Ukraine

TECHNOLOGY NEEDS ASSESSMENT REPORT
MITIGATION

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Ministry of Ecology
and Natural Resources of Ukraine

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MITIGATION

TECHNOLOGY PRIORITIZATION

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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 reduce overall national GHG emissions as much as possible.

However, GHG emission reduction activity itself is not an end in itself, it should be a stimulus for growth of innovative economy sector, population welfare and creation of fare market conditions. Such goals could not be achieved without transfer of technologies.

Ukraine has submitted its 1st NDC in 2016 where committed not to exceed 60% of 1990 GHG emissions level in 2030. Now Ukraine is working to undertake even more ambitious commitments on GHG reduction which will be recognized in 2nd NDC that is planned to be accepted till the end of this year.

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.

Ostap Semerak

Minister of Ecology and Natural Resources of Ukraine

Preface

Ukraine plays an active role in international climate change cooperation processes being 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 achieving Paris Agreement's goals and being guided by national priorities, Ukraine will ensure 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 also has 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. The latest approved inventory was submitted in 2018 and it covers the period of 1990-2016. 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 early 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.

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 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 broader and more sound basis;
- Ensure the interlink of the State policy in the climate change with the strategies, policies, plans and programs of the economic and social development;
- Implement the 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 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 ensure the adequate technological assistance and create a favorable environment for technology development and transfer, as well as establish 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 project of Technology Needs Assessment is to support developing countries and the country with economy 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 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.

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

The applied methodology has been adjusted to the country-specific conditions. 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.

The current report provides the existing national policies on climate change mitigation and development priorities of the country, the inventory of greenhouse gases emissions, stakeholder engagement and the institutional arrangements of Technology Needs Assessment, the process of sector prioritization, the identification of criteria, the assessment of technologies on the selected sectors by using the multi-criteria approach and technology's prioritization.

In this report prioritized technologies are described in details, summary, description and main conclusions provided. Technological fact sheets can be found in Annex I and Annex II.

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

Waste sector is only one, where greenhouse gases emissions increased since 1990 and remain on 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 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 GHGs emissions both in Agriculture sector and Land Use, Change in Land Use and Forestry sector due to the intensive application of fertilizers and soil mineralization.

These two sectors were selected for Technology Needs Assessment by the Ministry of Ecology and Natural Resources of Ukraine based on Ukraine's international commitments (the United Nations Convention on Climate Change, Paris Agreement, EU association etc.), scientific reports (the Assessment Reports of Intergovernmental Panel on Climate Change), progress in national policy (strategies, plans, laws, concepts), statistical analysis (the trends of greenhouse gases emission, economy indicators etc.) and national socio-economic trends.

Main arguments for the selection of Agriculture and Waste directions for mitigation activity in Ukraine are:

- The Solid waste management is one of the most conservative types of economy's activities in Ukraine that did not change its structure and key indicators since 1990. This sector is only one that has a trend of upward greenhouse gases emission since 1990.
- The Agriculture sector is one of the main economy sectors in Ukraine and gets large share in the structure of gross domestic product year by year. As well as the Waste sector, it has had a trend of upward greenhouse gases emission during the last decade.

Supporting the implementation of agricultural climate technologies will have the impact far beyond the reduction of greenhouse gases emissions in the agriculture sector. Climate technologies in Agriculture in addition to emissions reduction from agricultural soils, manure management and enteric fermentation will lead to the reduction emissions in energy sector due to the use of biomass to substitute fossil fuel, industry sector due to lower emissions related to ammonia production and fossil fuel combustion by machinery, as well as land use, change in land use and forestry sector due to the increased carbon sequestration caused by organic agriculture and conservative tillage practices. Besides, such technologies have climate adaptation co-benefits related to more efficient use of water and lower dependency on weather conditions.

Similarly, supporting the implementation of practices for the modern waste treatment will lead not only to the reduction of the greenhouse gases emissions in the Waste sector, but also to decrease of emissions in other sectors, such as Energy, Industry and Agriculture. The Waste sector has the most significant indirect ("hidden") reduction potential of greenhouse gases emission due to the fact that it could generate energy and material resources for other sectors.

On the basis of the proposed Technology Needs Assessment methodology, national experts have prepared a long list of possible technologies and technological fact sheets for each listed technology. Criteria for the prioritization of technologies have been clustered under Economic, Social, Environmental, Climate Related, Political, Technological and other groups. On the basis of documents for current national strategy and expert judgments, the following criteria were selected for the prioritization of mitigation technologies:

Agriculture sector (1-100)	**Waste sector (score 1-100)**
Economic: • *Capital expenditures* • *Operational expenses*	**Economic:** • *Capital expenditures* • *Operational expenses* • *Income*
Social: • *The potential of job creation* • *Impact on the human health and the level of morbidity*	**Climate related** • *The potential of GHG reduction* • *CO_2-eq. reduction cost per ton*
Environmental: • *Impact on water resources* • *Impact on land resources*	**Political** • *Coherence with national plans and goals* • *Coherence with the hierarchy of waste management*
Climate related: • Reduction of GHGs emissions • Climate change adaptation co-benefits	**Technological** • *Stage of technology development (maturity), the status of technology development in the country* • *Potential scale of implementation (market volume)* • *Implementation's complexity*

Other:

- *Aligning with state policy priorities*
- *Potential for replication in the country*

Social

- *Social benefits in term of jobs, health, waste management coverage etc.*
- *Gender aspects*

Environmental

- *Environmental benefit in term of air pollution*
- *Environmental benefit in term of water and soil pollution*

The expert evaluation of the technologies and further scoring based on the weights assigned to each criterion resulted in the list of prioritized technologies for each of the two sectors.

Mitigation technologies for Agriculture sector that received the highest scores include:

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 reductions of greenhouse gases emission in agriculture.

The five prioritized technologies have a potential to reduce greenhouse gases emissions by 24.6 Mt CO_2-eq., while the overall potential for the reduction of carbon emission of ten reviewed technologies is 34.5 Mt CO_2-eq.

For Waste sector the list of prioritized mitigation technologies includes:

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

The results of the technology prioritization process were shared with the members of the working groups and will be provided for all interested stakeholders to ensure the dissemination of project result and provide an opportunity to give feedback and comments. Feedback from stakeholders will be taken into account during the next steps for the process of the Technical Needs Assessment, which include the assessment of barriers to the implementation of prioritized technologies and the preparation of technology action plans.

The results of the Technology Needs Assessment project will be used in ongoing process of Ukraine's Nationally Determined Contribution revision.

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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
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
PPP	Purchasing Power Parity
RES	Renewable Energy Sources
RDF	Refused Derived Fuel
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 Introduction

1.1 About the TNA project

Technology Needs Assessment (TNA) is a country-driven set of activities directed mainly at the identification and prioritization of climate change mitigation and adaptation technologies. TNA supports national sustainable development, builds national capacity and facilitates the implementation of prioritized climate technologies.

The concept of TNA was formalized at 7th Conference of Parties under the United Nations Framework Convention on Climate Change (UNFCCC) process in 2001 by establishing the technology transfer framework with the purpose of increasing and improving transfer and access to environmentally sound technologies and know-how. The overall approach involves the cooperation among various stakeholders (private sector, governments, donor communities, bilateral and multilateral institutions, non-governmental organizations as well as academic and research institutions), including activities on TNAs, technology information, enabling environments, capacity building and mechanisms for technology transfer (COP 7, 2001).

Since 2001, during the three phases of the TNA Global Project more than 80 developing countries have undertaken TNAs to assess their technology needs to address climate change.

TNAs are conducted under the support of the Global Environment Facility, through its Poznan strategic programme on the technology transfer and under the technical and methodological support from UNEP Danish Technical University Partnership (UNEP DTU Partnership).

In 2017 Ukraine submitted a letter of endorsement to conduct a TNA in order to contribute to the priorities prescribed by Ukraine's nationally determined contribution (NDC), in particular:

(i) the development of a long-term action plan for climate change mitigation and adaptation;

(ii) the designing and implementation of long-term actions aimed at reducing greenhouse gas emissions; and

(iii) the development and implementation of measures aimed at increasing the absorption of greenhouse gases.

Ukraine was included as an emerging economy country in Technology Needs Assessments - Phase III (TNA Phase III) Project (GEF-6, 2017). In 2018 the Ministry of Ecology and Natural Resources of Ukraine signed a Memorandum of Understanding with UNEP DTU Partnership for Conducting a Technology Needs Assessment Project in Ukraine. Project activities include in-depth analysis and prioritization of technologies, analysis of potential barriers hindering the transfer of prioritized technologies and the analysis of potential market opportunities at the national level.

The key deliverables of the TNA are the following:

- TNA report describing the prioritized technologies for mitigation and adaptation in selected sectors including the process followed and the rationale for latter;
- Barrier Analysis and Enabling Framework (BA&EF) report on existing barriers for the prioritized technologies and enabling framework to facilitate the deployment and diffusion of technology priorities;
- Technology Action Plan (TAP) reports for mitigation and adaptation describing the approach for the uptake and diffusion of prioritized technologies that will contribute to the country's social, environmental and economic development.

1.2 Existing national policies on climate change mitigation and development priorities

National policy on climate change mitigation is guided by the main strategic documents in the area of economic development, energy, and environmental protection.

<u>Development priorities</u>

The Strategy for Sustainable Development "Ukraine 2020" is guided by the provisions of EU-Ukraine Association Agreement and declares national development priorities aiming at the introduction of European standards of living (SDSU, 2015). In turn, the EU-Ukraine Association Agreement envisions the gradual approximation of Ukraine's legislation to EU acquis, including directives and regulations in the areas of energy efficiency, renewable energy, and climate change (AA, 2014).

There are four development priorities defined by the «Ukraine – 2020» the Sustainable Development Strategy:

- development sector – safeguarding the sustainable development of the economy and structural reforms, including energy reform, energy efficiency program, agriculture sector reform, land reform, and reform of housing and utility sector;
- safety sector – ensuring the national security, energy security, the safety of business operation and individual safety, including safe environmental conditions;
- responsibility sector – safeguarding rights for education and medical help for every citizen, as well as the decentralization of governance system;
- vector of pride – ensuring the mutual respect and tolerance in the society, as well as pride for the state, its history, culture, science and sport.

The Strategy includes ten priority reforms focusing mainly on the national security and governance system (anti-corruption, judicial reform, reform of the law enforcement system, decentralization, etc.) but also includes the energy independence program.

The energy independence program aims at ensuring the energy security and transition to the efficient use of energy and consumption of energy resources and energy saving by using innovative technologies. The main goals of the state policy in this area include the reduction of energy intensity of GDP by 20% with the target of 0.2 toe per USD 1000 by the end of 2020, energy resources supply diversification, the liberalization of energy market and investment in the modernization projects of energy infrastructure.

Energy Policy

The Energy Strategy of Ukraine for the period till 2035 “Security, energy efficiency, competitiveness” defines key goals of the state energy policy and aims at solving energy security problem under the conditions of external aggression. Reducing the energy intensity of the economy, diversification of energy sources and supply routes and strengthening the national production will support the increase of economic, energy and environmental security and create grounds for sustainable energy future of the country (ESU, 2017).

Due to the expected economic recovery of Ukraine, the Energy Strategy envisions the growth of energy demand. Though the coal-fired power generation and nuclear energy are expected to continue covering a significant share of energy demand, renewable energy sources are considered as an important factor of Ukraine’s energy independence. The share of renewables is planned to be increased to 25% till 2035 in total primary energy supply and exceed 25% in the electricity generation.

The Energy Strategy also includes a number of targets for improving the energy efficiency both economy-wide and in the specific sectors and a target on reducing total GHGs emissions as indicated in Table 1.1 below.

Table 1.1. The Energy Strategy Indicators

Indicator	2015	2020	2025	2030	2035
GDP energy intensity, TPEC toe per USD 1000 of GDP (PPP)	0.28	0.20	0.18	0.15	0.13
Fuel use for power generation by thermal power plants, gram of coal equivalent per kWh	396	384	367	353	334
Electricity losses during transmission and distribution, %	> 12%	10%	9%	8%	< 7.5%
The share of renewables (including large hydro) in power generation, %	5%	7%	10%	> 13%	> 25%
The share of renewables (including large hydro) in total primary energy consumption, %	4%	8%	12%	17%	25%
CO_2 emissions compared to 1990 levels	-	< 60%	< 60%	< 60%	< 50%

In terms of heat energy generation, the Concept of State Policy Implementation in the Area of Heat Supply envisions the following key expected results of heat supply system modernization before 2035 (CSPIAHS, 2017):

- to ensure quality, reliable, safe and affordable district heat energy supply services and the supply services of hot water, as well as the increased payment rate for services provided;
- to increase the share of alternative energy sources to 40% and strengthen energy independence of the country;
- the reduction of heat energy losses to 10 % and to implement energy-saving measures and 100% consumption-based billing.

Energy policy is also guided by national action plans in the areas of renewable energy and energy efficiency:

- National Renewable Energy Action plan up to 2020 envisions that by 2020 the share of energy produced from renewables shall amount to 11% of energy consumption mix (NREAP, 2014);
- National Energy Efficiency Action Plan up to 2020 envisions to reach in 2020 the indicative energy saving target at the level of 9% from the average final energy consumption for the period 2005-2009 (NEEAP, 2015).

<u>Environmental Policy</u>

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 will be enforced starting from the 1st of January, 2020 (LU SEPU, 2019).

The main grounds of state environmental policy defined by the Environmental Strategy include a number of climate-related aspects:

- preserving the climate system in a state, which will make impossible the increase of risks to human health and wellbeing, as well as to the environment;
- achieving sustainable development goals;
- providing incentives to economic entities reducing GHGs emission reductions, improving energy and resource efficiency and implementing modernization measures with the positive environmental effect.

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 sustainable low carbon development of all areas of the Ukrainian economy. The specific target referenced in the Environmental Strategy is the reduction of GHGs emissions to the amount lower than 60% of emissions level in 1990.

<u>Climate Policy</u>

Ukraine was among the first countries to ratify the Paris Agreement in July, 2016 (LU RPA, 2016). Ukraine has prepared and communicated a nationally determined contribution (NDC) that it intends to achieve with the level of GHG emissions not exceeding 60% of 1990 GHG emissions level in 2030 (NDC, 2016). The NDC covers such economic sectors as energy; industrial processes and product use; agriculture, land use, land-use change and forestry; and waste.

The start of the revision process of Ukraine's NDC has been announced by the Minister of Environment and Natural Resources at COP24 in Katowice.

The priorities of national climate policy are defined in the Concept of State Policy Implementation in the Area of Climate Change for the Period till 2030 (CSPIACC, 2016). The defined goal of the state climate policy is to ensure the achievement of nationally determined contribution for 2030, as well as to ensure NDC ambition increase before 2020 taking into account the conditions of social and economic development of the country.

An action plan on the implementation of the Concept of state policy implementation in the area of climate change for the period till 2030 was approved in 2017 (AP, 2017). The document foresees the implementation of a number of climate-related policies (e.g. monitoring, reporting and verification and emission trading, the improvement of fiscal instruments for GHGs emission reduction, public-private partnership tools, etc.) and the development and approval of a complex National plan on energy and climate for the period 2021-2030 in the year 2020.

<u>Low Emissions Development Strategy</u>

Ukraine has submitted its Low Emissions Development Strategy to the UNFCCC Secretariat in 2018 (LEDS, 2017). According to the LEDS, being committed to achieving Paris Agreement goals and being guided by national priorities, Ukraine ensures that it will do its best to achieve the indicative GHG emissions target of 31-34% by 2050, compared to 1990 level.

The LEDS includes three main objectives:

- Objective I: Transition to energy system which envisions the use of energy sources with low carbon content, the development of the sources for clean electricity and heat energy, increase in energy efficiency and energy saving in all sectors of economy and at housing and utilities infrastructure facilities, stimulating the use of alternative to oil motor fuels and transition of cargo and passenger carrying operations to more environmentally clean types of transport;
- 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.

It can be seen that LEDS includes information on policies and measures aimed at the reduction of methane and nitrogen emissions, in particular, in waste and agriculture sectors.

Thus, climate aspects are integrated into existing national policies and development priorities with the focus on mitigation activities and in particular energy and industry sector. Other sectors, such as agriculture and waste are also incorporated into main policy documents, but with a few details on potential mitigation options and supporting policies.

The Waste Management Policy

The national waste treatment system in Ukraine is directed by harmonization with EU principles and practices. Currently, the acting legislation is partly out-of-date being based on Law "On Waste" (LW, 1998). The draft of new laws regarding waste have been developed in line with Directive 2008/98/EU. Now they have passed negotiation procedures. These laws are planned to be entered into force as soon as possible.

Nevertheless, a number of positive steps have been taken for the policy reform of national waste management during the last two years. Among them, the National Waste Management Strategy up to 2030. It was approved by the Cabinet of Ministers of Ukraine in 2017 (NWMS, 2017) identifying ambitious goals to be reached by 2030. The National Waste Management Plan up to 2030 (NWMP, 2019) was approved in 2019 specifying the mechanism to implement the strategy.

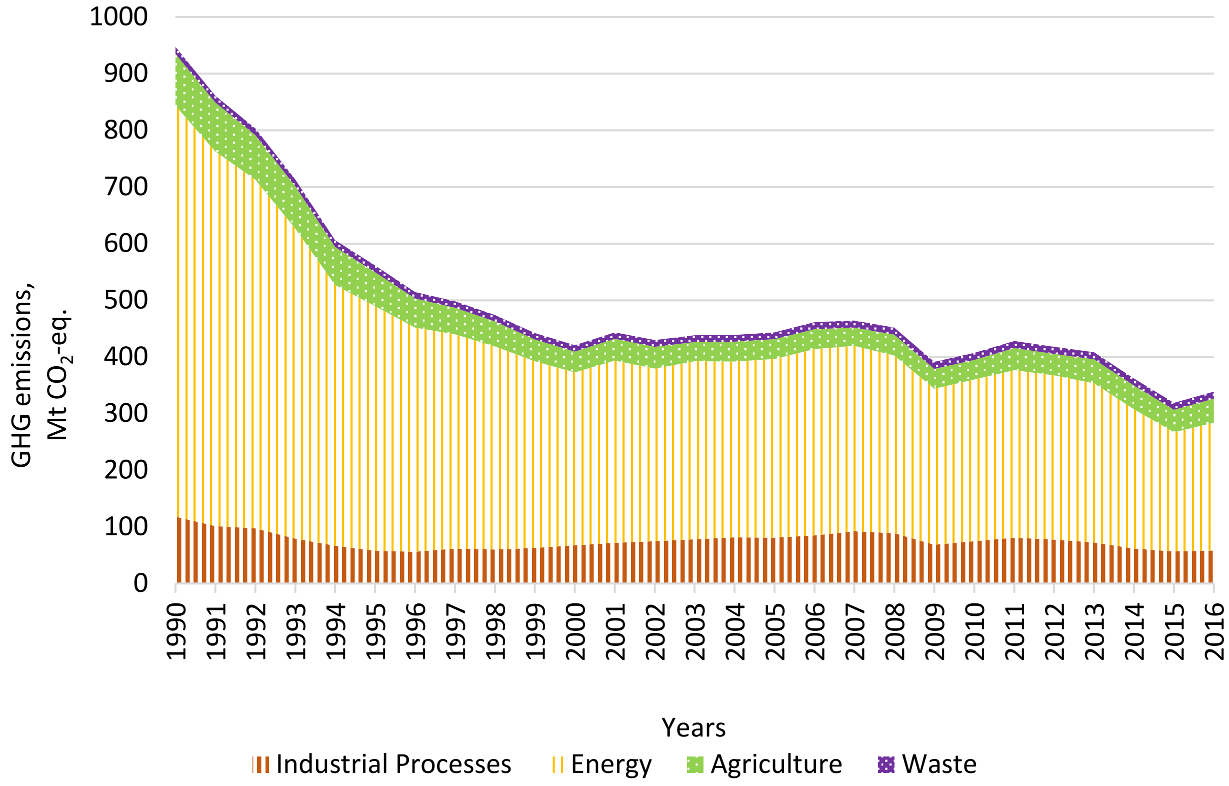
1.3 Sector selection

1.3.1 An overview of sectors, projected climate change, GHG emissions status and trends of the different sectors

Historical GHG emission trends

According to the latest Ukraine's GHG Inventory (GHGI, 2018), the overall national GHG emissions have decreased dramatically since 1990. Thus, total GHG emissions (excluding LULUCF) for 2016 were equal to 338.64 Mt CO_2-eq. being below 64.25 % in 1990.

Nevertheless, such an overall downward trend consists of opposing tendencies by specific sectors and emission sources through the time series. Figure 1.1 illustrates overall and sectoral GHG emission trends in Ukraine for the 1990-2016 period. In 2016 compared to base year 1990, GHG emission reduction in Energy was equal to 68.87 %, Industry – 50.81 %, Agriculture – 53.88 %. Only one with upward GHG emission trend in Ukraine is Waste sector with the increased amount of emissions equal to 3.70 %.



Source: https://unfccc.int/

Figure 1.1 – GHG emission trends in Ukraine by sectors, 1990-2016

During latest reporting decade GHG emissions continued to decrease in Energy and Industrial sectors, being stable in Waste sector and increasing in Agriculture sector.

Table 1.2 reflects the GHG emission changes by sectors and IPCC categories in 2016 compared to base year 1990 and 2007 (last reported decade), where sectors with upward trend in 2016 compared to 1990 either 2007 are marked with yellow, categories with GHG emissions more than 1 Mt of CO_2-eq. or the stable downtrend is marked with green.

Table 1.2. GHG Emission changes by categories in Ukraine

Sector/subsector/category	GHG emissions, Mt CO_2-eq.			Change from 1990 to 2016	Change from 2007 to 2016
	1990	2007	2016	%	%
1. Energy	725.32	327.21	225.79	-68.90	-31.00
A. Fuel combustion	597.85	252.69	179.83	-69.9	-28.8
1. Energy industries	272.68	128.50	101.46	-62.8	-21.0
2. Manufacturing industries and construction	111.26	40.28	17.93	-83.9	-55.5
3. Transport	111.79	44.94	32.21	-71.2	-28.3
4. Other sectors	102.01	38.90	27.71	-72.8	-28.8
5. Other	0.11	0.07	0.53	400.1	632.0
B. Fugitive emissions from fuels	127.47	74.52	45.96	-63.9	-38.3
1. Solid fuels	62.38	24.52	16.62	-73.4	-32.2
2. Oil and natural gas and other emissions from energy production	65.09	50.00	29.34	-54.9	-41.3
2. Industrial Processes	117.99	92.15	58.04	-50.8	-37.0
A. Mineral industry	15.11	10.05	6.40	-57.6	-36.4
B. Chemical industry	17.63	15.89	5.01	-71.6	-68.5
C. Metal industry	84.81	65.37	45.45	-46.4	-30.5

Sector/subsector/category	GHG emissions, Mt CO_2-eq.			Change from 1990 to 2016	Change from 2007 to 2016
	1990	2007	2016	%	%
D. Non-energy products from fuels and solvent use	0.43	0.22	0.13	-70.7	-42.5
E. Electronic industry	0.00	0.00	0.00	-	-
F. Product uses as ODS substitutes	0.00	0.56	0.89	-	58.4
G. Other product manufacture and use	0.02	0.06	0.17	1005.9	169.3
3. Agriculture	92.02	32.45	42.44	-53.9	30.8
A. Enteric fermentation	45.92	14.00	10.75	-76.6	-23.2
B. Manure management	7.31	2.24	2.13	-70.9	-5.3
C. Rice cultivation	0.22	0.16	0.09	-58.8	-43.2
D. Agricultural soils	35.71	15.73	28.88	-19.1	83.6
E. Prescribed burning of savannas	0.00	0.00	0.00	-	-
F. Field burning of agricultural residues	0.00	0.00	0.00	-	-
G. Liming	2.59	0.11	0.14	-94.6	24.7
H. Urea application	0.27	0.21	0.46	69.4	115.7
4. Land use. land-use change and forestry	-57.97	-42.56	-17.99	-69.0	-57.7
A. Forest land	-63.34	-57.70	-66.27	4.6	14.9
B. Cropland	-4.64	13.61	47.25	-1117.8	247.3
C. Grassland	-0.95	-2.43	-0.74	-21.7	-69.6
D. Wetlands	12.03	0.26	0.16	-98.7	-38.6
E. Settlements	0.00	0.70	0.65	21319.8	-8.2
F. Other land	1.72	2.45	0.25	-85.3	-89.6
G. Harvested wood products	-2.79	0.55	0.71	-125.4	28.5
5. Waste	11.92	12.38	12.37	3.7	-0.1
A. Solid waste disposal	6.53	7.86	8.23	26.0	4.7
B. Biological treatment of solid waste	0.03	0.00	0.03	0.9	620.3
C. Incineration and open burning of waste	0.04	0.06	0.01	-68.7	-80.5
D. Waste water treatment and discharge	5.32	4.45	4.09	-23.1	-8.2
Total, including LULUCF	889.28	421.63	320.64	-63.9	-24.0
Total, excluding LULUCF	947.25	464.19	338.64	-64.3	-27.0

Source: https://unfccc.int/

Waste sector is the only one sector which has an upward GHG emissions trend since 1990, for which GHG emissions have increased by 3.7 % in 2016 since 1990 being more or less stable during the last decade. Besides this, Agriculture sector is other sector for which GHG emissions have been decreased (by 53.9 %) in 2016 since 1990, nevertheless, they have increased during the last reporting decade by 30.6 %. For Energy and Industry sectors, GHG emission trends are constantly decreasing.

Projected climate changes

The latest all-encompassing projections on the issue of climate change in Ukraine under the UNFCCC obligations were published in Sixth National Communication (NC6, 2013). According to NC 6, it’s expected significant change in climate indicators both for national and regional levels during 20 years in future: in 2011-2030, 2031-2050 and as for the end of the XXI century (2081-2100) compared to historical 1991-2010 period. In particular, these changes are expected to be reflected in the following:

- the growth of average air temperature in the months of Summer as well as increasing of days with high and extreme temperatures;
- the growth of average air temperature in the months of Winter as well as increasing of precipitation amounts;

- the reduction of average values for river flows;
- increase in quantity and seasonal unevenness for precipitations;
- increase in the frequency of extreme rainfall and drought;
- the increased frequency of extreme weather events;
- the intense acidic precipitation;
- increase in the salinity of rivers and reservoirs.

Detailed forecasts for average annual air temperature changes in Ukraine are shown in tables 1.3 (a) and 1.3 (b) below.

Table 1.3 (a). – The projected average annual air temperatures for 20-year periods in Ukraine, ºC.

Region	Average annual air temperature		
	2011-2030	2031-2050	2081-2010
Northern	8.6	9.5	11.2
Western	8.4	9.3	11.1
Central	9.3	10.2	12.0
Eastern	9.2	10.2	12.0
Southern	10.9	11.8	13.7
Ukraine	9.3	10.2	12.0

Source: https://unfccc.int/

Table 1.3 (b). – The changes of expected annual average air temperatures changes in Ukraine compared to 1991-2010 period, ºC

Region	Changes of average annual air temperature compared to 1991-2010		
	2011-2030	2031-2050	2081-2010
Northern	0.45	1.36	3.08
Western	0.41	1.24	3.03
Central	0.44	1.39	3.14
Eastern	0.50	1.48	3.29
Southern	0.43	1.41	3.23
Ukraine	0.44	1.37	3.15

Source: https://unfccc.int/

In general, it's expected that the average annual temperature will constantly increase for all the regions of Ukraine during this century and reach the value of 3.15 ºC at the national level for the latest 20-year period of the XXI century compared to historical period of 1991-2010.

Projected GHG emission status and trends

Issues related to the prediction of the GHG emissions in Ukraine were considered in the following documents reported by the state:

- Ukraine's First National Communication on Climate Change (NC1, 1998);
- Ukraine's Second National Communication on Climate Change – (NC2, 2006);
- Ukraine's Third, Fourth and Fifth National Communication on Climate Change, (NC3-5, 2009);
- Ukraine's Sixth National Communication on Climate Change (NC6, 2013, provided in table 1.4);
- The Intended Nationally-Determined Contribution of Ukraine to a New Global Climate Agreement, (INDC, 2015);
- Ukraine's 2050 Low Emission Development Strategy (LEDS, 2017).

NC6 is the latest Ukraine's officially approved document which includes GHG emission forecasts for all the UNFCCC sectors, namely: Energy, Industry, Agriculture, LULUCF and Waste up to 2030.

Table 1.4. – Forecasted GHG emissions in Ukraine by 2030, kg CO_2-eq.

Sectors	Scenario without measures		Scenario with measures		Scenario with additional measures	
	2020	2030	2020	2030	2020	2030
Energy	386 840	607 310	334 086	423 377	326583	401343
Industry*	62261	97744	72190	68267	72190	68267
Agriculture	45 895	72 052	43 100	43 800	43100	43800
LULUCF	0	0	-11 340	-17 190	-11340	-17190
Waste	11 267	11 492	9 000	6 000	9 000	6 000
Total, including LULUCF	**507 152**	**789 994**	**448 125**	**525 260**	**440 257**	**502 776**
Total, excluding LULUCF	**507 152**	**789 994**	**459 465**	**542 450**	**451 597**	**519 965**

*including solvent and other product use

Source: https://unfccc.int/ (NC6, 2013)

Nevertheless, most of the published reports on Ukraine's GHG emission projections, including NC6, are out-of-day 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 LEDS which was focused mostly on Energy and Industry sectors without conducting the deep analysis in Agriculture and Waste sectors.

