 years (SBR, 2005).

The hardware component of landfill and dump closure includes: landfill gas degassing system (perforated pipes, sensors, flaring equipment etc.), covering multifunctional upper layer (soils, plants, drainage system etc.), filtrate collection and treatment system (anti-filtration curtains, dams, drainage and piping, control ponds, filtrate treatment facility etc.), monitoring infrastructure (measuring stations, wells etc.), specialized vehicles (bulldozers and excavators), roads, technical buildings (including security post), and environmental monitoring programs.

Software component includes personnel's knowledge and experience on how to adhere to building codes, carry out construction and monitoring activity, use modelling software and analyze obtained results etc.

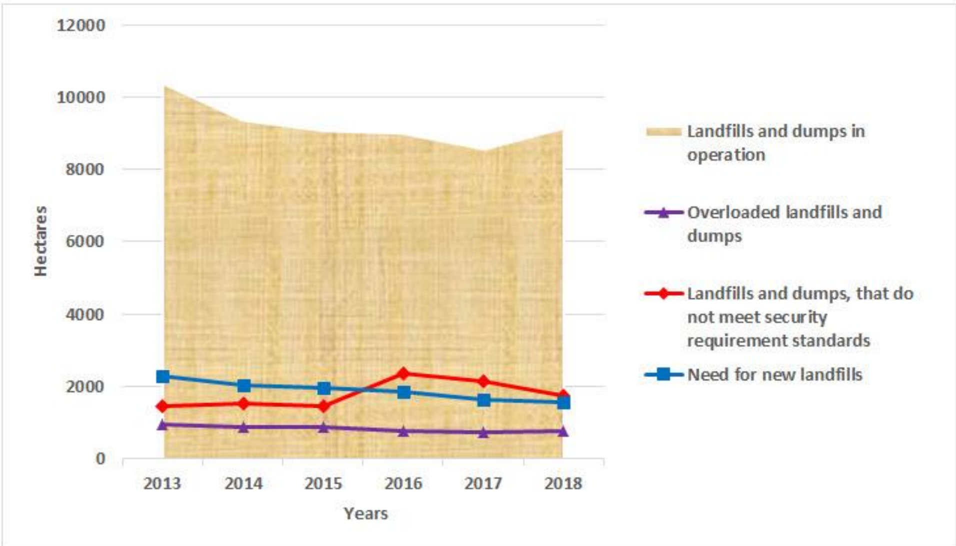
Orgware component includes cooperation between state institutions, business and society, legislation for landfill and dump closure procedures; funding mechanisms and further introduction of the landfill area into economic activity of a region or at least mitigation of negative impact on surrounding areas; tariffs, taxes and penalties, activity on people awareness on environmental influence of the closed landfills and dumps.

More than 9 Mt or 93.8 % of officially collected volumes of MSW were disposed in 6107 operating landfills and dumps occupying 9172 hectares in Ukraine during 2018 (MSWTS, 2019). Trends on the quantity and area of landfills and dumps in operation as well as needs for new one in 2014–2018 are illustrated in figures 2.9 and 2.10 respectively. The number of landfills and dumps in operation fluctuated within the range of 5470–6107 units or 8.6–9.2 thousand hectares; overloaded landfills and dumps – 256–960 units or 742–863 hectares; landfills and dumps, that do not meet environmental – 984–1646 units; needs in new landfills – 421–576 units. It should be mentioned, that the number of landfills and dumps has increased by 12.4 % (7.0 % for area) during the latest 2018 reporting year.



Source: MSWTS, 2019

Figure 2.9. – Number of landfills and waste dumps in Ukraine for the period of 2013–2018



Source: MSWTS, 2019

Figure 2.10. – Area of landfills and waste dumps in Ukraine for the period of 2013–2018

Waste management strategy sets the target for decreasing of MSW landfilling share up to 30 %, as well as the closure of all existing landfills/dumps and exploitation of only 300 new sanitary landfills by 2030, which seems to be hardly done, taking into account existing trends and efforts. Thus, statistics indicate that there are a number of barriers to implement landfill and dump closure technologies, among which are economic and financial, as well as non-financial ones.

The diffusion of landfill and dump closure technologies will contribute to gender equality by decreasing needs in jobs impacted by extreme sanitary conditions and leveling the informal sector especially in rural areas.

The diffusion of this technology requires the implementation of supporting mechanisms stimulating migration of hired workers, especially women with children, from the informal sector to legal business and provision of social guaranties to them at the stage of retraining for a new official position or profession.

2.5.2 The identification of barriers for technology W3 (Closure)

2.5.2.1 Economic and financial barriers

The number of landfills in operation has to be reduced from above 6000 to 300 units by 2030 in order to ensure the achievement of targets regarding landfill and dump closure, which have been set in the Waste Management Strategy up to 2030. Capital costs for closure (including methane flaring, covering and monitoring) of all poorly managed landfills and dumps are estimated at the level of 1700 M€ in total, including 1440 M€ by 2030. Provided estimates are based on the rehabilitation of an annual closure of approximately 500 landfills since 2020 with an average cost per closed unit of 280 k€ (EBRD, 2017).

It's expected that operational costs on all poorly managed landfills and dumps in Ukraine will be 522 M€, being equal to 9 % of all operational cost needs to create modern waste management system in the country by 2030. It is Estimated as difference between operational cost needs for disposal and operational costs needs for landfills in operation, (EBRD, 2017).

MSW landfill and dump closure technologies are publicly provided goods in conditions of Ukraine. The social policy of low waste disposal tariff had been the driving state's policy in waste management system in the country for many decades. The dissemination of landfill closure technologies will benefit to local communities living close to the disposal site, and will need financial support from the Government, local authorities and donors (Nygaard, I. & Hansen, U. E., 2015).

The following main economic and financial barriers for landfill and dump closure do occur in Ukraine:

- Inadequate access to financial resources;
- High cost of capital;
- Disincentives to foreign investment;
- Low tariffs on MSW disposal (do not include costs for closure, monitoring and recultivation);
- The absence of producer responsibility on the generated waste;
- The improper use of environmental protection fund.

2.5.2.2 Non-financial barriers

Non-financial barriers for the dissemination of landfill and dump closure technologies include legal and regulatory, network, institutional and organizational capacity, human skills; social, cultural and behavioural, information and awareness, technical and others.

Legal and regulatory. A new Law "On Waste Management" and following Law "On landfilling" should be entered into force. Wherein, these issues have to be regulated:

- low requirements on procedures of landfill operation;
- inadequately low responsibility for violation of legislation in waste treatment system, in particularly waste disposal procedures;
- the responsibility of operators for landfill post-operational period on practice;
- the issue of secondary raw materials extraction/mining from the closed or old landfills.

Network. Existing MSW treatment infrastructure is totally focused on MSW disposal as a dominant treatment practice. Local authorities, communities and MSW collecting companies haven't an alternative to waste disposal, moreover local (municipal) MSW collection systems cover the fixed area determined by the administrative boundaries.

Institutional and organizational capacity. Responsibilities in waste management system are over-dispersed between central and local authorities, that lead to the potential conflict of interest among them, among local authorities, communities and business. Informal sector has negative influence on institutional and organizational capacity in issues related to the illegal harvesting of recyclables in landfills.

Human resources. There's a lack of specialists in MSW disposal site's closure technologies. There is no practical experience on environmentally friendly post-operational management of landfills, monitoring and integration of areas close to landfills in the sustainable regional development plans.

Social, cultural and behavioural. Landfills provide an illegal employment opportunity for the poor people and people with financial problems. Being a part of grey economy sector, landfills guarantee a certain standard of living for such category of population. That's why, it's expected that at the first stage of landfill's closure activity, certain negative social and economy effect will occur.

Information and awareness. There is a lack of knowledge and awareness by local communities about negative effect caused by MSW landfills and dumps. People do not know alternatives to waste disposal and how to organize their lifestyle to prevent such a practice.

Technical. Population is limited in alternatives to waste disposal practice and haven't mainly an influence on MSW collecting companies regarding the future waste processing procedures. MSW collecting companies are also limited in the alternatives how to treat the collected waste due to the lack of waste processing infrastructure. There is a lack of accounting systems on waste disposal equipped with measuring scales. As a result, there is no reliable statistical data on MSW quantity disposed in the certain landfill as well in Ukraine as whole.

Other. Specific barriers at the local level can also occur depending on local circumstances.

2.5.3 Identified measures for technology W3 (Closure)

2.5.3.1 Economic and financial measures

The following measures to overcome economic and financial barriers for landfill and dump closure technologies have been identified:

- The increase of tariffs on waste disposal, which have to cover all expenditures including environmental and operational, as well as related to landfill closure;
- Increase in environmental tax on waste disposal;
- The introduction of penalties for violation of legislation in waste disposal issues.

2.5.3.2 Non-financial measures

The measures to overcome non-financial barriers for landfill and dump closure technologies were identified as follows.

Legal and regulatory. A new Law "On Waste Management" and following Law "On landfilling" should be entered into force. Wherein, at least following issues have to be regulated:

- The alignment of landfill operation procedures in Ukraine with the requirements of Directive 1999/31/ EC on the waste disposal (D. 1999/31/EC, 1999);
- The significant increase of responsibility for the violation of legislation in waste treatment system, especially waste disposal procedures;
- The responsibility of landfill operators for the post-operational period of landfills (closure and monitoring);
- The legalization and regulation of landfill mining activity (Burlakovs J., et al., 2013).

Network. The expansion of inter-municipal cooperation. It is ensured that at least 50 new sanitary regional landfills, 271 new waste reception/collection centres, 50 centres for collecting MSW materials with the purpose of reuse, 91 MSW sorting lines, approximately 92,000 additional containers and 630 additional collection vehicles, as well as 200 MSW reloading stations would be put into operation by 2030.

Institutional and organizational capacity. The creation of a new central authority was specified on waste management in Ukraine. An introduction of inter-municipal cooperation as a legal mechanism was supported by the Government. To cooperate with the European Commission on the harmonization of dates and targets with timelines in MSW management system development is realistic for Ukraine. Levelling an influence of informal sector, gives it an opportunity to work within the framework of acting legislation, wherein it's acceptable.

Human resources:

- Support on new specialties on sustainable waste management in universities;
- The consideration of waste management issues when developing higher education standards;
- The creation of guidelines in modern waste management opportunities for municipalities.

Social, cultural and behavioural. The creation of alternative legal jobs for the poor people from communities, located nearby the landfills that are planned to be closed.

Information and awareness should include activity on:

- National awareness company on sustainable waste management as an alternative to MSW disposal;
- Waste management awareness activities in school and pre-school institutions.

Technical. Ensuring the availability of MSW collecting companies to transfer cargo to modern MSW processing facilities and new sanitary regional landfills, in case of need.

2.6 Barrier analysis and possible enabling measures for technology W4 "Aerobic biological treatment (composting) of food and green residuals"(Composting)

2.6.1 The general description of technology W4 (Composting)

Green and food waste can be processed biologically by aerobic (composting in the presence of oxygen) or anaerobic methods (digestion in airtight reactors in the absence of oxygen). Final material after aerobic composting of green waste in windrow, aerated static pile, and in-vessel composting can be used in the garden and parks as well as for landscape construction.

Composting is defined as the biological degradation of waste under controlled aerobic conditions. The waste is decomposed into CO_2, water and the soil amendment or mulch. Today, many developed and developing countries practise the composting of mixed waste or biodegradable waste fractions (kitchen or restaurant wastes, garden waste, sewage sludge). It is the most suitable for source segregated biodegradable waste. In Ukraine, composting is still not common practice, the overall level of MSW composting is low in Ukraine. Only about 1640 tons (0.018%) of waste were composted in 2018.

Three composting techniques available are windrow, aerated static pile and in-vessel composting. Supporting techniques include sorting, screening and curing also. Each technique varies in procedures and equipment's needs. Other variations of technologies are issues, such as air supply, temperature control, mixing and time required for composting. Moreover, their capital and operating costs also differ widely. The composting of food waste requires the use of additional biofilters to reduce atmospheric emissions.

The compost process includes the following:

- The shredding of the green waste using a tub grinder;
- Moving the shredded green waste into long rows (windrows), using a loading shovel;
- Turning the rows on a weekly basis to improve porosity and oxygen content, to mix in or remove moisture and to redistribute cooler and hotter portions of the rows.

When the temperature within the rows has reduced, rows can be screened using a star screener and the resulting compost/mulch can be stockpiled and allowed to mature.

In relation to recycling and other recovery including composting, key challenge is the lack of an organized system capable of efficiently collecting the secondary raw materials of high quality.

The economy of Ukraine is based among others on the agrarian sector. When farms utilize compost, the need to purchase chemical fertilizers is reduced which thereby results in reduction in human and soil health problems.

Composting also provides benefits for waste handling companies. For the composting part of the waste, companies increase the landfill's lifetime and the marketable product in the form of compost.

The technology is applicable for both small-scale and large-scale applications. Each of these supports the generation of local employment.

The composting of one ton of MSW is approx. equivalent to 0.6 t CO_2-eq. GHG emission's reduction.

The cost of GHG reduction in enclosed, building with concrete floors, MRF processing equipment and in-vessel composting; enclosed building for the curing of compost product would vary between 50 and 85 EUR per t CO_2-eq.

The diffusion of large-scale composting technologies will contribute to gender equality by creating new environmentally friendly market niches and high qualified jobs in logistics, science, agriculture sector, monitoring services and related areas. These jobs will need modern knowledge in monitoring software, logistics and fertilizer market conditions unlike bulky MSW disposal. The dissemination of small-scale technologies in the private sector (single family buildings), suburban and rural areas will benefit to improving the comfort at home (food processing, kitchen waste processing, gardening). This issue is especially important for women, since they are most often engaged in maintaining home comfort at single family houses in Ukraine.

2.6.2 The identification of barriers for technology W4 (Composting)

The key challenge for composting is the lack of an organized system capable of efficiently collecting the organic waste of high quality. There is the requirement of the progressive implementation of MSW separate collection and establishing the mechanism for the practical implementation of the EPR (extended producer responsibility) principle, in order to improve the quality of secondary raw materials. Another challenge is the implementation of home composting in suburban areas in towns and cities and in rural areas.

2.6.2.1 Economic and financial barriers

Producing compost is found to be a profitable business in many parts of the world, if it is implemented in the models of public private partnerships and the right choice of centralized and decentralized composting units.

The compost application in farm fields also results in economic benefits by enhancing the availability of nutrients in the soil for crops and improving the effectiveness of other fertilizers.

Existing economic and financial barriers are associated with:

- Low tariffs for waste collection, treatment and landfilling. Waste disposal is still the cheapest option of MSW management;
- Inadequate access to financial resources;
- High cost of finance.
- Low population income

2.6.2.2 Non-financial barriers

In relation to recycling and other recovery, a key challenge is the lack of an organized system capable of efficiently collecting secondary raw materials of high quality.

Regulation/legislation barriers:

- Lack of comprehensive and strategic energy policy implementation;
- Insufficient institutional framework;
- Over-bureaucratic procedures;
- Lack of control for unofficial landfilling and activities.
- No incentives for organic waste separate treatment

Technical barriers:

- Low collecting efficiency of the high-quality organic waste

- Lack of separate waste collection

Information barriers:

- Limited awareness of technology;
- Lack of available information, pure population knowledge and involvement;
- Missing feedback among interested parties.

Others:

- No culture of home composting in suburban and rural areas

2.6.3 Identified measures for technology W4 (Composting)

In relation to composting of the organic fraction of the MSW for the initial period of the MSW management strategy, it could be proposed to focus on the home composting of household organic waste and windrow composting of green wastes (e.g. waste from gardens and parks) (EBRD, 2017). As part of the Strategy, it could be proposed that basic windrow compost's centres will be co-located with the Waste Reception/Collection Centres. The type of wastes accepted as 'green waste' should include grass cuttings, hedge/shrub cuttings, fallen leaves, plant and flower heads, branches, tree stumps and timber.

It is also proposed to establish pilot projects for the biological stabilisation of residual waste. A system of certification should be developed for the different categories of compost or compost-like-output (CLO) produced from municipal solid waste or its components.

By 2022, home composting for 6% of the urban population and 12% of the rural population (i.e. approximately 1.3 million households in Ukraine) are to be implemented. Home composting units are being used in individual houses in suburban areas in cities and towns and in rural areas (approximately 2.5 million households). Indicative estimate is 105.5 M€ (EBRD, 2017).

There is a wide range of costs dependent upon the complexity of the technology and the degree of mechanisation and automation employed. By 2030, a total 271 Waste Reception/Collection Centres are to be provided in cities with a population above 20,000. Basic windrow compost centres are to be co-located in these Centres for green waste. Indicative estimate is 41 M€.

2.6.3.1 Economic and financial measures

The following measures to overcome economic and financial barriers for composting technologies have been identified:

- The creation of conditions for modern home and industry composting;
- The development of the program for composting including home composting;
- The development of the program for compost use as soil improver and organic fertilizer
- Adequate access to financial resources;
- Reduction in the cost of finance.

2.6.3.2 Non-financial measures

Measures to overcome non-financial barriers for composting were identified as follows:

- The improvement of legislation and regulatory system;
- To create a condition for industry composting;
- Capacity building activities;
- Involving population including children in composting and sorting activities.

Legal and regulatory. A new Law "On Waste Management" should be entered into force. In this case, at least following issues have to be regulated:

- The introduction of national waste classification based on the European practice;
- The implementation and use of cost-effective tools to encourage creation of waste management facilities infrastructure;

- The introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of recycling/composting practice;
- The introduction of a mechanism for providing subsidies for the collection and transportation of green waste suitable for compost production.

Network. The expansion of inter-municipal cooperation. It is ensured that Waste Reception/Collection and Compost Centres in cities with a population above 20,000 are put into operation by 2030.