To update Ukraine's NDC, project "Support to the Government of Ukraine on updating its Nationally Determined Contribution (NDC)" under the support of EBRD on updating Ukraine's NDC has been launched on November 2018 finishing by the end of 2019 or early 2020. The results of this project will include the detailed information on GHG emission forecasts till 2030 and vision by 2050 for all the sectors of UNFCCC, reporting formats are planned to be taken into account in the reports of further stages under TNA activity.

1.3.2 The process and results of sector selection

The TNA covers Agriculture, Waste and Water sectors in Ukraine. The TNA for climate change mitigation is focused on Agriculture and Waste sectors, Agriculture and Water sectors are the objects for the adaptation activity of climate change.

These directions were identified by the Ministry of Environment and Natural Resources of Ukraine on the basis of Ukraine's international commitments (UNFCCC, Paris agreement, EU association etc.) and scientific reports (Assessment Reports of IPCC), progress in national policy (strategies, plans, laws, concepts), statistical analysis (GHG emission trends, economy indicators etc.) and national socio-economic trends.

This view was openly and widely discussed during the national workshop which took place in Kyiv on the 21st August, 2018. (see Annex V) where stakeholders (central and regional authorities, international donors, scientific institutions and NGOs) confirmed the relevance of above-mentioned choice and recommended to approve this list of proposed directions to be conducted in TNA activity. Moreover, a number of stakeholders informed that they are interested in actively contributing to TNA process to get the solid profitable result of the project.

Main arguments for this selection TNA activity directions in Ukraine are following.

Waste: the solid waste management is one of the most conservative branches of Ukrainian economy that did not change its structure and key indicators since the collapse of USSR (it is illustrated by figures 4.3-4.5). This sector is only one that has an upward GHG emission trend since 1990.

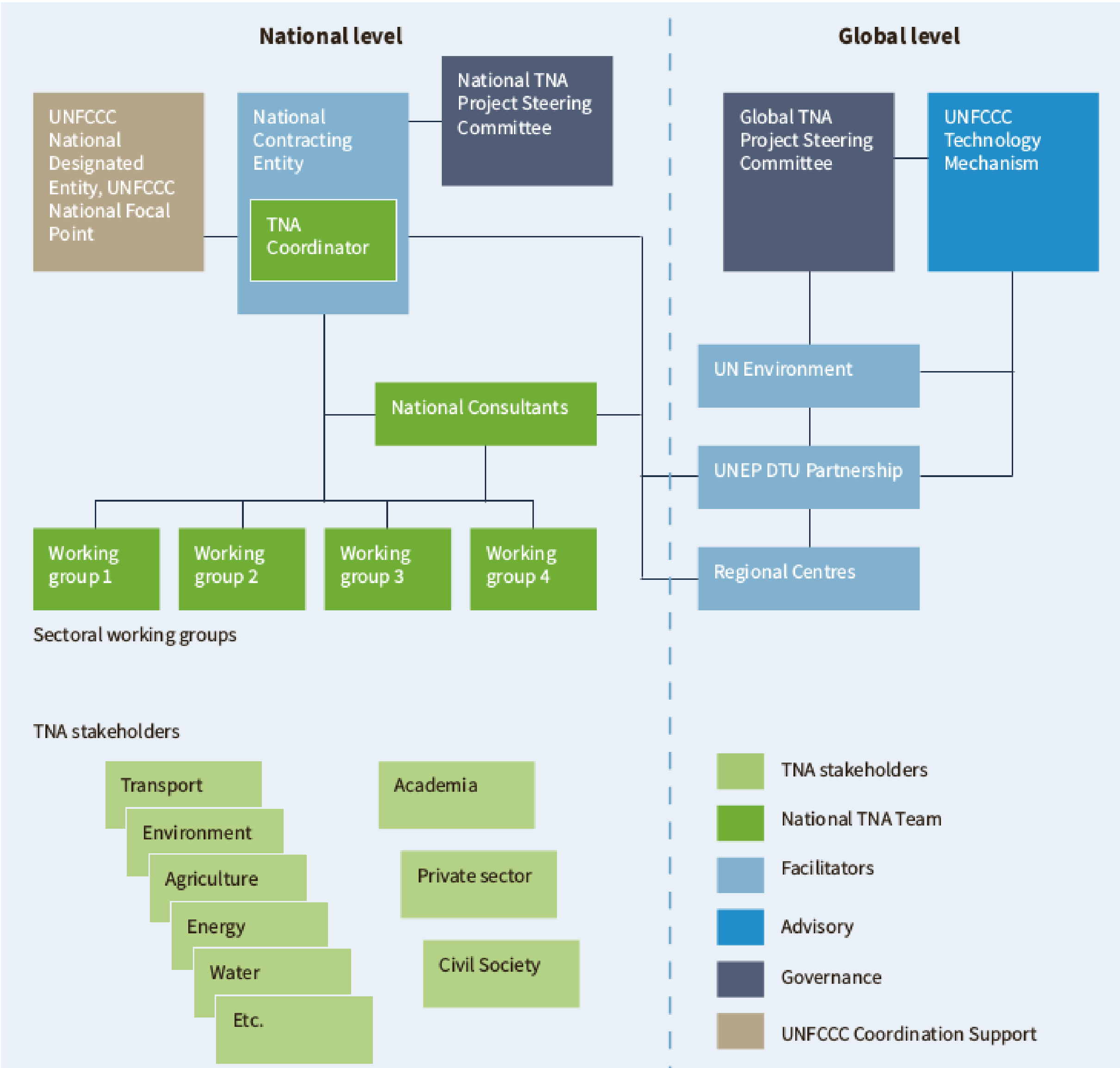
Agriculture: agriculture sector is one of the main economy sectors and gets large share in GDP structure year by year. As well as the Waste sector, it has had an upward GHG emission trend during the last decade.

Chapter 2 The institutional arrangement for the TNA and the stakeholder involvement

2.1 National TNA team

The Ministry of Ecology and Natural Resources of Ukraine is a designated national institution, which leads and coordinates the TNA process in Ukraine.

The essential elements of the institutional arrangement of the TNA process within the country include a TNA Coordinator, a National TNA Committee, National Expert Consultants and Sector working groups (see fig. 2.1).



Source: (Haselip, et al., 2019)

Figure 2.1 – TNA Institutional set-up

<u>TNA Coordinator</u>

The Ministry of Ecology and Natural Resources of Ukraine designated Mr. Anatolii Shmurak as a TNA Coordinator for Ukraine. Mr. Shmurak is the 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, the NDE Focal Point and also nominated from Ukraine into the UNFCCC Roster of Experts.

<u>National TNA Committee</u>

The role of the National TNA Committee is assigned to the Inter-agency Commission on the implementation of the United Nations Framework Convention on Climate Change (UNFCCC). Inter-agency Commission on the implementation of the UNFCCC is an advisory body for the coordination of activities on different aspects related to climate change. The commission was created by the Cabinet of Ministers of Ukraine in 1999 and it includes officials at the level of Deputy Ministers of key ministries and other executive bodies, the members of Ukrainian parliament, representatives of R&D institutions and NGOs.

The role of the National TNA Committee is to provide the high-level guidance to the national TNA team and help to secure political acceptance for the TAP. The first meeting of the National TNA Committee has been conducted within the meeting of the Inter-agency Commission on implementation of the UNFCCC on 15 of May 2019 and included presentation of the TNA project by National TNA Coordinator.

National Consultants

TNA in Ukraine is performed with the involvement of national mitigation and adaptation experts. The lead National Consultants were selected by the National TNA Coordinator in close consultation with UDP, following an open and transparent selection process.

Mitigation technologies are assessed by two experts on Waste sector (Dr. Yuri Matveev and Dr. Sergii Shmarin) and one expert in Agriculture sector (Dr. Mykola Shlapak).

National expert consultants are responsible for:

- identifying and prioritizing technologies for the specific sector through a participatory process with the broad involvement of relevant stakeholders and experts;
- leading the process of analysis, along with the stakeholder groups, how the prioritized technologies can be implemented in the country and how implementation conditions can be improved by addressing the barriers and developing an enabling framework;
- preparing TNA report.

National Consultants were responsible for the identification of the list of nominated technologies, selection criteria, development of questionnaires and guidance for technology assessment by the members of the sector working groups, as well as for the analysis of responses and preparation of the TNA report.

Sector working groups

Ministry of Environment and Natural Resources based on the suggestion of the National TNA Coordinator and National consultants established two working groups on mitigation technologies for Agriculture and Waste sectors and two working groups on adaptation technologies for Waste and Water sectors.

Working groups are comprised of experts from academic institutions, private companies, and non-governmental organizations. The members of the working groups contributed to the development of the list of nominated technologies and selection criteria and provided their assessment of the technologies based on the selected criteria.

2.2 Stakeholder Engagement Process followed in the TNA – Overall assessment

TNA process included stakeholder engagement activities. The list of relevant stakeholders was identified by national consultants in close cooperation with the National TNA Coordinator.

Stakeholders identified include government institutions and departments with responsibility for policy formulation and regulation in relevant sectors (i.e. Agriculture and Waste), private and public sector industries, business associations, technology end users and/or suppliers within private sector, relevant academic institutions and consultants, as well as international organizations and donors.

2.3 Consideration of Gender Aspects in the TNA process

Ukraine has adopted a Law of Ukraine On Ensuring Equal Rights and Opportunities for Women and Men, which aims at achievement of the parity of women and men in all spheres of society's life through the legal provision of equal rights and opportunities for women and men, as well as the elimination of gender discrimination and eliminating the imbalance between the opportunities of women and men to exercise equal rights conferred upon them by the Constitution and laws of Ukraine (LU EEROWM, 2005).

The Cabinet of Ministers of Ukraine appointed the position of the Governmental Commissioner for Gender Policy, who is responsible for the coordination of work of all ministries and state authorities on the gender issues, as well as monitoring the compliance with the principle of gender equality, assistance in the development of relevant state programs and cooperation with international organizations and civil society (CMU, 2017).

In 2018, the Cabinet of Ministers of Ukraine adopted the State Social Program on Ensuring Equal Rights and Opportunities for Women and Men for the Period till 2021 (SSPOEEROWM, 2018). Legislative acts and regulations adopted in Ukraine are subject to legal review on conformity with the legislation on gender issues (CMU GE, 2018).

Climate change affects women and men differently, as in all countries it has a greater impact on those sections of the population that are most reliant on natural resources for their livelihoods and/or have the least capacity to respond to natural hazards, such as droughts, landslides, floods and hurricanes (De Groot, 2018).

National TNA team is comprised of both men and women. Among 6 national consultants there are 4 men and 2 women. All national TNA team members were acquainted with the “Guidance for a gender-responsive Technology Needs Assessment” to ensure familiarity with gender analysis tools and processes.

Women were involved in the decision-making process at all stages of technology needs assessment in Ukraine. In the working group “Mitigation technologies for agricultural sector” women comprised 33% of all members (7 out of 21 experts). In the working group “Mitigation technologies for waste sector” there were 47% of women (7 out of 15 experts). National consultant ensured that behaviors, aspirations and needs of women and men were considered, valued and favored equally, as well as ensuring women’s full and effective participation and equal opportunities for leadership at all levels of decision-making within the technology needs assessment process.

Stakeholder consultation process ensured that both women and men have an opportunity to voice their opinions and provide their perspectives.

Chapter 3 Technology prioritization for Agriculture Sector

3.1 GHG emissions and existing technologies of the Agriculture Sector

According to Ukraine's Greenhouse Gas Inventory 1990-2016, Agriculture sector generated GHGs emissions in the amount of 42.44 million tons of CO_2-eq. in 2016 and the share of the sector in total GHG emissions without LULUCF was 12.5% (GHGI, 2018).

During 1990-2016 emissions in the Agriculture sector decreased by 53.88% due to the reduction in the number of livestock animals and changes in the consumption of feed and diets, decreased amounts of fertilizer and liming materials applied, as well as changes in manure management practices (i.e. replacement of liquid manure management systems with solid storage at cattle-raising enterprises). The overall reduction in GHGs emissions in Agriculture sector comparing to 1990 is lower than the reduction of total GHGs emissions in Ukraine (-64.3%) and during last 5 years emissions levels remained relatively stable at the level of 38-42 million tons CO_2-eq. (GHGI, 2018).

The major current sources of emissions in the Agricultural sector are agricultural soils (68%), enteric fermentation (25%) and manure management (5%), while the contribution of the other categories accounts for only about 2% (see Fig. 3.1).

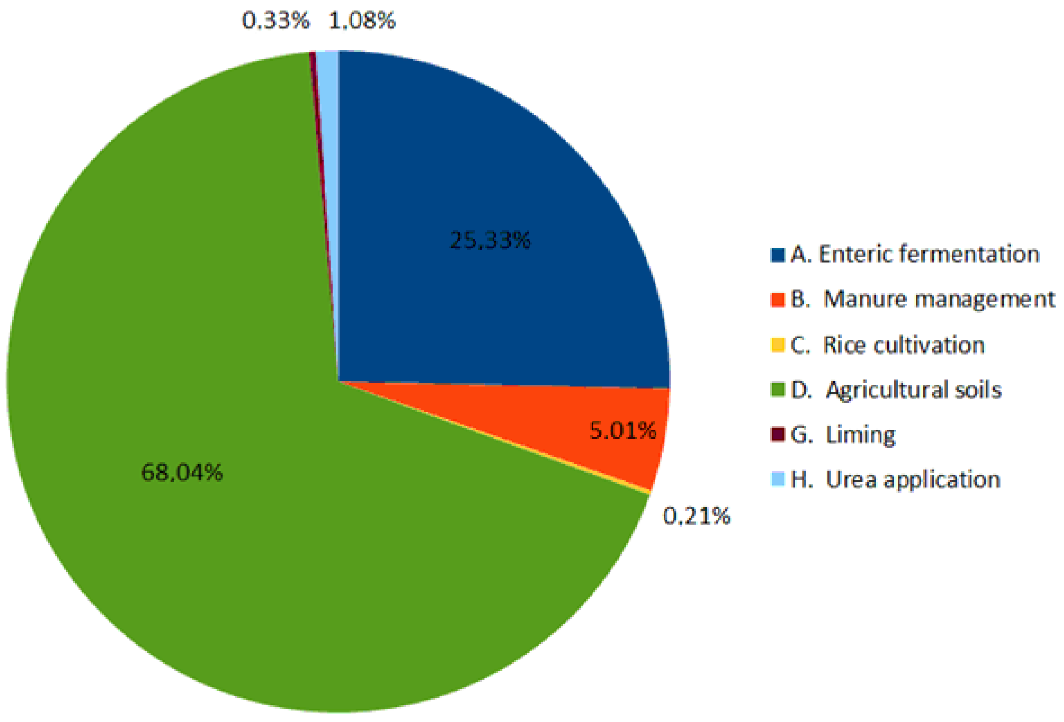


Figure 3.1 – GHGs emissions structure in Ukraine in 2016

The key GHGs gases in the Agriculture sector are nitrous oxide (70.56%) and methane (28.04%), while the share of CO_2 emissions (emissions from liming and urea application) is only 1.41%.

The volume of CH_4 emissions was 475.95 kt in 2016 and the main source was enteric fermentation (90.4%).

The Agriculture sector is the largest source of nitrous oxide emissions in Ukraine responsible for the 86.3% of total nitrous oxide emissions in 2016. The volume of N_2O emissions in Agriculture sector was 100.49 kt in 2016 and the main sources were agricultural soils (96.4%). The level of emissions is determined mainly by the grain and leguminous crops harvest volumes and resulted volumes of the amount of crop residues going into the soil, as well as the volumes of applied nitrogen fertilizers.

Manure management practices result in 8.9% pf sectorial CH_4 emissions and 3.6% of sectorial N_2O emissions in 2016.

Agricultural activities also impact GHGs emissions levels in other sectors of national emission inventory, including Energy (emissions from stationary fuel combustion in agriculture, mobile fuel combustion in agriculture, the substitution of fossil fuels with agricultural biomass residues, etc.) and LULUCF.

Agricultural soils

The Agricultural Soils category is the largest contributor to agricultural greenhouse gases emissions in Ukraine and the largest source of nitrogen dioxide emissions.

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.

The main contributors to N_2O emissions from agricultural soil include crop residues (including nitrogen fixation), inorganic nitrogen fertilizers and mineralization associated with the loss of soil organic matter resulting from the change of land use or the management of mineral soils, which together were responsible for the 70.6% of emissions in the category in 2016 (see also Table 3.1).

Table 3.1 – The structure of N_2O emissions in agricultural soils category in Agriculture sector in Ukraine

Emissions' sources	N_2O, kt		CO_2-eq., kt		Share in the category	
	1990	2016	1990	2016	1990	2016
Inorganic N Fertilizers	28.89	19.59	8,611	5,838	24.1%	20.2%
Organic N Fertilizers	8.58	2.37	2,557	705	7.2%	2.4%
Urine and Dung Deposited by Grazing Animals	12.79	4.27	3,812	1,272	10.7%	4.4%
Crop Residues	46.26	32.65	13,784	9,729	38.6%	33.7%
Mineralization Associated with Loss of Soil Organic Matter		18.60	0	5,542	0.0%	19.2%
Cultivation of Organic Soils	5.99	6.01	1,786	1,792	5.0%	6.2%
Atmospheric Deposition	7.31	3.77	2,177	1,124	6.1%	3.9%
Nitrogen Leaching and Run-off	10.01	9.64	2,983	2,874	8.4%	10.0%
Total	119.83	96.90	35,710	28,876	100.0%	100.0%

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. According to the data of 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 ratio and the expending area of agricultural land, where synthetic fertilizers are applied (SSU, 2019). The average N input per hectare of land where synthetic fertilizers were applied has increased almost by 45% from 57.2 kg N per ha in 2008 to 82.7 kg N per ha in 2017, which is even greater than the N input ratio in 1990 (70.4 kg N per ha). Simultaneously, the land area, where synthetic fertilizers have been applied, has grown from 12.9 million ha to 16.5 million ha. This value is still below the relevant parameter for the year 1990, when the area of land with the application of synthetic fertilizers was equal to 26.4 million ha. Therefore, there is a potential for further growth of N_2O emissions from synthetic fertilizers application in Ukraine.

In 2016, GHGs emissions from synthetic fertilizers application were equal to 5.8 million tons CO_2-eq. or 13.8% of all Agriculture sector emissions (GHGI, 2018).

The implementation of technologies improving the efficiency and reducing the amount of nitrogen fertilizers application could contribute significantly to climate change mitigation activities in Ukraine.

According to the UNEP, the global economy-wide nitrogen use is extremely inefficient with over 80% of anthropogenic reactive nitrogen lost to the environment, which leads to water, soil and air pollution that threatens human health, wellbeing and ecosystem services and contributes to climate change, due to increases in greenhouse gas emissions, and stratospheric ozone depletion (UNEP, 2019).

The technologies that could reduce the emission of nitrogen dioxide in Agricultural Soils category include the following:

- using slow- or controlled- release fertilizer forms or nitrification inhibitors;
- use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture;
- organic agriculture.

Crop residues when plowed into the soil increase the nitrogen input. The amount of nitrogen in the biomass residues is estimated on the basis of yield data for the key agricultural crop products, as it depends on the biological properties of the cultivated plants, ecological (mainly soil and climate) conditions, the agricultural technologies and productivity levels, the ways of sowing, seeding rates and a number of other reasons. According to the GHGs national inventory report, the side-products plowed into the soil include those of corn for grain, soybeans, potatoes, vegetables, sunflowers, as well as food and fodder melons, while straw, tops and side-products of other agricultural crops are harvested as forage or bedding for animals. The estimate of N_2O emissions from biomass residues was based on harvested areas and yields, regression coefficients to determine biomass residue volume and the content of nitrogen in the mass of side-products and surface residues. In 2016 GHGs due to the input of crop residues into the soil amounted to 9.7 Mt CO_2-eq. (equivalent of 2.01 million tons of nitrogen in crop resides returned to soil) or 22.9% of all emissions from Agriculture sector (GHGI, 2018).

The emissions of crop residues input mainly depends on yield volumes but the increased use of biomass residues for energy purposes would contribute to the reduction of GHGs emission from Agriculture sector.

In 2016 GHGs due to nitrogen mineralization associated with soil carbon loss amounted to 5.5 Mt CO_2-eq. (equivalent of 1.18 million tons of nitrogen in mineral soils that is mineralized in association with loss of organic carbon) or 13.1% of all emissions from Agriculture sector (GHGI, 2018).

Enteric fermentation

The emissions of CH_4 from animal digestive process primarily depends on the type of animals and their digestive system, their number and size, as well as the type and amount of consumed fodder. Methane emissions from Enteric Fermentation in Ukraine includes emissions from such types of farm animals as cattle, sheep, swine, and other animals (goats, horses, mules, rabbits, etc.).

The main contributors of CH_4 emissions from enteric fermentation are cattle farms (see Table 3.2). The methane emission factors from enteric fermentation is 101.97 kg/head/year for cattle and the average rate of feed energy conversion into CH_4 applied in national inventory is 6.5%. For comparison, the emission factor for sheep is 8.65 kg/head/year and emission factor for swine is only 1.5 kg/head/year (GHGI, 2018).

Methane conversion rate depends on the quality of feed. Feed with high digestibility and energy content reduce methane generation and lower values of methane conversion ratio could be applied during the calculation of GHGs emissions from enteric fermentation.

Table 3.2 – The structure of CH_4 emissions in enteric fermentation category in Agriculture sector in Ukraine

Emission sources	CH_4, kt		CO_2-eq., kt		Share in the category	
	1990	2016	1990	2016	1990	2016
Cattle	1726.00	398.65	43,150	9,966	94.0%	92.7%
Sheep	60.91	8.12	1,523	203	3.3%	1.9%
Swine	29.53	10.68	738	267	1.6%	2.5%
Other animals	20.55	12.62	514	316	1.1%	2.9%
Total	1836.99	430.08	45,925	10,752	100.0%	100.0%

The emissions from enteric fermentation has been reduced significantly since 1990 due to the reduced population of livestock being grown in Ukraine. The declining trend continues during recent years.

Manure management

The animal manure management is associated with the emissions of methane (CH_4), nitrous oxide (N_2O), and non-methane volatile organic compounds (NMVOCs). The details on emission volumes are provided in the Table 3.3.

The key factor determining the decline in GHGs emissions from manure management comparing to 1990 levels is the reduction of livestock population in Ukraine.

Table 3.3 – The structure of emissions in manure management category in Agriculture sector in Ukraine

Emission sources	CH_4, kt		N_2O, kt		CO_2-eq., kt		Share in the category	
	1990	2016	1990	2016	1990	2016	1990	2016
Cattle	101.75	13.58	4.67	0.93	3,935	618	53.8%	29.1%
Sheep	1.79	0.22	0.15	0.02	88	11	1.2%	0.5%
Swine	30.70	16.51	1.47	0.53	1,204	571	16.5%	26.8%
Other animals	15.65	11.99	0.66	0.52	587	455	8.0%	21.4%
Indirect emissions			5.01	1.58	1,494	472	20.4%	22.2%
Total	149.89	42.31	11.95	3.59	7,308	2,126	100.0%	100.0%

The level of methane emissions from manure depends on the following key factors: manure storage conditions (in the liquid or solid form); the type of climate (cold, temperate, or warm); the composition of feed rations for animals; the type of manure (cattle, swine, sheep, poultry manure, etc.); dry matter content in manure (GHGI, 2018).

Methane emissions from solid storage are much lower than in the case of liquid storage, since a large part of it decomposed under aerobic conditions. Agricultural enterprises use both solid and liquid manure management system, but the share of liquid systems has reduced comparing to 1990 year. Households, however, use only solid storage of manure (e.g., clamps with straw bedding). Overall, about 25% of swine manure and less than 1% of cattle manure is managed in liquid systems.

The N_2O emissions are generated in both solid and liquid manure management systems, as N_2O can be produced both under aerobic conditions as a result of the oxidative processes of NH_3 nitrification and in anaerobic conditions due to recovery denitrification processes. The indirect N_2O emissions include the amount of emissions that have occurred as a result of GHG volatilization from manure management systems.

3.2 Decision context

An Agriculture sector is one of the key sectors of the Ukrainian economy, which ensures the national food security and makes a significant contribution to the national export volumes. In 2018, Agriculture, Forestry and Fishing sector generated UAH 360.8 billion of gross value added (10.1% of GDP) demonstrating annual growth rate of 7.8% comparing to the GDP growth rate of 3.3%.

The Strategy of Agrarian Sector Development for the period till 2020 includes a strategic goal of the rational use of agricultural lands and the reduction of 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).

A draft of a united complex strategy and an action plan for the development of the agricultural sector and rural areas in Ukraine for the period 2015-2020 included a strategic priority on the environmental protection and natural resources management (MAPF, 2015). This strategic priority included the implementation of environmental standards, the development of organic agriculture and bioenergy, as well as such priorities as the development of climate adaptation measures and the reduction of greenhouse gases emissions in the agricultural sector. Specific expected results included the reduction of greenhouse gases emissions in agricultural sector by 20% before 2020, 10% increase in humus amount in the soils, the reduction of mineral and organic nitrous fertilizers application to 250 kg of nitrogen per ha, the increase of land areas used in organic agriculture to 500,000 ha, as well as an increase of energy crops production areas to 500,000 ha by 2020.

Low Emissions Development Strategy of Ukraine includes the following policy options for climate mitigation in agriculture sector (LEDS, 2017):

- drafting nationally acceptable recommendations on animal feeding practice improvement (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;
- incentivizing more efficient use of water.

The development of agriculture sector also impacts the strategic objectives of the energy sector, in particular, the goals of increasing renewable energy share in both electricity and heat energy generation by using biomass. The Energy Strategy of Ukraine for the period till 2035 "Security, energy efficiency, competitiveness" foresees the growth of renewables to 25% till 2035 in total primary energy supply and more than 25% in electricity generation (ESU, 2017). According to the National Plan on Renewable Energy for the period till 2020 (NREAC, 2014), the electricity generation from biomass is expected to increase from 150 GWh in 2014 to 4220 GWh in 2020, while the heat energy generation from biomass is expected to grow from 2.28 Mtoe to 5 Mtoe.

Energy efficiency and renewable energy policies proposed by the Low Emissions Development Strategy of Ukraine include the policies related to agriculture sector, in particular (LEDS, 2017):

- the introduction of farming technologies reducing fossil fuel consumption (e.g. conversion from diesel to biofuel or hybrid technology in agricultural machinery);
- the promotion of energy efficiency in agricultural sector;
- the promotion energy generation from renewable energy sources by agricultural enterprises (e.g., the installation of solar or wind energy devises, the use of hydroelectricity generators for irrigation purposes, the use of biomass and biofuel for energy purposes, extending the energy audit programs, etc.).

The Concept of state policy implementation in the area of climate change for the period till 2030 (CSPIACC, 2016) establishes the goal to ensure the achievement of nationally determined contribution for 2030, which will not exceed to 60% of emission level in baseline year 1990, as well as ensure the growth of NDC ambition before 2020 taking into account the conditions of social and economic development of the country.

The main goals of the technology needs assessment would include the identification of technologies, which could contribute to the achievement of agriculture sector development priorities, and also would contribute to the achievement energy and environmental policy goals.

3.3 An overview of possible mitigation technology options in Agriculture Sector and their mitigation potential and other co-benefits

The National Expert Consultant in consultations with the Sector Working Groups members identified the following 10 mitigation technologies for Agriculture sector:

- Using slow- or controlled- release fertilizer forms or nitrification inhibitors
- The use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture
- Conservation tillage technologies (low-till, no-till, strip-till, etc.)
- Efficient Irrigation Systems (Sprinkler and Drip Irrigation)
- Biogas production from agricultural crops products
- Biogas production from animal waste
- Organic agriculture
- The production and use of solid biofuels from agricultural residues
- The production of liquid biofuels from agricultural products
- The improved feeding practices and dietary additives for livestock for the reduction of GHGs emission from enteric fermentation.

Technologies are briefly described in the technology fact sheets in Annex I, including information on their costs and sustainability impacts (environmental, social and economic).

For the purposes of technology needs assessment and technology prioritization the high-level estimation of mitigation potential for each nominated technology has been prepared by the National Consultant. The results are provided in the table below and additional information is available in the technology factsheets. The estimate is used for the purpose of technology prioritization only and additional studies would be required to provide more detailed evaluation of GHGs emission reduction potential for the prioritized technologies.