Institutional and organizational capacity. The creation of a new central authority was specified on waste management in Ukraine. The introduction of inter-municipal cooperation as a legal mechanism is supported by the Government. Levelling an influence of informal sector, giving it an opportunity to work within the framework of acting legislation, wherein it's acceptable.

Human resources:

- Support on new specialties on sustainable waste management in universities;
- Launching of targeted programs at high school
- Consideration of waste management issues when developing higher education standards;
- The support of new specialties on sustainable waste management in universities;
- The creation of guidelines in modern waste management opportunities for municipalities.

Information and awareness should include activity on:

- National awareness company on sustainable waste management as an alternative to MSW disposal;
- Waste management awareness activities in school and pre-school institutions.

2.7 Barrier analysis and possible enabling measures for technology W5 "The mechanical-biological treatment of waste with biogas and energy production (the anaerobic digestion of organic fraction of MSW)" (MBT-AD)

2.7.1 The general description of technology W5 (MBT-AD)

Mechanical and biological treatment of solid waste (MBT) is used for the processing of mixed waste with pre-sorting or without it. The primary concept of the technology involves a reduction in the amount of waste deposited in landfills. Currently, this method is also used to produce fuel and for additional extraction of valuable materials. It combines mechanical methods (separation with sieves, drums, magnets, etc.) and biological methods (composting and anaerobic digestion).

In the first case, the mechanical separation of the total waste flows into fractions suitable for different types of utilization is carried out for energy production or further biological treatment. Anaerobic digestion or composting, as well as the combination of both methods, can be used for biological treatment. In anaerobic digestion, the main attention is paid to optimize biogas production. When the composting of the mixed residue is used, the main task is to obtain biologically stabilized material purified from harmful components or material suitable for the use of energy.

Green and food waste can be processed biologically by anaerobic digestion in airtight reactors in the absence of oxygen. Anaerobic methods are associated with high capital cost, but when they are applied, they generate biogas – an additional source of energy. MBT is not a method of final waste abolition, as soon as solid residue after MBT must be disposed or incinerated.

Thus, these are the following basic possibilities of MBT application:

1. Sorting with the separation of valuable and inert components, the digestion of the organic fraction of solid waste with biogas production, energy generation from biogas, digestate composting and disposal/utilization of compost;

2. Sorting with the separation of valuable and inert components, biological stabilization by composting and disposal/utilization of compost;

3. The production of fuels from solid waste (SRF).

The total theoretical potential of biogas production in MBT process in Ukraine (in case of treatment of the total amount of organic fraction of MSW generated in Ukraine) is 600 Mnm^3/yr or 5800 GWh. Thus, the potential of biogas production in MBT is much higher than LFG recovery for two reasons:

- in controlled reactors, there is possibility to use almost all generated biogas in contrast to landfills, where the amount of recovered LFG is limited by recovery efficiency as well as the possible oxidation of methane in the upper layers of landfill;
- Unlike the disposal of substantial amount of MSW at small and medium-sized waste disposal sites, the MBT technology involves the concentration of MSW on regional basis with almost complete utilization of biogas potential.

Moreover, the advantages of biogas production in MBT process are multiple acceleration of digestion in comparison with natural processes occurring inside landfills and waste dumps and the potential possibility of obtaining conditionally clean compost in the case of separately collected organic waste.

The mechanical-biological treatment of waste with biogas and energy production reduces the amount of waste to be disposed in landfills. This directly prevents the emissions of methane (which is 25 times a more potent GHG than CO_2) that would have occurred from waste disposal on land. Additionally, the combustion of biogas for the production of energy produces less CO_2 emission than conventional fossil fuel combustion. The cost of GHG's reduction for the mechanical-biological treatment of waste would vary between 20 and 75 €/t CO_2-eq.

The diffusion of MBT-AD technologies will contribute to gender equality by creating new environmentally friendly market niches and high qualified jobs in energy, logistics, public utility sector, monitoring services and related areas. These jobs will need modern knowledge in public utility infrastructure, monitoring software, logistics and energy market conditions unlike bulky MSW disposal.

2.7.2 The identification of barriers for technology W5 (MBT-AD)

2.7.2.1 Economic and financial barriers

There is considerable discrepancy in the cost of various MBT, because there is no "universal" way for mixed MSW processing. Various solutions can be considered to be the most beneficial for different areas/clusters. The expediency of biogas generation from MSW with the further production of electricity is determined by the possibility of selling electricity at a fixed green tariff (0.1239 EUR/kWh without VAT).

Biogas (methane) productivity of one ton of Ukrainian MSW is 60-75 nm^3/t. As conservative estimate, a value of 60 nm^3 CH_4/t could be used. The net calorific value of methane is 10 kWh/nm^3. Therefore, the total potential of electric energy generation per ton of mixed solid waste with electric efficiency 40% is

$$60\ (nm^3/t) \times 10\ (kWh/nm^3) \times 0{,}4 = 240\ kWh/t$$

With green tariff of 0.1239 EUR/kWh, potential income from electricity sales is equal to 29.7 EUR/t of mixed solid waste. The utilization of heat with the efficiency of 45% by the tariff of 1200 UAH/Gcal (37.5 EUR/Gcal) without VAT can bring another 0.240 MWh x 0.45/0,4 x 0.86 x 37.5 = 8.7 EUR/t of mixed waste.

One more source of income for MBT could be compost from digestate after biogas production or without biogas component in the project. However, to make the production of commodity compost possible, it is essential to improve separate waste collection.

Capital expenditures on the implementation of MBT technologies depend on many factors and for this reason cannot be assessed reliably. Specific capital cost will vary depending on:

1. Initial MSW content (solid waste after separate collection or mixed solid waste);
2. The availability and type of sorting process before MBT (manual, automatic);
3. treatment capacity (scale effect).

The cost of the MBT plant in the capacity range of 50-150 kt/yr can range from 10 to 25 M€. The cost of similar capacity projects may vary in two or more times probably mainly due to the difference in technological solutions. According to (Ramboll, 2018), the cost of MBT projects with a capacity of 85-200 kt/yr, which were implemented in Germany and the UK from 2001 to 2012, was in the range of 20 to 75 M€ with average CAREX around 250 €/t of MSW processed during the year.

The expert analysis of the MBT projects announced in the period 2017-2018 showed similar result. Typical specific costs for the projects in capacity range of 100-200 kt/yr are from 150 to 400 €/t in countries such as France, Spain, USA, and Australia. In Ukraine, announced project's planned cost is in the range of 120 to 250 €/t. Operational costs (OPEX) for MBT technology are primarily related to electricity consumption, repairs and maintenance costs, staff remuneration, and cost of residuals disposal. It is typically in the range from 8 to 12% of capital expenditures.

The final cost of MSW processing is determined by CAPEX and OPEX as well as the terms of project financing. If the project's specific capital cost amounts 150 €/t, the final cost of MSW treatment is 30-40 €/t depending on conditions and share of involved bank capital.

For more costly projects 300 €/t the final cost of MSW treatment can be 60-80 €/t, and in case of involving Ukrainian commercial banks with actual lending terms up to 100 €/t. If in the first case (CAPEX= 150 €/t) there is a potential possibility to cover project expenses by electricity sale from biogas at green tariff, and in some cases heat sale, then in another case (CAPEX= 300 €/t) there is a need for substantial increase of gate fee for MSW treatment.

These considerations did not take into account the hypothetical possibilities of attracting targeted non-repayable financing and the use of budget funds, for example, environmental or development funds.

As a result, financial and economic barriers for MBT-AD implementation include:

- Low feasibility (low IRR, NPV, long payback period) of MBT projects;
- Low tariffs for waste landfilling and treatment;
- Low population income;
- Inadequate access to financial resources;
- High cost of capital;
- High cost of finance.

2.7.2.2 Non-financial barriers

Technological barriers:

- The low technical standards of waste management;
- Lack of information regarding waste content and amount;

Market conditions barriers:

- Lack of local suppliers;
- Disincentives to foreign investment.

Regulation/legislation barriers:

- Lack of comprehensive and strategic energy policy implementation;
- Insufficient institutional framework;
- Over-bureaucratic procedures;
- Lack of control for unofficial landfilling and activities.

Information barriers:

- Limited awareness of technology;
- Lack of available information, pure population knowledge and involvement;
- Missing feedback among interested parties.

2.7.3 Identified measures for technology W5 (MBT-AD)

In the medium- to long-term, bio-stabilisation of organic waste within an overall MBT facility may be proved to be the best practicable option for stabilising the organic fraction of MSW (EBRD, 2017).

2.7.3.1 Economic and financial measures

The following measures to overcome economic and financial barriers for MBT-AD technologies have been identified:

- The introduction of high gate fee/ tax for waste disposal;
- The creation of conditions for MBT with biogas and energy production;
- To create a condition for biogas use as heat and biomethane production source
- Development of the program for MBT projects implementation;
- Adequate access to financial resources;
- Reduction in the cost of finance.

These measures should support the development of MBT technology including the construction of full scale MBT plants and intensive use of biogas for electricity, heat and biomethane production. MBT technology will become standard practice, the minimal amount of green and food waste will be disposed at landfills and waste dumps.

2.7.3.2 Non-financial measures

The measures to overcome non-financial barriers for MBT technology were identified as follows:

- The improvement of legislation and regulatory system;
- To create a condition for MBT technology;
- Capacity building activities;
- Involving population in separate waste collection and sorting activities.

Legal and regulatory. A new Law "On Waste Management" should be entered into force. Wherein, at least following issues have to be regulated:

- The introduction of national waste classification on the basis of European practice;
- the implementation and use of cost-effective tools to encourage the creation of advance waste treatment facilities infrastructure;
- the introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of biological waste treatment practice;
- the introduction of a mechanism for providing subsidies for the collection and transportation of green waste suitable for biogas production.

Network. An expansion of inter-municipal cooperation. Ensuring the implementation of MBT Centres in territorial clusters with total population above 200,000 inhabitants by 2030.

Institutional and organizational capacity. The creation of a new central authority was specified on waste management in Ukraine. Introduction of inter-municipal cooperation as a legal mechanism was supported by the Government. Levelling an influence of informal sector, an opportunity is given to work within the framework of acting legislation, wherein it's acceptable.

Human resources:

- Support on new specialties on sustainable waste management in universities;
- Launching of targeted programs at high school
- The consideration of waste management issues when developing higher education standards;
- The support of new specialties on sustainable waste management in universities;
- The creation of guidelines in modern waste management opportunities for municipalities.

Information and awareness should include activity on:

- National awareness company on sustainable waste management as an alternative to MSW disposal;
- Waste management awareness activities in school and pre-school institutions.

2.8 Barrier analysis and possible enabling measures for technology W6 "The mechanical-biological treatment of waste with alternative fuel (SRF) production for cement industry"(MBT-Cement)

2.8.1 The general description of technology W6 (MBT-Cement)

MBT is a common approach for all concepts that involve the treatment of waste with a combination of mechanical and biological methods. The main difference between different approaches is the order of the process stages and the purpose of biological treatment. Technological chain is oriented either on the concept of splitting or on the idea of stabilization.

When "stabilization" is the main goal, the waste is biologically processed without separation. It is done by the convective or diffusion biological drying and maximal hygienisation of waste before the next mechanical separation of non-combustible components. The remaining material can be used as RDF/SRF with energy production at appropriate incineration plants. Thus, the production of fuel from solid waste is the basic possibility of MBT application. In the simplest case, it may consist in preliminary sorting, the removal of certain components from mixed waste and shredding the residue for:

- The use of RDF/SRF in specialized incinerators for the electric and/or thermal energy production;
- Transfer/sale of RDF/SRF to the nearest cement plant.

The use of RDF/SRF in the cement industry allows to utilize not only fuel energy but also its mineral part in the process of clinker production.

Combustion of fuels from MSW in cement plants or in specialized boiler houses requires the fuel's classification. The tasks and activities of National Waste Management Plan up to 2030 envisage the development of local Ukrainian standard on the basis of the existing European Standard EN 15359: 2011 "Solid recovered fuels - Specification and classes", as well as recommendations for the use refuse derived fuel (RDF). As a result, Ukraine has already a standard for solid recovered fuel (DSTU, 2018). This document was accepted by confirmation method and submitted in the original language (English) only. The document contains the following classification of SRF (Table 3.3).

Table 3.3 – Classification system for solid recovered fuels

Classification characteristic	Statistical measure	Unit	Classes				
			1	2	3	4	5
Net calorific value (NCV), Q	Mean	MJ/kg	≥ 25	≥ 20	≥ 15	≥ 10	≥ 3
Chlorine (Cl)	Mean	%	≤ 0,2	≤ 0,6	≤ 1,0	≤ 1,5	≤ 3
Mercury (Hg)	Median	mg/MJ	≤ 0,02	≤ 0,03	≤ 0,08	≤ 0,15	≤ 0,50
	80^{th} percentile	mg/MJ	≤ 0,04	≤ 0,06	≤ 0,16	≤ 0,30	≤ 1,00

SRF (class 3) consists predominantly of biological waste. It is homogeneous dry raw material with the low content of undesirable impurities, suitable for storage. The calorific value for class 3 is 15 MJ/kg suitable for the most cement plants and/or CHP plants working on solid fuels. SRF of this type is characterized by low chlorine content (<1,0%), which is also permissible for cement production.

In Ukraine, there is an interest in implementing demonstration projects for the SRF's utilization in cement industry as a part of the of the waste management strategy (NWMS, 2017) implementation. However, this possibility requires an additional discussion, the Ukrainian Cement Manufacturers Association "Ukrcement" (www.ukrcement.com.ua) and SAEE may be partners for discussion.

In most cases, for the use of alternative fuels, cement plants need to be modernized. In addition, the feasibility for using SRF is determined by logistics, mainly the distance between SRF producer and cement plant. It should be mentioned that Ukrainian cement plants are located mainly in the west and south-east regions of the country.

The use of RDF as an alternative to fossil fuels for cement manufacture would result in the following environmental benefits:

- Fossil fuel substitution;
- Less GHG emissions;
- The elimination of health problems associated with open dumping of MSW.

The diffusion of MBT-Cement technologies will contribute to gender equality by creating new environmentally friendly market niches and high qualified jobs in energy, cement industry, logistics, monitoring services and related areas. These jobs will need modern knowledge in cement industry, monitoring software, logistics and energy market conditions unlike bulky MSW disposal.

2.8.2 The identification of barriers for technology W6 (MBT-Cement)

In the medium- to long-term, bio-stabilisation of organic waste within an overall MBT facility with SRF production and use by cement plants may be proved to be one of the best practicable option for MSW treatment.

2.8.2.1 Economic and financial barriers

The potential source of income for MBT could be the production of RDF/SRF for further use in the cement industry. There are barriers for this approach due to the absence of relevant legislation and precedent in Ukraine and, as a result, the uncertainty about conditions for the transfer of SRF for cement industry.

Cement plants are ready to accept RDF/SRF as fuel for substitution of natural gas. The financial condition of fuel transfer is not yet defined. The use of RDF/SRF as a fuel in power or cement plants is associated with the need to install additional equipment for flue gases cleaning and controlling. Therefore, such enterprises can both buy fuel and charge for the RDF/SRF's utilization, considering it as waste, not fuel. It means that RDF/SRF can have both positive and negative market value.

The cost of GHG's reduction for mechanical-biological treatment of waste with RDF/SRF production for cement industry would vary between 20 and 25 €/t CO_2-eq. The feasibility of producing RDF/SRF is determined, besides the actual treatment of solid waste, with substitution of fossil fuels, first of all, natural gas.

Having the involvement of high costs, the biological treatment of separately collected bio-waste or of the organic fraction of the residual MSW stream is not viable, on a widespread basis, in the absence of a significant increase in the environmental tax on the deposit of waste.

As a result, financial and economic barriers for MBT-Cement implementation include:

- Low feasibility or even unprofitability (low IRR, NPV, long payback period) of MBT projects;
- Low tariffs for waste landfilling and treatment;
- Low population income;
- High cost of capital;
- High cost of finance.

2.8.2.2 Non-financial barriers

Technological barriers:

- The low technical standards of waste management;
- Lack of information regarding waste content and amount;

Market conditions barriers:

- Lack of local suppliers;

Regulation/legislation barriers:

- Lack of comprehensive and strategic energy policy implementation;
- Insufficient institutional framework;
- Over-bureaucratic procedures;
- Lack of control for unofficial landfilling and activities.

Information barriers:

- Limited awareness of technology;

- Lack of available information, pure population knowledge and involvement;
- Missing feedback among interested parties.

2.8.3 Identified measures for technology W6 (MBT-Cement)

In the medium- to long-term, bio-stabilisation of organic waste within an overall MBT facility may be proved to be the best practicable option for stabilising the organic fraction of MSW.

2.8.3.1 Economic and financial measures

The following measures to overcome economic and financial barriers for MBT-Cement technologies have been identified:

- The introduction of high gate fee/ tax for waste disposal;
- The creation of conditions for MBT with SRF for cement industry production;
- To create a condition for the use of SRF as natural gas and other conventional fuels substitution;
- The development of the program for MBT project's implementation;
- Adequate access to financial resources;
- Reduction in the cost of finance.

These measures should support the development of MBT technology including construction of full scale MBT plants and an intensive use of SRF in cement industry. MBT technology will become standard practice, the minimal amount of green and food waste will be disposed at landfills and waste dumps.

2.8.3.2 Non-financial measures

Measures to overcome non-financial barriers for MBT technology were identified as follows:

- The improvement of legislation and regulatory system;
- Capacity building activities;
- Involving population in separate waste collection and sorting activities.

Legal and regulatory. A new Law "On Waste Management" should be entered into force. Wherein, at least the following issues have to be regulated:

- The introduction of national waste classification on ths basis of European practice;
- The implementation and use of cost-effective tools in order to encourage the creation of infrastructure for the advance waste treatment's facilities
- The introduction of economic incentives for the dissemination of environmentally friendly technologies and expansion of biological waste treatment practice;
- The introduction of a mechanism for providing subsidies for the collection and transportation of waste suitable for SRF production.

Network. An expansion of inter-municipal cooperation. Ensuring the implementation of MBT Centres in territorial clusters with total population above 200,000 inhabitants by 2030.

Institutional and organizational capacity. The creation of a new central authority was specified on waste management in Ukraine. An introduction of inter-municipal cooperation as a legal mechanism was supported by the Government. Levelling an influence of informal sector, an opportunity was given to work within the framework of acting legislation, wherein it's acceptable.

Human resources:

- Support on new specialties on sustainable waste management in universities;
- Launching of targeted programs in high school
- The consideration of waste management issues when developing higher education standards;
- The support of new specialties on sustainable waste management in universities;
- The creation of guidelines in modern waste management opportunities for municipalities.

Information and awareness should include activity on:

- National awareness company on sustainable waste management as an alternative to MSW disposal;
- Waste management awareness activities in school and pre-school institutions.

2.9 Linkages of barriers identified

Chapter 2.2 demonstrates in detail that numerous interconnected groups of barriers are related to the implementation of technology in the Waste Management sector exist, in particular:

1) economic and financial;
2) regulation and legislation;
3) market conditions;
4) technological;
5) informational.

General market mapping on MSW management system of Ukraine is illustrated in fig. 2.6 and fig. 2.7, including related information on all MSW treatment technologies. Market mapping for waste closure technology, being a publicly provided goods is presented individually in fig. AI-01. The process of barrier identification made clear that certain barriers for all the discussed MSW's treatment technologies are common.

One of the most important barriers, hampering the waste sector development, is the fact that general public and business have a low level of awareness and do not approach waste as a business model. Low tariffs on MSW collecting and disposal lead to disincentives to domestic and foreign investments as well as to the absence of business attractiveness for alternatives to waste disposal respectively. Thus, lack of financial resources is also a serious obstacle.

Another shared barrier is a lack of favorable national policies implementation and economic promotion mechanisms from the Government, designed for the waste management sector. Furthermore, existent weak legislation has the lack of law enforcement mechanisms. Another barrier, related to the state authorities and common for all of modern waste treatment technologies diffusion, is poor coordination among state bodies. Problem Trees on the basis of LPA for Waste sector technologies are presented in fig. AII-6-11.

2.10 Enabling framework for overcoming the barriers in Waste management sector

Identified barriers and proposed measures to overcome barriers to technology transfer in the Waste management sector are summarized and presented in table 3 a,b. Enabling framework for overcoming barriers in waste management sector may be established first of all, by arranging awareness, raising activities and forming image of waste as a business model among general public and business.

Another crucial factor is facilitating an access to finance. Mechanisms of easy loans for waste management sector's projects should be developed and incentives should be provided to the existing financing system. Besides, the relevant legal framework should be developed and law enforcement mechanisms should be in place. Effective economic promotion mechanisms should be elaborated. Furthermore, coordination among different ministries, departments, agencies, services and local authorities should be improved. Objective Trees on the basis of LPA for Waste management sector's technologies are presented in fig. AIII-6-11.

Conclusions

Agriculture is an important sector of national economy of Ukraine with significant contribution to Ukrainian export. Simultaneously, during recent years the sector demonstrates a growing trend of GHGs emissions and also associated with other environmental impact, including water pollution and soil degradation. Further development of the sector and its state support should take into account a broad range of sustainable development goals, including climate change mitigation.

Identified priority climate mitigation technologies that could contribute to the achievement of Ukraine's (Intended) Nationally Determined Contribution under the Paris Agreement and other climate and environment policy priorities, include the following:

- the use of information and telecommunication technologies for GHG emission reductions in agriculture;
- conservation tillage technologies (low-till, no-till, strip-till, etc.);
- biogas production from animal waste;

- organic agriculture; and
- the production and use of solid biofuels from agricultural residues.

The priority climate mitigation technologies for agricultural sector face a number of barriers, and state policy measures are required to create an enabling environment and foster their further diffusion in Ukraine. The identified priority policy measures include the following:

- introducing environmental and climate related conditions for the state subsidies provision in agriculture;
- strengthening and improving regulatory requirements;
- capacity building policies;
- information policies; and
- supporting the development of project-based carbon crediting mechanisms.

Further promotion of climate mitigation technologies in agricultural sector will also have climate adaptation co-benefits, as well as contribute to the environmental objectives and social objectives, including job creation and gender equality.

Existing waste management system of Ukraine is outdated and ineffective. As a result, approximately 95 % of generated municipal solid waste is landfilled, leading, in particular, to environmental pollution and significant amount of GHG emissions, and in general, to high human health and climate change risks. Implementation of a new environmentally friendly and cost effective waste management system could be possible only due to diffusion of modern technologies and waste treatment practice.

To achieve the goals set up in Waste management strategy of Ukraine by 2030 (in line with EU Association agreement), and the obligations set up in (Intended) Nationally Determined Contribution under the Paris Agreement, the Government has to ensure wide dissemination of at least the following technologies:

- methane capture at landfills and dumps;
- waste sorting; closure of old waste dumps with methane destruction;
- aerobic biological treatment (composting) of food and green residuals;
- mechanical-biological treatment of waste with biogas and energy production – AD of organic fraction of MSW;
- The mechanical-biological treatment of waste with SRF production for cement industry.

Table 3a and 3b contains systematized information on barriers and measures to overcome them for the prioritized waste treatment technologies.

Diffusion of modern technologies will contribute to gender equality in Agriculture and Waste sectors of Ukraine through creation of new highly qualified jobs. Nevertheless, to ensure equal opportunities in part of salary amount and carrier growth, general measures should be conducted, among which are: to guarantee, that requirements on vacancies should be gender neutral both for government and business; encouraging governmental institutions and business to engage women in leadership positions; and implementation of awards focused on promoting women to be involved in agriculture and waste management issues.

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Annex I Market maps

Figure AI-01. Market mapping of agricultural sector in Ukraine

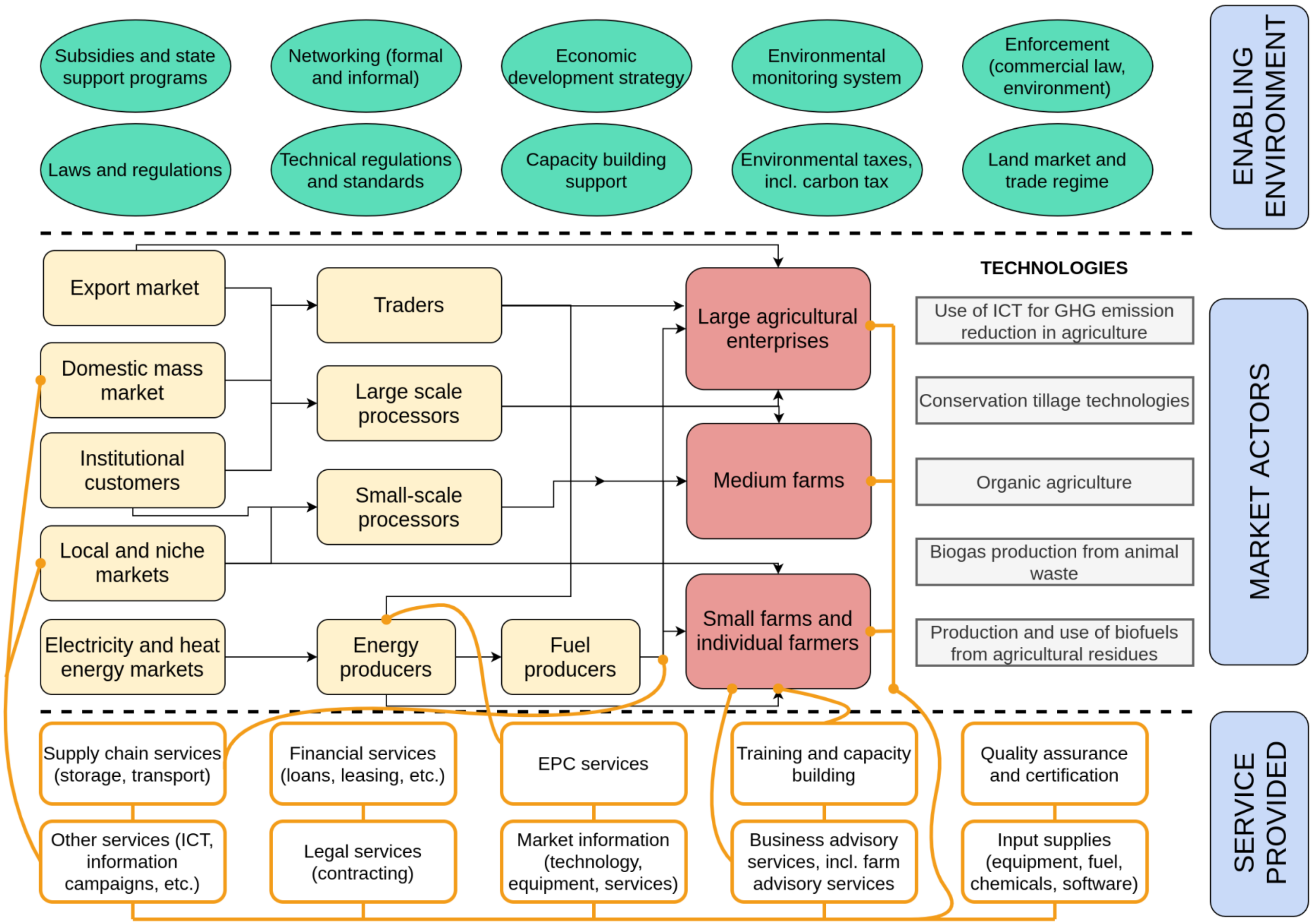
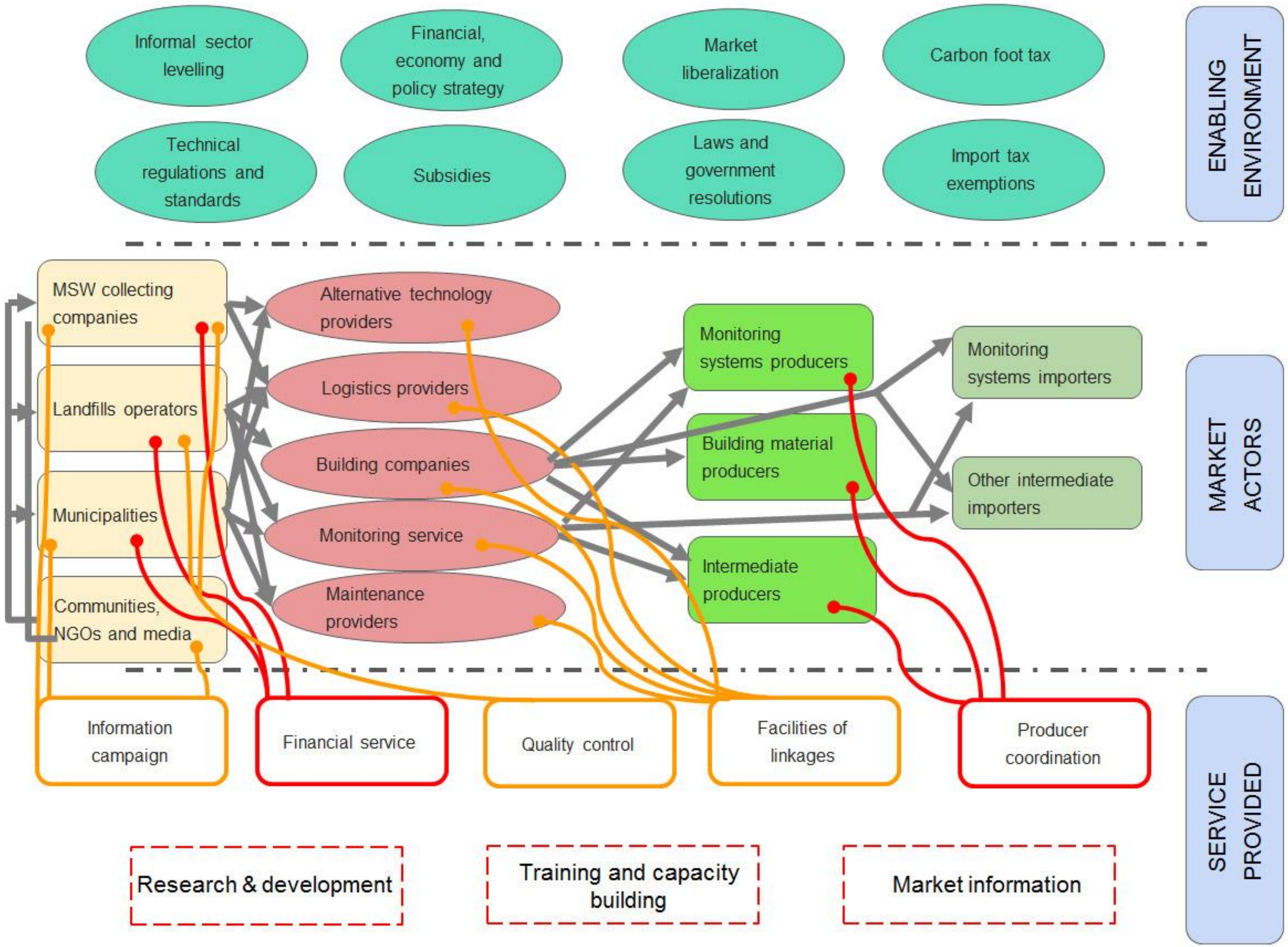


Figure AI-02. Market mapping of MSW landfill and dump closure technology



Annex II Problems trees

Figure AII-1. Problem tree for technology A1 "Use of information and telecommunication technologies for GHGs emission reductions in agriculture"

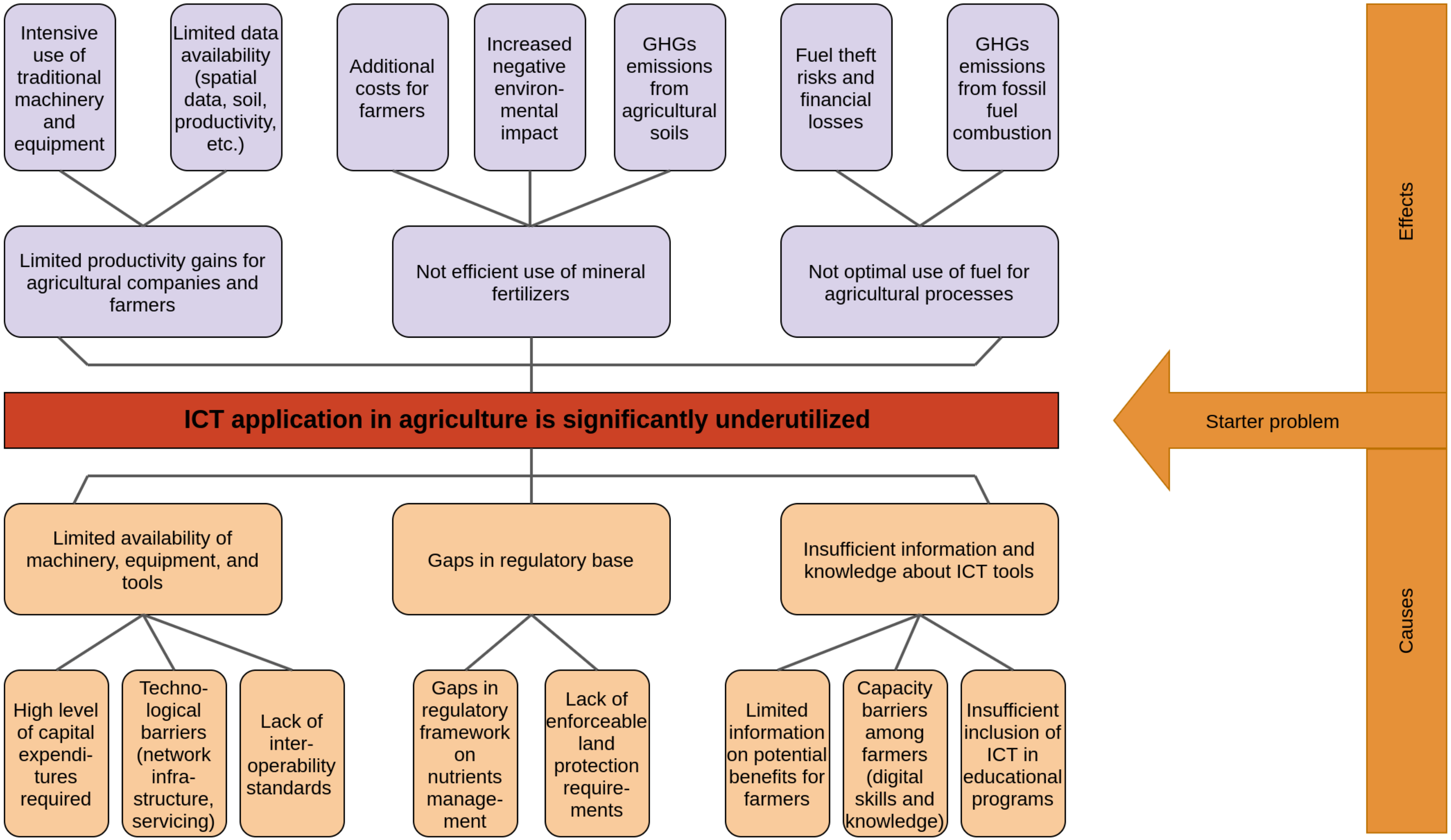


Figure AII-2. Problem tree for technology A2 "Conservation tillage technologies (low-till, no-till, strip-till, etc.)"