Table 3.4 - Information on the potential of GHGs emissions reduction

#	Technology	GHG Emissions Reduction Potential, Mt CO_2-eq.	Comments
1	Using slow- or controlled- release fertilizer forms or nitrification inhibitors	1.6	The emission reduction would be achieved in Agricultural Soils sub-sector (Agriculture) due to the reduced N_2O emissions in inorganic N fertilizers category and also in Chemical Industry sub-sector (Industrial processes and product use) due to reduced CO_2 emissions in Ammonia production category.
2	The use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture	1.6	The emission reduction would be achieved in Agricultural Soils sub-sector (Agriculture) due to the reduced N_2O emissions in inorganic N fertilizers category and also in Chemical Industry sub-sector (Industrial processes and product use) due to reduced CO_2 emissions in Ammonia production category.
3	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	7	The emission reduction would be achieved in Agricultural Soils sub-sector (Agriculture) due to the reduced N_2O emissions from Mineralization Associated with the Loss of Soil Organic Matter and also in Cropland sub-sector (Land Use, Land Use Change, and Forestry sector) due to the reduced CO_2 emissions associated with carbon stock change in mineral soils.
4	Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	1.1	Though the technology's implementation leads to the additional GHGs emissions from fossil fuel combustion in Energy sector, increasing irrigation areas allows reducing the specific land-use GHGs emissions per ton of harvested crops. The emission reduction would be potentially achieved in Agricultural Soils sub-sector (Agriculture) and Land Use, Land Use Change, and Forestry sector.
5	Biogas production from agricultural crops products	4.4	The emission reduction would be achieved in Fuel Combustion Activities sub-sector (Energy) due to reduced CO_2 emissions from fossil fuel combustion in public electricity and heat production category and other categories.
6	Biogas production from animal waste	1.8	The emission reduction would be achieved in Manure management sub-sector (Agriculture) due to the reduced CH_4 emissions and Fuel Combustion Activities sub-sector (Energy) due to the reduced CO_2 emissions from fossil fuel combustion in public electricity and heat production category and other categories.
7	Organic agriculture	4	The emission reduction would be achieved in Agricultural Soils sub-sector (Agriculture) due to the reduced N_2O emissions from Mineralization Associated with the Loss of Soil Organic Matter and inorganic N fertilizers application, as well as in Cropland sub-sector (Land Use, Land Use Change, and Forestry sector) due to the reduced CO_2 emissions associated with the carbon stock's change in mineral soils.
8	The production and use of solid biofuels from agricultural residues	10.2	The emission reduction would be achieved in Fuel Combustion Activities sub-sector (Energy) due to the reduced CO_2 emissions from fossil fuel combustion in public electricity and heat production's category and other categories.

#	Technology	GHG Emissions Reduction Potential, Mt CO_2-eq.	Comments
9	The production of liquid biofuels from agricultural products	0.6	The emission reduction would be achieved in Fuel Combustion Activities sub-sector (Energy) due to the reduced CO_2 emissions from fossil fuel combustion in road transportation category and other categories.
10	The improved feeding practices and dietary additives for livestock for the reduction of GHGs emission from enteric fermentation	2.2	The emission reduction would be achieved in Enteric Fermentation sub-sector (Agriculture) due to reduced CH_4 emissions.

Total GHGs emission reduction potential of nominated technologies is estimated at the level of 34.5 million tons CO_2-eq.

The prioritization of the technologies has been carried out by the working group through a multi criteria analysis facilitated by the National Expert Consultant.

Adaptation co-benefits

Agricultural technologies could not only provide the reduction in greenhouse gases emissions but also contribute to the climate change adaptation. As it is noted by IPCC, a number of options have been identified as potentially beneficial for mitigation and adaptation, including soil and water conservation (including conservation agriculture, low or minimum tillage, vegetation strips, terraces, structures such as bunds contours, shade trees, tied ridges, small-scale water harvesting, compost production, cover crops, improved fallows, crop residues), agroforestry, and the improved pasture and grazing management including restoration. These options generally are based on sustainable agricultural land management (SALM) practices, which reduce risks related to climate in the form of rainfall variability and soil erosion, the increase in soil organic matter and soil fertility (thus increasing productivity), and reduce the emissions by either reducing soil emissions or preventing other more emission intensive activities (Somanathan et al, 2014).

3.4 The criteria and process of technology prioritization for Agriculture sector

Nominated mitigation technologies for Agriculture sector were assessed on the ground of their social, economic and environmental benefits. The National consultant in consultations with Agriculture working group members has identified 10 criteria covering 4 categories. Criteria used in the assessment process are presented in the Table 3.5 below.

Table 3.5 - Criteria used for technologies prioritization in Agriculture sector

Category	Units	Description
Economic	USD/EUR per 1000 ha / MW / 1000 tons	Criterion A. Capital expenditures (equipment and infrastructure)
	USD/EUR per 1000 ha / MW / 1000 tons	Criterion B. Operational expenses (energy, wages, etc.)
Social	Qualitative	Criterion C. Job creation potential
	Qualitative	Criterion D. Impact on human health and level of morbidity
Environmental	Qualitative	Criterion E. Impact on water resources (underground water contamination, water resources depletion)
	Qualitative	Criterion F. Impact on land resources (erosion, degradation)
Climate related	Tons CO_2-eq.	Criterion G. The reduction of GHGs emissions
	Qualitative	Criterion H. Climate change adaptation co-benefits
Other	Qualitative	Criterion I. Aligning with state policy priorities

Category	Units	Description
	Qualitative	Criterion J. Potential for replication in the country

Three criteria (i.e. capital expenditures, operational expenditures and potential for the reduction of greenhouse gases emission) were quantitative and respondents were invited to provide figures on the cost of the technology in monetary units (in USD per ha, USD per MW of the installed electric capacity, USD per ton of a solid fuel, or USD per 1000 heads of livestock), as well as information on the potential of reduction for greenhouse gases emission in tons of CO_2-eq. Due to the limited quantitative information provided by the working group members on some technologies, information has been complemented with the data from a desktop study conducted by the National Consultant.

At the scoring stage, the quantitative values for capital and operational expenditures were analysed in consultation with the experts of the working group "Mitigation Technologies in Agriculture" on the basis of principles described in Table 3.6 below. Such an approach was applied as the simple normalization of capital expenditures and operational expenditure was not possible due to using different units of cost for different technologies.

Table 3.6 - Principles for assigning scores to the quantitative criteria on technology costs

Quantitative criteria	Scores				
	0-20	30-40	50-60	70-80	90-100
Capital expenditures (equipment and infrastructure)	Very high and not feasible to current market conditions	High and usually require state subsidies to support market penetration	Medium and affordable to some market players	Relatively small and affordable to many market players	Not applicable to farmers or very low
Operational expenses (energy, wages, etc.)					

The normalization approach was applied for the reduction estimate of GHGs emission.

Information on the cost of technologies and scores received is provided in the tables 3.7 and 3.8 below.

Table 3.7 - Information on capital expenditures (CAPEX)

#	Technology	Information about CAPEX	Score
1	Using slow- or controlled-release fertilizer forms or nitrification inhibitors	Capital cost for agricultural producers are not applicable or very low, as standard equipment and machinery used for traditional fertilizers application could be utilized.	90
2	The use of information and telecommunication technologies in agriculture for the reduction of GHGs emission in agriculture	Direct costs are relatively low or not applicable to the framers due to the availability of specialized service providers. Indirect cost related to investment in the machinery and equipment, which will allow practical application of the recommendations developed using ICT tools, could be significant.	70
3	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	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.	70
4	Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	The approximate capital expenditures for extending irrigation systems in Ukraine range from USD 1100 per ha for the modernization of existing and operational irrigation systems to about USD 2500 per ha for the construction of new irrigation systems (without the cost of major water supply infrastructure).	40
5	Biogas production from agricultural crops products	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. Biogas projects are economically feasible taking into account state support in the form of green tariff.	60

#	Technology	Information about CAPEX	Score
6	Biogas production from animal waste	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. Biogas projects are economically feasible taking into account state support in the form of green tariff.	60
7	Organic agriculture	There are no significant capital expenditures associated with organic agriculture. Certification expenditures are relatively low.	80
8	The production and use of solid biofuels from agricultural residues	Capital expenditures for biomass boiler 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. Capital expenditures for biomass CHPs varies in the range of EUR 2.5 – 3.5 million per MW of installed electric capacity.	70
9	The production of liquid biofuels from agricultural products	Capital expenditures for biofuel projects could be estimated in the range of EUR 0.3 – 2 million per 1000 tons with lower bound applicable to biodiesel plants and higher bound applicable to second generation bioethanol production plants.	40
10	The improved feeding practices and dietary additives for livestock for the reduction of GHGs emission from enteric fermentation	Capital expenditures for the technology is relatively low or absent for the agricultural enterprises.	90

Table 3.8 - Information on operational expenditures (OPEX)

#	Technology	Information about OPEX	Score
1	Using slow- or controlled-release fertilizer forms or nitrification inhibitors	Operational expenses for the fertilizers input process are same as for the conventional fertilizers. The operational expense for fertilizers purchase is however significantly higher and could reach USD 800 per ha. Utilization could be driven by legal limitations of fertilizers input rates or additional benefits from the microelements contained in encapsulated fertilizers on poor soils.	30
2	The use of information and telecommunication technologies in agriculture for the reduction of GHGs emission in agriculture	Operational cost ranges from USD 3 per ha to USD 100 per ha and it more depends on the complex of applied technologies and required additional soil monitoring tests.	80
3	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	Conservation tillage practices allow the reduction of operational and maintenance cost (fuel, spare parts, labor, etc.) for agricultural enterprises	90
4	Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	According to the estimate of the experts of the working group Mitigation technologies in Agriculture, operational expenditures for water, electricity, labour and other range from USD 60 to 190 per ha.	60
5	Biogas production from agricultural crops products	Assuming the average experts' estimate operational expenses are in the range of EUR 300 000 – 400 000 per MW (10% of CAPEX).	60
6	Biogas production from animal waste	Annual operational expenditures for biogas power plants varies in the range of EUR 120 000 – 400 000 per MW of the installed electric capacity	70

#	Technology	Information about OPEX	Score
7	Organic agriculture	Examples of both higher and lower cost of organic crops production could be found in the literature. Overall, organic agriculture has similar operational cost to the non-organic agriculture.	80
8	The production and use of solid biofuels from agricultural residues	Main operational costs are related to biomass fuel cost (market price of biomass residues or biomass residues collection and logistics cost). The price of biomass fuel from agricultural residues could vary from EUR 20 per ton in case of straw to as much as EUR 100 per ton or more in case of agricultural pellets.	70
9	The production of liquid biofuels from agricultural products	There are significant variations in biofuel production cost reflecting the wide range of production processes and types of feedstock. The cost of biodiesel production ranges from EUR 0.36 to 0.99 per liter. The cost of bioethanol production ranges from EUR 0.29 to 0.95 per liter (excluding lower cost of cane sugar bioethanol production in Brazil).	50
10	The improved feeding practices and dietary additives for livestock for the reduction of GHGs emission from enteric fermentation	Operational expenditures depend on the types of additives used and their prices. Nitrates and lipids are the most affordable additives as their inclusion in diets is associated with additional cost below 10% of typical diet cost. The inhibitors and other types of additives could be cost prohibited especially if there is no economic cost related to methane emissions. The lack of carbon price associated with methane emissions limits the economic feasibility of additional expenses in the technology.	60

Seven criteria were qualitative and were evaluated by Agriculture working group members based on a Likert scale. Respondents specified their level of agreement or disagreement on a symmetric agree-disagree scale for a series of statements formulated by the National Consultant. The answers proposed to the experts ranged from 1 to 10, where 1 correspondent to “Totally disagree” answer and 10 - “Totally agree answer”.

At the scoring stage, the average of each qualitative criteria for each technology was multiplied by 10 to arrive at the score ranging from 0 to 100.

3.5 The results of technology prioritisation for Agriculture sector

Technology prioritization has been performed on the basis of the performance matrix, prepared for using the evaluation of technologies by the experts of the working group “Mitigation Technologies for Agriculture” and national consultant. The performance matrix has been converted into a scoring matrix, in which the scales for all criteria data are same and range from 0 to 100. The most preferred option is assigned with the highest score, while the least preferred option is given to the lowest score. The scores of other options reflect differences in the strength of each preference. The performance matrix, the scoring matrix and resulting decision matrix are presented in Annex VII, while the total scores received by each technology is presented in the table 3.9 below.

Table 3.9 – Total scores based on the decision matrix for the technologies in Agriculture sector

Technologies	Total score
Using slow- or controlled- release fertilizer forms or nitrification inhibitors	5903
The use of information and telecommunication technologies in agriculture for the reduction of GHGs emission in agriculture	**6753**
Conservation tillage technologies (low-till, no-till, strip-till, etc.)	**6991**
Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	5550
Biogas production from agricultural crops products	6637
Biogas production from animal waste	**7044**
Organic agriculture	**7764**

Technologies	Total score
The production and use of solid biofuels from agricultural residues	**6955**
The production of liquid biofuels from agricultural products	4873
Improved feeding practices and dietary additives for livestock for the reduction of GHGs emission from enteric fermentation	5510

The prioritized technologies with the highest score include:

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.

The sensitivity analysis was conducted to test the results of technology prioritization depending on the chosen weights of different criteria using the following three alternative scenarios:

1) equal weights for all ten criteria;
2) relatively higher weight of economic and social criteria and lower weight of environmental and climate-related criteria;
3) relatively higher weight of environmental and climate-related criteria and lower weight of economic and social criteria.

In all tested scenarios the five selected technologies received the highest scores. In the scenario of relatively higher weights of economic and social criteria, the score of “Biogas production from agricultural crops” technology was just 4 points higher than the result of “Use of information and telecommunication technologies in agriculture for the reduction of GHGs emission in agriculture” technology.

Technology fact sheets for the technologies that are selected through the technology prioritization are provided in Annex I of the report.

The results of technology prioritization for Agriculture sector will be used in ongoing process of Ukraine’s NDC revision.

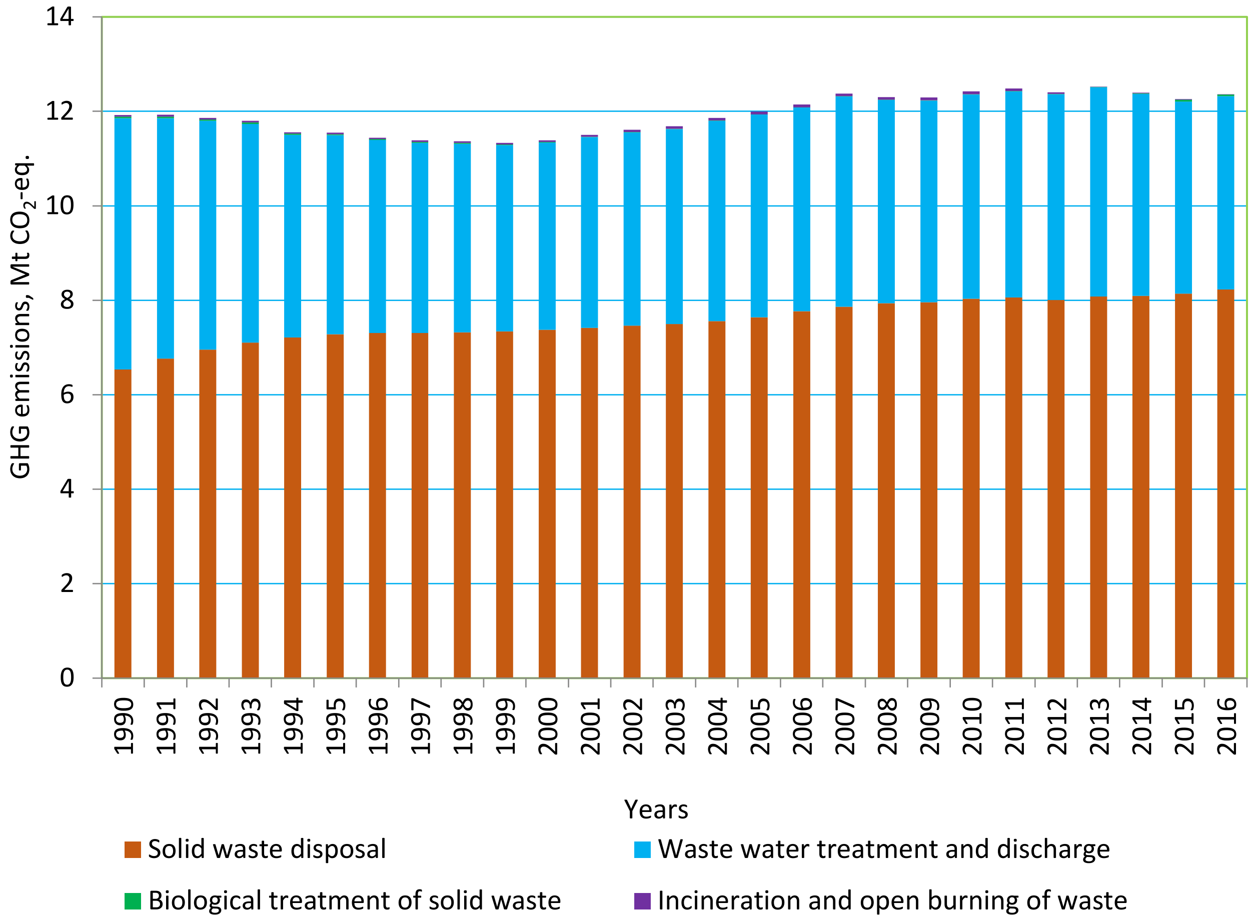
Chapter 4 Technology prioritization for Waste Sector

4.1 GHG emissions and existing technologies in Waste Sector

<u>Historical GHG emission trends in Waste sector.</u>

According to the latest approved Ukraine's GHG Inventory (GHGI, 2018), GHG emissions in Waste sector amounted to 12.37 Mt CO_2-eq. in 2016 that is equal to 3.65 % of total national emissions (excluding LULUCF). Nevertheless, it's the only sector where the GHG emission upward trend has been observed since 1990 increasing by 3.70 % in 2016 compared to 1990.

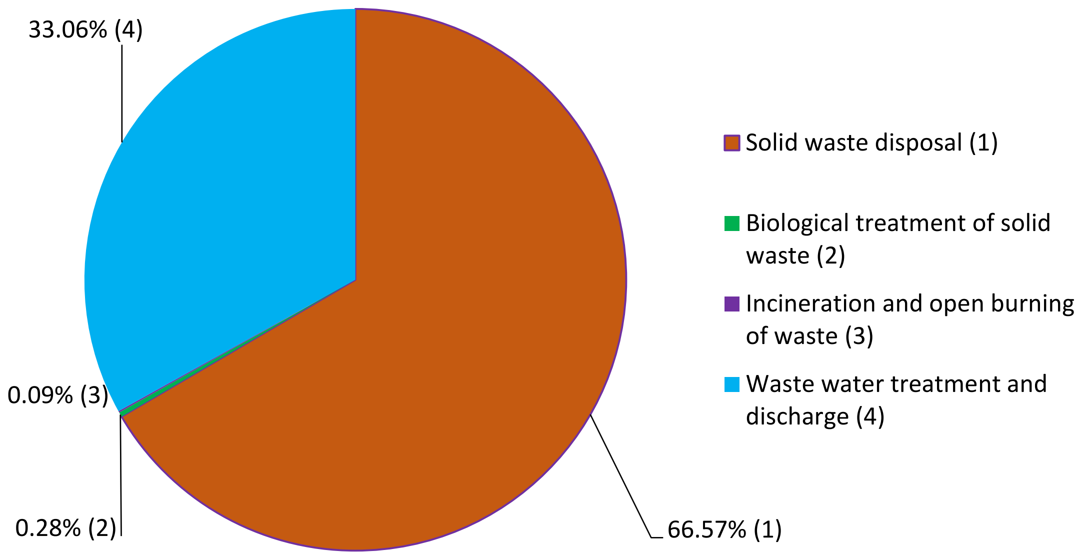
Such an overall sectoral trend was caused by the two main factors: rapid increasing of landfilled municipal solid waste (MSW) since 1997 and the gradual reduction of waste water generation in industrial and household sectors, especially since global economy crisis in 2008. GHG emissions from waste incineration (without energy recovery) and biological treatment are minor because these types of waste treatment technologies are very limited in Ukraine. GHG emissions by IPCC categories in Waste sector for 1990-2016 are illustrated in figure 4.1 and its structure for the latest reporting 2016 year – in figure 4.2.



Source: https://unfccc.int/

Figure 4.1 – GHG emission trends in Waste sector of Ukraine by UNFCCC categories, 1990-2016

It follows from figure 4.2 below, that more than 65 % of GHG emissions in 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 management practice in Ukraine. Approximately 33 % of emissions correspond to the waste water treatment, the rest 0.3 % and 0.1 % correspond to solid waste biological treatment and incineration respectively.



Source: https://unfccc.int/

Figure 4.2 – GHG emission structure in the Waste sector of Ukraine by IPCC categories, 2016

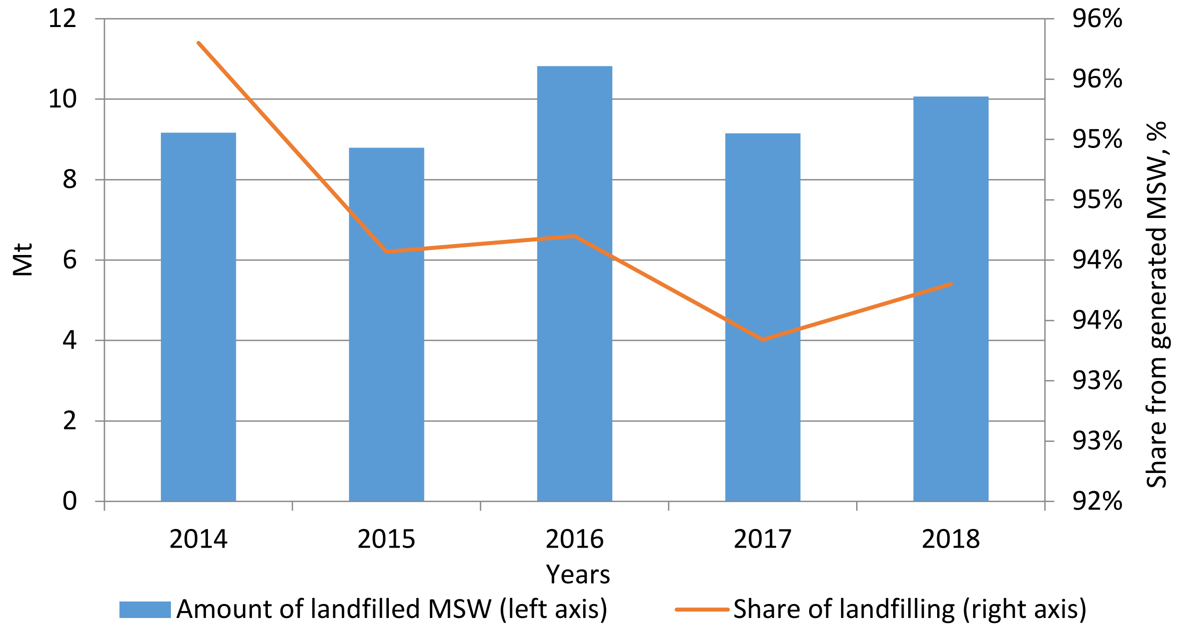
Key driver for the Waste sector regarding GHG emissions: common MSW treatment practice and statistics.

According to the Ministry of Regional Development, Building and Housing and Communal Services of Ukraine, more than 9 Mt of MSW were generated in the country during 2018 (MSWTS, 2019). The reported share of landfilling was approximately 93.8 % of generated MSW. The rest 6.2 % of MSW was reused, recycled or incinerated, namely: 2.0 % was incinerated and 4.2 % was treated at secondary raw materials procurement points and waste processing facilities. The share of population covered by centralized MSW collecting systems was equal to 78 % and a number of settlements with the implemented separate collecting system reached 1181 compared to 822 in previous 2017 year.

It has to be mentioned that official statistics for MSW treatment is not full enough and do not reflect number of factors, among which are: MSW generated but not covered by the centralized collecting system is not included in official statistics; main indicators are estimated based on the basis of volumes but not on weight; the operators of MSW treatment facilities do not provide the transparent information; secondary raw material markets often operate unofficially, etc. Thus, the accurate information regarding actually generated, reused, recycled and landfilled MSW is not available in Ukraine.

Figure 4.3 shows the amount of landfilled MSW and its share from the total amount of generated MSW according to official statistics since 2014. Landfilling of MSW corresponds to the left axis and the share of landfilling corresponds to the right axis.

The amount of MSW landfilling fluctuated within the range of 8.8-10.8 Mt per year and the share of landfilling fluctuated from 93.3 % to 95.8 % during the period 2014-2018. A slight decrease of MSW landfilling share took place since 2015.

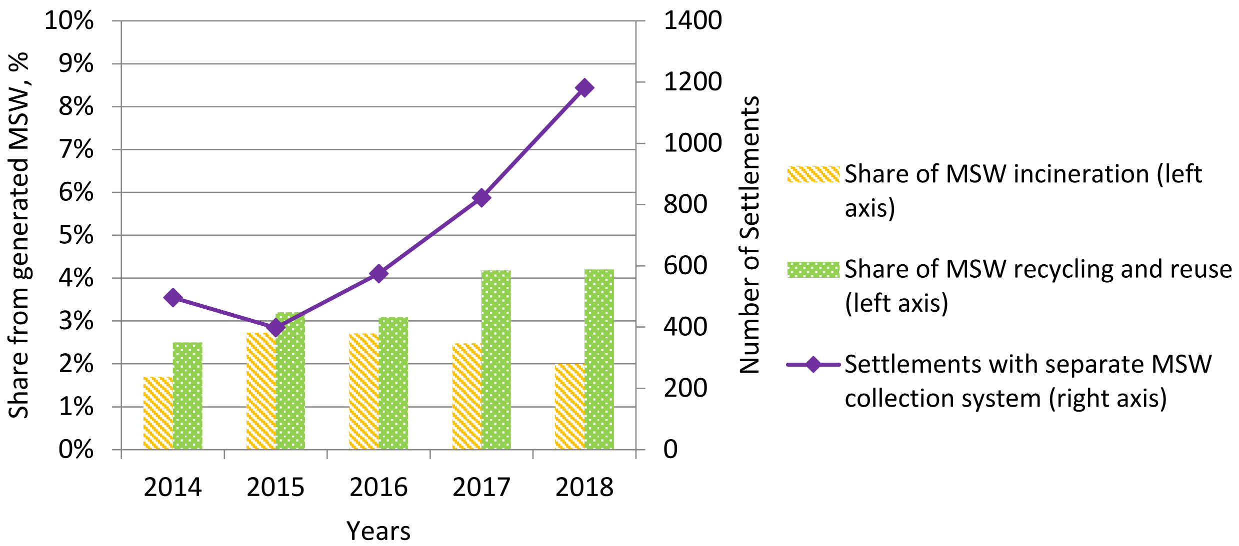


Source: http://www.minregion.gov.ua/

Figure 4.3 – MSW landfilling in Ukraine, 2014-2018.

Figure 4.4 illustrates the share of MSW incineration, recycling, reuse and a number of settlements with the implemented separate collection system in Ukraine according to official statistics since 2014, where the shares of MSW treatment practices correspond to the left axis and a number of settlements corresponds to the right axis. It's seen from figure 4.4 that the share of MSW incineration fluctuated from 1.7 % to 2.7 %. These fluctuations were affected by the operational parameters of the only MSW incineration plant located in Kyiv city, such as: the schedules of reconstruction and repair, environmental procedures etc.

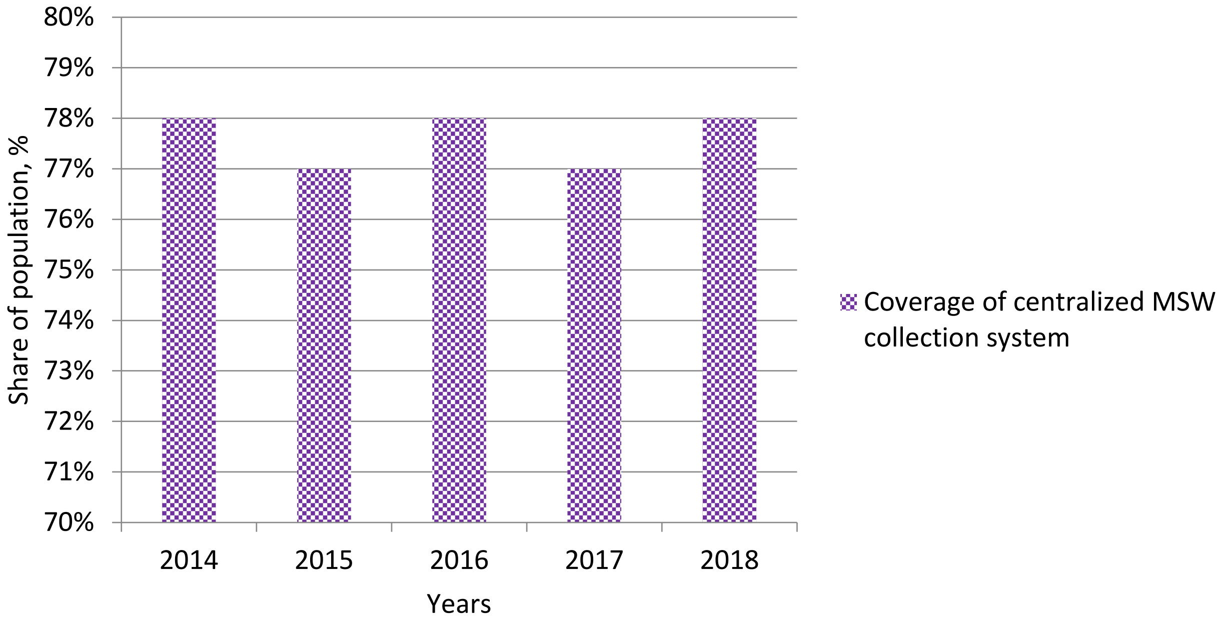
The share of MSW recycling and reuse was in the range of 2.5-4.2 %. It's obvious that separate collection systems at the municipal level are not effective in Ukraine and do not lead to statistically successful results. As for example, the number of settlements with implemented separate MSW collection system has increased from 822 to 1181 during 2018 but the share of recycling and reuse remained constant with value of 4.2 %. Unfortunately, the implementations of such systems at the municipal level in Ukraine have declarative form without reaching success.



Source: http://www.minregion.gov.ua/

Figure 4.4 – MSW incineration, recycling, reuse and a number of settlements with implemented separate collecting system in Ukraine, 2014-2018

Figure 4.5 illustrates the share of population covered by the centralized MSW collection system in Ukraine according to official statistics since 2014. This share remains practically constant at the level of 78-79 % since 2014 and do not have any tendency for growth in the nearest future.



Source: http://www.minregion.gov.ua/

Figure 4.5 – Population covered by centralized MSW collection system in Ukraine, 2014-2018

4.2 Decision context

Waste sector is one of the most conservative branches of Ukrainian economy. The technology progress had very limited influence on the national MSW treatment practice. Nevertheless, certain successful results have been achieved due to the flexible economy mechanism under Kyoto Protocol and implemented green tariffs for electricity based on renewable energy sources (RES) since 2013. Thus, about 9.7 % of Methane generated at MSW landfills in 2016 where flared or used for energy recovery (GHGI, 2018).

The acting waste management legislation is partly out-of-date. Presently it is based on the Law “On Waste” (LW, 1998) which is planned to be replaced as soon as possible. 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. These documents have been analyzed in details by Bioenergy Association of Ukraine (BAU, 2019).

In general, the Waste Management Strategy includes three phases, each of them is directed to resolve a number of specified issues taking into account the current state of waste treatment in Ukraine.

Phase I (2017-2018) is a preparatory stage which provides the development of a basis for the modern waste management system in Ukraine, including: the creation of interdepartmental working groups, legislation development for waste management (e.g. new Laws On Waste Management; On Waste Disposal, On Waste Incineration, On Industrial Waste Management, On Municipal Waste, On Package Waste etc.), technical regulations, scientific and research works.

Phase II (2019-2023) provides the implementation of the policy measures prepared at the phase I. Among such measures are the following:

- the approval of all new laws dedicated for waste management;
- the creation of a central executive body responsible for waste management, by the Cabinet of Ministers of Ukraine through the Minister of Ecology and Natural Resources of Ukraine;
- the standardization and certification of technologies for waste processing and utilization;

- the development of National Register of waste generation facilities, waste treatment activities and best available waste treatment technologies.

Phase III (2024-2030) provides an implementation of new MSW management policy fully harmonized with EU legislation and achievement. There are several targets among which are:

- 50 % of generated MSW has to be processed until 2030 by development of MSW separate collection covering 48 % of population as well as putting into operation additional waste sorting lines and waste processing facilities;
- the creation of facilities for RDF and SRF production from MSW based on the mechanic-biological treatment in case of close location to cement plants within the framework of pilot projects;
- the implementation of a number of pilot projects on MSW biological stabilization; the share of MSW reuse has to reach 10 %, recycling – 20 %; incineration – 10 %; disposal/landfilling – 30 %.
- the Waste Management Plan up to 2030 describes required activities to be realized, sets time schedule and defines responsible executive bodies. The following activities could be mentioned;
- the establishment of a central executive body on the waste management, submission to the Cabinet of Ministers of Ukraine in 2019;
- the development of the plan to reduce the volume of biodegradable waste disposal that has to be approved not later than in a year after approval of new Law on Waste Management;
- the approval of reference documents on the best available waste treatment technologies in 2022-2023;
- the introduction and use of economic instruments to stimulate the creation of waste management infrastructure that has to be approved not later than in a year after new executive waste management body is created;
- the introduction of economic instruments to stimulate the use of biomass from agricultural waste products to produce biofuels, electric and thermal energy in 2020;
- the introduction of economic incentives for environmentally friendly production technologies and the expansion of recycling not later than in a year after new executive waste management body is created;
- ensuring the development of a national standard harmonized with EN 15359: 2011 "Solid Recovered Fuels (SRF). Specification and classification" not later than in a year of new law on municipal waste approval;
- the development of recommendations for the use of RDF not later than in six months after new executive waste management body is created;
- the development of a draft order on technical requirements for compost resulting from biological treatment of household waste not later than in a year of new law on municipal waste approval;
- the establishment of municipal waste collection centers in settlements with a population of more than 50 thousand persons within the framework of regional waste management plans in 2020-2022;
- the determination of the location for regional waste management facilities in the framework of regional waste management plans on the basis of a cluster approach in 2022;
- the construction of regional landfills in the framework of regional waste management plans on the basis of a cluster approach in 2023-2030;
- the closure of old solid waste dumps and landfills, which do not meet environmental requirements in parallel with construction of new regional landfills;
- drafting a decree on the reuse of treated wastewater and sludge being a subject to compliance with the maximum permissible concentrations of pollutants;
- the establishment of requirements for processing, recycling, and disposal of animal by-products;
- the stimulation of agricultural waste composting;
- the development of requirements for green waste incineration;
- the development of requirements for the quality of compost and composting raw materials (separately for green and animal waste) as well as using composting material as a fertilizer in 2020.

The National Waste Management Plan also requires that regional waste management plans have to be developed not later than in two years after its approval. These regional plans form a basis for further financing of infrastructure projects on waste management from state and local budgets.

Thus, the Waste Management Strategy up to 2030 has legislated national targets to be achieved in waste management by 2030 as well as preliminary priority technologies to be implemented for efficient waste management, among which are separate collection, reuse, recycling, composting, incineration with energy recovery. The Waste Management Plan up to 2030 determines activities to be realized, terms and responsibilities to ensure its fulfillment in Ukraine.

4.3 An overview of possible mitigation technology options in Waste Sector and their mitigation potential and other co-benefits

The National Expert Consultants in consultations with the Sector Working Groups members identified the following 12 mitigation technologies for Waste sector:

1. Methane capture at landfills and waste dumps for Energy Production (***LFG-to-E***)
2. The closure of old waste dumps with methane destruction (flaring, biocovers, passive vent etc.) (***Closure***)
3. The construction of new regional sanitary MSW landfills (***Construction***)
4. Waste sorting (the sorting of valuable components of MSW with subsequent treatment of waste residual by other technologies) (***Sorting***)
5. Aerobic biological treatment (composting) of food and green residuals (***Composting***)
6. The mechanical-biological treatment of waste with biogas and energy production (anaerobic digestion of organic fraction of MSW) (***MBT-AD***)
7. The mechanical-biological treatment of waste with alternative fuel (SRF) production for cement industry (***MBT-Cement***)
8. The mechanical-biological treatment of waste with alternative fuel (RDF/SRF) for district heating and/or electricity production (***MBT-DH***)
9. The combustion of residual municipal solid waste for district heating and/or electricity production (***Combustion***)
10. The gasification/pyrolysis of MSW for large-scale electricity/heat applications (***Gasification***)
11. The biological stabilization of municipal solid waste (***Biostabilization***)
12. The anaerobic treatment (digestion) of sewage sludge) (***AD-sludge***)

Technologies are briefly described in the technology fact sheets in Annex II (TFS 1W – TFS 12W), including information on their costs and environmental, social and economic impacts. The prioritization of the technologies has been carried out by the working group members (Annex IV) through a multi-criteria analysis facilitated by the National Expert Consultants. All together fourteen responds from working group members were obtained.

4.4 The criteria and process of technology prioritization for Waste Sector

Nominated mitigation technologies for waste sector were assesses based on their economic, social and environmental benefits. The National consultants together with waste working group members have identified 15 criteria covering 5 categories. Criteria used in the assessment process are presented in the table below.

Table 4.1 - Criteria used for the technologies prioritisation in Waste sector

Category	#	Units	Description
Economic	1	Qualitative	Capital expenditures (CAPEX), €/t of MSW/an
	2	Qualitative	Operational expenses (OPEX, incl. energy, wages, etc.), €/t of MSW
	3	Qualitative	Income (possibility to get an additional profit), €/t of MSW
	4	Other	Other
Climate related	5	Qualitative	GHG reduction potential, tons of CO_2-eq./an
	6	Qualitative	CO_2-eq. reduction cost per ton, €/t CO_2-eq.

Category	#	Units	Description
	7		Other
Political (waste management)	8	Qualitative	Coherence with national plans and goals
	9	Qualitative	Coherence with waste management hierarchy
	10		Other
Technological	11	Qualitative	The stage of technology development (maturity), status of technology development in the country
	12	Qualitative	The potential scale of implementation (market volume)
	13	Qualitative	Implementation complexity
	14		Other
Social	15	Qualitative	Acceptability by local population
	16	Qualitative	Social benefits in term of jobs, health, waste management coverage etc.
	17	Qualitative	Gender aspects
	18		Other
Environmental	19	Qualitative	Environmental benefit in term of air pollution
	20	Qualitative	Environmental benefit in term of water and soil pollution
	21		Other

Waste working group members were asked to define the weight of each criteria.

In two cases waste working group members have used own criteria in the process of preparation their technology evaluation. These cases are: 1. Additional CAPEX for cement plants and Special CHPs for RDF/SRF combustion (Economic). 2. Landscape influence (Environmental).

These special opinions were taken into the account by introduction of additional item “others” for each criteria category.

The result of expert’s evaluation is shown in figure 4.6 below for criteria categories.

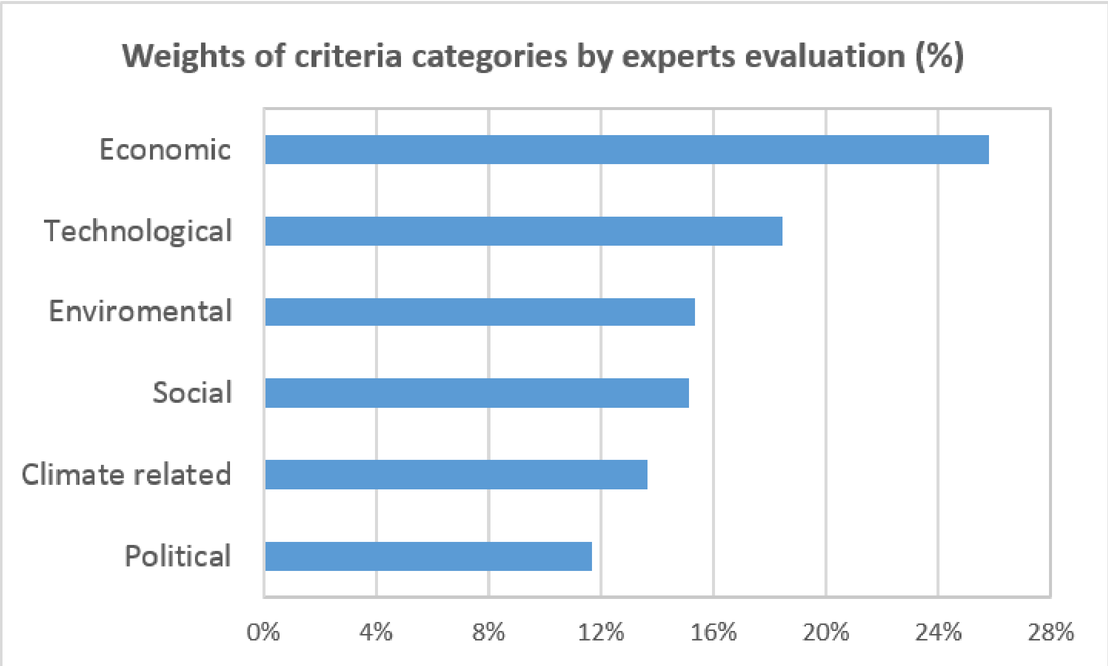


Figure 4.6 – The weight of the categories criteria evaluated by waste working group members

In the figure 4.7 one could see the relative importance of each criteria and individual input into the evaluation of all waste working group members. Here Arabic numbers correspond the numbering in the table 4 above and roman numbers belongs the individual working group members.

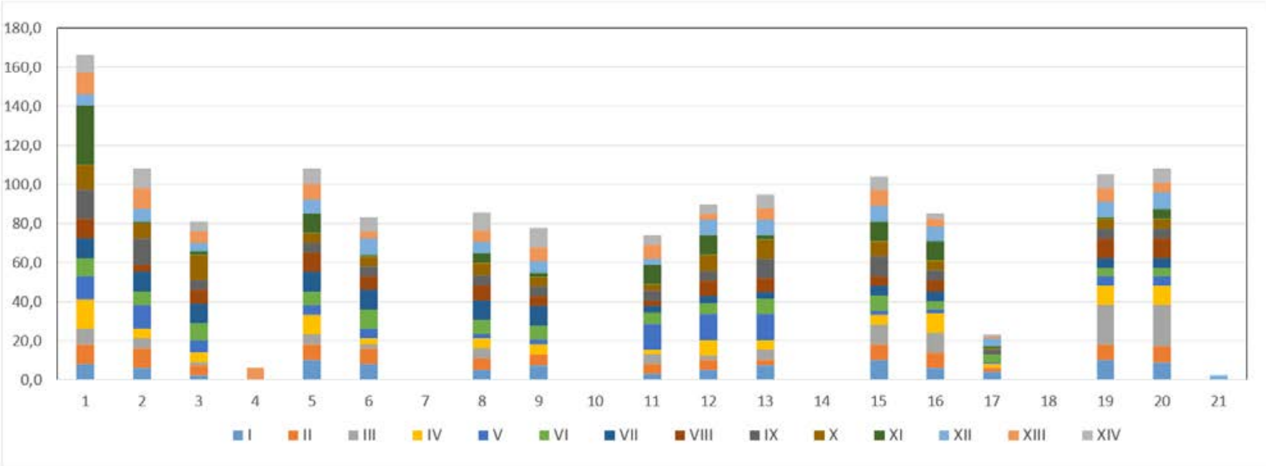


Figure 4.7 – Individual inputs into the criteria evaluation by waste working group members

4.5 The Results of technology prioritization for Waste Sector

The scoring matrix is presented in the Annex VII (Table W7-1) where the score is average value calculated based on the responses of all experts. The decision matrix is presented in the Annex VI (Table W7-2).

The results of twelve technology priotisation for waste sector are shown in the table 4.2 and by the figure 4.8 below as relative average value obtained based on working group member avaluation.

Table 4.2 – Total scores based on the decision matrix for the technologies in Waste sector

#	Technologies	Total scope	Relative score
TFS 1W	Methane capture at landfills and waste dumps for Energy Production (*LFG-to-E*)	5602	1157
TFS 4W	Waste sorting (sorting of valuable components of MSW with subsequent treatment of waste residual by other technologies) (*Sorting*)	5375	929
TFS 2W	The closure of old waste dumps with methane destruction (flaring, biocovers, passive vent etc.) (*Closure*)	5095	649
TFS 5W	Aerobic biological treatment (composting) of food and green residuals (*Composting*)	4980	534
TFS 6W	The mechanical-biological treatment of waste with biogas and energy production (anaerobic digestion of organic fraction of MSW) (*MBT-AD*)	4690	244
TFS 12W	Anaerobic treatment (digestion) of sewage sludge) (*AD-sludge*)	4646	200
TFS 7W	The mechanical-biological treatment of waste with alternative fuel (SRF) production for cement industry (*MBT-Cement*)	4498	52
TFS 3W	The construction of new regional sanitary MSW landfills (*Construction*)	4154	-292
TFS 8W	The mechanical-biological treatment of waste with alternative fuel (RDF/SRF) for district heating and/or electricity production (*MBT-DH*)	4116	-330
TFS 11W	The biological stabilization of municipal solid waste (*Biostabilization*)	3761	-685

#	Technologies	Total scope	Relative score
TFS 9W	The combustion of residual municipal solid waste for district heating and/or electricity production (*Combustion*)	3442	-1004
TFS 10W	The gasification/pyrolysis of MSW for large-scale electricity/heat applications (*Gasification*)	2991	-1455

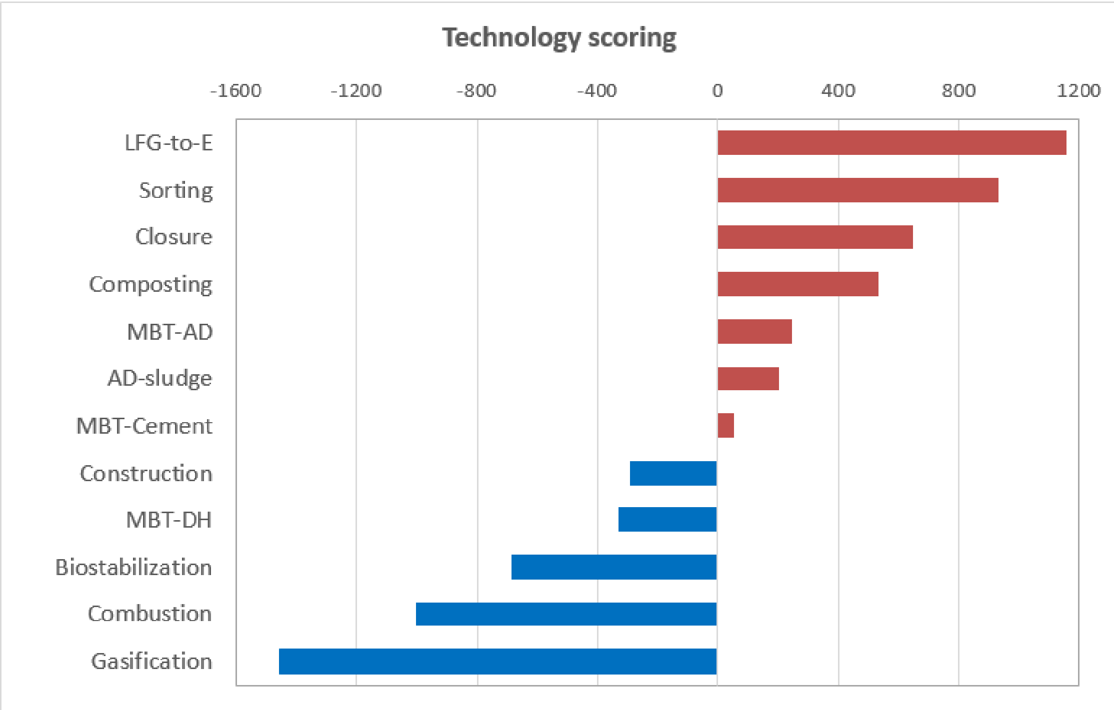


Figure 4.8 – Technology scoring relative to average obtained value

The maximal score was obtained by the technologies:

- Methane capture at landfills and waste dumps for energy production.
- Waste sorting (sorting of valuable components of MSW with subsequent treatment of waste residual by other technologies)

The following technology were also positively evaluated:

- 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 (anaerobic digestion of organic fraction of MSW)
- The anaerobic treatment (digestion) of sewage sludge
- The mechanical-biological treatment of waste with the alternative fuel (SRF) production for cement industry.

Following technologies were less positive evaluated in comparison with already mentioned technologies:

- The construction of new regional sanitary MSW landfills
- The mechanical-biological treatment of waste with alternative fuel (RDF/SRF) for district heating and/or electricity production
- The biological stabilization of municipal solid waste.

The most negative scores were obtained by technology of the thermal treatment of mixed waste:

- The combustion of residual municipal solid waste for district heating and/or electricity production
- The gasification/pyrolysis of MSW for large-scale electricity/heat applications.

The figure 4.9 below demonstrates the individual input of each working group member in technology evaluation.

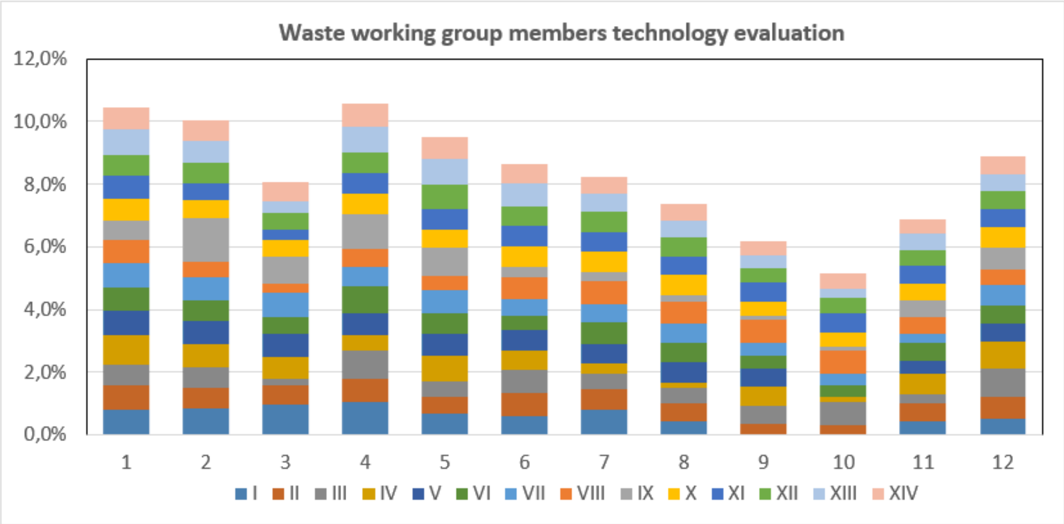


Figure 4.9 – Individual inputs into the technology evaluation by waste working group members

The sensitivity analysis was conducted to test the results of technology prioritization depending on the chosen weight of different criteria using the following four alternative scenarios:

1) Expert's choice (as shown in the table W7-1);
2) relatively higher weight of economic and technology criteria (80% in total) and lower equals weights of other criteria;
3) relatively lower weight of economic and technology criteria (20% in total) and higher equals weights of other criteria/
4) equal weight for all fifteen criteria (without others);

The general conclusion is that changing the criteria weight has virtually no effect on the choice of technology. In all tested scenarios the seven technologies received the highest scores (Fig. 4.10.).

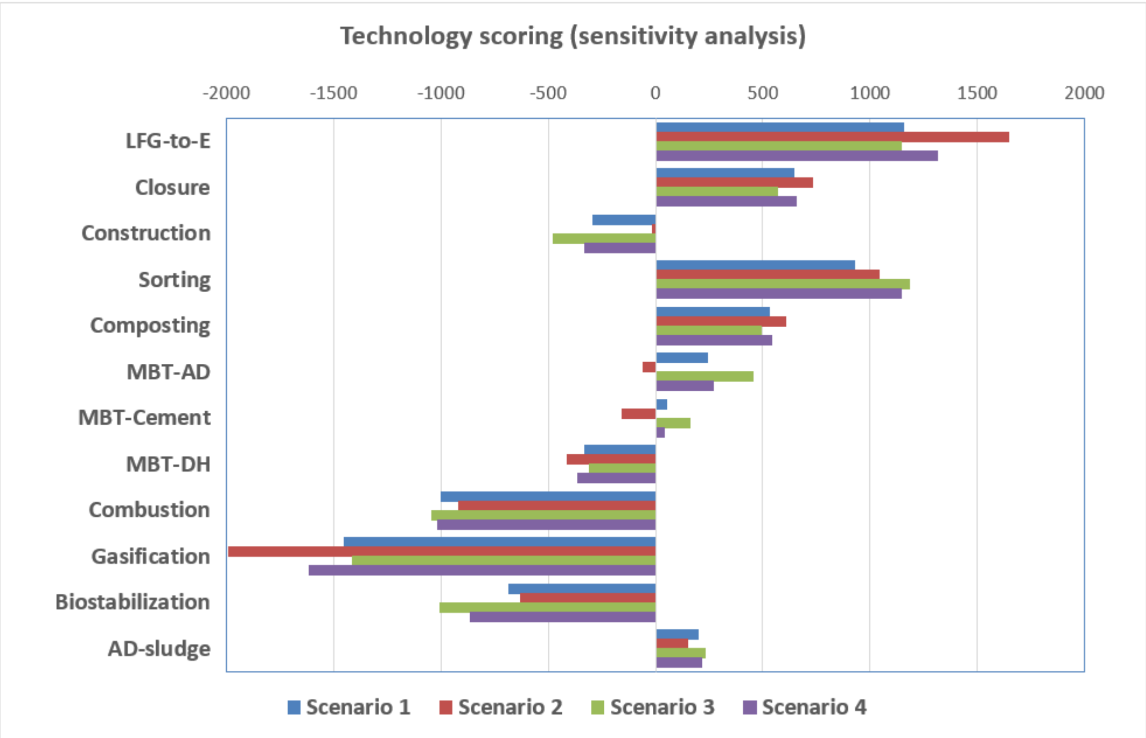


Figure 4.10 – Technology scoring within four sensitivity analysis scenario

However, in the second scenario of relatively higher weight of economic and technology criteria, the score of "Methane capture at landfills and waste dumps for Energy Production" technology is highest. The criteria weight has minor influence on "Waste sorting (sorting of valuable components of MSW with the subsequent treatment of waste residual by other technologies", "The closure of old waste dumps with methane destruction (flaring, biocovers, passive vent etc.)", "The aerobic biological treatment (composting) of food and green residuals", and "Anaerobic treatment (digestion) of sewage sludge" technology.

"The mechanical-biological treatment of waste with biogas and energy production (anaerobic digestion of organic fraction of MSW" and "Mechanical-biological treatment of waste with alternative fuel (SRF) production for cement industry" have slightly negative result within second scenario probably due to relatively high cost of the technologies.

In opposite "the construction of new regional sanitary MSW landfills" obtains better score within second scenario in comparison with others scenario.

After being obtained during the preparation of this report, information is distributed among interested stakeholders for their consideration and comprehensive analysis.

Technology factsheets for selected waste technologies (see Annex II) include background information and short description of the technology options, assumptions how the technologies could be implemented and disseminated across the sector, implementation barriers, GHG emission reduction potential, capital and operational costs as well as other important technology parameters which can form the basic understanding how to identify efficient GHG reduction pathways and provide investment needs assessment in the Waste sector within ongoing process of Ukraine's Nationally Determined Contribution revision.

Chapter 5. Summary and Conclusions

As a result of consultations with the stakeholders at the initial phase of the TNA project Agriculture and Waste sectors were selected for the Mitigation.

Decisions were based on the actual GHG emissions data presented in national emission inventories and existing GHG emission forecasts and trends up to 2030, as well as identified economic, social and environmental development priorities, on the basis of the potential mitigating effect on climate change and compliance with country development priorities.

This report is focused on the technology prioritization for Agriculture and Waste mitigation. Expert groups for each sector were involved in the discussions with project team and stakeholders.

Based on proposed TNA methodology, national experts have prepared the long lists of possible technologies options. All together 22 technology facts sheets (TFSs) were developed (10 for Agriculture mitigation and 12 for Waste mitigation subsectors).

Based both on TNA methodology and application of MCA approach conducted in accordance with the handbook 22 TFSs have been scored (the details of assessment are presented in chapters 3 and 4 above, as well as in the Annex VII).

In addition to information on the parameters of technology, impact statements, financial requirements and costs, TFSs include information on limitations for the technology implementation, such as related to geographic location, climate, soil type, the availability of water resources, energy or road infrastructure, etc. Such information could be used for the visualization of potential for prioritized climate technologies. An example of such visualization for organic agriculture technology is provided in Annex VIII.

As a result of the first stage of the TNA process 11 technologies (5 for Agriculture mitigation and 6 for Waste management mitigation) obtained higher scores and were chosen for further consideration and final approval. Information obtained during the preparation of this report is distributed among interested stakeholders for their consideration and comprehensive analysis. The selected technologies are shown in the table 5.1.

Table 5.1 – List of priority technologies for climate change mitigation in Ukraine

No	Technology	Sector
1	Organic agriculture	Agriculture
2	Conservation tillage technologies (low-till, no-till, strip-till, etc.)	Agriculture
3	Biogas production from animal waste	Agriculture
4	The use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture	Agriculture
5	The production and use of solid biofuels from agricultural residues	Agriculture
6	Methane capture at landfills and waste dumps for energy production	Waste
7	Waste sorting (sorting of valuable components of MSW with subsequent treatment of waste residual by other technologies)	Waste
8	The closure of old waste dumps with methane destruction (flaring, biocovers, passive vent etc.)	Waste
9	The mechanical-biological treatment of waste with biogas and energy production	Waste
10	The anaerobic treatment (digestion) of sewage sludge)	Waste
11	The mechanical-biological treatment of waste with the alternative fuel (SRF) production for cement industry	Waste

These technologies are related to a wide spectrum of economic, social, environmental and political factors. The barrier analysis and development of TAP for these selected technologies will reflect the need for technology actions in chosen sectors and subsectors. In general, there is a need to develop a comprehensive technology database for the users and policy-makers, as well as to support local technology and expertise development.

The results of TNA project will be used in ongoing process of Ukraine’s NDC revision for efficient GHG reduction pathways identification and investment needs assessment to reach more ambitious reduction targets.

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Annex I: Technology Factsheets for selected technologies (Agriculture)

Agriculture Technologies (TFS 1A – TFS 10A)

Technology fact sheets were developed on the basis of the information of Climate-tech Wiki, international and national studies, as well as inputs and comments from the members of the working groups “Mitigation Technologies in Agriculture Sector” and “Mitigation Technologies in Waste Sector” established within the TNA project.