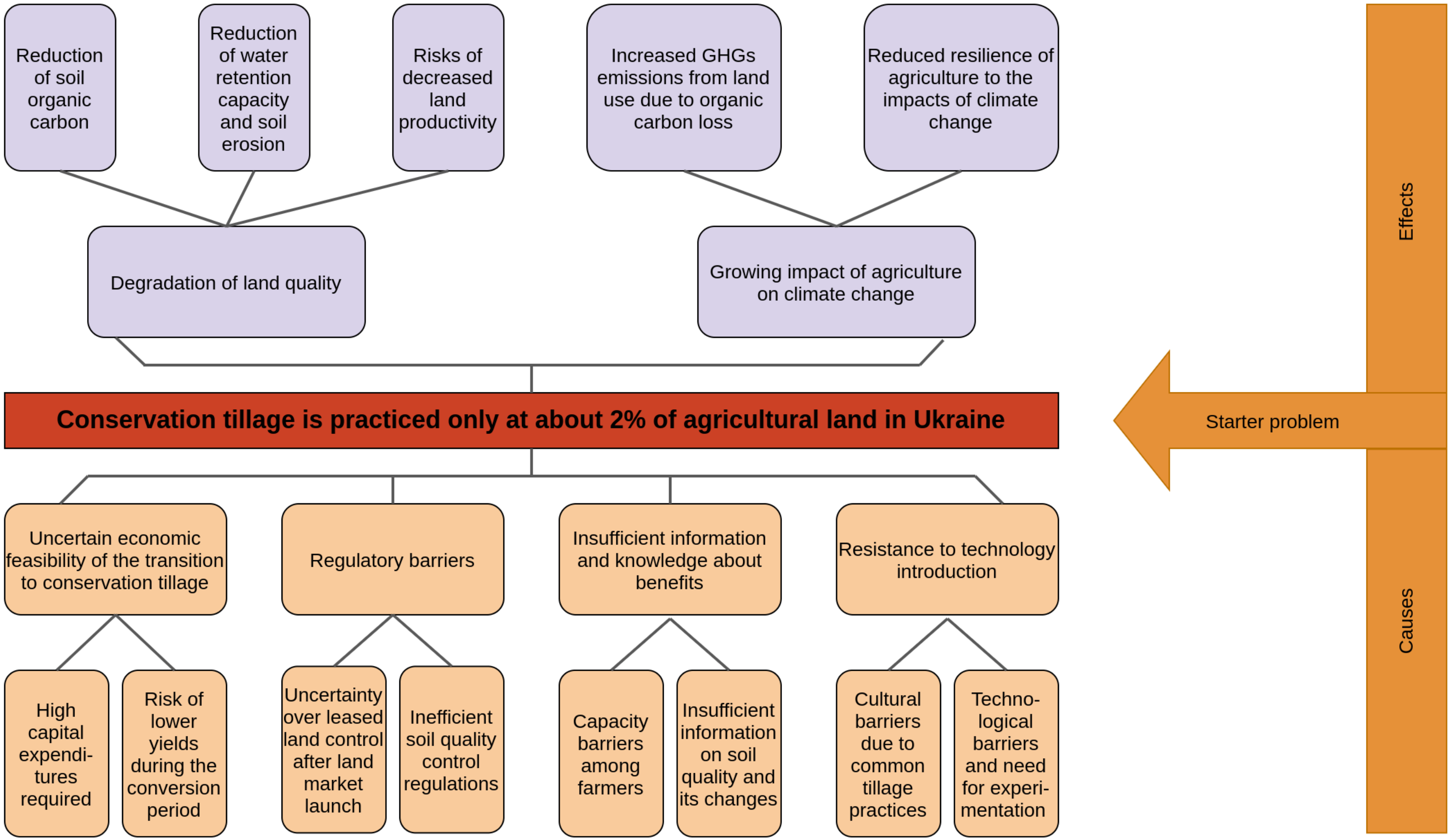


Figure AII-3. Problem tree for technology A3 “Biogas production from animal waste”

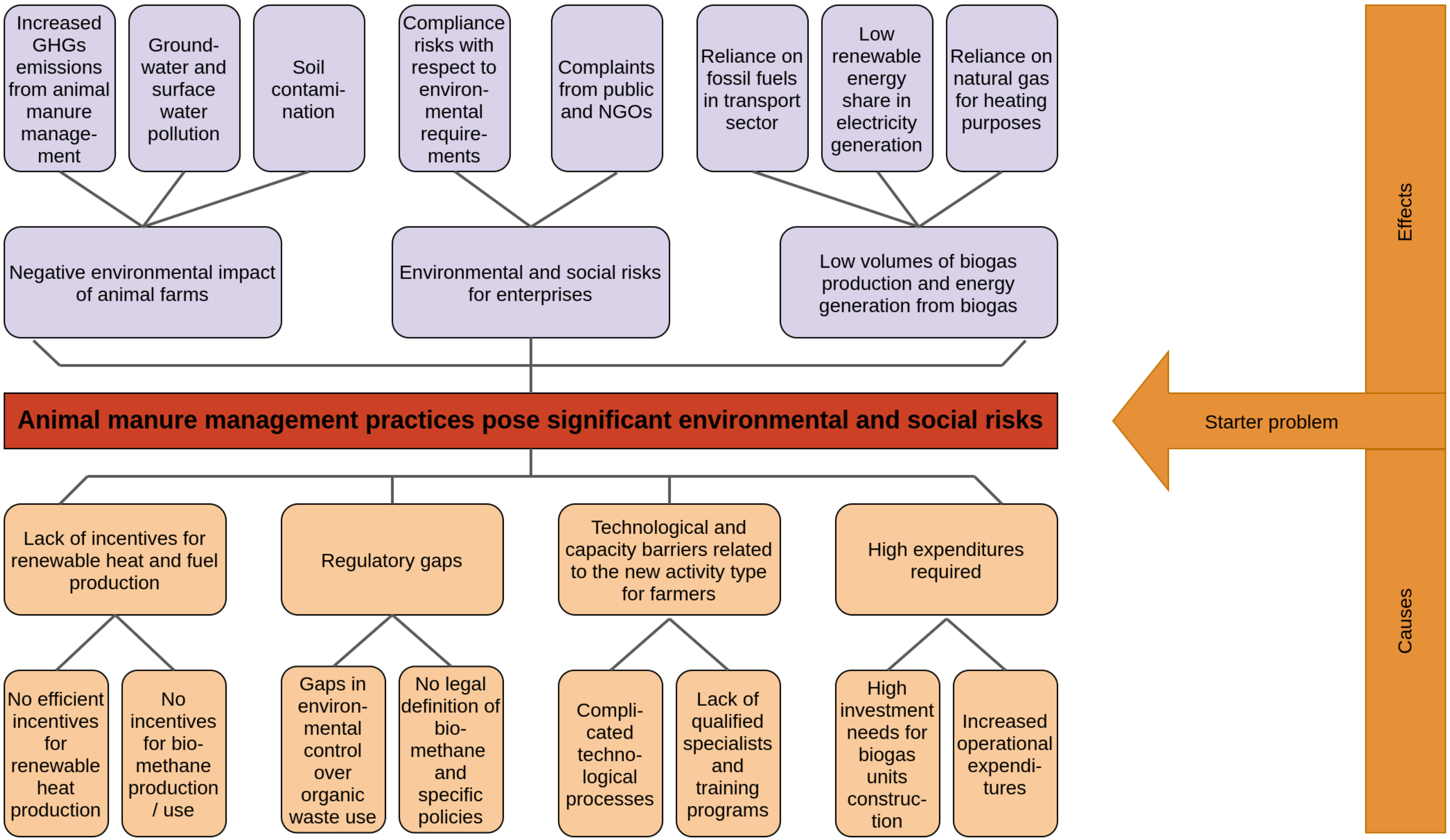


Figure AII-4. Problem tree for technology A4 “Organic agriculture”

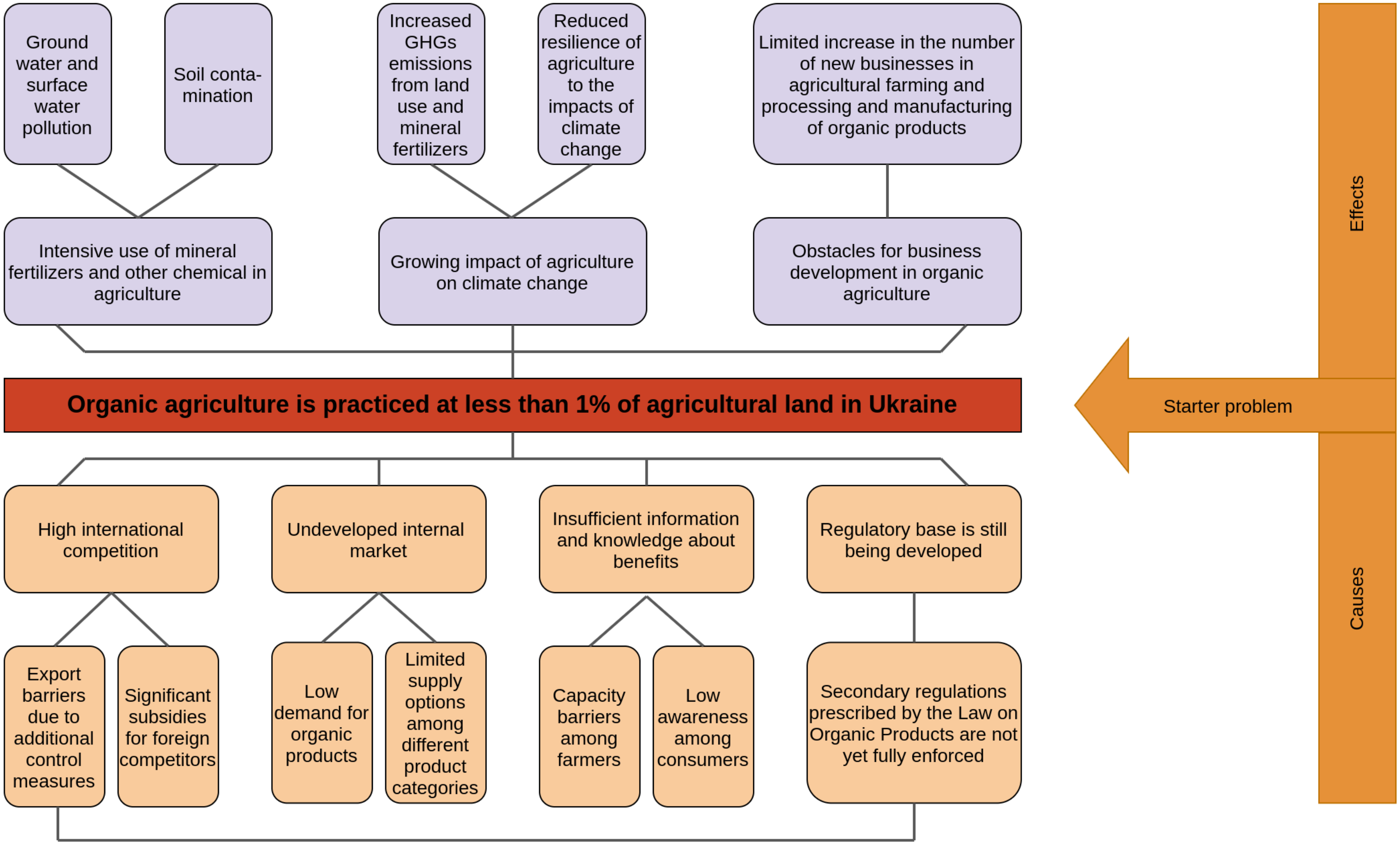


Figure AII-5. Problem tree for technology A5 “The production and use of solid biofuels from agricultural residues”

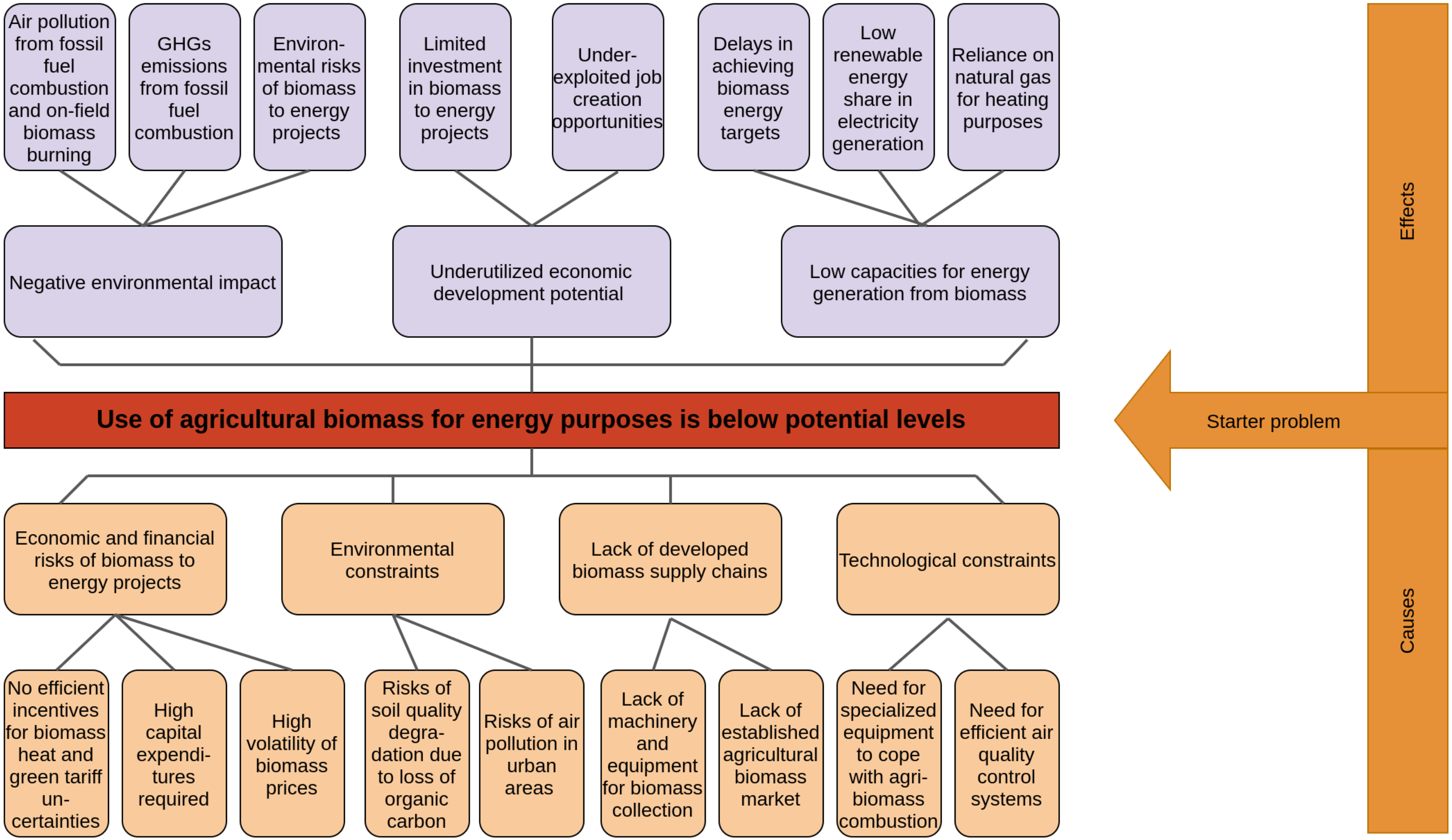


Figure AII-6. Problem tree for technology W1 – LFG-to-E

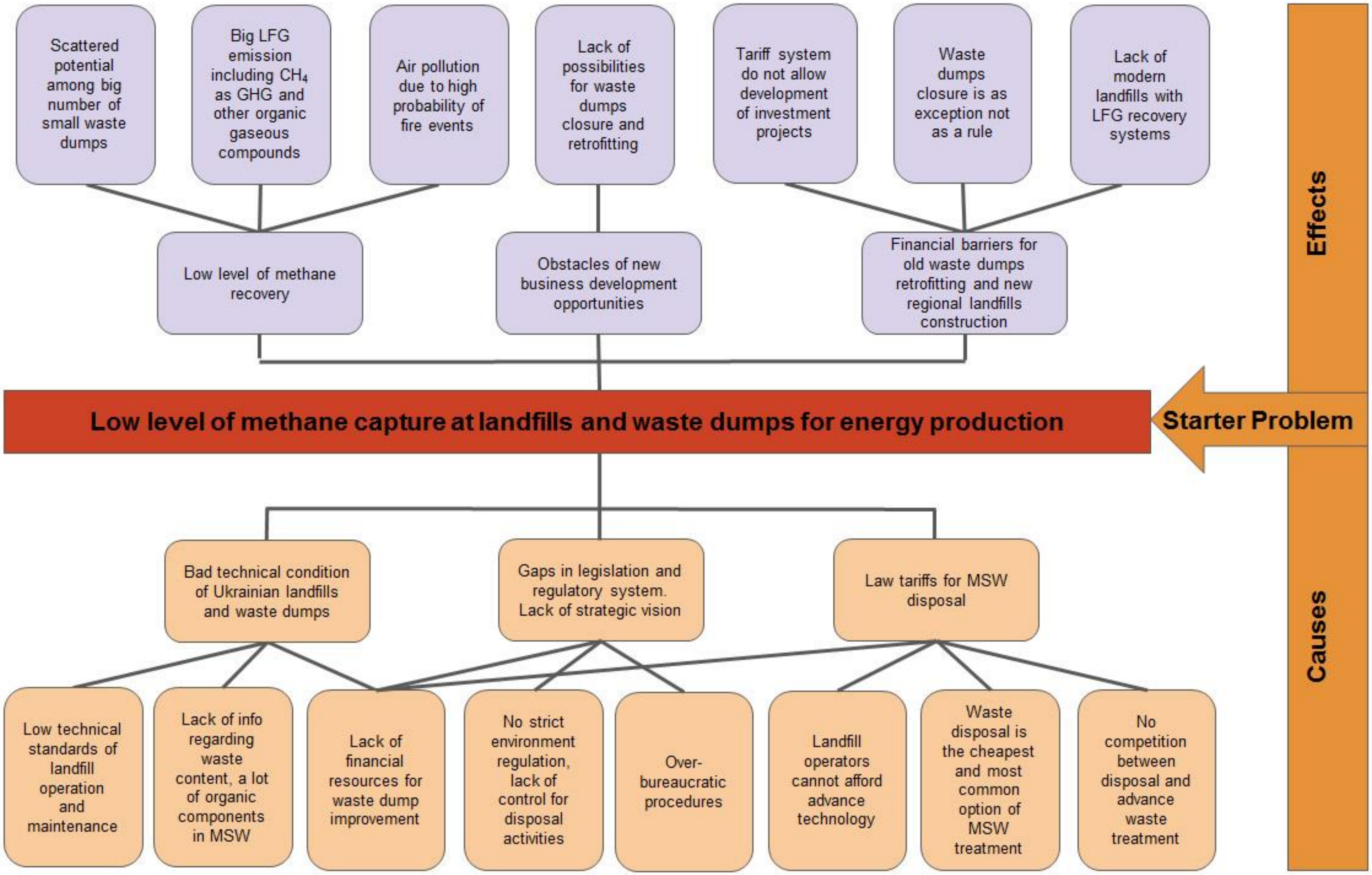


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Figure AII-7. Problem tree for technology W2 - MSW sorting