TFS 1A

Technology Name	**Using slow- or controlled-release fertilizer forms or nitrification inhibitors**
Sub-sector	Agriculture, Agricultural Soils
Sub-sector GHG emission (Mt CO_2-eq.)	42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) 5.8 - Inorganic N fertilizers category (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Global nitrogen use for food production is highly inefficient with only 20% of nitrogen added in farming ending up in human food, while the 80% is wasted as pollution and N_2 to the environment[1]. The efficient use of nitrogenous fertilizers can reduce N_2O emissions from agricultural fields, as well as CO_2 emissions associated with fertilizers manufacturing. The slow release of urea and NH_4 based fertilisers can be achieved by using various coatings, chemical modifications and changing the size of fertiliser granules (e.g. increasing the size of urea granules from conventional 0.01g to 1g). Release control factors could include moisture, temperature and microbial activity. The emission of N_2O can be reduced by using nitrification inhibitors, which reduce the activity of nitrifying bacteria and slow the microbial processes that lead to N_2O formation. The examples of nitrification inhibitors include S. benzylisothiouronium butanoate (SBT butanoate), S. benzylisothiouronium fluroate (SBT fluroate), and dicyandiamide.[2] The additional practices of improving fertilizers application efficiency include choosing fertilizer type (e.g. nitrate-based fertilizers results in significantly lower emissions of N_2O than ammonium-based fertilizers), timing (e.g. aligning fertilizer input with the period of increased nitrogen demand by plants in spring), placement (e.g. injection into the soil near the zone of active root uptake) and the rate of fertilizer application, as well as coordinating the time of application with irrigation and rainfall events (e.g. the application of fertilizer immediately after rain will increase N use efficiency of plants and mitigate N_2O emissions).
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	The annual nitrogen fertilizers application in Ukraine reaches 1.365 million tons of nitrogen. Due to a high cost, the short-term potential of encapsulated and controlled release fertilizers application is assessed as small-scale, but it could be increased in the medium-term period in case of stricter control over the soil quality on agricultural lands and implementing fertilizers rates restrictions.

1 UN Environment, Frontiers 2018/19: Emerging Issues of Environmental Concern, https://www.unenvironment.org/resources/frontiers-201819-emerging-issues-environmental-concern

2 ClimateTech Wiki, http://www.climatetechwiki.org/technology/nitrogenous-fertilisers

Status of technology in country	Fertilizers with the slow or controlled release of nitrogen as well as nitrofication inhibitors are available on a local market (import from Germany, Netherlands, Italy, China, Japan, etc.) but their application is not a common practice in Ukraine. There is no local production of slow or controlled release fertilizers.
Implementation barriers	The main barrier is the economic barrier due to a high cost of fertilizers with slow or controlled nitrogen release.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	Encapsulated fertilizers are most relevant for degraded lands as they usually include micro-elements and other substances improving soil quality. Chemical inhibitors of N_2O emissions may not be effective in certain types of soil.
Reduction in GHG emissions (Mt CO_2-eq.)	The use of efficient fertilizers management technologies could reduce N_20 emissions by about 20%. The maximum potential of GHGs emission reduction due to lower N_2O emissions is estimated at the level of 1.2 Mt of CO_2-eq. (20% of GHGs emissions due to inorganic N fertilizers in Agricultural Soils category in 2016). Additional GHGs emission reductions could be caused 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 results 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 of GHGs emission reduction 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 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.
Impact Statements - How this option impacts the country's development priorities	
Social development priorities	The development of local manufacturing of encapsulated fertilizers would contribute to the job creation in the chemical industry of Ukraine and support chemical and biotechnology science. More efficient use of fertilizers will also contribute to health protection due to lower nitrates content in agricultural products and reduced soil and water pollution.
Economic development priorities	The development of local manufacturing of encapsulated fertilizers would contribute to economic development by additional job creation and increasing value added of the chemical industry.
The priorities of environmental development	The development of the technology meets national environmental priorities on the reduction of water pollution and soil conservation. The slow or controlled release of nitrogen is better matching nitrogen demand by plants reducing nutrient runoff pollution. Encapsulated fertilizers stabilize soil microbiocenosis and contribute to soil structure improvement. Potential soil contamination with chemicals contained in capsules' materials should be considered.
Other considerations and priorities such as market potential	The application of the technology improves the soil's structure and leads to more efficient soil water content used by plants. Thus, the technology has adaptation of co-benefits related to the conservation of water resources. The utilization of the technology could be driven by legal limitations of fertilizers input rates or additional benefits from the micro-elements contained in encapsulated fertilizers.
Financial Requirements and Costs	

Capital costs	Capital cost for agricultural producers are not applicable or very low, as standard equipment and machinery used for traditional fertilizers application could be utilized. Capital costs related to the cost of additional technological unit for encapsulation of fertilizers are applicable for fertilizers manufacturers only.
Operational and Maintenance costs	There are almost no additional operational costs related to the fertilizers input process as the technology foresees relatively simple changes, such as increasing particle size of the fertilizers and changing the timing of applications and the same machinery and technological operations are used. Operational expenses for the fertilizers input process is in the range of USD 40-80 per ha. However, both encapsulated fertilizers and chemical inhibitors are significantly more expensive than traditional fertilizers. While the price of traditional fertilizers as of May, 2019 ranges from UAH 4600 per ton for ammonia water (N – 20.5%) to UAH 11 800 per ton for urea (N – 46%)[3], which is the equivalent of about USD 1 per kg of N. The price of encapsulated fertilizers could reach UAH 120 000 – 160 000 per ton. Thus, the operational expenses for fertilizers could be up to 10 times higher in case of slow-release and the use of coated fertilizers compared to traditional one and could reach USD 800 per ha (assuming the average input rate of 80 kg N per ha as reported by the State Statistical Service of Ukraine for 2016-2017). Encapsulated fertilizers however also contain micro-elements. Besides, extra savings could be achieved because of the avoiding operations for the input of additional fertilizers.
Cost of GHG reduction	Not estimated

3 Ministry of Agrarian Policy and Food, https://new.minagro.gov.ua/ua/napryamki/roslinnictvo/monitoring-cin-na-mineralni-dobriva

TFS 2A

Technology Name	**Use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture**
Sub-sector	Agriculture, Agricultural Soils
Sub-sector GHG emission (Mt CO_2-eq.)	42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) 5.8 - Inorganic N fertilizers category (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Information and telecommunication technologies for agricultural sector include, in particular, the following: - the use of drones for the aerial monitoring of agricultural lands with photo and video fixation, as well as applying different sensors; drones are used for the development of fertilizers input maps, as well as 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; - the use of specialized applications and software, including cloud-based systems, for fertilizers input management, irrigation, crop protection, etc. Multispectral and hyper-spectral aerial and satellite imagery helps in creating Normalized Difference Vegetation Index (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.[4] Data collected with drones are also combined with other information sources like soil testing, weather data and satellite images. The use of information and telecommunication technologies allows differentiated fertilizers input and resulting fertilizers savings. The savings could reach as much as 20% of fertilizers without productivity losses.
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon**	The technology could be broadly applied in all regions of Ukraine and there are both local and international service providers available on the market. The application of the technology could be extended in a short-term period.
Status of technology in country	The application of the information and telecommunication technologies in agriculture is growing in Ukraine. 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 startups.[5]

4 The Food and Agriculture Organization of the United Nations, E-agricuture in action: drones for agriculture, http://www.fao.org/e-agriculture/news/new-publication-fao-itu-e-agriculture-action-drones-agriculture

5 Agritech Market Map, http://agritech.unit.city/guide/f98ewf9fewfw/AgriTech_Industry_guide_en.pdf

Implementation barriers	Implementation barriers include: - the regulatory barrier due to the lack of approved and enforceable fertilizers input limits; - capacity barrier due to the lack of understanding of the benefits related to the application of modern information and telecommunication technologies and experience in their implementation, especially in small and medium enterprises.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	No material limitations were identified.
Reduction in GHG emissions (Mt CO_2-eq)	The use of efficient fertilizers management technologies could reduce N_20 emissions by about 20%. The maximum potential of GHGs emission reduction due to lower N_2O emissions is estimated at the level of 1.2 Mt of CO_2-eq. (20% of GHGs emissions due to inorganic N fertilizers in Agricultural Soils category in 2016). The reduction additional GHGs emission could be caused due to the use of the reduced 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 GHGs emission 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.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology could support job creation in IT sector of Ukraine. The demand of agricultural workers could be reduced, though. 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.
Economic development priorities	The implementation of the technology could reduce the operational cost of agricultural enterprises due to savings on fertilizers and improve the economic efficiency of their operations.
Environmental development priorities	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.
Other considerations and priorities such as market potential	None identified
Financial Requirements and Costs	
Capital costs	Direct capital cost is not significant and could be applicable in case of establishing own divisions for ICT tools application as an alternative to using specialized service providers (starting from USD 20,000). However, potential capital expenditures are mainly related to indirect cost for the investment in the machinery and equipment, which will allow the practical application of the recommendations developed using ICT tools (tractors with computer systems, specialized software, machinery for differentiated fertilizers input, etc.). These indirect costs could not be totally attributed to

	the implementation of the technology as many farmers invest in such machinery for other efficiency reasons.
Operational and Maintenance costs	Operational cost ranges 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.
Cost of GHG reduction	Not estimated

TFS 3A

Technology Name	**Conservation tillage technologies (low-till, no-till, strip-till, etc.)**
Sub-sector	Agriculture
Sub-sector GHG emission (Mt CO_2-eq.)	The technology would have an impact on emissions in both Agriculture and LULUCF sectors: 42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) -18.1 – Land Use, Land Use Change, and Forestry sector (2016) 47.3 – Cropland sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Conservative agriculture reduces the disruption of soil structure by minimizing tillage. The technology allows raising soil carbon content due to 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-tillage 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 the complete soil cover, fertilizer and amendments are either broadcast on the soil surface or applied during seeding.[6] 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 water and nutrients supply.
Country specific applicability and potential, incl.: Capacity Scale of application Time horizon- Short /Medium/long term	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.[7] More conservative estimates provided by the experts of the working group Mitigation Technologies in Agriculture is in the range of 10-15 million ha.
Status of technology in country	Ukrainian agricultural companies actively experiment with no-till and other conservation tillage practices. Some companies operate almost exclusively applying no-till practice. The companies actively using conservation tillage practices, include Agrosoyuz, Kernel, Vinnytska Agro-Industrial Group, Agro Generation, I&U Group, KSG Agro, Agromino, Ukrlandfarming, etc. Cover crops most typically used in Ukraine include winter rye, lupine, lean, and oilseed radish.

6 Food and Agriculture Organization of the United Nations, http://www.fao.org/conservation-agriculture/in-practice/minimum-mechanical-soil-disturbance/en/
7 Food and Agriculture Organization of the United Nations, http://www.fao.org/fileadmin/templates/tci/pdf/Investment_Days_2013/17_December/1a._TCI_support_to_conservation_agriculture_in_Kazakhstan_and_Ukraine_-_Guadagni.pdf

	According to the latest available data from the FAO Aquastat database[8], in 2013 conservation agriculture area in Ukraine comprised of 700 000 ha (2.14% of all arable land area).
Implementation barriers	Implementation barriers include the following: • information barrier about the region- and plant-specific requirements for the application of conservation tillage, as well as the requirements for equipment and technological operations; • financial barrier due to the lack of affordable sources of financial resource to invest in new machinery.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	The application of the technology and potential limitations should be analyzed 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.
Reduction in GHG emissions (Mt CO_2-eq.)	Conservation tillage contributes to the reduction of GHGs emission due to reduced emissions of CO_2 from fossil fuel combustion by agricultural machinery, increased carbon dioxide sequestration and reduced soil mineralization. Joint implementation projects implemented in Ukraine estimated the reduction of GHGs emission from no-till technology only due to the increased carbon sequestration in the range of 9-24 tons of CO_2-eq. per ha per year.[9] However, scientific literature provides more conservative carbon sequestration rates due to no-tillage application in the range of 270 – 500 kg of C per ha per year for US[10] and 200 – 400 kg of C per ha per year for Europe[11], which correspond to GHGs emission reductions 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 GHGs emission are estimated at the level of 7 Mt CO_2-eq.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology could reduce labour demand in agriculture sector. Trainings and capacity raising activities for the workers should be considered to avoid the unemployment growth. Potential negative human health impact from increased crop protection agents use should be explored. The use of cover crops in combination with conservation tillage practices could reduce the application of crop protection agents lowering human health risks.

8 Food and Agriculture Organization of the United Nations, http://www.fao.org/nr/water/aquastat/data/query/results.html

9 See, for instance, project design documentation for the following projects: https://ji.unfccc.int/JIITLProject/DB/NUZNTNB6PLFNZDZROEQFPE78259Z49/details, https://ji.unfccc.int/JIITLProject/DB/1COT37LYX8IL7O7Z7JCPONPOPA5HNL/details, https://ji.unfccc.int/JIITLProject/DB/EJ7R9MD7T98KPQ8KZ61LEIM8ZOPMZX/details, https://ji.unfccc.int/JIITLProject/DB/WA2R0FHVJYUUMH2TNEKBI82WQWD5LS/details, https://ji.unfccc.int/JIITLProject/DB/V1HAAJ2DJXNYNZH7V0VF1X86JB4LVW/details, https://ji.unfccc.int/JIITLProject/DB/D7ZOU4RMCP5T0B1MLCNCD5QSD9VRUS/details

10 Olson, K. R. (2013). Soil organic carbon sequestration, storage, retention and loss in U.S. croplands: Issues paper for protocol development. Geoderma, 195–196, 201–206, doi: 10.1016/j.geoderma.2012.12.004

11 Smith, P. et al. (2005). Carbon sequestration potential in European croplands has been overestimated, Global Change Biology, 11, 2153–2163, doi: 10.1111/j.1365-2486.2005.01052.x

Economic development priorities	The implementation of the technology allows enhance the economic efficiency of agricultural production because of reduced operational expenses. Crops yields are similar to those achieved under conventional tillage practices.
Environmental development priorities	The implementation of the technology supports national environmental priorities on the reduction of soil erosion and agricultural run-off minimization through keeping biomass residues on fields. Tillage is the main driver of soil erosion, which is a growing environmental problem in Ukraine. Conservation tillage improves chemical, physical, and biological characteristics of the soil, as well as increase soil organic content. Cover crops also reduce 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 to plants. Soil compaction risks and pollution related to increased crops protection agents and the use of pesticides should be considered in case of the conservation tillage application. 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.
Other considerations and priorities such as market potential	The implementation of the technology has significant adaptation co-benefits due to lower dependency of weather conditions and more efficient water resources use.
Financial Requirements and Costs	
Capital costs	The implementation of the technology requires significant capital investment in the procurement of specialized planters (direct seeders or modified seeders) as well as equipment for herbicides and fertilizers input. 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.[12] In the examples from Paraguay and Kazakhstan, the cost of the new machinery was estimated in the range of USD 100 - 120 per ha.[13, 14] Experts of the working group Mitigation Technologies in Agriculture estimated the capital expenditures required at the level of UAH 3 million per 1000 ha (USD 115 per ha). The specialized planters for no-till technology are at least 30% more expensive than standard planters.
Operational and Maintenance costs	Conservation tillage practices allows reduction of operational and maintenance cost for agricultural enterprises, in particular due to[15]: • 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; • reduced irrigation water use compared with conventional practices. Operational expenses for crop protection agents could be increased.

12 Epplin, Francis. (2007). Economics: No-till versus Conventional Tillage Economics: No-till versus Conventional Tillage. No-Till Cropping Systems Oklahoma, E-996, https://bit.ly/2J2x7jh
13 Rolf Derpsch, Economics of No-till farming. Experiences from Latin America, http://notill.org/sites/default/files/economics-of-no-till-farming-by-rolf-derpsch.pdf
14 FAO Investment Centre, Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan, http://www.eastagri.org/publications/pub_docs/Info%20note_Print.pdf
15 Climate TechWiki, http://www.climatetechwiki.org/technology/conservation-tillage

	In Kazakhstan, the overall savings due to no-till practices for wheat production was estimated at the level of USD 15 per ha[16].
Cost of GHG reduction	Not estimated

16 FAO Investment Centre, Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan, http://www.eastagri.org/publications/pub_docs/Info%20note_Print.pdf

TFS 4A

Technology Name	**Efficient Irrigation Systems (Sprinkler and Drip Irrigation)**
Sub-sector	Agriculture, Agricultural Soils
Sub-sector GHG emission (Mt CO_2-eq.)	42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Non-optimal precipitation conditions, especially in the Southern regions of Ukraine, which are becoming even more unfavourable due to climate change, limit the efficiency of agricultural production. Irrigation could increase harvesting volumes by 2 to 3 times comparing with rainfed conditions.[17] Irrigation investments increase the productivity of land and reduce the impacts of climate change, which are estimated to be significant for rainfed agriculture.[18] The efficiency of irrigation system includes micro-sprinklers, drip irrigation and other efficient applications. Sprinkler irrigation is a type of pressurised irrigation that consists of applying water to the soil surface using mechanical and hydraulic devices that simulate natural rainfall. One of the main advantages of the sprinkler irrigation technology is more efficient use of water for irrigation in agriculture and increased crop yields. Such systems are suited for most row, field and tree crops that are grown closely together, such as cereals, vegetables, fruits.[19] Drip irrigation is based on the constant application of a specific and focused quantity of water to soil crops. The system uses pipes, valves and small drippers or emitters transporting water from the sources to the root area and applying it under particular quantity and pressure specifications. With comparison to sprinklers systems, it can provide 75% efficiency, drip irrigation can provide as much as 90% water-use efficiency.[20]
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	The existing infrastructure (capacity of pumping stations, water supply channels, etc.) and water resources availability allows the additional water intake and supply to ensure irrigation at the area of 1.5 – 1.8 million ha. There are 884,500 ha of land with existing irrigation systems that could be restored after modernization.[21] According to the latest available data from the FAO Aquastat database[22], total irrigation potential in Ukraine is 5.5 million ha. The application of the technology could be extended in a short-term perspective.
Status of technology in country	Ukraine has large-scale irrigation systems in Southern regions, which were constructed mostly 40-50 years ago and require significant modernization due outdated and inefficient pumping equipment and deteriorated water distribution infrastructure. Water is supplied mostly by using open channels covered with concrete slabs. Equipment used for irrigation include high-pressure center-pivot

17 Draft Order of the Cabinet of Ministries of Ukraine On the Approval of the Irrigation and Drainage Strategy in Ukraine for the period up to 2030, https://menr.gov.ua/news/32835.html
18 Beyond the Gap How Countries Can Afford the Infrastructure They Need while Protecting the Planet, Julie Rozenberg and Marianne Fay, Editors, https://elibrary.worldbank.org/doi/abs/10.1596/978-1-4648-1363-4
19 ClimateTech Wiki, http://www.climatetechwiki.org/content/sprinkler-irrigation
20 ClimateTech Wiki, http://www.climatetechwiki.org/content/drip-irrigation
21 Draft Order of the Cabinet of Ministries of Ukraine On the Approval of the Irrigation and Drainage Strategy in Ukraine for the period up to 2030, https://menr.gov.ua/news/32835.html
22 Food and Agriculture Organization of the United Nations, http://www.fao.org/nr/water/aquastat/data/query/results.html

	sprinklers (Fregate, Dnipro), modern low-pressure lateral sprinklers, as well as drip irrigation. The irrigated areas are significantly below the design areas established during the irrigation network construction (2.65 million ha). In 2017 irrigation was performed on the area of only 497,000 ha (less than 20% of the initial area). This area includes 70,000 ha of land with dripping irrigation systems and 165,000 – 190,000 ha of land with modernized irrigation systems (e.g. new pipelines and modern sprinklers). Operational irrigation systems supplying water to about 250,000 – 300,000 ha of land require modernization.[23]
Implementation barriers	The implementation barriers include the following: - organizational barrier due to various ownership and management structures (main irrigation networks are mostly state owned and managed by the State Water Agency of Ukraine, while irrigation networks on the fields could be either privately owned or owned by the state, but it could be managed by different public authorities (national, regional, or local); - technical barriers – low efficiency and reliability of irrigation systems with high energy cost and significant water losses levels; - financial barrier – the limited access to capital and reliance on state subsidies to cover operational costs, as well as high capital cost for the modernization or building new water delivery systems; - economic barrier – high electricity cost and potential for further increase after the launch of a new electricity market in Ukraine; - administrative barriers – illegal and uncontrolled water off-take from the irrigation channels; - environmental barriers due to the risk of water over-extraction.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	Limitations include: - the availability of clean water resources in the region taking into account the competing demand from households, industry and energy sectors; - the availability of power supply for pumping stations; - climatic conditions and the demand for irrigation (crops to be cultivated and their water requirements throughout the growing season). The Sprinkler irrigation technology is well adapted to a range of topographies and it is suitable in all types of soil, except heavy clay. The application rate of the sprinkler system must be matched to the infiltration rate of the most restrictive soil in the field (to avoid ponding and surface runoff). However, even the moderate wind can seriously reduce the effectiveness of sprinkler systems by altering the distribution pattern of the water droplets. Likewise, when it is operated under high temperatures, water can evaporate at a fast rate reducing the effectiveness of the irrigation.[24]
Reduction in GHG emissions (Mt CO_2-eq.)	Extension of irrigation technology use does not lead to direct reductions of greenhouse gases emissions as additional emissions are occurring due to energy use for water abstraction and pumping. Assuming water consumption at the level of 2,000 m^3 per ha, specific electricity consumption of 261.4 kWh[25] per 1000 m^3, and electricity emission factor of 1.1 tons CO_2 per MWh reflecting additional power generation by coal fired powerl plants, additional GHGs emissions for irrigation are about 575 tons CO_2 per 1000 ha or 2.9 Mt CO_2-eq. in case of full realization of

23 Draft Order of the Cabinet of Ministries of Ukraine On the Approval of the Irrigation and Drainage Strategy in Ukraine for the period up to 2030, https://menr.gov.ua/news/32835.html
24 ClimateTech Wiki, http://www.climatetechwiki.org/content/sprinkler-irrigation
25 Методичні аспекти розрахунку компенсації витрат сільгоспвиробникам за використанн води для зрошення. М.І. Ромащенко, Ю.І. Гринь, Р.В. Сайдак.

	irrigation potential (additional 5 million ha). GHGs emissions could be avoided in case of the use of renewable energy. At the same time, larger harvesting volumes at irrigated lands also increase the formation of biomass residues and enhance carbon sequestration, as well as reduce land demand for the agricultural production. Irrigation allows reducing specific land-use GHGs emissions per ton of harvested crops. Twofold increase of yields at irrigated lands potentially allows avoiding equivalent land area conversion from other uses (e.g. grassland, forest land) to arable land and avoiding potential GHGs emissions at the level of 4 Mt CO_2-eq. (average level of agricultural soil emissions of 0.8 tons CO_2-eq. per ha of cropland area multiplied by 5 million ha). Therefore, the GHGs emission reduction volume used for technology needs assessment is 1.1 Mt CO_2-eq. (4 Mt CO_2-eq. minus 2.9 Mt CO_2-eq.).
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology will contribute to job creation (e.g. the design and construction of irrigation systems, workers responsible for the operation and maintenance of irrigation equipment and infrastructure, additional employment for harvesting, etc.) in agricultural regions, including the rural areas. Moreover, increased agriculture products yields could foster job creation in other industries.
Economic development priorities	The implementation of the technology will improve the economic efficiency of agricultural industry and increase the export of agricultural products.
Environmental development priorities	The implementation of the technology contributes to the environmental development priorities, including the adaption to climate change and the efficient use of water resource. Environmental impact due to the increased withdrawal of water should be assessed on a case by case basis.
Other considerations and priorities such as market potential	None identified
Financial Requirements and Costs	
Capital costs	In many regions, transforming traditional rainfed systems or upgrading water-inefficient irrigation systems into productive irrigation systems will require investments that go well beyond the economic means of farmers. Partial subsidies for capital costs from government agencies or basin authorities are common even in high-income countries (like Australia, Canada, France, Greece, Italy, and Spain).[26] The cost of installing a sprinkler system ranges from USD 600 to USD 2,500 per ha, depending on the type of materials used and the amount of labour contributed.[27] The cost of a drip irrigation system ranges from USD 800 to USD 2,500 per ha depending on the specific type of technology, automatic devices, and materials used as well as the amount of labour required.[28] Drip irrigation systems requires capital expenditures for filtration station, liquid fertilizers input system, pipes, assembling works, water tanks and pumps. According to the estimate of experts from Mitigation Technologies in Agriculture working group, the expenditures (without water supply infrastructure) are in the range of USD 400 – 1,200 per ha.

26 Beyond the Gap How Countries Can Afford the Infrastructure They Need while Protecting the Planet, Julie Rozenberg and Marianne Fay, Editors, https://elibrary.worldbank.org/doi/abs/10.1596/978-1-4648-1363-4
27 ClimateTech Wiki, http://www.climatetechwiki.org/content/sprinkler-irrigation
28 ClimateTech Wiki, http://www.climatetechwiki.org/content/drip-irrigation

	According to the Draft Irrigation and Drainage Strategy,[29] the approximate capital expenditures for extending irrigation systems in Ukraine are the following: • up to USD 1,100 per ha for the modernization of existing and operational irrigation systems; • USD 2,000 – 2,500 per ha for existing but damaged irrigation systems; • about USD 2,500 per ha for the construction of new irrigation systems (without the cost of major water supply infrastructure). Total capital expenditures for the modernization of irrigation systems in Ukraine with addition of 1,180,000 ha of irrigated land are estimated at the level of USD 3 billion. According to the estimate of the members of the working group Mitigation Technologies in Agriculture capital expenditures could be even higher in some cases reaching USD 4,500 per ha.
Operational and Maintenance costs	Main operational cost relates to electricity cost for water pumping. In many low- and middle-income countries, including China and India, the part of operational and maintenance costs are subsidized by state agencies and the organizations of water users. Irrigation water is commonly available for free or at very low prices. Subsidizing the price of water for irrigation was common practice until recently in Europe and the United States to encourage the agricultural development. However, many of these policies are being reformed due to their environmental impacts, including over-extraction and water pollution.[30] In Ukraine about 50% of irrigation and drainage expenditures are financed by the state budget, while the other half is financed by water consumers. The specific operational expenditure from the state budget depends on the conditions and capacity load factor of irrigation infrastructure in the region. In 2017 the share of operational expenditures covered from the state budget ranged from 24.7% (UAH 438 per ha) in Kherson region, where the irrigation is operational at 69% of the designed irrigation area, to 67.8% (UAH 2594 per ha) in Odesa region, were only 17.8% of irrigation land is actually irrigated.[31] According to the estimate of the experts of the working group Mitigation technologies in Agriculture, operational expenditures for water, electricity, labour and other range from UAH 1,500 to UAH 5,000 per ha (USD 60 – 190). Operational expenditures for the drip irrigation also include storage, cleaning and replacement (once per every 2-3 years) of drip irrigation pipes.
Cost of GHG reduction	Not estimated

29 Draft Order of the Cabinet of Ministries of Ukraine On the Approval of the Irrigation and Drainage Strategy in Ukraine for the period up to 2030, https://menr.gov.ua/news/32835.html
30 Beyond the Gap How Countries Can Afford the Infrastructure They Need while Protecting the Planet, Julie Rozenberg and Marianne Fay, Editors, https://elibrary.worldbank.org/doi/abs/10.1596/978-1-4648-1363-4
31 Draft Order of the Cabinet of Ministries of Ukraine On the Approval of the Irrigation and Drainage Strategy in Ukraine for the period up to 2030, https://menr.gov.ua/news/32835.html

TFS 5A

Technology Name	**Biogas production from agricultural crops products**
Sub-sector	Agriculture
Sub-sector GHG emission (Mt CO_2-eq.)	The technology would have an impact on emissions in both Agriculture and Energy sectors: 42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) 225.8 – Energy sector (2016) 179.8 – Fuel combustion activities sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Biogas is produced as a result of the biochemical decomposition of macromolecular compounds for agricultural crops into simple organic compounds (organic acids, salts of organic acids, alcohols) and further into methane (CH_4), carbon dioxide (CO_2), and ammonia (NH_4). The process is performed under anaerobic conditions. Agricultural crops products that could be used for the biogas production include corn silo and other green grasses. About 200 m^3 of biogas could be produced from 1 ton of corn silo. Agricultural crops could be used in combination with animal waste. The produced biogas is used for heat energy and / or electricity generation. The key technological equipment used for biogas production include reactors for anaerobic fermentation with substrate mixing units and gas holders and co-generation units. The produced biogas could also be cleaned into biomethane and used as a fuel in transport sector or supplied to the natural gas grid. The by-products of biogas production (i.e. processed substrate) are used as bio-fertilizers.
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	According to the National Action Plan on Renewable Energy by 2020 the capacity of biogas plants is expected to be increased to 290 MW and the electricity production from biogas is expected to reach 1,279 GWh. IRENA[32] estimated additional cost-competitive potential of biogas power plants in Ukraine at the level of 1,696.8 MW and the potential of electricity generation at the level of 10,278 GWh per year. According to the estimate of Bioenergy Association of Ukraine, the theoretical potential of biogas production from agricultural crops products include 3 billion cubic meters of CH_4 from corn silo (harvested at the area of 1 million ha) and 1.6 billion cubic meters of CH_4 from agri-industrial residues and by-products.[33] The latter category includes sugar beet bagasse, by-products of beer and ethanol production plants and animal waste. The potential of biogas production for sugar beet bagasse is 975.5 million m^3 per year[34] (0.5 billion of CH_4 assuming 50% methane content). The Bioenergy Association of Ukraine estimates that 50% of theoretical potential for agri-industrial residues and by-products and 100% for corn

32 Cost-competitive Renewable Power Generation: Potential across South East Europe, https://www.irena.org/publications/2017/Jan/Cost-competitive-renewable-power-generation-Potential-across-South-East-Europe

33 Bioenergy Association of Ukraine (2019): Analysis of barriers to the production of energy from agribiomass in Ukraine – 21th Position Paper of UABio, http://www.uabio.org/activity/uabio-analytics/3889-position-paper-uabio-21

34 Bioenergy Association of Ukraine, http://www.uabio.org/img/files/docs/position-paper-uabio-4-ua.pdf

	silo are available for energy purposes, which is the equivalent of substituting 3.25 billion cubic meters of natural gas.
Status of technology in country	As of April, 2019, there are 12 companies operating 13 biogas units using agricultural biomass and supplying electricity to the national grid under green tariff mechanism[35], including: - 6 biogas units with the capacity of 12.9 MW working on biomass from agricultural crops (corn silo, sugar beet pulp, etc.); - 4 biogas units with the capacity of 5.8 MW working on animal waste (swine, cattle and chicken manure); - 3 biogas units with the capacity of 9.6 MW working with the combination of biomass from agricultural crops and animal waste. Examples of biogas plants using agricultural crops include: - Teofopil Energy Company LLC with the biogas plant of 5.1 MW electric capacity using sugar beet pulp as biomass source and the second biogas unit of 10.5 MW working on corn silo; - Gorodyshche-Pustovarivska Agrariran Company LLC with the biogas plant of 2.4 MW capacity working on sugar beat pulp; - Agrienterprise Zeleyi Gai LLC with the biogas plant of 125 kW electric capacity using grass silo and grape distillery waste as biomass source; the plant initially operated in autonomous mode covering the energy demand of the enterprise but, it was later on connected to the national grid and received green tariff in 2018. 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. There are also examples of biogas plants not supplying electricity to the national grid but covering the energy demand of the enterprises. For instance, agricultural holding Astarta-Kyiv operates a biogas plant with the capacity of 150,000 m^3 per day Hlobyno city using sugar beet pulp and agricultural crops residues as a biomass source.
Implementation barriers	The key implementation barriers for biogas technology in Ukraine include the following: - technical barrier due to complicated technological processes, various biomass sources used, and low capacity utilization factors of operational biogas plants in Ukraine; - the financial barrier due to the limited access to affordable financial resources; - the economic barrier due to lack of efficient mechanisms for supporting the generation of heat energy from biogas and biomethane production; - the capacity barrier due to not sufficient number of qualified managers and operational personnel with the practical experience in biogas plants construction and biogas production.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	Technology could be implemented in all regions of Ukraine. Limitations could include infrastructure limits to organize biomass logistics and export electricity to the national grid, as well as environmental restrictions with respect to sanitary protection zones, water protection zones, etc.
Reduction in GHG emissions (Mt CO_2-eq.)	The implementation of the technology leads to the reduction of GHGs emission due to the substitution of fossil fuel-based energy with renewable energy.