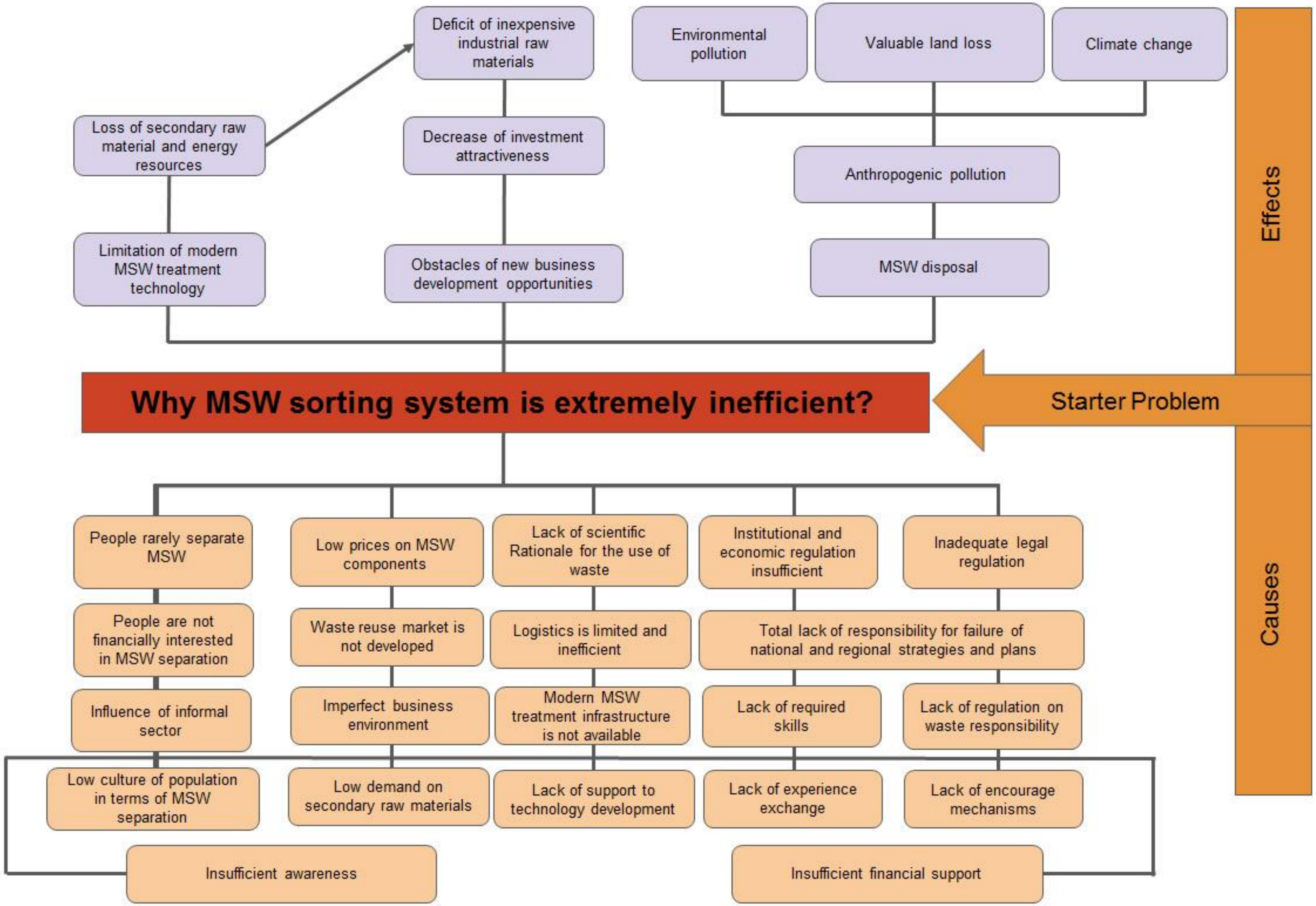


Figure AII-8. Problem tree for technology W3 - MSW landfill and dump closure technologies

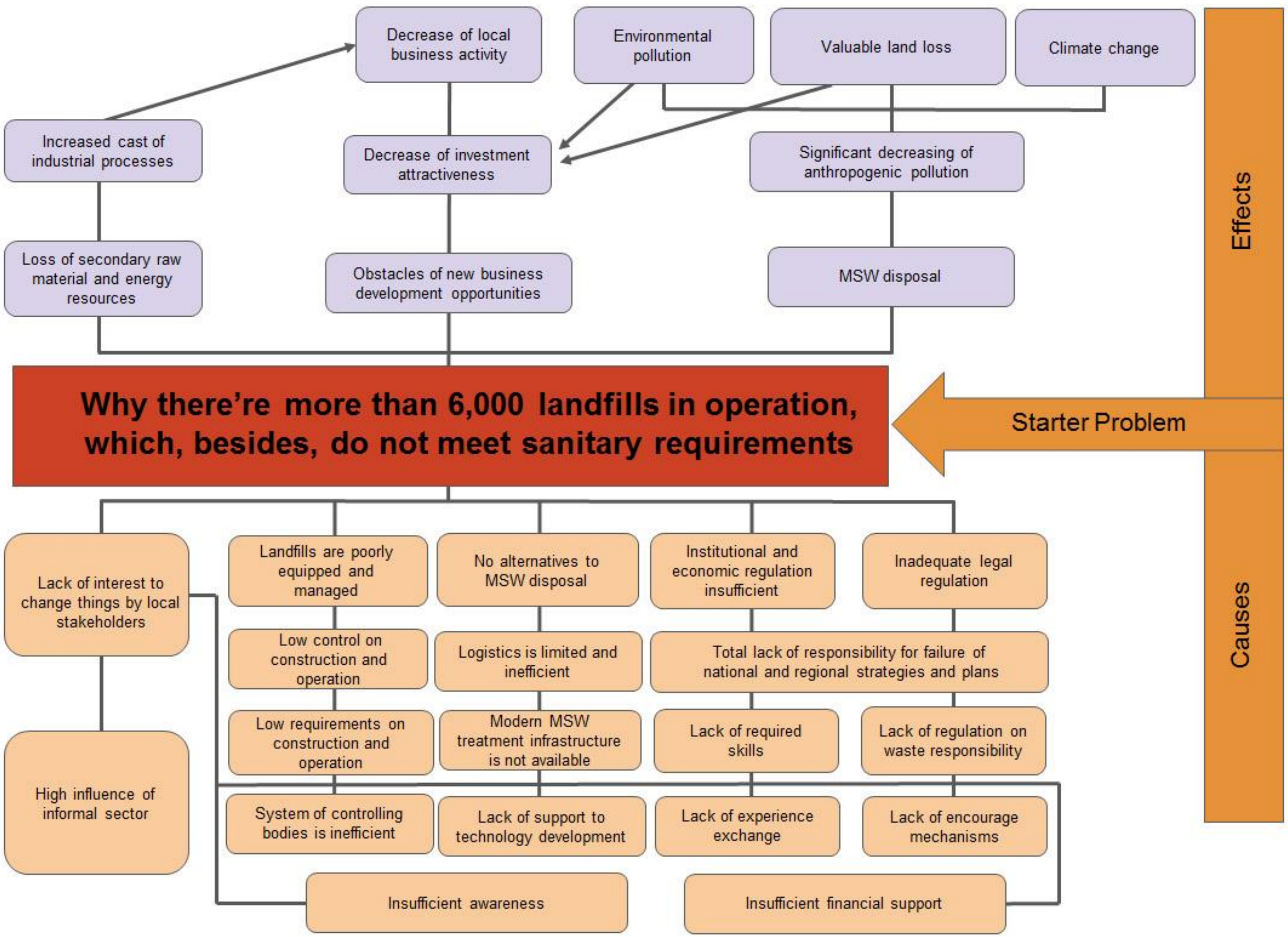


Figure AII-9. Problem tree for technology W4 - Composting

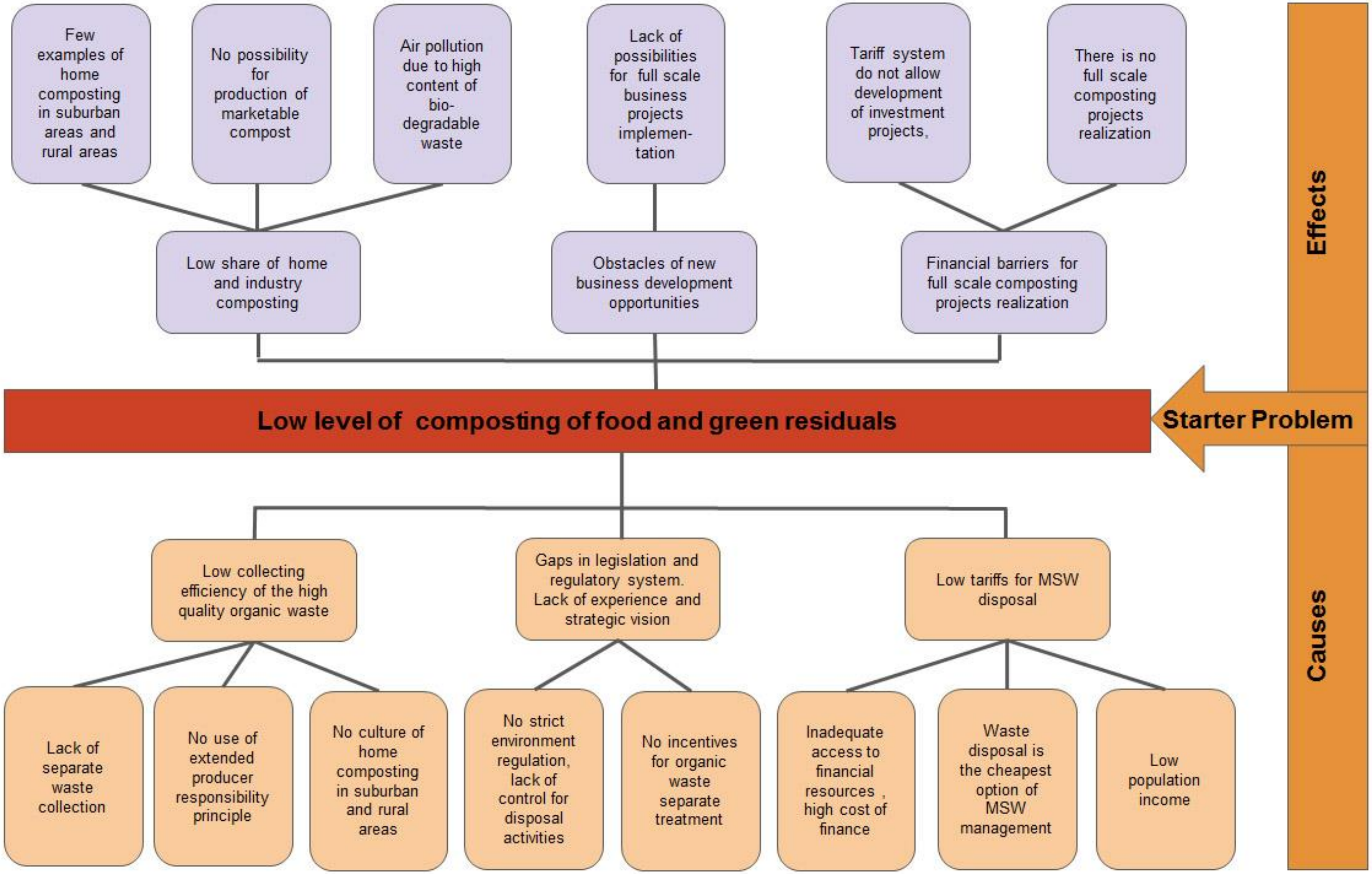


Figure AII-10. Problem tree for technology W5 - MBT-AD

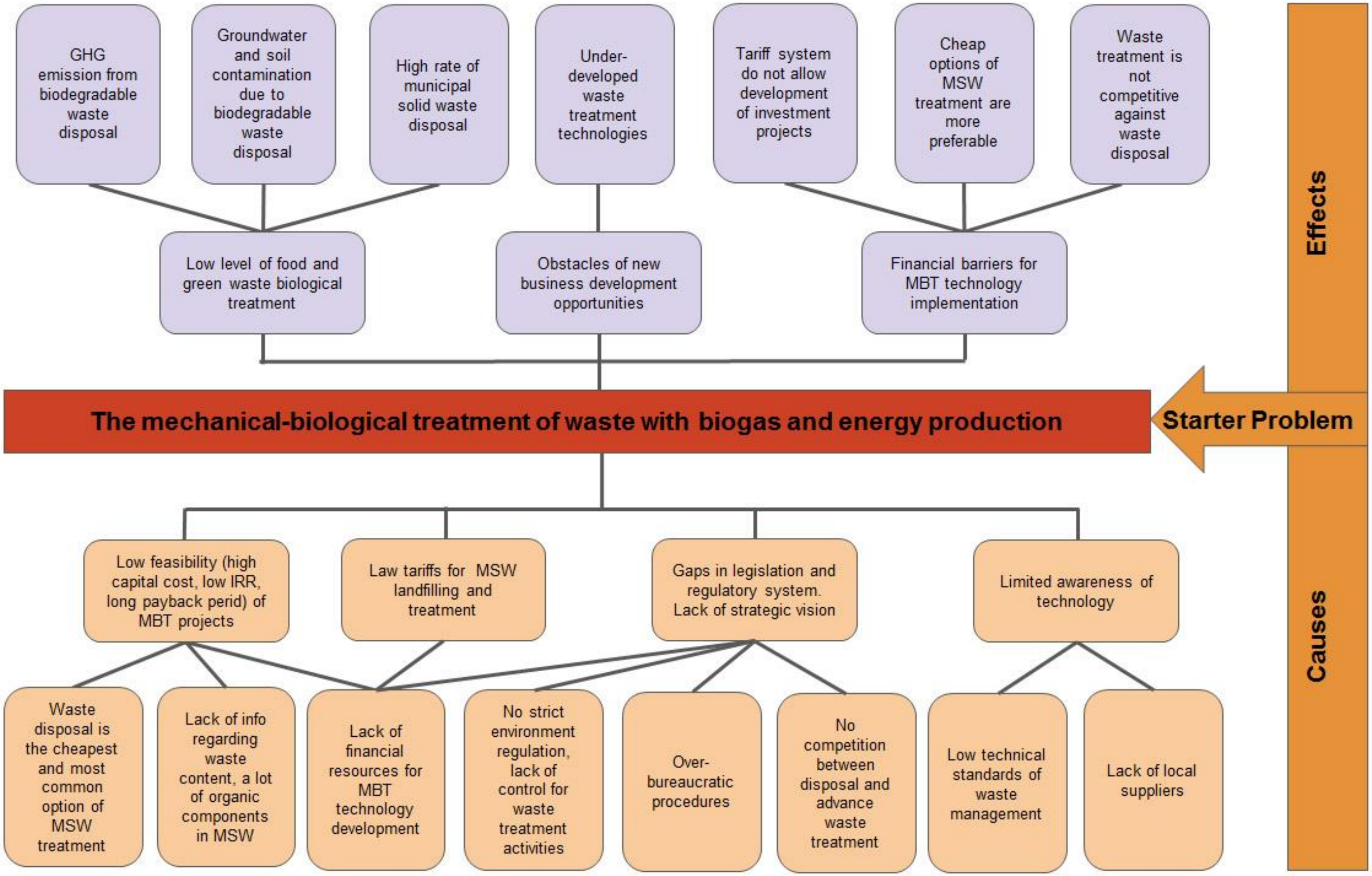
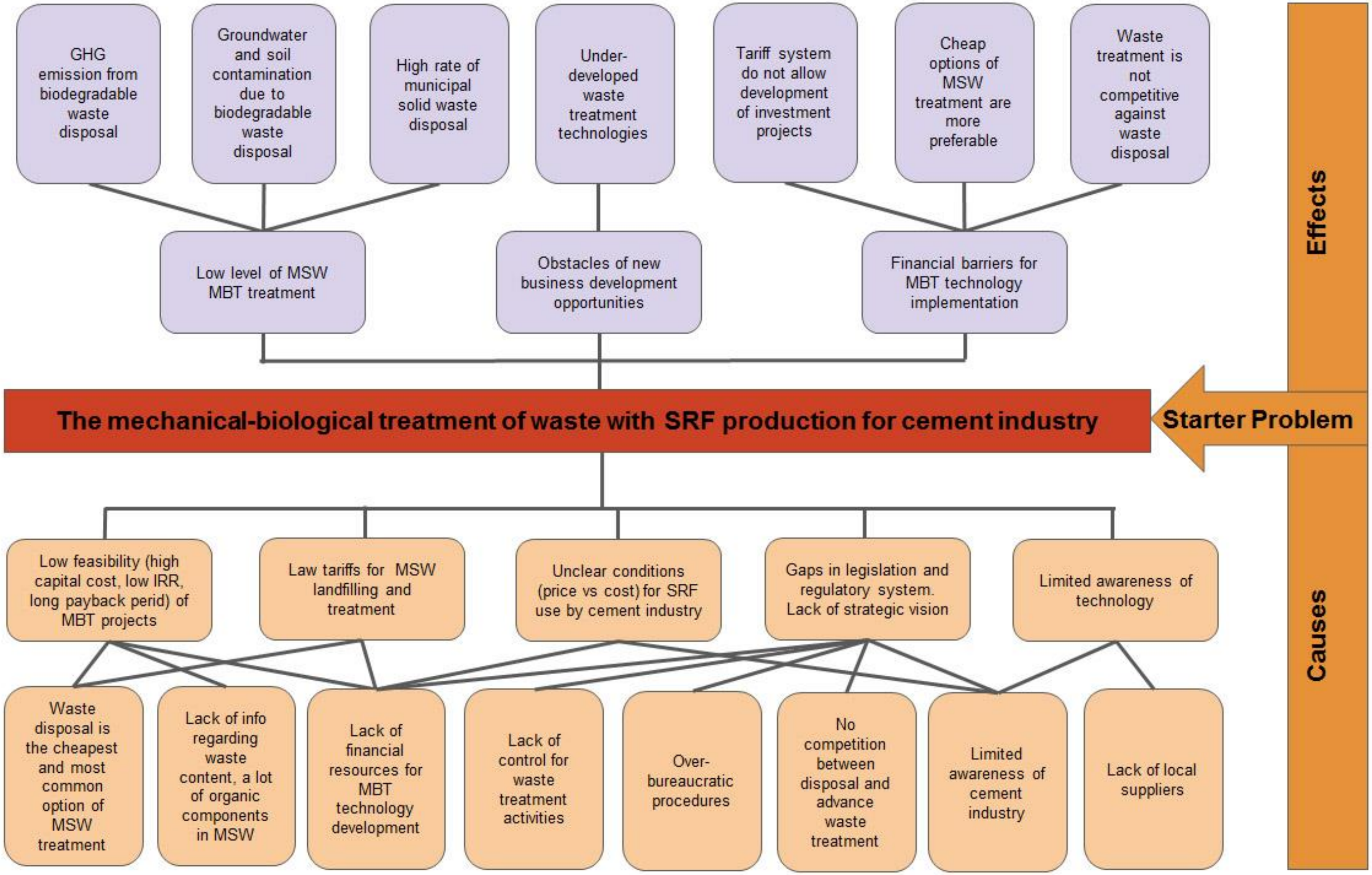


Figure AII-11. Problem tree for technology W6 - MBT-Cement



Annex III Objective trees

Figure AIII-1. Objective tree for technology A1 “Use of information and telecommunication technologies for GHGs emission reductions in agriculture”

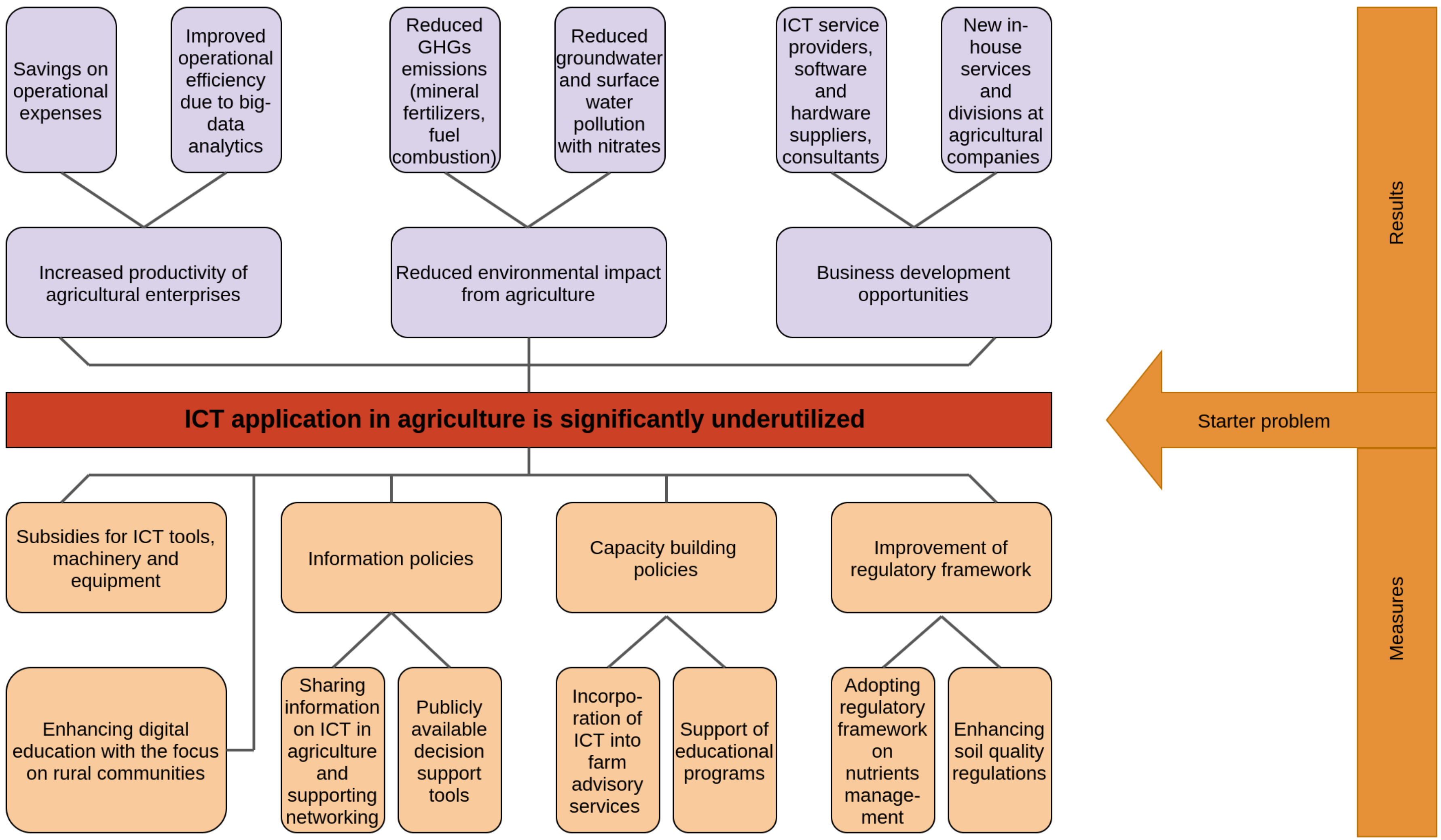


Figure AIII-2. Objective tree for technology A2 "Conservation tillage technologies (low-till, no-till, strip-till, etc.)"

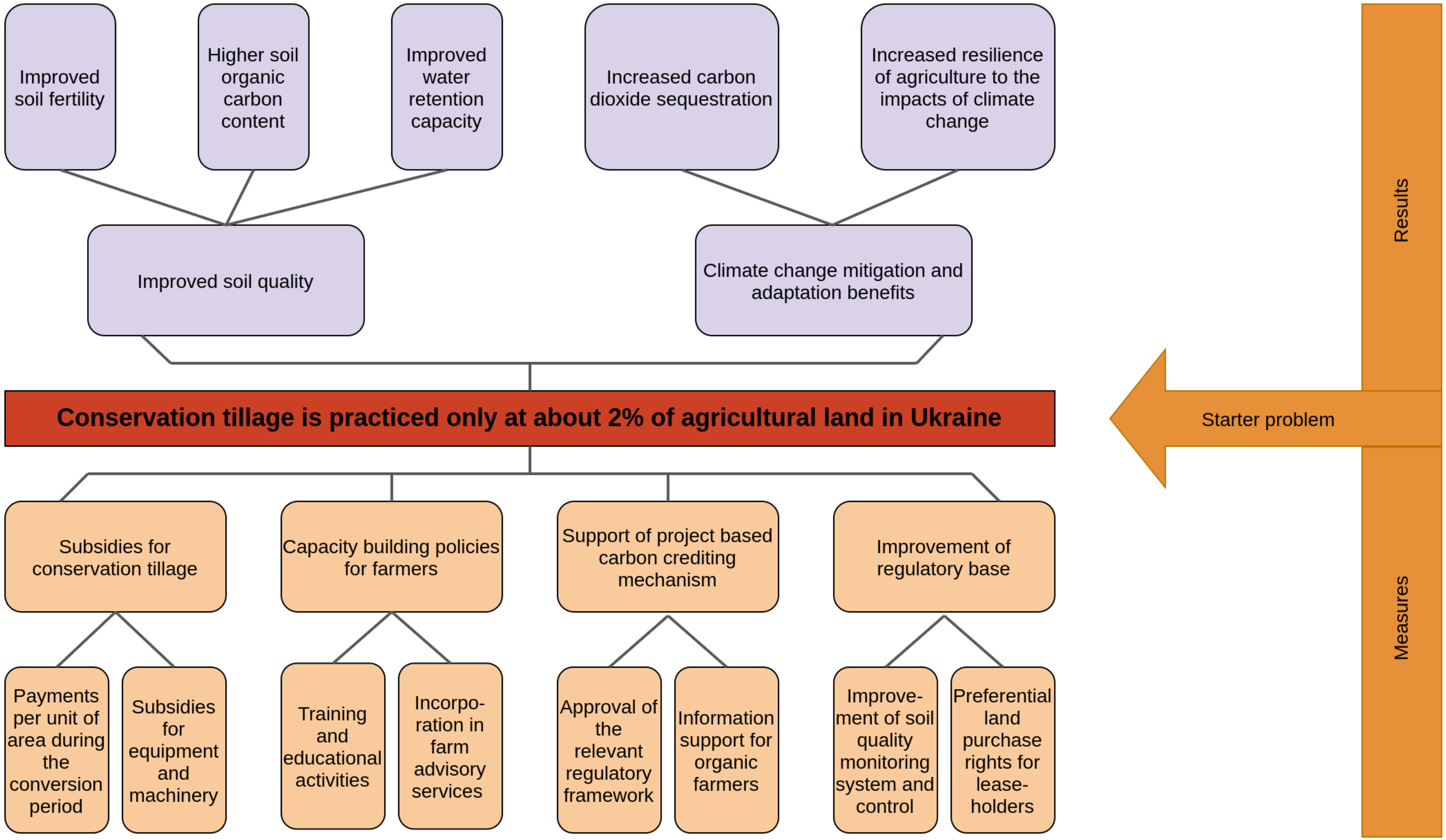


Figure AIII-3. Objective tree for technology A3 “Biogas production from animal waste”

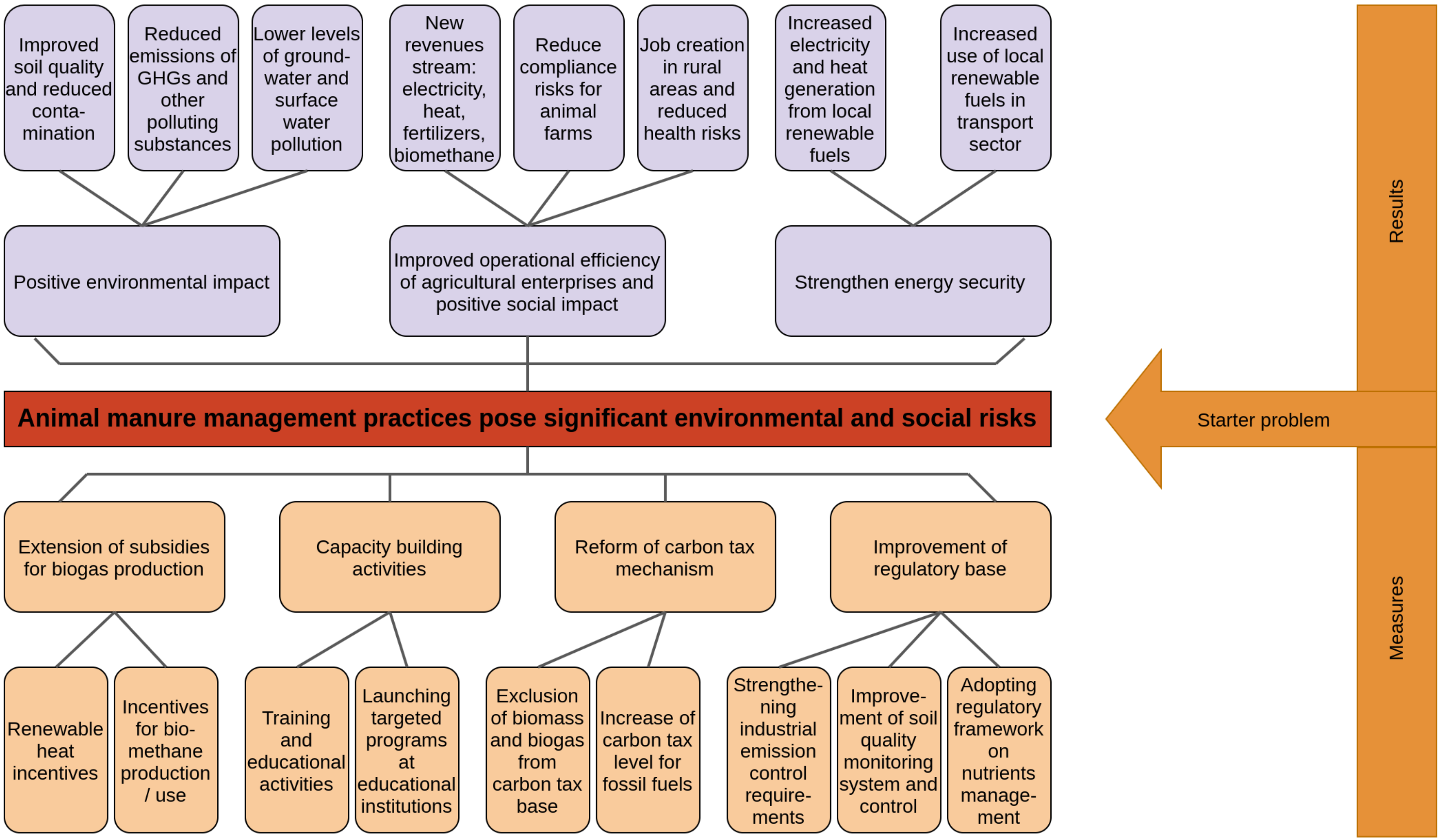


Figure AIII-4. Objective tree for technology A4 "Organic agriculture"

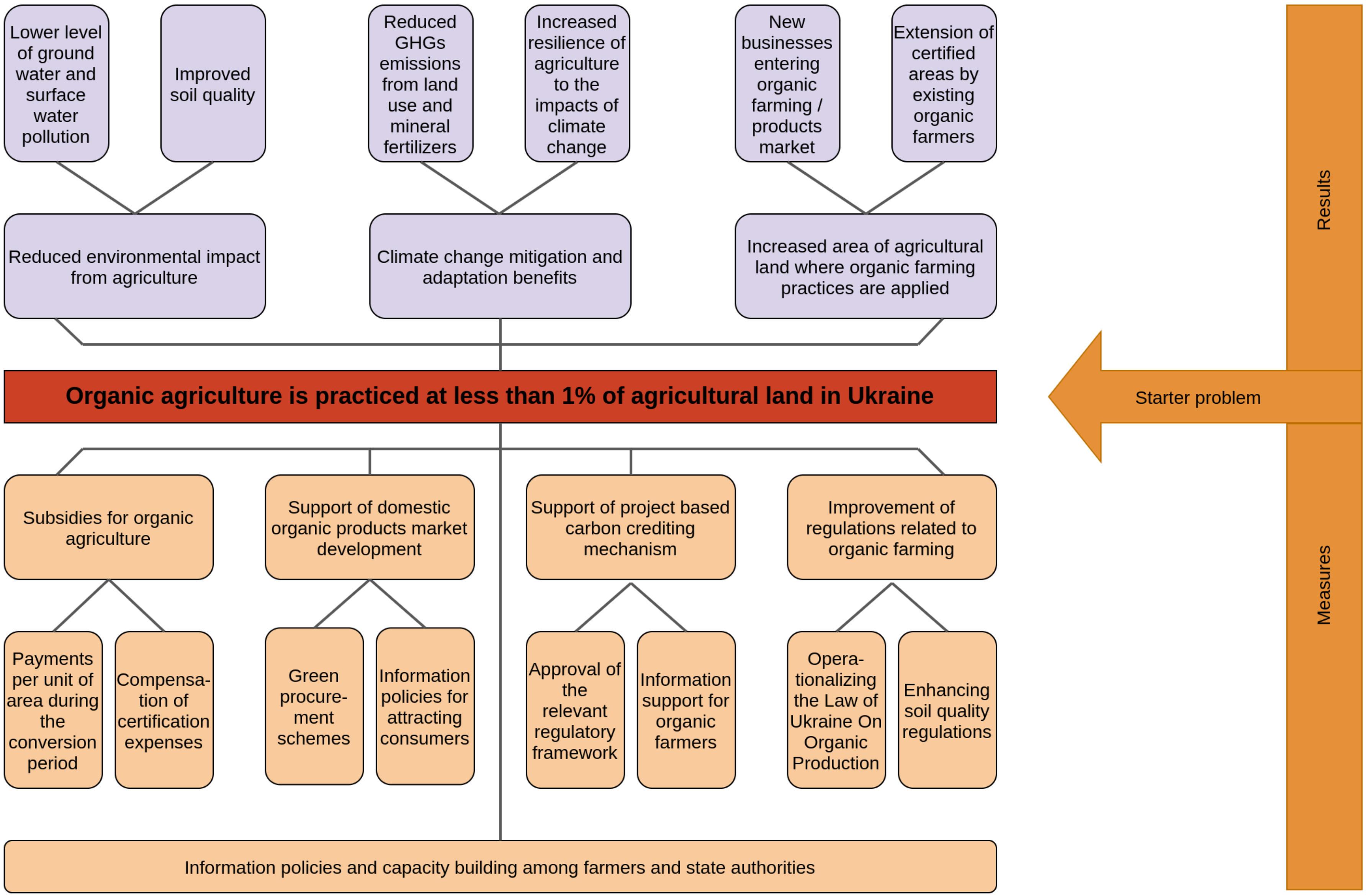


Figure AIII-5. Objective tree for technology A5 "The production and use of solid biofuels from agricultural residues"