35 National Commission for State Energy and Public Utilities Regulation, http://www.nerc.gov.ua/data/filearch/elektro/energo_pidpryemstva/stat_info_zelenyi_taryf/2019/stat_zelenyi-taryf.03-2019.pdf

	Assuming the potential for substituting 3.25 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 GHGs emission would constitute 6.3 Mt CO_2-eq. GHGs emissions associated with the biomass collection, transportation and processing should be considered during estimation of GHGs emission to the potential of reduction. Assuming the required reduction of greenhouse gas emissions set by EU sustainability criteria at the level of 70% for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021, the potential reduction of GHGs emission from technology implementation is estimated at the level of 4.4 Mt CO_2-eq. The actual reduction of emission would be higher as the part of 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 ensuring the consistent approach between different technologies.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology leads to job creation in agricultural industry both due to the direct employment at biogas plants and indirect impact (crops harvesting, logistics, etc.).
Economic development priorities	The implementation of the technology contributes to economic development and energy security of Ukraine.
Environmental development priorities	None identified
Other considerations and priorities such as market potential	Crops production for biogas generation is the most feasible on degraded or low-quality soils due to the potential competition with food production.
Financial Requirements and Costs	
Capital costs	According to the estimation of 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. Biogas projects are economically feasible taking into account state support in the form of green tariff.
Operational and Maintenance costs	According to the estimation of expert from the working group Mitigation Technologies in Agriculture the annual operational expenditures for biogas power plants varies in the range 5-15% of the CAPEX. Assuming the average value of 10% the operational expenses would be in the range of EUR 0.3-0.4 million per MW.
Cost of GHG reduction	Not estimated

TFS 6A

Technology Name	**Biogas production from animal waste**
Sub-sector	Agriculture, Manure Management
Sub-sector GHG emission (Mt CO_2-eq.)	The technology would have an impact on emissions in both Agriculture and Energy sectors: 42.4 - Agriculture sector (2016) 2.1 - Manure Management (2016) 225.8 – Energy sector (2016) 179.8 – Fuel combustion activities sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	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 used for heat energy and / or electricity generation. The key technological equipment used for biogas production include reactors for anaerobic fermentation with substrate mixing units and gas holders and co-generation units. The produced biogas could also be cleaned into biomethane and used as a fuel in transport sector or supplied to the natural gas grid. The by-products of biogas production (i.e. processed substrate) are used as bio-fertilizers.
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	According to the estimate of Bioenergy Association of Ukraine, total biogas production potential 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.[36] 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.
Status of technology in country	As of April, 2019, there are 12 companies operating 13 biogas units using agricultural biomass and supplying electricity to the national grid under green tariff mechanism[37], including: - 6 biogas units with the capacity of 12.9 MW working on biomass from agricultural crops (corn silo, sugar beat pulp, etc.); - 4 biogas units with the capacity of 5.8 MW working on animal waste (swine, cattle, and chicken manure); - 3 biogas units with the capacity of 9.6 MW working on combination of biomass from agricultural crops and animal waste. 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;

36 Bioenergy Association of Ukraine, http://www.uabio.org/img/files/docs/position-paper-uabio-4-ua.pdf
37 National Commission for State Energy and Public Utilities Regulation, http://www.nerc.gov.ua/data/filearch/elektro/energo_pidpryemstva/stat_info_zelenyi_taryf/2019/stat_zelenyi-taryf.03-2019.pdf

	- 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 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.
Implementation barriers	The key implementation barriers for biogas technology in Ukraine include the following: - the technical barrier due to complicated technological processes, various biomass sources used, and low capacity utilization factors of operational biogas plants in Ukraine; - the financial barrier due to limited access to affordable financial resources; - the economic barrier due to lack of efficient mechanisms for supporting heat energy generation from biogas and biomethane production; - the capacity barrier due to not sufficient number of qualified managers and operational personnel with the practical experience in biogas plants construction and biogas production; - the regulatory barrier due to lack of environmental control over the use of organic waste and enforceable mitigation measures.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	Technology could be implemented near animal farms to ensure the stable centralized source of animal manure as transportation of manure is not economically feasible. Technology could be implemented in all regions of Ukraine. Limitations could include infrastructure limits 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 take into account environmental restrictions with respect to sanitary protection zones, water protection zones, etc.
Reduction in GHG emissions (Mt CO_2-eq.)	The implementation of the technology leads to the reduction of GHGs emission due to the substitution of fossil fuel based energy with renewable energy. 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 0.7 Mt CO_2. As animal manure are processed at the place of generation GHGs emissions associated with biomass collection, transportation and processing is not taken into account. The actual reduction of emission would be higher as 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 ensuring the consistent approach between different technologies. The additional reduction GHGs emission are achieved due to the avoidance of animal manure decay in the lagoons or other storages. The potential for

	the reduction of GHGs emission 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 GHGs emission reduction potential for the technology is 1.8 Mt CO_2-eq.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology leads to job creation in agricultural industry. The biogas production from animal waste will also reduce health risks related to environmental pollution by animal waste for the people living near the farms.
Economic development priorities	The implementation of the technology contributes to the economic development and energy security of Ukraine.
Environmental development priorities	The implementation of the technology supports national environmental priorities due to 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 the technology could be combined with natural-based solutions for wastewater treatment such as constructed wetlands further extending environmental benefits.
Other considerations and priorities such as market potential	None identified
Financial Requirements and Costs	
Capital costs	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. Biogas projects are economically feasible taking into account state support in the form of green tariff.
Operational and Maintenance costs	According to the estimation of the experts from the working group Mitigation Technologies in Agriculture 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 due as animal manure has either low cost or free.
Cost of GHG reduction	Not estimated

TFS 7A

Technology Name	**Organic agriculture**
Sub-sector	Agriculture
Sub-sector GHG emission (Mt CO_2-eq.)	The technology would have an impact on emissions in both Agriculture and LULUCF sectors: 42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) -18.1 – Land Use, Land Use Change, and Forestry sector (2016) 47.3 – Cropland sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	The 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.[38]
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	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.[39] According to the estimates of the experts of "Mitigation Technologies in Agriculture" 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 2017 the area of organic land in EU was 12.8 million ha or 7.2% of total farmland with leading countries having more than 20% share (e.g. Estonia – 20.5%, Austria – 24%). The increase from previous year was 0.8 million ha or 6.4%.[40] Thus, potential for organic agriculture is estimated at the level of 4 million ha.
Status of technology in country	The Law of Ukraine On Main Principles and Requirements for Organic Production was adopted in 2018 and it will be enforced in August 2019.[41] 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), which is only 0.7% of total agricultural land. 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. The

38 ClimateTech Wiki, http://www.climatetechwiki.org/technology/organic-agriculture
39 О. Ю Чигрин, А. А. Треус, А. А. Іскаков. Органічне землеробство як перспективна галузь української економіки, http://essuir.sumdu.edu.ua/bitstream/123456789/68509/1/Chygryn_Organic_Agriculture.pdf
40 The World of Organic Agriculture - Statistics and Emerging Trends 2019, https://shop.fibl.org/CHen/mwdownloads/download/link/id/1202/?ref=1
41 Law of Ukraine On Main Principles and Requirements for Organic Production, Trading and Labeling of Organic Products, https://zakon.rada.gov.ua/laws/show/2496-19

	reported area of organic land was reduced by 92,173 ha comparing to 2016. In 2017 there were 304 organic agricultural producers in Ukraine.[42] The largest organic agricultural companies include Arnica (15,800 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).[43]
Implementation barriers	The barriers for the implementation of the technology include the following: • the economic barrier due to the low internal demand for organic products because of low purchasing power of the population; • the economic barrier due to the additional controls or requirements on products imported from Ukraine to the EU (i.e. the complete documentation check at point of entry and sampling and analysing for presence of pesticide residues)[44] leading to higher costs and impacting competitiveness (96% of Ukrainian organic products export went to EU in 2017[45]); • the capacity barrier due to the lack of sufficient knowledge about the organic agriculture and lack of specialists with practical experience; • the regulatory barriers due to the lack of state incentives for organic agriculture development; • the information barrier due to low awareness about the benefits of organic products.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	The map of soils most suitable for organic agriculture has been developed by the National Academy of Agrarian Science of Ukraine (see also Annex VI).[46] However, the organic agriculture could be applied on all lands, including for the restoration of degraded lands.
Reduction in GHG emissions (Mt CO_2-eq.)	The organic agriculture has the potential of sequestering carbon into soils at rates 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 as compared to ploughed conventional cropping systems, but as the soil C dynamics reach a new equilibrium, these rates will decline in future.[47] Other studies report the similar average sequestration potential of about 200 to 400 kg C per ha per year for all croplands.[48] This corresponds to the sequestration of 0.7-1.4 tons of CO_2-eq. per ha per year. Besides, the organic agriculture requires 28% to 32% less energy compared to conventional systems. Input costs for seed, fertilisers, pesticides, machinery, and hired labour are approximately 20% lower in a rotation that includes a legume compared with a conventional rotation system[49]. These lead to the additional reduction of greenhouse gases emissions.

42 The World of Organic Agriculture - Statistics and Emerging Trends 2019, https://shop.fibl.org/CHen/mwdownloads/download/link/id/1202/?ref=1
43 BakerTilly, 5 фактів про органічне землеробство в Україні, https://bakertilly.ua/news/id45259
44 European Commission, https://ec.europa.eu/info/food-farming-fisheries/farming/organic-farming/trade_en
45 Ministry of Agrarian Policy and Food of Ukraine, https://minagro.gov.ua/ua/napryamki/organichne-virobnictvo/organichne-virobnictvo-v-ukrayini
46 National Academy of Agrarian Sciences, http://naas.gov.ua/newsall/newsnaan/5028/
47 ClimateTech Wiki, http://www.climatetechwiki.org/technology/organic-agriculture
48 Müller-Lindenlauf, M. (2009): Organic Agriculture and Carbon Sequestration. Possibilities and constrains for the consideration of organic agriculture within carbon accounting systems, http://www.fao.org/fileadmin/user_upload/rome2007/docs/Organic_Agriculture_and_Carbon_Sequestration.pdf
49 Kimble, J.M., Rice, C.W., Reed, D., Mooney, S., Follett, R.F., and Lal, R. (2007): Soil Carbon Management, Economic, Environmental and Social Benefits. CRC Press, Taylor & Francis Group.

	A diversified crop rotation with green manure in organic farming improves soil structure and diminishes 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.[50] 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 soil-based greenhouse gas emissions from organic and conventional agriculture in temperate climates based on 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.[51] The conservative estimate is the potential for the reduction of GHGs emission at a rate of 1 ton of CO_2-eq. per ha of land under organic agriculture practice. Total potential for reduction of GHGs emission is 4 Mt CO_2-eq.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	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 lower amount of man hours per ha comparing to the traditional agriculture because of more efficient machinery.[52] The implementation of the technology will have positive impact on human health due to the avoidance of chemicals and higher quality of agricultural products.
Economic development priorities	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.
Environmental development priorities	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.
Other considerations and priorities such as market potential	None identified
Financial Requirements and Costs	
Capital costs	There are no significant capital expenditures associated with organic agriculture. Certification expenditures are relatively low.
Operational and Maintenance costs	There are various studies comparing the operational cost of organic and non-organic agricultural production. Examples of both higher and lower cost of organic crops production could be found in the literature. Overall, the organic agriculture has similar operational cost to the non-organic agriculture.
Cost of GHG reduction	Not estimated

50 ClimateTech Wiki, https://www.climatetechwiki.org/technology/nitrogenous-fertilisers
51 Thünen Report 65 (2019): Leistungen des ökologischen Landbaus für Umwelt und Gesellschaf, https://www.boelw.de/fileadmin/user_upload/Dokumente/Pflanze/190121_Th%C3%BCnen-Report_65_final.pdf
52 FIBL (2018): Соціально-економічне дослідження розвитку органічного ринку та сектору в Україні, http://orgprints.org/35335/1/Socio-economic-study_UA_Dec2018_published.pdf

TFS 8A

Technology Name	**The production and use of solid biofuels from agricultural residues**
Sub-sector	Agriculture
Sub-sector GHG emission (Mt CO_2-eq.)	The technology would have an impact on emissions in both Agriculture and Energy sectors: 42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) 225.8 – Energy sector (2016) 179.8 – Fuel combustion activities sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	The technology foresees 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.
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	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.[53] Besides, the Concept of State Policy Implementation in the Area of Heat Supply aims achieving 30% renewable sources share in heat generation by 2025 and 40% share by 2035. 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 the energy generation, include straw, sunflower seeds husk, as well as corn and sunflower stalks and other residues. The availability of biomass residues depends on yield volumes in a particular year but the overall trend 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) 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 ton of straw per ton of grain yield[54]. 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.[55] Biomass residues should partly remain on the fields to ensure soil protection from erosion, compensating organic content loss and reducing evaporation. For Ukraine, it is recommended that 30%-40% of cereals

53 National Renewable Energy Action Plan of Ukraine until 2020, https://zakon.rada.gov.ua/laws/show/902-2014-%D1%80

54 World energy council (2016): World Energy Resources, https://www.worldenergy.org/wp-content/uploads/2017/03/WEResources_Bioenergy_2016.pdf

55 Методика узагальненої оцінки технічно-досяжного енергетичного потенціалу біомаси. –. К.: ТОВ "Віол-принт", 2013.

	straw could be used for energy purposes.[56,57] 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.). 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. [58] 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 last 20 years with the simultaneous increase in processing volumes and sunflower seed husk generation. Total sunflower seed husk generation is estimated at the level of 1.8 Mt, however about 50% is already used for direct combustion at oil processing plants or nearby enterprises[59]. Another 50% are mostly used for pelleting with further use for heat energy generation either in Ukraine or abroad but will be increasingly used for electricity generation due to the announced plans of CHP units construction by major oil extraction plants. According to the Bioenergy Association of Ukraine, the energy potential of sunflower seed husk is 0.99 Mtoe. The bioenergy Association of Ukraine estimates energy 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 of 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).
Status of technology in country	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 biomass use for energy purposes is the generation of heat energy. In 2018, 22.5% of heat energy was generated in Ukraine by using alternative fuel types and renewable energy sources[60]. 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 10 biomass CHPs supplying electricity to the national grid utilizing green tariff support mechanism. Total biomass-based power generation capacity equals 51 MW. Most of the biomass CHPs use wood biomass and three of them (APK Evgroil LLC, Kropyvnytskyi OEM PJSC, and Singa Energies LLC) use sunflower seed husk as fuel. With total current annual biomass power generation of about 100 GWh, biomass

56 Scientific Engineering Centre "Biomass", http://biomass.kiev.ua/useful-info/background-materials/1202-praktichnij-posibnik-dlya-predstavnikiv-derzhavnikh-ta-komunalnikh-ustanov-z-vikoristannya-biomasi-v-yakosti-paliva-u-munitsipalnomu-sektori-ukrajini
57 International Finance Corporation. 2013. Producing Cellulose from Straw: Opportunities in Ukraine. Kiev. © World Bank, https://openknowledge.worldbank.org/handle/10986/20175
58 Bioenergy Association of Ukraine (2019): Analysis of barriers to the production of energy from agribiomass in Ukraine – 21th Position Paper of UABio, http://www.uabio.org/activity/uabio-analytics/3889-position-paper-uabio-21
59 Bioenergy Association of Ukraine, http://uabio.org/activity/uabio-analytics/3165-comprehensive-analysis-of-the-ukrainian-biomass-pellets-market
60 Ministry of Regional Development, Construction and Utilities Sector of Ukraine, http://www.minregion.gov.ua/wp-content/uploads/2019/05/Reytingova-otsinka-za-2018-rik-prezentatsiyni-materiali.pdf

	consumption for electricity generation is estimated at the level of 500 GWh (approximately 30,000 tons of SSH and 140,000 tons of wood chips). However, there are new projects being developed in different regions foreseeing the use of agricultural biomass, including sunflower seeds husks and straw. For instance, Khmelnytskyi Biomass Power Plant will have the electric capacity of 46 MW and heat energy capacity of 130 MW. The plant will consume 270 000 tons of straw (14 GJ per ton) per year and produce 368 GWh of electricity.[61]
Implementation barriers	The analysis of barriers for the use of agricultural biomass for energy purposes was performed by the Bioenergy Association of Ukraine[62]. The key barriers include the following: - technological barriers due to the lack of machinery for the harvesting of crop production by-products (e.g. balers, loading and unloading equipment, transportation equipment) as well as the limited availability of equipment suitable for agricultural biomass combustion; - organizational and legal barriers due to the lack of established biomass fuel market in Ukraine, the violation of prohibition to burn crop residues on fields, and lack of state policy supporting agribiomass use; - economic barriers due to the limited access to capital; - ecological barriers due to risks for soil quality associated with the removal of crop residues from fields; - informational barriers due to poor dissemination of information about successful projects on energy production from agribiomass.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	The key limitations for the technology are associated with infrastructure requirements (e.g. power substations for electricity export, district heating infrastructure or nearby heat energy consumer for heat energy supply, road infrastructure for organizing biomass residues logistics, etc.).
Reduction in GHG emissions (Mt CO_2-eq.)	The use of agricultural biomass residues for energy generation leads to the reduction of GHGs emission due to substitution of fossil fuels. Assuming the additional energy potential of agricultural biomass at the level of 7 Mtoe (293 million GJ) and a conservative assumptions 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 comparing to natural gas (80% vs 90%), the potential GHGs emissions reduction from fossil fuel substitution would constitute 14.6 Mt CO_2. GHGs emissions associated with biomass residues collection, transportation and processing should be considered during the estimation of potential for the reduction of GHGs emission. Assuming the required reduction of greenhouse gas emissions set by EU sustainability criteria at the level of 70% for electricity, heating and cooling production from biomass fuels used in installations starting operation from 1 January 2021, the potential reduction of GHGs emission from technology implementation is estimated at the level of 10.2 Mt CO_2-eq.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology will contribute to job creation in biomass logistics and heat energy generation sectors.
Economic development priorities	The technology would contribute to the economic development of Ukraine by fostering renewable energy sector development.

61 Ministry of Ecology and Natural Resources, Environmental Impact Assessment Registry, http://eia.menr.gov.ua/places/view/1097
62 Bioenergy Association of Ukraine (2019): Analysis of barriers to the production of energy from agribiomass in Ukraine – 21th Position Paper of UABio, http://www.uabio.org/activity/uabio-analytics/3889-position-paper-uabio-21

Environmental development priorities	Environmental impact and mitigation measures to reduce air emissions from biomass combustion should be analyzed on a case by case basis.
Other considerations and priorities such as market potential	Competing the use of agricultural crops residues (as organic fertilizers substitutes, feed for livestock, etc.) should be considered in estimating technology application potential.
Financial Requirements and Costs	
Capital costs	According to the estimations of the experts from the working group Mitigation Technologies in Agriculture capital expenditures for biomass boiler 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. According to IRENA's report "Cost-competitive renewable power generation: Potential across South East Europe", the average investment costs for solid biomass incineration plant (CHP) is EUR 3487.5 per kW.[63] The capital expenditures could be reduced due to construction/materials localization. According to the estimations of the experts from the working group Mitigation Technologies in Agriculture capital expenditures for biomass CHP could be in the range of EUR 2.5 – 3.5 million per MW.
Operational and Maintenance costs	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.
Cost of GHG reduction	Not estimated

63 International Renewable Energy Agency (2017): Cost-competitive renewable power generation: Potential across South East Europe, https://www.irena.org/publications/2017/Jan/Cost-competitive-renewable-power-generation-Potential-across-South-East-Europe

TFS 9A

Technology Name	**Production of liquid biofuels from agricultural products**
Sub-sector	Agriculture
Sub-sector GHG emission (Mt CO_2-eq.)	The technology would have an impact on emissions in both Agriculture and Energy sectors: 42.4 - Agriculture sector (2016) 28.9 - Agricultural Soils sub-sector (2016) 225.8 – Energy sector (2016) 179.8 – Fuel combustion activities sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Biofuels can be derived from biomass sources such as corn, sugar cane, sorghum, soybean, crop residues, etc. The most widespread biofuels include bioethanol and biodiesel. The first generation of biofuel technologies include producing ethanol from sugar and starch-based feedstocks, and producing biodiesel from vegetable oils and other lipid feedstocks (including wastes and by-products). The second generation or advanced biofuel technologies include sustainable fuels produced from non-food crop feedstocks, which are capable of delivering significant life-cycle GHG emissions savings compared with fossil fuel alternatives and which do not directly compete with food and feed crops for agricultural land or cause adverse sustainability impacts.[64]
Country specific applicability and potential, incl.: **Capacity** **Scale of application** **Time horizon- Short /Medium/long term**	Most of rape seeds and soy beans produced in Ukraine are being exported. Assuming export volumes for the marketing year 2017-18, the potential of biodiesel production is 1.6-1.9 Mt, which is equivalent to about 30% of national diesel consumption. There are 10 plants in Ukraine with the capacity of 125 170 tons per year, which can produce bioethanol. However, actual production amounted only 28 596 tons in 2015. Assuming large volumes of corn and wheat harvesting in Ukraine the potential for bioethanol production is significant. 8 out of 46 largest sugar producers declared the availability of production capacities to launch bio-ethanol production.[65]
Status of technology in country	In Ukraine, the consumption of biofuels is less than 1% of total fuel consumption in transport sector. In 2017, total consumption of biofuels was at the level of 71,000 tons, of which only 21,000 tons were produced in Ukraine. There are 14 large biodiesel production plants in Ukraine but their operation is mostly suspended. About 50 small-scale biodiesel plants produce biodiesel, which is used either for the own needs of agricultural companies or sold to oil industry companies. There are also 5 oil processing plants, which have the right to produce petrol with bio-ethanol component. However, only two of them are operational (Kremenchuk OPP and Shebelynskyi OPP).[66]

64 International Energy Agency (2017), Technology Roadmap - Delivering Sustainable Bioenergy, https://webstore.iea.org/technology-roadmap-delivering-sustainable-bioenergy

65 Офіс ефективного регулювання (2019). Зелена книга. Регулювання виробництва рідких моторних біопалив, https://bit.ly/2X3hfab

66 Офіс ефективного регулювання (2019). Зелена книга. Регулювання виробництва рідких моторних біопалив, https://bit.ly/2X3hfab

Implementation barriers	Implementation barriers for the technology include the following: - economic barriers due to the high cost of production and lack of state support mechanisms to improve the financial feasibility of biofuel production projects; - the lack of obligatory requirements for biofuel share in fuel for transport; - technical barriers due to additional requirements for fuel storage and use, as well as lack of reliable quality control system for biofuels.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	None identified
Reduction in GHG emissions (Mt CO_2-eq.)	The use of biofuels contributes to the reduction of GHGs emission because of the substitution of fossil fuel consumption (i.e. diesel and petrol). However, biofuel production is also associated with GHGs emissions related to energy consumption, fertilizers use and land use change. Therefore, the actual reduction of emission could be at the level of 30%-80% comparing to the traditional use of fuel. According to the expert evaluation of the members of the Working Group Mitigation Technologies in Agriculture, the level of GHGs emission for biofuel production could be below the 60% benchmark defined as a sustainability criterion defined in EU requirements. The potential reduction of GHGs emission was estimated assuming 60% reduction comparing to the use of fossil fuel and potential substitution of 1.6 Mt of diesel and 0.2 Mt of bio-ethanol (10% of petrol consumption in Ukraine). Total potential reduction of GHGs emission was estimated at the level of 0.6 Mt.
Impact Statements - How this option impacts the country development priorities	
Social development priorities	The implementation of the technology could contribute to job creation.
Economic development priorities	The implementation of the technology would support the economic development of Ukraine by contributing to the national production and value-added generation.
Environmental development priorities	The production of crops used for biodiesel production contribute to soil degradation.
Other considerations and priorities such as market potential	The production of crops used for biofuel production could compete with production of crops for food. The development of the technology would enhance the national energy security as most of the diesel and petrol is imported. However, currently most of the rapeseed products in Ukraine are being exported.
Financial Requirements and Costs	
Capital costs	According to the information of experts from Mitigation Technologies in Agriculture working group, the typical capital expenditures for sugar beet bioethanol plants are in the range of EUR 0.9 -1.8 million per 1000 tons. According to the information of State Energy Efficiency and Energy Saving Agency of Ukraine, the map of investment projects in Ukraine UAMap includes information about the bioethanol production plant (second generation) with the capacity of 50,000 tons per year and total cost of EUR 75 million (EUR 1.5 million per 1000 tons). Most recent second-generation bioethanol project in Eastern Europe started in 2018 in Romania. At full capacity, the new plant will process approximately 250,000 tons of wheat straw to produce 50,000 tons of

	ethanol annually.[67] The investment in the project exceeds to EUR 100 million[68] (CAPEX are above EUR 2 million per 1000 tons). IRENA reports that the total installed cost for biodiesel plant is typically cheaper than for ethanol and is between USD 0.45 to USD 0.8 per litre per year of capacity in developed countries. The cost can be lower in developing countries (the estimated cost for the range of countries in North Africa and the Middle East is USD 0.25 litre/year of production capacity), where the local cost component of the manufacturing can help keep costs down.[69] Thus, the specific cost of biodiesel plants are in the range of EUR 0.3 – 0.8 million per 1000 tons of capacity. Thus, capital expenditures for biofuel projects could be estimated in the range of EUR 0.3–2 million per 1000 tons with lower bound applicable to biodiesel plants and higher bound applicable to the second-generation bioethanol production plants.
Operational and Maintenance costs	Operational expenses are estimated at the level of 10-15% from capital expenditures. The International Institute for Sustainable Development reports[70] significant variations in biofuel production cost reflecting the uncertainty of modelling approaches and the wide range of production processes and types of feedstock. The cost of biodiesel production ranges from EUR 0.36 to 0.99 per liter. The cost of bioethanol production ranges from EUR 0.29 to 0.95 per liter (excluding lower cost of cane sugar bioethanol production in Brazil).
Cost of GHG reduction	Not estimated