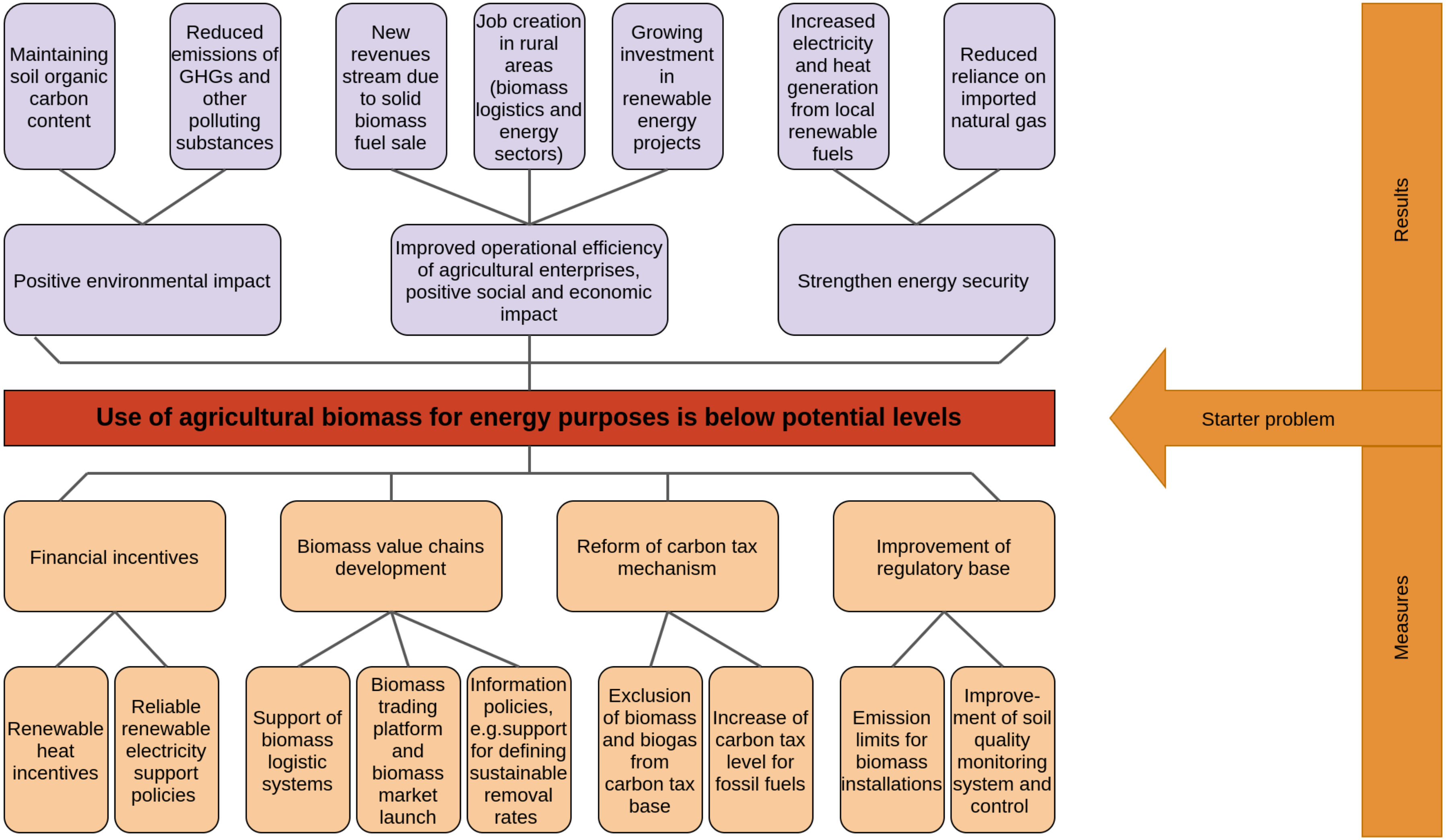


Figure AIII-6. Objective tree for technology W1 – LFG-to-E

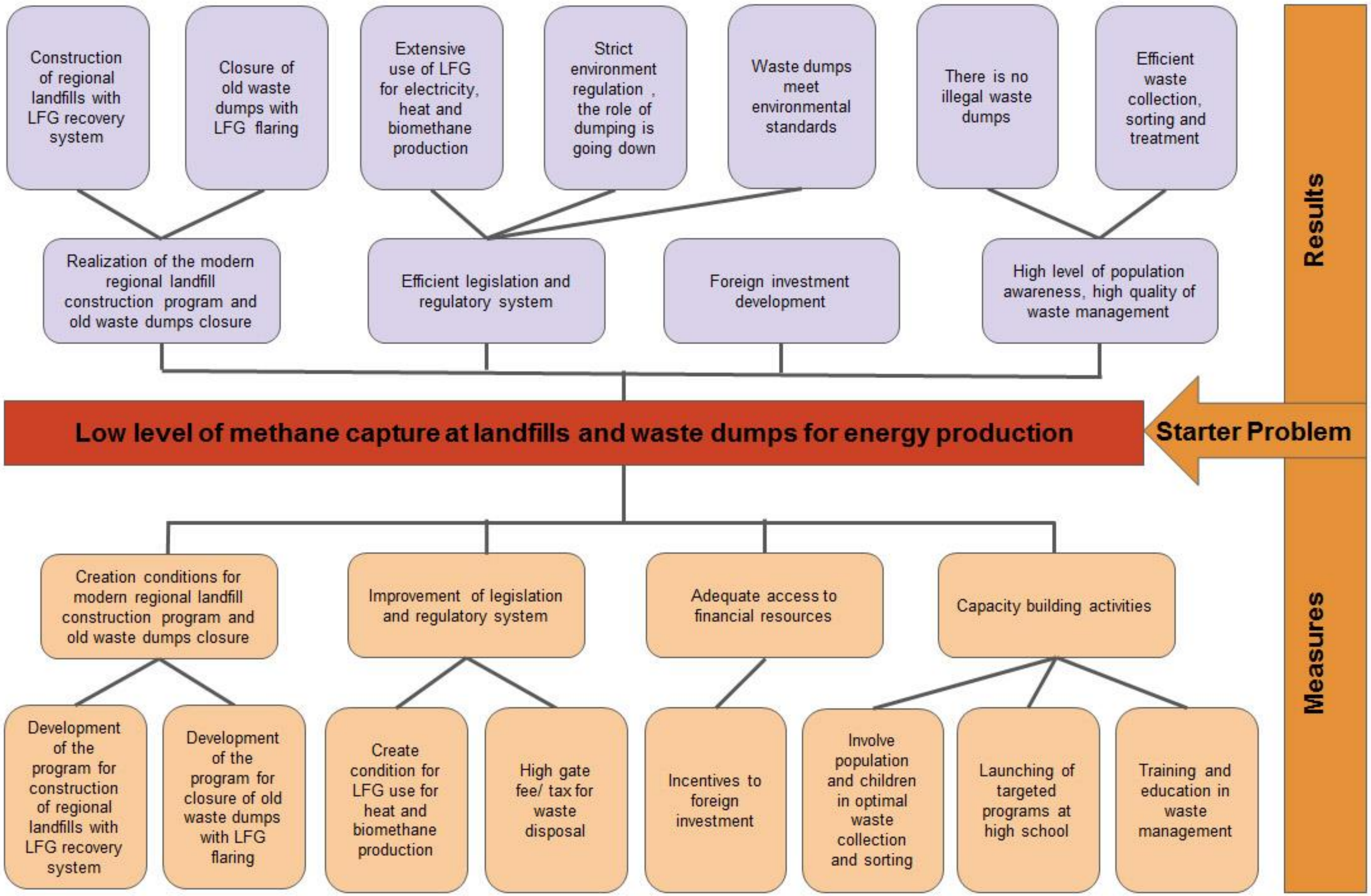


Figure AIII-7. Objective tree for technology W2 – MSW sorting

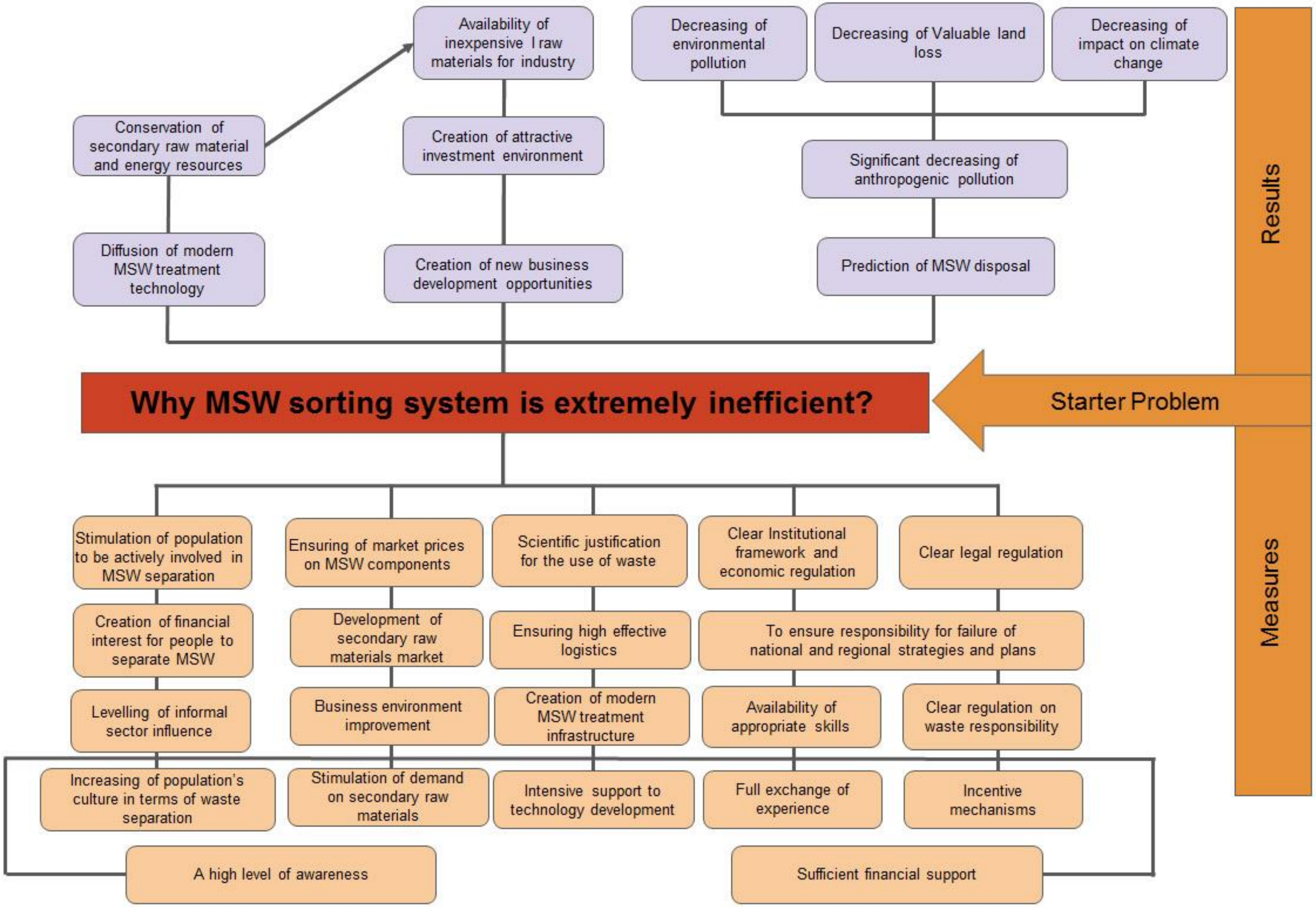


Figure AIII-8. Objective tree for technology W3 – MSW landfill and dump closure

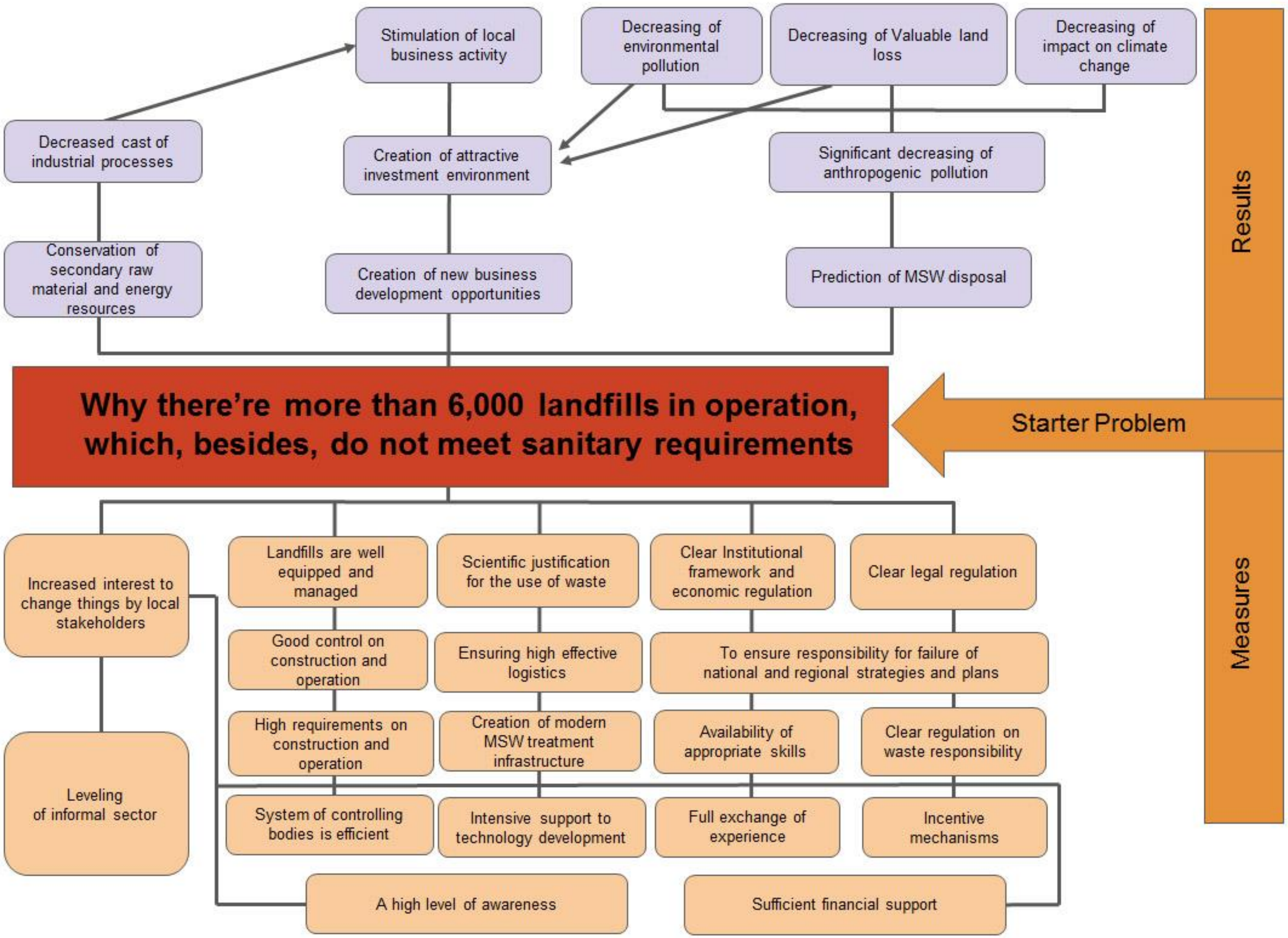


Figure AIII-9. Objective tree for technology W4 – Composting

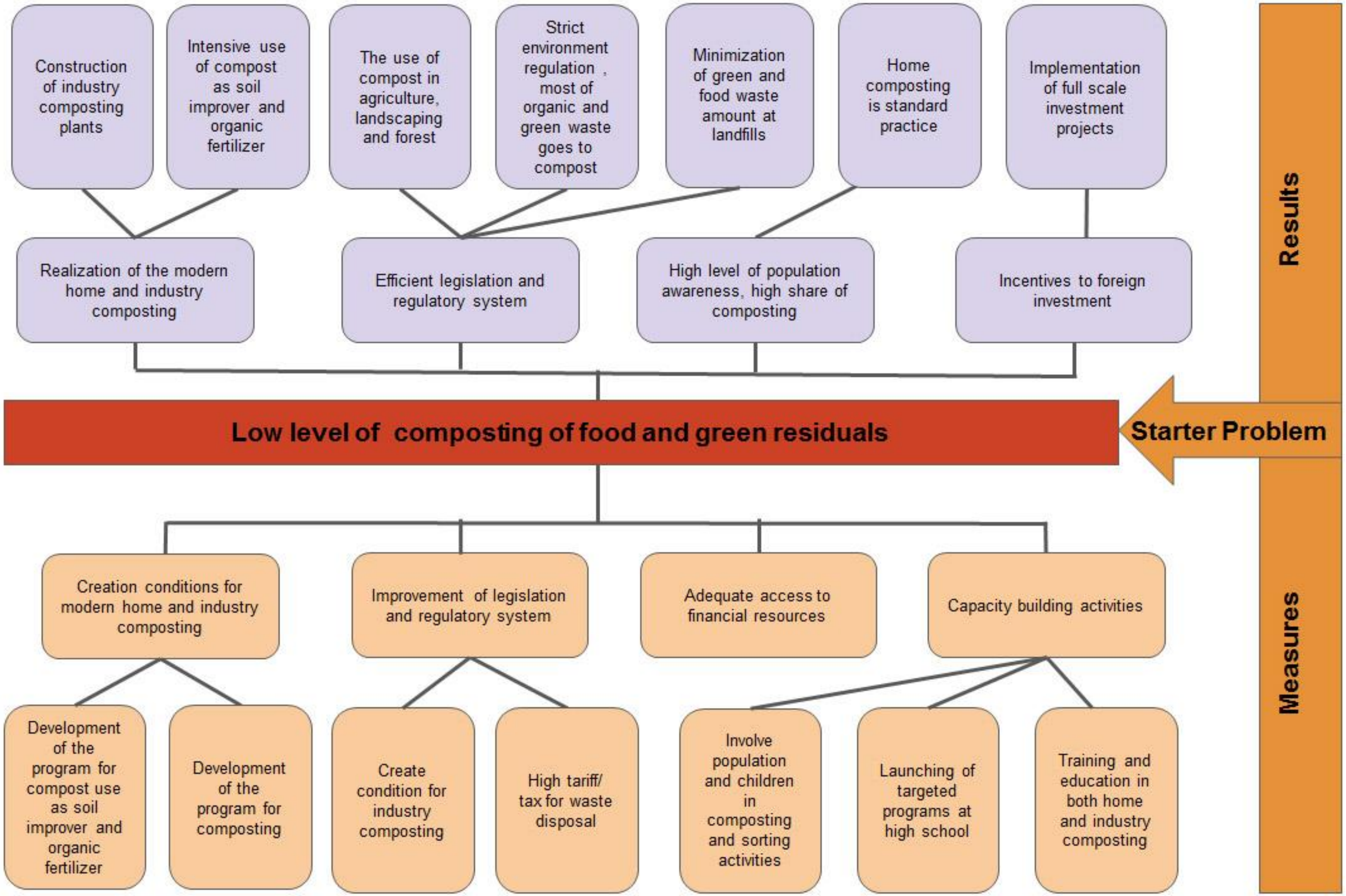


Figure AIII-10. Objective tree for technology W5 – MBT-AD

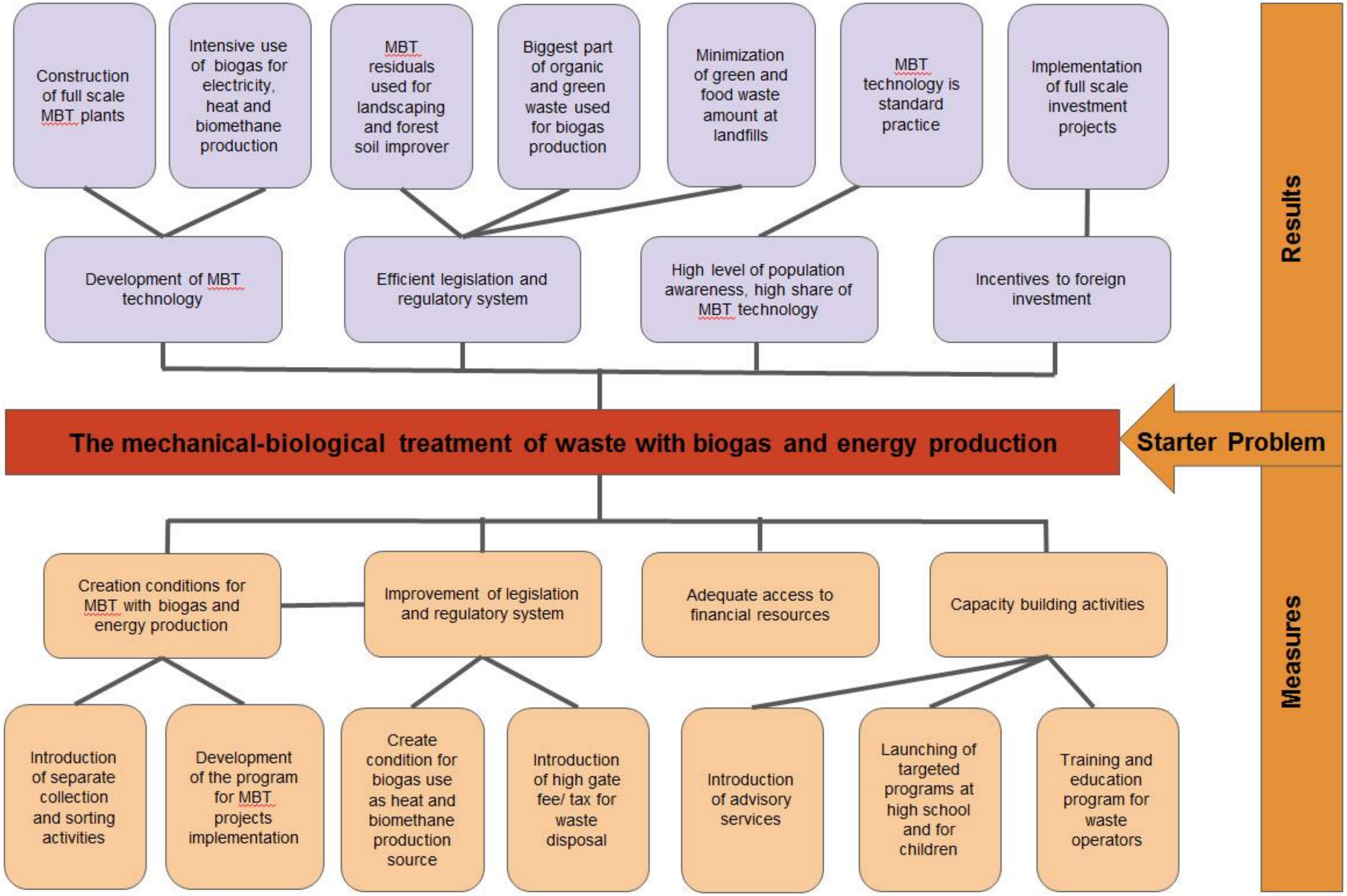
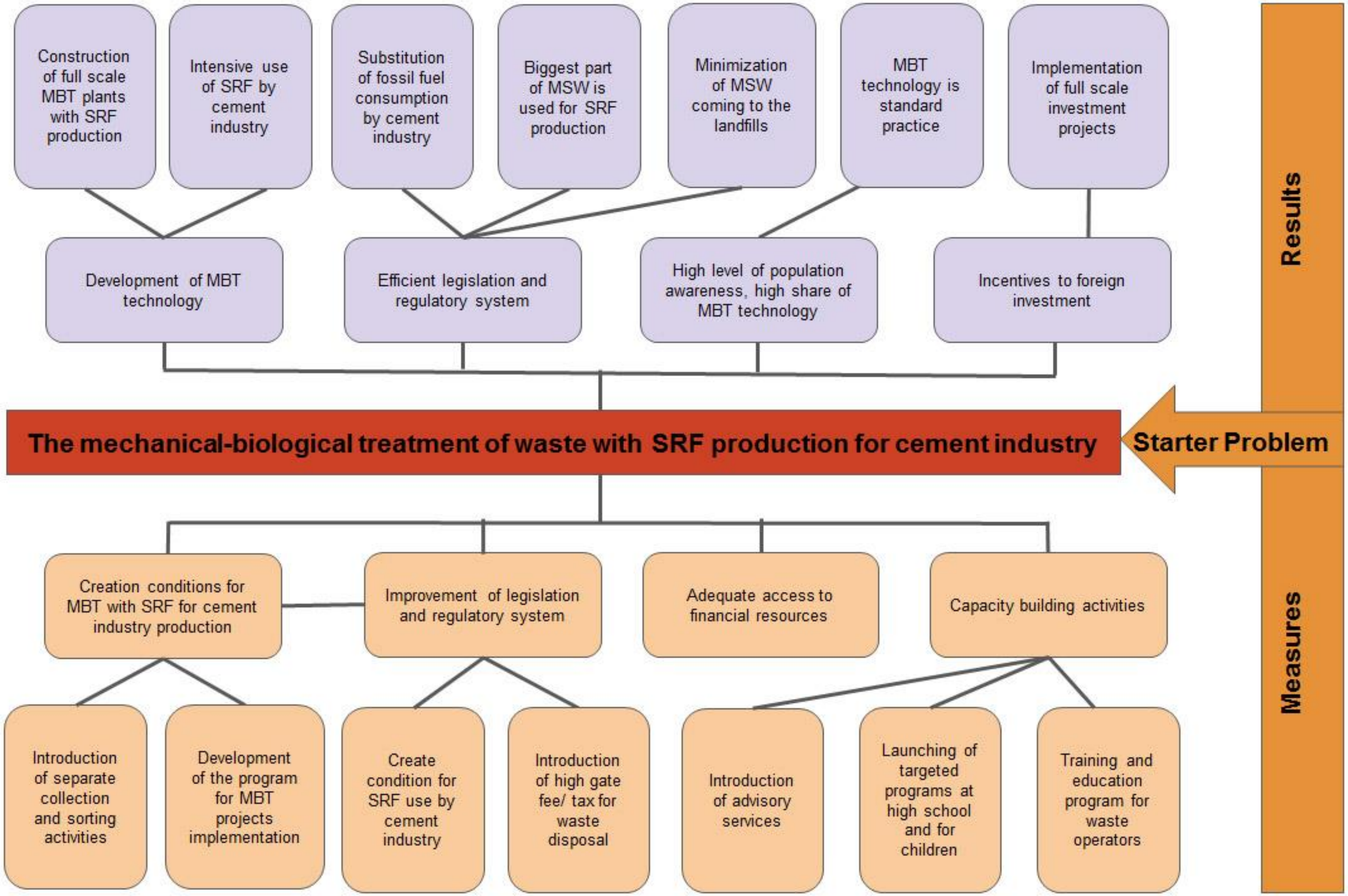


Figure AIII-11. Objective tree for technology W6 – MBT-Cement



Annex IV List of stakeholders involved in Agricultural sector and their contacts

Name	Affiliation	Position	Comments on Consultations
Georgii Geletukha	The Bioenergy Association of Ukraine	PhD in Technical Sciences, Head of the Board	Review of the position papers of the Bioenergy Association of Ukraine on the analysis of barriers for the use of agricultural biomass for energy purposes and presentations during Biomass for Energy 2019 conference, 24-25.09.2019
Yuriy Epshtein	Accord Ltd	Director	Presentation during the Biomass for Energy 2019 conference, 24-25.09.2019 and online communication, comments on barriers for biogas projects development.
Olha Sydorchuk	AgroBiogas LLC	PhD in Technical Sciences, CEO	In-person interview during the Biomass for Energy 2019 conference, 24-25.09.2019, comments on barriers for biogas projects development.
Kyryl Tomliak	KT-Energy LLC	Director	In-person interview, 15.01.2020, comments on the barriers for biomass use for heat energy generation based on the results of “KeepWarm – Improving the performance of district heating systems in Central and Eastern Europe” Horizon 2020 project
Kateryna Shor	International Charitable organisation “Information Center "Green Dossier"	Project manager	In person interview, 30.01.2020; comments on the barriers for organic agriculture development and potential mitigation measures
Anastasiia Bilych	Arnika Organic	Head of Market Development	Personal communication on 19.02.2020, comments on barriers and enabling framework for organic agriculture development
Oleg Riabov	Gals-Agro	Deputy Director, Head of Renewable Energy	Presentation during the Biomass for Energy 2019 conference, 24-25.09.2019, comments on barriers for biogas projects development.
Oleksandr Hyzhniak	Kernel	Head of IT projects in AgriBusiness, manager of #DigitalAgriBusiness project	Discussions during Netherland-Ukrainian Agro-IT Forum on 18.02.2020, comments on policy measures to support ICT in agriculture and current status of the technology
Yuriy Petruk	AgTech Ukraine Association	Head of the Board	Discussions during the Open meeting of sub-committee on agrarian technologies (Agro IT) of the Union of Ukrainian Entrepreneurs (SUP) on 30.01.2020 and Netherland-Ukrainian Agro-IT Forum on 18.02.2020; comments on policy measures to support ICT in agriculture and current status of the technology

Valerii Iakovenko	Drone.UA	Founder	Discussions during the Open meeting of sub-committee on agrarian technologies (Agro IT) of the Union of Ukrainian Entrepreneurs (SUP) on 30.01.2020; comments on policy measures to support ICT in agriculture and current status of the technology
Yuri Matveev	Bioenergy Association of Ukraine	Expert	Review of the position papers of Bioenergy Association of Ukraine, personal communication; comments on barriers and enabling framework for biogas projects development
Oksana Riabchenko	“Integrated Natural Resources Management in Degraded Landscapes in the Forest-Steppe and Steppe Zones of Ukraine” Project	Project coordinator	In person interview on 30.01.2020; comments on policy measures to support conservation tillage practices and other climate mitigation technologies
Oleksiy Vasyliuk	Ukrainian Nature Conservation Group	Head	Presentation and discussions during the public launch of the civil society position paper “Climate Policies Roadmap for Ukraine” on 18.02.2020; comments on land use violations and control and relevant policy measures, including the role of ICT
Tetiana Zhelyezna	Bioenergy Association of Ukraine	Expert	Presentation on barriers and mitigation measures for the development of biomass energy sector of Ukraine during the seminar - «Development for Opportunities for Utilisation of Biomass Residues in the Renewable Sector of Ukraine» together with experience transfer between Ukrainian and Finnish companies in bioenergy sector on 05-06.02.2020