67 Bilfinger Tebodin, Biomass Energy: First-of-a-kind Plant in Romania, https://www.tebodin.bilfinger.com/fileadmin/tebodin/Biomass_Energy_-_First_of_a_Kind_Plant_in_Romania.pdf
68 Groundbreaking for Clariant's sunliquid® cellulosic ethanol plant in Romania, https://www.sunliquid-project-fp7.eu/clariant-to-build-flagship-sunliquid-cellulosic-ethanol-plant-in-romania-2/
69 International Renewable Energy Agency, Road Transport: the Cost of Renewable Solutions, https://www.irena.org/documentdownloads/publications/road_transport.pdf
70 Charles, C. et al. (2013): Biofuels—At What Cost? A review of costs and benefits of EU biofuel policies, Technical Annex, http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.362.9728&rep=rep1&type=pdf

TFS 10A

Technology Name	Improved feeding practices and dietary additives for livestock for the reduction of GHGs emission from enteric fermentation
Sub-sector	Agriculture, Enteric Fermentation
Sub-sector GHG emission (Mt CO_2-eq.)	42.4 - Agriculture sector (2016) 10.8 - Enteric Fermentation sub-sector (2016)
Technology characteristics	
Short description of the technology option (hardware, software, orgware)	Ruminant animals possess a rumen, or large fore-stomach, in which microbial fermentation breaks down coarse plant material for digestion. Non-ruminant domesticated animals (e.g., swine, horses, mules) also produce CH_4 emissions through enteric fermentation, although this microbial fermentation occurs in the large intestine, where the capacity to produce CH_4 is lower.[71] Methane emissions from enteric fermentation could be mitigated by improved feeding practices and the use of specific agents or dietary additives. Feed supplements with CH_4 mitigation potential include[72]: - inhibitors: chemical substances reducing suppressing methanogenesis and reducing the methane generation in rumen; up to 50% reduction in methane generation has been reported, however, some of the substances tested were banned due to ozone depleting effect or were reported as carcinogens; - electron receptors: the category includes fumarate, nitrates, sulphates and nitroethane; up to 50% reduction in methane generation has been reported; the gradual introduction is required to allow digestive system adaptation and avoid animal's health problems; - plant bioactive compounds: the category includes a variety of plant secondary compounds, specifically tannins, saponins, essential oils and their active ingredients; up to 30% reduction in methane generation has been reported, but negative effect on animal productivity was also observed; - dietary lipids: the category includes vegetable oil and animal fat, which could reduce methane generation by 10-20% but also have negative impact on animals' productivity; - direct-fed microbial: the category includes live yeast (highly concentrated live yeast), yeast culture (yeast cells with varying viability and the fermentation medium on which they were grown) and yeast products (a general term representing both live yeast and yeast culture); yeasts appear to stabilize pH and promote rumen function, especially in dairy cattle, resulting in small but relatively consistent responses in animal productivity and feed efficiency, which might moderately decrease the intensity of CH_4 emission. The fermentation of fibre leads to more intensive methane generation compared to starch fermentation. Therefore, increasing the share of grain or feeding forages with higher starch content, such as whole-crop cereal silages, in ruminant diets lowers enteric CH_4 production. The difference in

71 US-EPA, 2006: Global Mitigation of Non-CO_2 Greenhouse Gases. United States Environmental Protection Agency, EPA 430-R-06-005, Washington, D.C., http://www.epa.gov/nonco2/econ-inv/downloads/GlobalMitigationFullReport.pdf

72 Mitigation of Greenhouse Gas Emissions in livestock Production. A review of technical options for non-CO_2 emissions. Editors: Pierre J. Gerber, Benjamin Henderson and Harinder P.S. Makkar, http://www.fao.org/3/i3288e/i3288e.pdf

	emission intensity for pasture-finished cattle and cattle in a grain-based feedlot system could reach 30%. The improved feed quality could also reduce methane generation due to enteric fermentation. Factors, such as plant species, variety, maturity at harvest and preservation can all affect forage quality and digestibility. Precision feeding, i.e. closely matching animal requirements and dietary nutrient supply, is important for maximizing feed utilization, stabilizing rumen fermentation, improving rumen and animal health, and minimizing nutrient excretion in manure. These effects of precision feeding are expected to decrease enteric and manure GHG emissions. There are also many technologies and strategies to improve the feeding value of low-quality feeds, such as green feeds (cultivated fodder, grass), crop residues from coarse cereals and legumes and fine cereal straws, and concentrates (grains, cakes, and bran). For instance, chemical treatments (e.g. urea, NH_3 or sodium hydroxide) and biological treatments (direct by growing fungi on the straw or by administering fungal enzymes to the straw) improve straw digestibility by disrupting the cell wall structure and making hemicellulose and cellulose fractions more available for rumen digestion.
Country specific applicability and potential, incl.: Capacity Scale of application Time horizon- Short /Medium/long term	The potential of the technology in Ukraine is limited due to significant barriers for implementation.
Status of technology in country	The technology is not applied in Ukraine.
Implementation barriers	The implementation barriers for the technology include the following: - economic barrier due to additional operational expenses to farmers without any economic efficiency gains as there is no additional costs associated with methane emissions; - capacity barriers due to lack of knowledge about the impact and application rules of different additives, as well as about the benefits of the technology; - organizational barriers due to large share of livestock being grown by households and complicated mechanisms for technology dissemination.
Limitations for the technology (geographic, climate, soil, water resources, infrastructure, etc.)	None identified
Reduction in GHG emissions (Mt CO_2-eq.)	Most of the mitigation strategies for reducing GHGs emissions from enteric fermentation are reported to have either low or medium effect[73], which is equivalent to potential GHGs emission reduction at the level of 10-20% comparing to traditional feeding practices. Maximum potential is estimated at the level of 2.2 Mt (20% of GHGs emissions from enteric fermentation in 2016).
Impact Statements - How this option impacts the country development priorities	
Social development priorities	None identified

73 Grossi, G., P. Goglio, A. Vitali and A. G. Williams (2019): Livestock and climate change: impact of livestock on climate and mitigation strategies. Animal Frontiers, Volume 9, Issue 1, 69–76, https://doi.org/10.1093/af/vfy034

Economic development priorities	None identified
Environmental development priorities	The climate change mitigation is the main environmental benefit of the technology, which is in line with national environmental priorities.
Other considerations and priorities such as market potential	None identified
Financial Requirements and Costs	
Capital costs	Capital expenditures for the technology is relatively low or absent for the agricultural enterprises.
Operational and Maintenance costs	Operational expenditures depend on the types of additives used and their prices. Nitrates and lipids are the most affordable additives. For instance, the analysis of lipids and nitrates inclusion in diets to reduce methane emissions in Scotland revealed that the cost of diet will not change more than 6%.[74] While inhibitors and other types of additives could be cost prohibited especially if there is no economic cost related to methane emissions.
Cost of GHG reduction	Not estimated

74 ClimateXChange, Nutritional strategies to reduce enteric methane emissions, https://www.climatexchange.org.uk/media/2033/nutritional_strategies_to_reduce_enteric_methane_emissions.pdf

Annex II: Technology Factsheets for selected technologies (Waste)

Waste Technologies (TFS 1W – TFS 12W)

TFS 1W

Technology name	**Methane capture at landfills and waste dumps for energy production**
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	Methane is formed in the landfill through a biological/chemical process called *Anaerobic Digestion.* Biogas composition (*e.g*. the percentage of methane per unit of biogas) can vary significantly across locations as this depends on such factors as climate and waste management practices. The basic idea behind the technology is that the landfills are covered and that LFG is extracted from landfills using a series of wells and a blower/flare system. This system directs the collected gas to a central point where it can be processed and treated depending upon the ultimate use of gas. From this point, gas can be simply flared (thereby converting methane into CO_2) or used to generate electricity and/or heat, replace fossil fuels in industrial and manufacturing operations, or fuel greenhouse operations. Gas could also be upgraded (purified) to natural gas standards. The main part of methane capture takes place via internal combustion in (reciprocating) engines
Implementation assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	In Ukraine, the development of the LFG capture and combustion technology has reached the status of deployment of the technology in the market. First Ukrainian LFG projects were implemented as joint implementation projects in 2008 ... 2012 during the first period of the Kyoto Protocol. At present in Ukraine, the expediency of biogas utilization is determined by the possibility of selling electricity by "green" tariff (0.1239 EUR/kWh without VAT). Starting from 2012 the main objective of LFG recovery at landfills and waste dumps was electricity generation and sale. Currently all LFG projects in the country produce electricity using gas engines with efficiency 35 ... 42%. The total installed electric capacity at landfills was 18.4 MW at 01.01.19.
Implementation barriers	The financial performance of such projects could generally be insufficient to attract enough investment funding from financial institutes (*i.e.* the project is unattractive compared to the interest rates provided by local banks). Waste management is carried out by municipalities with little or no private sector involvement. With waste tariffs and taxes being too low, municipalities generate insufficient income for waste management in an environmentally friendly way. The low standards of landfill operation form the high risk of feasible project implementation due to uncertain amount of recovered LFG
Reduction in GHG emissions	The combustion of LFG for the production of energy contributes to the reduction of GHG 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. For the calculation of the reduction of GHG emission for large scale methane capture at landfills project, it is recommended to apply the Approved Consolidated Methodology ACM0001 (Consolidated baseline and monitoring

	methodology for landfill gas project activities --- Version 11) under the Clean Development Mechanism of the UNFCCC Kyoto Protocol (CDM). 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 potential of biogas collection in Ukraine is 60 mln m^3/year (CH_4) = 2.1 million GJ = 580 GWh. It corresponds to 1.05 Mt CO_2-eq./year by methane avoiding and 0.64 Mt CO_2-eq./year by fossil electricity substitution. Total potential for the reduction of GHG emission is 1.7 Mt CO_2-eq./year.
Impact statement – how this option impacts the priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating LFG capture plants create jobs associated with the design, construction and the operation of energy recovery systems. LFG projects involve engineers, construction firms, equipment vendors and utilities or end-users of the power produced. Many of these costs are spent locally for drilling, piping, construction and operational personnel, helping communities to realize economic benefits from the increased employment and local sales. By linking communities with innovative ways to deal with their LFG, it helps them to enjoy the increased environmental protection, better waste management and responsible community planning.
The priorities of country economic development – economic benefits	In some cases, additional payment by the project sponsor to support community programmes for stakeholders, including support for people living nearby the sites and who are affected by the project (*e.g.* the sites under the baseline conditions could be considered a source of living for some groups).
The priorities of country environmental development	The improved groundwater quality as the management of the site could relatively and easily be combined with leachate collection and disposal action, The improvement of local air and safety (fewer emissions of SOx, NOx, and particulates) through burning less coal for electricity generation and the reduction of landfill gas released into the air Reduces the risk of dangerous methane gas concentrations in landfills and reduced exposure of residential areas to odour.
Other considerations and priorities such as market potential	The market potential of LFG energy utilization is limited by percentage of landfills with one million tons of waste in place and percentage of waste in anaerobic condition
Costs	
Capital cost	USD 2.5 and USD 3.5 per kW
Operational and maintenance cost	Electricity generation costs for the plant would vary between USD 0.05 and 0.064 per kWh.[75]
Cost of GHG reduction	**Cost of GHG reduction** would vary between 5 and 10 EUR per t CO_2-eq.
Lifetime	The gas yield will depend on the nature of the landfill. For a large modern landfill, useable LFG may be generated for between 15 and 30 years after landfill closure

[75] World Bank, 2005

TFS 2W

Technology name	**The closure of old waste dumps with methane destruction (flaring, biocovers, passive vent etc.)**
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	According to the report of Ukrainian Ministry of Regional Development, 9 - 12 million tons of solid waste are generated annually in Ukraine. Due to the introduction of separate collection of household waste in Ukraine in 2018, about 6.2% of household waste were recycled and utilized, of which 2.0% was burned, and 4.2% of waste re-used and recycled. The rest (about 93%) were landfilled at six thousand landfills and waste dumps with total area of more than 9 thousand hectares. Among the main goals of the waste management strategy until 2030, there is the closure of existing landfills and waste dumps, the search for suitable locations for new landfills and waste treatment plants. The basic idea behind the technology is that the landfills are covered during the closure and LFG is extracted or vented from landfills actively using a series of wells and a blower/flare system or passively using natural pressure of LFG in the landfill body. This system directs the collected gas to a central point where it can be processed and treated. From this point if the use of energy is not feasible, gas can be simply flared or vented through oxidize layer (thereby converting methane into CO_2).
Implementation's assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	Total number of landfills in Ukraine is about 6,064. By the expert's estimation, almost any of them are hardly in compliance with standards in the EU Landfill Directive, 1999/31/EC. They have to be according to the standard and directives of EU, otherwise they have to be closed or rehabilitated. It has been assumed that it will not be practicable to keep in good 'condition' a significant number of the existing landfills. It has accordingly been assumed that 99.9% of the existing landfills should be closed and rehabilitated. The closure and rehabilitation of the old and non-compliant landfills will be in parallel with the construction of new regional landfills.
Implementation barriers	The financial performance of such projects is generally insufficient to attract investment funding from financial institutes (*i.e.* the project is unattractive with comparison to the interest rates provided by local banks). Waste management is carried out by municipalities with little or no private sector involvement. With waste tariffs and taxes being too low, municipalities generate insufficient income for waste management in an environmentally friendly way.
Reduction in GHG emissions	The combustion of LFG without the energy production contributes to GHG emission reduction in such a way that LFG capture prevents the release of methane into the atmosphere (as a GHG methane is 25 times as powerful as CO_2). For the calculation of GHG emission's reduction for large scale methane capture at landfills project, it is recommended to apply the Approved Consolidated Methodology ACM0001 (Consolidated baseline and monitoring methodology for landfill gas project activities --- Version 11) under the Clean Development Mechanism of the UNFCCC Kyoto Protocol (CDM). Ukrainian MSW disposal at landfills generate 8.0 Mt CO_2-eq. of GHG emission. Methane destruction with energy production could reduce this amount of GHG emission by 1.05 Mt CO_2-eq./year. The closure of old waste

	dumps with methane destruction having efficiency 50% could reduce GHG emission by another 3.5 Mt CO_2-eq./year.
Impact statement – how this option impacts the priorities of the country development	
The priorities of country social development	The process of designing, constructing and rehabilitation of old landfills and waste dumps create jobs associated with the design, construction and rehabilitation of old landfills and waste dumps. Closure projects involve engineers, construction firms and equipment vendors. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from increased employment and local sales. By linking communities with innovative ways to deal with their landfills, it helps them enjoy the increased environmental protection, better waste management, and the responsible community planning.
The priorities of country economic development – economic benefits	In some cases, additional payment is made by the project sponsor to support community programs for stakeholders, including support for people living nearby the sites and who are affected by the project (*e.g.* the sites under the baseline conditions could be considered a source of living for some groups).
The priorities of country environmental development	The improved groundwater quality as the management of the site could relatively easily be combined with leachate collection and disposal action. The improvement of local air and safety (fewer emissions of SOx, NOx and particulates) through the reduction of landfill gas released into air Reduces the risk of dangerous methane gas concentrations in landfills and reduced exposure of residential areas to odour
Other considerations and priorities such as market potential	The market potential of LFG energy utilization is limited by the percentage of landfills with one million tons of waste in place and percentage of waste in anaerobic condition. Most of old waste dumps are small and need methane destruction without energy production.
Costs	
Capital cost	EUR 1.7 billion overall. EUR 1.44 billion for the period of the waste management strategy until 2030 (13 years)[76]. The provided estimate is based on the rehabilitation of an average of 467 closed landfills per year beginning from in 2020 with an average cost per landfill of about EUR 280,000.
Operational and maintenance cost	To be identified
Cost of GHG reduction	**The cost of GHG reduction** would be at the level of 25 EUR per t CO_2-eq.
Lifetime	The gas yield will depend on the nature of the landfill. It is expected that for old landfills LFG may be generated for between 15 and 20 years after landfill closure

[76] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

TFS 3W

Technology name	**The construction of new regional sanitary MSW landfills**
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	Methane is formed in the landfill through a biological/chemical process called *Anaerobic Digestion.* Biogas composition (*e.g*. the percentage of methane per unit of biogas) can vary significantly across locations, as this depends on such factors as climate and waste management practices. According to the report of Ukrainian Ministry of Regional Development 9 - 12 million tons of solid waste are generated annually in Ukraine. Among the main goals of the waste management strategy, there is planning for the closure of existing landfills and waste dumps by 2030 and the search for sites for new landfills and waste treatment plants and construction of new regional controlled landfills. The basic idea behind the technology is that the landfills are equipped by LFG collection system from the very beginning, LFG is extracted from landfills using system of horizontal collectors and a series of wells and blower system. This system directs the collected gas to a central point where it can be processed and treated. At modern sanitary landfills, LFG will be used to generate electricity and/or heat, replace fossil fuels. The gas could be upgraded to natural gas standards.
Implementation's assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	Construction of about 100 state-of-the-art landfill facilities in full compliance with the EU Landfill Directive, 1999. The indicative estimates are based on 92 'regional' landfill facilities, as follows[77]: • 3 landfills with capacity 400,000 tons per year; • 7 landfills with capacity 200,000 tons per year; • 82 landfills with capacity 100,000 tons per year.
Implementation barriers	With waste tariffs and taxes being too low, municipalities generate insufficient income for waste management in an environmentally friendly way. Cost recovery should be organized via consumer tariffs for MSW management services. The financial performance of landfill construction and operation could generally be insufficient to attract enough investment funding from financial institutes (*i.e*. the project is unattractive compared to the interest rates provided by local banks). Waste management is carried out by municipalities with little or no private sector involvement.
Reduction in GHG emissions	The combustion of LFG for the production of energy contributes to the reduction of GHG emission in two ways. LFG capture prevents the release of methane into the atmosphere and the electricity subsequently produced by LFG combustion produces less CO_2 emission than conventional fossil fuel combustion.

[77] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

	For the calculation of the reduction of GHG emission for large scale methane capture at landfills project, it is recommended to apply the Approved Consolidated Methodology ACM0001 (Consolidated baseline and monitoring methodology for landfill gas project activities --- Version 11) under the Clean Development Mechanism of the UNFCCC Kyoto Protocol (CDM). Ukrainian solid waste disposal at landfills generate 8,0 Mt CO_2-eq. of GHG emission. Methane recovery at modern landfill could be done with efficiency at least 75%. Therefore, construction of new landfills with methane destruction having efficiency 75% could reduce GHG emission by 6.0 Mt CO_2-eq./year in long term perspective (after 20 years of operation).
Impact statement – how this option impacts the priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating landfills and LFG capture plants creates jobs associated with the design, construction and the operation of energy recovery systems. Landfill construction and LFG projects involve engineers, construction firms, equipment vendors and utilities or end-users of the produced power. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from the increased employment and local sales. By linking communities with innovative ways to deal with their landfills and LFG, it helps them to enjoy the increased environmental protection, better waste management and the responsible community planning.
The priorities of country economic development – economic benefits	In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby the sites and who are affected by the project (*e.g.* the sites under the baseline conditions could be considered a source of living for some groups).
The priorities of country environmental development	The improved groundwater quality as the management of the site could easily be combined with leachate collection and disposal action. The improvement of local air and safety (fewer emissions of SOx, NOx and particulates) through burning less coal for electricity generation and the reduction of landfill gas released into air Reduces the risk of dangerous methane gas concentrations in landfills and reduced exposure of residential areas to odour
Other considerations and priorities such as market potential	About 100 state-of-the-art landfill facilities in full compliance with the EU Landfill Directive, 1999
Costs	
Capital cost	The investment costs of EUR 0.66 billion for the period of the waste management strategy until 2030 (13 years). . The indicative estimates are based on 92 ‘regional’ landfill facilities, as follows: • 3 landfills with capacity 400,000 tons per year; • 7 landfills with capacity 200,000 tons per year; • 82 landfills with capacity 100,000 tons per year.
Operational and maintenance cost	Electricity generation costs for the plant would vary between USD 0.05 and 0.064 per kWh[78].

[78] World Bank, 2005

Cost of GHG reduction	The cost of GHG reduction would be at the level of 25 EUR per t CO_2-eq.
Lifetime	The gas yield will depend on the nature of the landfill. For a large modern landfill, useable LFG may be generated for between 15 and 30 years after landfill closure

TFS 4W

Technology name	Waste sorting (the sorting of valuable components of MSW with the subsequent treatment of waste residual by other technologies)
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	Waste sorting lines (WSLs) separate waste into secondary raw materials which can be sold in the market. There are two main types, 'clean' and 'dirty'. **'Clean' Sorting Lines** typically receive mixed 'dry' recyclables from MSW separate collection, such as paper, cardboard, plastic, metals and glass and these materials are separated or sorted into the different fractions after which they are typically baled for transfer to industrial plants that can use the secondary captured raw materials. Waste sorting lines can use a combination of manual and mechanical handling operations. Depending on the level of awareness of the public, the level of efficiency achieved in such plants can be quite high (i.e. in the order of 80%) and the captured materials tend to be 'clean' and readily marketable. The use of waste sorting lines to process clean, 'dry' recyclables from MSW separate collection is considered to be an effective and cost-efficient option to improve recycling levels, in particular from the household waste stream. Depending on the extent of public participation in the source separation of recyclables, the purity of the collected recyclables, the efficiency of sorting and the market for secondary raw materials, the operational costs of MSW separate collection can potentially be recovered by revenues from the captured secondary raw materials. **'Dirty' Sorting Lines** typically receive mixed 'residual' MSW with recyclables, such as paper, cardboard, plastic, metals and glass mixed with organic and other wastes. Sorting lines for such waste streams predominantly use manual handling techniques and the materials separated or sorted into the different fractions are also typically baled for transfer to industrial plants that can use the secondary raw materials. Some mechanical components, such as bag opening devices and over-ban magnets, may also be included. The level of contamination of the captured recyclables can be significant which will reduce the revenue from the sale of recyclables and the level of efficiency achieved in such plants is typically quite low (i.e. in the order of 10% of waste input). Because of the low level of capture of useful recyclables, sorting lines handling mixed residual waste are not considered an appropriate, sustainable solution and do not reflect current best practice.
Implementation's assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	Waste sorting lines should be developed on the basis of inter-municipal cooperation arrangements serving a catchment with an appropriate critical mass. It is considered that a minimum capacity of 10,000 tons of 'dry' recyclables should apply to new waste sorting lines in Ukraine. An adequate, national infrastructure to meet the needs of modern MSW management will be required to facilitate the following targets over the next 13 years:[79] • The development of about 250 to 300 new waste reception/collection centres and about 90 waste sorting lines employing environmentally beneficial technologies, as an alternative to landfill.

[79] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

	• The purchase of approximately 36,000 additional containers and approximately 230 additional collection vehicles, together with construction of 42 additional waste sorting lines in order to achieve a 7% recycling rate of household waste by 2022. The indicative estimate of EUR 144 million. • The purchase of further approximately 62,000 additional containers and approximately 400 additional collection vehicles, together with construction of a further 49 additional waste sorting lines in order to achieve the 15% recycling rate of household waste by 2030. The indicative estimate of EUR 190 million.
Implementation barriers	The population lacks awareness and willingness to sort out their wastes. Especially in rural areas, the general levels of organised MSW separate collection is very low. The disruptive impact of the informal sector in MSW separate collection, needs to be addressed. A significant proportion of the recyclable material content of waste removed from the containers assigned to the MSW separate collection by informal sectoral workers prior to the bins being emptied. This reduces significantly the quantity of dry recyclables from reaching waste sorting lines, with a consequent reduction in the revenues from the sale of captured secondary raw materials. This, in turn, can affect cost-recovery of the investment and operational costs incurred in MSW separate collection and waste sorting lines.
Reduction in GHG emissions	Ukrainian solid waste disposal at landfills generates 8.0 Mt CO_2-eq. of GHG emission. Paper and cardboards take 5…15% in original mixed MSW in Ukraine. This component is responsible for approx. 20…40% of the GHG emission from landfills and waste dumps. The attention is to be paid that for 75% recycling rate for paper and cardboards, the potential reduction of GHG emission equals 1,2…2.4 Mt CO_2-eq. could be achieved. GHG emission could also be achieved by other recyclable uses (ferrous and non-ferrous metals, glass, textile, and plastic). It will be assessed at the next stages of the project.
Impact statement – how this option impacts the priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating sorting lines create jobs associated with the design, construction, and operation. Sorting lines construction involves engineers, construction firms, and equipment vendors. These costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from increased employment and local sales. By linking communities with innovative ways to deal with their waste, it helps them to enjoy the increased environmental protection, better waste management and the responsible community planning.
The priorities of country economic development – economic benefits	In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of country environmental development	The improved groundwater quality due to reduction of MSW disposal The improvement of local air and safety (fewer emissions of SOx, NOx, and particulates) through the reduction of landfill gas released into air
Costs	
Capital cost	Capacity of WSL in tons/yr: 50,000 / 30,000 / 20,000 /10,000

	Population served: more than 640,000 / 250,000-640,000 / 200,000-250,000 / less than 200,000 CAPEX: EUR 5.0 mln / EUR 3.0 mln / EUR 2.5 mln / EUR 2.0 mln The construction of 42 additional waste sorting lines (WSLs) by 2022 – EUR 115 million. The development of further 49 WSLs by 2030 – EUR 140 million. The investment costs for construction of new MSW facilities, such as regional landfills or waste sorting lines are typically covered by the state mainly through loans from International Financing Institutions and in some cases bilateral financial institutions.
Operational and maintenance cost	Capacity WSL in tons/y: 50,000 / 30,000 / 20,000 / 10,000 Population served: More than 640,000 / 250,000-640,000 / 200,000-250,000 / Less than 200,000. OPEX (annual cost): EUR 625,000 / EUR 400,000 /EUR 300,000 /EUR 220,000. OPEX (cost per ton): EUR 12.50 / EUR 13.00 / EUR 15.00 / EUR 22.00. In relation to the OPEX for MSW separate collection and waste sorting, it should be noted that it is anticipated that the revenues from recycling will potentially offset these operating costs. However, this scenario is dependent on market prices for secondary raw materials and does not take into account the impact of the informal sector in this regard.
Cost of GHG reduction	The cost of GHG reduction by avoiding methane emission from paper and cardboards at the landfills would vary between 25 and 100 EUR per t CO_2-eq. The cost of the GHG emission’s reduction achieved by other recyclable use (ferrous and non-ferrous metals, glass, textile, and plastic) will be assessed in the next stages of the project
Lifetime	20 years for sorting equipment Waste sorting is a part of waste management system and do not have certain lifetime period.

TFS 5W

Technology name	Aerobic biological treatment (composting) of food and green residuals
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	The term composting is defined as 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 practice the composting of mixed waste or biodegradable waste fractions (kitchen or restaurant wastes, garden waste, sewage sludge). It is the best suited for source segregated biodegradable waste. 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 between the technologies are issues such as air supply, temperature control, mixing and time required for composting. Moreover, their capital and operating costs also differ widely.
Implementation's assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	The overall level of composting of MSW in Ukraine is low. Only about 17,000 m^3 (0.003%) of waste were composted in 2015. In relation to recycling and other recovery, a key challenge is the lack of an organized system capable of efficiently collecting the secondary raw materials of high quality. The following objectives are set out: • 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. • The implementation of home composting in suburban areas in towns and cities and in rural areas. In relation to the biological treatment of the organic fraction of the MSW for the initial period of the MSW management strategy, it is proposed that the focus will be put on the home composting of household organic waste and windrow composting of green wastes (e.g. waste from gardens and parks)[80]. As part of the Strategy, it is proposed that basic windrow compost centres will be co-located with the Waste Reception/Collection Centres, as set out above. The type of wastes accepted as 'green waste' include grass cuttings, hedge/shrub cuttings, fallen leaves, plant and flower heads, branches, tree stumps and timber. The compost process will include the following: • The green waste will be shredded using a tub grinder; • The shredded green waste will be moved into long rows (windrows), using a loading shovel; • Rows will be turned 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. It is also proposed to establish pilot projects for the biological stabilisation of residual waste. A system of certification will be developed for the different

[80] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

	categories of compost or compost-like-output (CLO) produced from municipal solid waste or its components
Implementation 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.
Reduction in GHG emissions	Composting of waste reduces the amount of waste to be disposed of 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.
Impact statement – how this option impacts the country development priorities	
Country social development priorities	Composting done by utilizing municipal solid waste generated from cities/municipalities can result in effective management of waste thereby assisting local authorities in providing critical waste management services for city dwellers' overall social wellbeing. 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 will support the generation of local employment.
Country economic development priorities – economic benefits	Composting programs launched by small communities can provide benefits to the local community in the form of the increased local employment and reduced costs for waste removal. 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.
Country environmental development priorities	Composting directly leads to the avoidance of methane emissions, thereby improves the air quality. Composting results in a reduced waste volume going into landfills. The leachate from conventional waste management practices in developing countries can be addressed through the implementation of composting technology. Composts directly replace the application of chemical fertilizers in farm lands thereby it results in the reduction of chemical effects on soil and water.
Costs	
Capital cost	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 the suburban areas in cities and towns and in rural areas (approximately 2.5 million households). Indicative estimate of EUR 105.5 million[81].