Tetiana Markuta	EBRD	Principal, Sustainable Resource Investment	Presentation of the “Sustainable Bioenergy Value Chain Innovation” Programme in Ukraine on 18.11.2019
Anna Danyliak	Center for Environmental Initiatives Ecoaction	Sustainable Rural Development Project Coordinator	Group discussions with EcoAction team on 13.02.2019; comments on barriers and enabling framework for mitigation technologies in agriculture
Mykhailo Amosov	Center for Environmental Initiatives Ecoaction	Land Matrix Initiative Coordinator	Group discussions with EcoAction team on 13.02.2019; comments on barriers and enabling framework for mitigation technologies in agriculture
Volodymyr Bunetskyi	Pellet Association of Ukraine / BM Engineering	Head / CEO	Personal communication on 17.02.2019, review of publications and presentations; comments on bioenergy sector development in Ukraine.

Annex V List of stakeholders involved in Waste sector and their contacts

Name	Affiliation	Position	Comments on Consultations
Alina Dychko	National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”	Doctor in technical sciences, Professor of Engineering Ecology Chair	In person interviews and discussions, electronic mail exchange
Natalya Gusyeva	State Statistics Service of Ukraine	Head of Environmental Statistics Compartment, Department for Agricultural and Environmental Statistics	In person interviews and discussions, electronic mail exchange
Borys Kostiukovskyy	NGO "Bureau of Integrated Analysis and Forecasts"	PhD in technical sciences, scientific director	In person interviews and discussions, electronic mail exchange
Valeriy Mykhaylenko	Taras Shevchenko National University of Kyiv	PhD in geographical sciences, Associate Professor	In person interviews and discussions, electronic mail exchange
Ivan Oleksiyevets	Limited Liability Company "ECOINTECHNO"	PhD in geographical sciences, Managing Partner	In person interviews and discussions, electronic mail exchange
Iuliia Zakharchuk	Budget Institution «National Center for GHG Emission Inventory»	Chief Specialist of Inventory Department	In person interviews and discussions, electronic mail exchange
Maksim Barinov	Association “Ukrainian Ecological Alliance”	General director	Participation in key waste exhibitions and conferences and following discussion (Waste Forum Kyiv 2019, Waste Management 2019, etc.)
Pavel Bondarev	Association “Ukrcement”	Environmental project development manager	Participation in key waste exhibitions and conferences and following discussion (Biomass for Energy 2019, Waste Forum Kyiv 2019, Waste Management 2019, etc.)
Georgii Geletukha	The Bioenergy Association of Ukraine	PhD in Technical Sciences, Head of the Board of Bioenergy Association of Ukraine	Review of position papers and other communications, in person interviews and discussions

Svetlana Nemesh		Y-ISWA (Young International Solid Waste Association, Ukrainian branch)	In person interviews and discussions, electronic mail exchange
Tetyana Omelyanenko	Independent waste manager expert	PhD in economy sciences	Review of position papers and other communications, in person interviews and discussions, electronic mail exchange
Nonna Pavlyuk	Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine	PhD in Technical Sciences, Principal Scientist	In person interviews and discussions, electronic mail exchange
Ludmila Poltorachenko	Ministry of Development of Communities and Territories of Ukraine	Head of department	Participation in key waste exhibitions and conferences and following discussion (Biomass for Energy 2019, Waste Forum Kyiv 2019, Waste Management 2019, etc.), , electronic mail exchange
Oleg Popenko	NGO “Center of support of energy efficiency and ecology projects development”	Head of the Board	In person interviews and discussions. Participation in key waste exhibitions and conferences and following discussion (Biomass for Energy 2019)
Evgen Rubalchenko	Prof.Pererobka Ltd (Professional waste treatment)	CEO	In person interviews and discussions, electronic mail exchange
Sergey Savchuk	Clear Energy Company	Executive Director	In person interviews and discussions, electronic mail exchange
Vsevolod Savenko	LLC TSK	Executive Director	Discussions using social media and email communication