[81] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 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 of EUR 41 million.
Operational and maintenance cost	30-50 EUR /t
Cost of GHG reduction	Composting of one ton of MSW is approx. equivalent of 0.6 t CO_2-eq. GHG emission reduction. The cost of GHG reduction in enclosed building with concrete floors, MRF[82] 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.
Lifetime	20 years

[82] Material Recovery Facility

TFS 6W

Technology name	The mechanical-biological treatment of waste with biogas and energy production (the anaerobic digestion of organic fraction of MSW)
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	The term Mechanical-Biological Treatment (MBT) covers a wide-range of processes, but it typically involves the capture of recyclables and some form of biological treatment for the organic fraction of MSW. In some cases, the 'dry' fraction of MSW is converted to refuse-derived fuel (RDF) or solid-recovered fuel (SRF), while the 'wet' fraction is converted to compost-like-output (CLO). The process is generally carried out in MBT plants for the stabilisation of the Organic Fraction of the residual MSW stream. The residual MSW fraction is initially run through a trommel screen, where the heavier organic fines (i.e. material ≤ 60mm) fall through the screen, while the larger, lighter, combustible material (i.e. the 'overs') is captured at the end of the screen. The organic fines can comprise 45% of the infeed material. These organic fines can then be subjected to bio-stabilisation (i.e. composting) or anaerobic digestion (AD). AD is an alternative form of biological treatment the production of biogas. Anaerobic digestion (or anaerobic fermentation) refers to a process in which biodegradable material (e.g. the organic fraction of MSW) breaks down in the absence of oxygen to produce biogas with high methane (i.e. CH_4) concentration. It is usually undertaken in large vessels, where the process can be controlled in order to speed up reactions and harvest the resulting biogas, which has a high-methane content and which can be used for the energy generation. The produced biogas can be refined by removing water's vapour and used in a combined heat and power (CHP) plant to produce electricity and heat. AD still produces an organic residue called digestate which is similar in nature to compost. The digestate often requires a brief stage of aerobic treatment to fully stabilise any remaining biodegradable content and it can be used in similar applications as compost.
Implementation assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	The most significant progress towards national targets and standards can be met initially with lower-cost solutions (e.g. the MSW separate collection of recyclables, home composting, green waste composting, etc.). Even with the adoption of a 'regional' approach in Ukraine (i.e. at oblast level) many of the biological treatment technologies are expensive to be established and operated that they may only be open to consideration when Ukraine's economic position is stronger. In relation to the biological treatment, it is considered that the initial focus should be put on home composting and the windrow composting of green wastes (e.g. waste from gardens and parks), at least in the short-term (i.e. up to 2022). 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[83].
Implementation barriers	Low taxes and tariffs for waste treatment 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

[83] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

	not viable, on a widespread basis, in the absence of a significant increase in the environmental tax on the deposit of waste.
Reduction in GHG emissions	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. The combustion of biogas for the production of energy produces less CO_2 emission than conventional fossil fuel combustion.
Impact statement – how this option impacts the priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating MBT plants create jobs associated with the design, construction and the operation of energy recovery systems. MBT projects involve engineers, construction firms, equipment vendors and utilities or end-users of the produced power. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from the increased employment and local sales. By linking communities with innovative ways to deal with their MSW, it helps them to enjoy better waste management and the responsible community planning.
The priorities of country economic development– economic benefits	The possibility of obtaining an additional source of energy replacing fossil fuels such as natural gas or coal. The possibility of obtaining additional income by the sale of electricity and heat. In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of country environmental development	The improvement of local air and safety (fewer emissions of SOx, NOx and particulates) through burning less coal for electricity generation and the reduction of landfill gas released into air Reduces the risk of dangerous methane gas concentrations at the landfills and reduced exposure of residential areas to odour.
Costs	
Capital cost	Investment cost per ton: MBT – bio-drying: 200-350 EUR MBT – AD: 200-400 EUR
Operational and maintenance cost	O&M Cost per ton / Total Cost per ton MBT – bio-drying: 20-35 / 40-70 MBT – AD: 25-50 / 50-90
Cost of GHG reduction	The cost of GHG reduction mechanical-biological treatment of waste would vary between 20 and 75 EUR per t CO_2-eq.
Lifetime	20 years

TFS 7W

Technology name	The mechanical-biological treatment of waste with alternative fuel (SRF) production for cement industry
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, short description of the technology option	The term Mechanical-Biological Treatment (MBT) covers a wide-range of processes, but it typically involves the capture of recyclables and some form of the biological treatment of the organic fraction of MSW. In some cases, the 'dry' fraction of MSW is converted to refuse-derived fuel (RDF) or solid-recovered fuel (SRF), while the 'wet' fraction is converted to compost-like-output (CLO). A key advantage of MBT is that it can be configured to achieve several different aims. In line with the EU Landfill Directive and in order to achieve certain recycling targets, typical aims of MBT plants include: • The pre-treatment of waste prior to disposal on landfill; • The diversion of non-biodegradable and biodegradable MSW going to landfill through the mechanical sorting of MSW into materials for recycling and/or energy recovery, such as RDF or SRF; • Drying materials to produce a high calorific fraction for use as RDF/SRF; • The diversion of biodegradable MSW going to landfill by the stabilisation of MSW into CLO (i.e. also referred to as 'stabilised bio-waste') for use as landfill cover material or in the rehabilitation of landfills and dumpsites; While some capture of secondary raw materials is associated with RDF/SRF production facilities, the main difference between waste sorting lines and RDF/SRF production facilities is that the former generally processes source-separated recyclables while the latter processes residual waste.
Implementation assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	RDF/SRF production facilities will be supported, where it is appropriate, as part of MBT plants, at locations across Ukraine which are close to cement kilns, in the initial stage, as pilot projects. The exact number and location of such facilities should be related to obtaining agreement in principle from one of the cement companies to pay for RDF/SRF delivered to specification. Appropriate specifications for the composition and characteristics of RDF and SRF will be developed at national level in this regard. The determination whether or not an RDF/SRF production facility is commercially viable, the following completion of a Feasibility Study (FS) or Pre-feasibility Study (PFS) should be made in the matter.
Implementation barriers	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. Cement plants are not ready to accept RDF/SRF as fuel for substitution of natural gas yet. The financial condition of fuel transfer is not yet defined.
Reduction in GHG emissions	The mechanical-biological treatment of waste with alternative fuel (SRF) production for cement industry reduces the amount of waste to be disposed at 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.

	The use of RDF produces less CO_2 emission than the substituted conventional fossil fuel combustion (usually natural gas).
Impact statement – how this option impacts the priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating MBT plants creates jobs associated with the design, construction and the operation of energy recovery systems. MBT projects involve engineers, construction firms, equipment vendors and utilities or end-users of the power produced. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from increased employment and local sales. By linking communities with innovative ways to deal with their MSW, it helps them to enjoy better waste management and the responsible community planning.
The priorities of country economic development – economic benefits	The possibility of increasing of waste processing depth including ash utilization by cement plants in order to minimize disposal and the need for new landfills. The possibility of replacing fossil fuels such as natural gas or coal. In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including the support for people living nearby and who are affected by the project.
The priorities of country environmental development	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.
Costs	
Capital cost	Capacity in ton/yr of mixed waste: 100,000 / 200,000 Population served: 350,000 / 900,000 CAPEX: EUR 6,500,000 / EUR 9,250,000[84]
Operational and maintenance cost	Capacity in ton/yr of mixed waste: 100,000 / 200,000 Population served: 350,000 / 900,000 OPEX (annual): EUR 856,000 / EUR 1,638,000 OPEX (per ton): 10.25 EUR / 8.25 EUR Overall cost/ton: 25.25 EUR / 18.25 EUR[84]
Cost of GHG reduction	The cost of GHG reduction for mechanical-biological treatment of waste with the alternative fuel (SRF) production for cement industry would vary between 20 and 25 EUR per t CO_2-eq.
Lifetime	20 years

[84] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

TFS 8W

Technology name	**The mechanical-biological treatment of waste with alternative fuel (RDF/SRF) for district heating and/or electricity production**
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is MSW landfills
Background/Notes, short description of the technology option	The Mechanical-Biological Treatment (MBT) covers a wide-range of processes, but it typically involves the capture of recyclables and some form of biological treatment of the organic fraction of MSW. In some cases, the 'dry' fraction of MSW is converted to refuse-derived fuel (RDF) or solid-recovered fuel (SRF), while the 'wet' fraction is converted to compost-like-output (CLO). A key advantage of MBT is that it can be configured to achieve several different aims. In line with the EU Landfill Directive and in order to achieve certain recycling targets, typical aims of MBT plants include: • The pre-treatment of waste prior to disposal on landfill; • The diversion of non-biodegradable and biodegradable MSW going to landfill through the mechanical sorting of MSW into materials for recycling and/or energy recovery, such as RDF or SRF; • Drying materials to produce a high calorific fraction for use as RDF/SRF; • The diversion of biodegradable MSW going to landfill by the stabilisation of MSW into a compost-like-output (i.e. also referred to as 'stabilised bio-waste') for use as landfill cover material or in the rehabilitation of landfills and dumpsites. While some capture of secondary raw materials is associated with RDF/SRF production facilities, the main difference between waste sorting lines and RDF/SRF production facilities is that the former generally processes source-separated recyclables while the latter processes residual waste.
Implementation's assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country's environment	RDF/SRF production facilities will be supported, where it is appropriate, as part of MBT plants, at locations across Ukraine which are close to district heating systems (DHS), in the initial stage, as pilot projects. The exact number and location of such facilities should be related to obtaining agreement in principle from one of the municipal DH companies to pay for RDF/SRF delivered to specification. Appropriate specifications for the composition and characteristics of RDF and SRF will be developed at national level in this regard. The determination whether or not an RDF/SRF production facility is commercially viable, the following completion of a Feasibility Study (FS) or Pre-feasibility Study (PFS) should be made in the matter. The direct use of heat is one of the keys to achieve environmental and financial benefits is finding a direct outlet for heat generated by the combustion of waste-derived fuels rather than the use of heat to generate steam and then electricity.
Implementation barriers	Having the involvement of the 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. Municipal CHPs and boiler houses are not yet ready to accept RDF/SRF as fuel for the substitution of natural gas. The financial condition of fuel transfer is not yet defined.
Reduction in GHG emissions	The mechanical-biological treatment of waste with alternative fuel (SRF) production for district heating and/or electricity 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. The use of RDF for electricity and /or heat produces less CO_2 emission than substituted conventional fossil fuel combustion (usually natural gas).
Impact statement – how this option impacts The priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating MBT plants create jobs associated with the design, construction, and operation of energy recovery systems. MBT projects involve engineers, construction firms, equipment vendors and utilities or end-users of the power produced. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from increased employment and local sales. By linking communities with innovative ways to deal with their MSW, it helps them to enjoy better waste management and the responsible community planning.
The priorities of country economic development– economic benefits	The possibility of increasing of waste processing depth in order to minimize disposal and the need for new landfills. The possibility of obtaining an additional source of energy replacing fossil fuels such as natural gas or coal. The possibility of obtaining additional income by sale of electricity and heat. In some cases, additional payment by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of country environmental development	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.
Costs	
Capital cost	Capacity in ton/y of mixed waste: 100,000 / 200,000 Population served: 350,000 / 900,000 CAPEX: EUR 6,500,000 / EUR 9,250,000[85]
Operational and maintenance cost	Capacity in ton/y of mixed waste: 100,000 / 200,000 Population served: 350,000 / 900,000 OPEX (annual): EUR 856,000 / EUR 1,638,000 OPEX (per ton): 10.25 EUR / 8.25 EUR Overall cost/ton: 25.25 EUR / 18.25 EUR[85]
Cost of GHG reduction	The cost of GHG reduction mechanical-biological treatment of waste with alternative fuel (SRF) production for district heating and/or electricity production would vary between 20 and 25 EUR per t CO_2-eq.
Lifetime	20 years

[85] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

TFS 9W

Technology name	**The combustion of residual municipal solid waste for district heating and/or electricity production**
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, short description of the technology option	Thermal treatment (i.e. incineration or waste-to-energy) is a waste treatment process widely used throughout the world, particularly in developed countries (i.e. Sweden and Denmark are particularly notable in this regard). The main purposes of thermal treatment/incineration are sterilization and reduction of hazardous matter contained in the waste. The incineration of waste materials converts the waste into ash, flue gas and heat. Energy production, a highly significant benefit of the incineration treatment, improves with an increase in the calorific value of the incinerated waste. The total volume of the waste input is reduced to ash, which comprises 10 – 30% of its original size. This ash is either deposited in a landfill or used for other purposes.
Implementation assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	Giving very high investment costs, mass burn waste-to-energy plants (i.e. incinerators with energy recovery) are generally not considered to be economic, unless above a minimum intake of 150,000 tons per annum (i.e. population in excess of about 500,000). In this regard, thermal treatment/waste-to-energy recovery facilities would be open to consideration only in respect of the largest cities in Ukraine. Waste-to-energy recovery may be considered as an option for residual MSW in a limited number of situations where, for example, there is a very high population density, a feasible grid connection, a ready outlet for the waste heat generated (i.e. such as greenhouses, etc.) and, in particular, where there is a lack of available land for the development of an appropriate landfill. Any new incineration facility in Ukraine should be configured as a ‘recovery’ operation rather than a ‘disposal’ operation. As a first step, prior to the implementation of pilot thermal treatment projects, all of the relevant environmental as well as energy efficiency requirements should be transposed into Ukrainian legislation. In the absence of such legislation, there is a risk that old technologies will come into Ukraine as a country with lower legal standards.
Implementation barriers	The very high cost of incineration, both in terms of CAPEX and OPEX, The modification of Ukrainian legislation is needed to make the requirements for incineration/ waste-to-energy facilities consistent with the EU Industrial Emissions Directive (IED).
Reduction in GHG emissions	The combustion of mixed municipal solid waste for district heating and/or electricity production reduce the amount of waste to be disposed at landfills. This directly prevents the emissions of methane that would have occurred from waste disposal on land. The use of combustion of mixed municipal solid waste (50% of renewables) for electricity and/or heat produces less CO_2 emission than substituted conventional fossil fuel combustion (usually natural gas).
Impact statement – how this option impacts The priorities of the country development	

The priorities of country social development	The process of designing, constructing and operating waste incineration facility create jobs associated with the design, construction and the operation of energy recovery systems. Such projects involve engineers, construction firms, equipment vendors and utilities or end-users of the produced power. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from the increased employment and local sales. By linking communities with innovative ways to deal with their MSW, it helps them to enjoy better waste management and the responsible community planning.
The priorities of country economic development – economic benefits	The possibility of increasing of waste processing depth in order to minimize the disposal and the need for new landfills. The possibility of obtaining an additional source of energy replacing fossil fuels such as natural gas or coal. The possibility of obtaining additional income by the sale of electricity and heat. In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of Country environmental development	The improvement of local air and safety (fewer emissions of SOx, NOx, and particulates) through burning less coal for electricity generation and reduction of landfill gas released into air Reduces the risk of dangerous methane gas concentrations at the landfills and reduced exposure of residential areas to odour.
Costs	
Capital cost	The investment cost required to implement waste-to-energy as the applied solution for overall residual MSW management in Ukraine would be in the order of EUR 8.8 billion[86]. The total costs of incineration with energy recovery are well in excess of 100 EUR/t. Such costs are not considered generally sustainable or affordable for Ukraine. The modernisation of the incineration plant “Energy”, so that the incineration process can be classified as a ‘recovery’ rather than a ‘disposal’ operation - EUR212 million cost. The investment cost of modern incineration (waste-to-energy) plant varies between 500-1200 EUR/t/year
Operational and maintenance cost	O&M Cost: 25-45 EUR/t. Total Cost: 100-200 EUR/t.
Cost of GHG reduction	The cost of GHG reduction by combustion of residual municipal solid waste for district heating and/or electricity production would vary between 50 and 100 EUR per t CO_2-eq.
Lifetime	At least 20 years

[86] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

TFS 10W

Technology name	Gasification/pyrolysis of MSW for large-scale electricity/heat applications
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, short description of the technology option	Thermal treatment (i.e. incineration or waste-to-energy) is a waste treatment process widely used throughout the world, particularly in developed countries (i.e. Sweden and Denmark are particularly notable in this regard). The main purposes of thermal treatment/incineration are the sterilization and reduction of hazardous matter contained in the waste. The total volume of the waste input is reduced to ash, which comprises 10 – 30% of its original size. This ash is either deposited in a landfill or used for other purposes. Other forms of thermal treatment (also referred to as 'advanced thermal treatment') include pyrolysis and gasification: • Pyrolysis involves the thermal degradation of organic material in the absence of oxygen; and • Gasification can be considered a process between pyrolysis and combustion in that it involves the partial oxidation of organic substances (i.e. by contrast with incineration which comprises full oxidative combustion) to produce gases that can be used as a feedstock, or as a fuel. Pyrolysis and gasification plants follow a similar basic structure to waste incineration installations, but differ significantly in detail. Main differences include the following: • More extensive pre-treatment to provide a narrow profile feedstock; • Additional equipment for handling/treating/storing the rejected material; • Greater attention required for sealing the loading of infeed material; • The need for a thermal reactor; • The need for handling, storage and possible further treatment of gaseous and solid products; and • The possible need for a separate combustion stage with energy recovery and subsequent gas/water/solid treatment and management. The technological risk associated with gasification and pyrolysis technologies for many wastes remains significantly greater than that for more proven, incineration-type, thermal treatments[87]. These technologies, although they are being implemented in recent years, are also less mature and their implementation entails significantly higher operational risk, especially as the market for fuel from these facilities is not well developed in Europe in general or in Ukraine in particular. Pyrolysis and gasification treatment are typically applied to specific waste streams such as mixed plastic wastes. Thermal treatment by pyrolysis and/or gasification is rarely applied to MSW, in particular to MSW which has not been pre-treated. There is a limited track record of commercial-scale pyrolysis plants accepting municipal derived wastes in the world. Moreover, like incineration, the specific costs (EUR/t) of these technologies are very high.
Implementation assumptions, how the technology will be	The very high cost of advance thermal treatment, both in terms of CAPEX and OPEX, means that this is not considered, in principle, to be a practicable or affordable solution generally for MSW management in Ukraine.

[87] Supporting investments in sustainable municipal management and recycling in Ukraine. Draft MSW strategy. - EBRD. - March 2017.

implemented and diffused across the subsector?	
Implementation barriers	The very high cost both in terms of CAPEX and OPEX. In relation to advanced treatment technologies, such as pyrolysis and gasification, the limited track record of commercial-scale plants and the high specific costs of these technologies lead to the conclusion that such plants would generally not be affordable for Ukraine in the short- to medium- term. The modification of Ukrainian legislation is needed to make the requirements for any waste-to-energy facilities consistent with the EU Industrial Emissions Directive (IED)
Reduction in GHG emissions	The gasification of mixed municipal solid waste for district heating and/or electricity production reduces the amount of waste to be disposed in landfills. This directly prevents the emissions of methane that would have occurred from waste disposal on land. The use of gasification of mixed municipal solid waste (50% of renewables) for electricity and/or heat produces less CO_2 emission than substituted conventional fossil fuel combustion (usually natural gas).
Impact statement – how this option impacts The priorities of the country development	
The priorities of country social development	The process of designing, constructing and operating waste gasification/ pyrolysis facility creates jobs associated with the design, construction, and operation of energy recovery systems. Such projects involve engineers, construction firms, equipment vendors and utilities or end-users of the power produced. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from the increased employment and local sales. By linking communities with innovative ways to deal with their MSW, it helps them to enjoy better waste management and the responsible community planning.
The priorities of country economic development – economic benefits	The possibility of increasing the waste processing depth in order to minimize disposal and the need for new landfills. The possibility of obtaining an additional source of energy replacing fossil fuels such as natural gas or coal. The possibility of obtaining additional income by sale of electricity and heat. In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of country environmental development	The improvement of local air and safety (fewer emissions of SOx, NOx, and particulates) through burning less coal for electricity generation and reduction of landfill gas released into the air Reduces the risk of dangerous methane gas concentrations at the landfills and reduced exposure of residential areas to odour.
Costs	
Capital cost	The investment cost of modern gasification (waste-to-energy) plant varies between 500-1200 EUR/t/year
Operational and maintenance cost	O&M Cost: 25-45 EUR/t. Total Cost: 100-200 EUR/t.

Cost of GHG reduction	The cost of GHG reduction by gasification of municipal solid waste for district heating and/or electricity production would vary between 50 and 100 EUR/t CO_2-eq.
Lifetime	At least 20 years

TFS11W

Technology name	The biological stabilization of Municipal Solid Waste
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills
Background/Notes, the short description of the technology option	Biological treatment or the organic fraction of waste can either be aerobic treatment (i.e. composting), which is classified as recycling or anaerobic digestion (AD) (which is classified as recycling or recovery, as appropriate). In relation to MSW streams the following biological processes typically apply: • Home composting; • The composting of green waste; • The stabilisation of the organic fraction of the residual waste stream; and • The primary source separation of bio-waste and biological processing of this fraction. Bio-stabilisation typically takes place in an enclosed tunnel system with forced aeration (i.e. in-vessel composting - IVC) or in a closed dynamic system (e.g. windrow composting with automated turning). The intense composting phase can take up to 4 weeks and the material then needs to be matured or cured for a further 8 weeks. A relatively large building is required to house the intense composting units (i.e. tunnels) and the refinement or maturation phase. The atmosphere within the composting area is highly corrosive. Composting plants can give rise to intense odours and require the incorporation of a bio-filter (i.e. filter with moist organic material such as compost, wood chips, sea shells, etc.) to adsorb and biologically degrade the odorous compounds.
Implementation assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	The EU-Ukraine Accession Agreement, 2014 requires compliance with Article 6 of the Landfill Directive, 1999. Accordingly, the stabilisation of the organic fraction of MSW will ultimately be required for Ukraine. By 2024, a number of pilot schemes are to be established by involving bio-stabilisation of the residual MSW stream. It is also proposed to establish pilot projects for the biological stabilisation of residual waste. A system of certification will be developed for the different categories of compost or compost-like-output (CLO) produced from municipal solid waste or its components. The proper sorting of MSW and stabilisation of the organic fraction of MSW is one of the key challenges for Ukraine. There are two main options in this regard: 1. Separate collection and treatment of the bio-waste fraction of MSW; 2. The bio-stabilisation of the organic fraction of the residual waste stream. Each of the above options will be relatively costly with Option 1 significantly more costly than Option 2. It is important to promote the setting up of appropriate pilot projects for the biological processing of the organic fraction of residual waste so that lessons can be learned and the best practicable option for Ukraine can be determined.
Implementation barriers	In relation to the biological stabilization of MSW, a key challenge is the lack of an organized system capable of efficiently collecting the secondary raw materials of high quality.
Reduction in GHG emissions	The biological stabilization (composting) of waste reduces the amount of waste to be disposed of 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.
Impact statement – how this option impacts The priorities of the country development	
The priorities of country social development	Biological stabilization (composting) done by utilizing municipal solid waste generated from the cities/municipalities can result in the effective management of waste. The biological stabilization also provides benefits for waste handling companies. The waste stabilization helps the companies to increases the landfill's lifetime and in some cases marketable product in the form of compost. The technology is applicable for both small-scale and large-scale applications. Each of these will support the generation of local employment.
The priorities of country economic development– economic benefits	The possibility of increasing the waste processing depth in order to minimize disposal and the need for new landfills. In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of country environmental development	The improvement of local air and safety (fewer emissions of SOx, NOx, and particulates) through burning less coal for electricity generation and reduction of landfill gas released into the air Reduces the risk of dangerous methane gas concentrations at the landfills and reduced exposure of residential areas to odour.
Costs	
Capital cost	Bio-stabilisation investment cost, EUR/t/year: 100-200
Operational and maintenance cost	Bio-stabilisation O&M Cost, EUR/t: 10-25 Bio-stabilisation Total Cost, EUR/t: 20-40
Cost of GHG reduction	The biological stabilization of one ton of MSW is approx. equivalent of 0.6 t CO_2-eq. GHG emission reduction. The cost of GHG reduction by biological stabilization would vary between 30 and 55 EUR per t CO_2-eq.
Lifetime	20 years

TFS 12W

Technology name	Anaerobic treatment (digestion) of sewage sludge
Subsector GHG emission	Waste sector. The contribution of the Waste sector in 2015 in total emissions is 3.7 %. The main source of CH_4 emissions is municipal solid waste (MSW) landfills GHG emissions in the category ”Wastewater Treatment and Discharge” amounted to 4.1 Mt CO_2-eq. (32.6 % of total GHG emissions in the "Waste" sector) in 2016, having decreased with respect to 1990 (5.3 Mt CO_2-eq.) by 23.1 %.
Background/Notes, short description of the technology option	The goal of waste water treatment is to reduce the amount of sludge that needs to be disposed of. The most widely employed method for sludge treatment is anaerobic digestion. In this process, a large fraction of the organic matter is broken down into carbon dioxide (CO_2) and methane (CH_4) and this is accomplished in the absence of oxygen. About half of the amount is converted into gases, while the remainder is dried and becomes a residual soillike material. The treatment of wastewater sludge, from both primary and secondary treatment steps, consists in biological conversion. In further processes the settled sludge is dewatered and thickened. The goal is to separate as much water as possible to decrease the volume of material. Finally, a phase known as sludge stabilization reduces the level of pathogens in the residual solids, eliminates offensive odours and reduces the potential for putrefaction.
Implementation assumptions, how the technology will be implemented and diffused across the subsector? Explain if the technology could have some improvements in the country environment	Services of water supply and water treatment to urban areas are provided by communal water utilities owned by municipalities. Most of cities have their separate utilities. The performance of water utilities is inefficient due to the deteriorated infrastructure and the lack of adequate commercial management. In line of approved reforms, to which Ukrainian government is itself committed, several financial institutions provided loans to Ukraine allocated for modernising the sector’s infrastructure, improving service quality, and reducing energy consumption. Anaerobic treatment of sewage sludge could be broadly applied in all settlements of Ukraine, therefore the implementation of the technology has large potential in Ukraine. The expediency of biogas utilization in Ukraine is determined by the possibility of selling electricity by "green" tariff (0.1239 EUR/kWh without VAT). There is only one example of wastewater treatment with biogas production in Ukraine in Bortnichi WWTP (Kyiv).
Implementation barriers	Having involved the high costs, the biological treatment of sewage sludge **is** not viable, on a widespread basis, in the absence of a significant increase in the environmental tax on the deposit of sewage sludge.
Reduction in GHG emissions	The anaerobic treatment of sewage sludge with biogas and energy production reduces the amount of waste to be disposed of after treatment. This directly prevents the emissions of methane (which is 25 times a more potent GHG than CO_2) that would have occurred from the disposal on land. The combustion of biogas for the production of energy produces less CO_2 emission than conventional fossil fuel combustion.
Impact statement – how this option impacts The priorities of the country development	
The priorities of Country social development	The process of designing, constructing and operating the anaerobic treatment of sewage sludge create jobs associated with the design, construction and the operation of energy recovery systems on the basis of the treatment facility of waste water. Digestion projects involve engineers, construction firms,

	equipment vendors, and utilities or end-users of the power produced. Many of these costs are spent locally for construction and operational personnel, helping communities to realize economic benefits from increased employment and local sales. By linking communities with innovative ways to deal with their waste water, it helps them to enjoy better waste water management and the responsible community planning.
The priorities of country economic development–economic benefits	The possibility of increasing of waste water processing depth in order to minimize need for disposal. The possibility of obtaining an additional source of energy replacing fossil fuels such as natural gas or coal; The possibility of obtaining additional income by sale of electricity and heat. In some cases, the additional payment is made by the project sponsor to support community programmes for stakeholders, including support for people living nearby and who are affected by the project.
The priorities of country environmental development	The improvement of local air and safety (fewer emissions of SOx, NOx, and particulates) through burning less coal for electricity generation and reduction of landfill gas released into the air Reduces the risk of dangerous methane gas concentrations at the landfills and reduced exposure of residential areas to odour.
Costs	
Capital cost	Investment cost per ton of sludge digestion: 200-400 EUR/t
Operational and maintenance cost	O&M Cost: 25-50 EUR/t Total Cost: 50-100 EUR/t
Cost of GHG reduction	The cost of GHG reduction by the anaerobic treatment (digestion) of sewage sludge would vary between 40 and 80 EUR per t CO_2-eq.
Lifetime	20 years

Annex III: The list of stakeholders

Sector	Organization	Contacts
Government Bodies		
Agriculture	The Ministry of Agrarian Policy and Food of Ukraine	http://minagro.gov.ua/
Agriculture Waste	The Ministry of Ecology and Natural Resources of Ukraine	https://menr.gov.ua/
Waste	The Ministry of Regional Development, Construction, Housing and Communal Services of Ukraine	http://www.minregion.gov.ua/
Agriculture Waste	State Agency on Energy Efficiency and Energy Saving of Ukraine	http://saee.gov.ua/
Waste	The National Regulatory Commission of Energy and Utilities of Ukraine	http://www.nerc.gov.ua/
Agriculture	The State Agency of Water Resources of Ukraine	https://www.davr.gov.ua/
Waste	Lviv City Council	https://city-adm.lviv.ua
Waste	Kyiv City State Administration	https://kyivcity.gov.ua/
Agriculture	State Farmers Support Fund of Ukraine	https://udf.gov.ua/
Agriculture Waste	The National Centre of Greenhouse Gases Emissions Inventory	http://nci.org.ua/
Academic/Research Institutions		
Agriculture	The National Academy of Agrarian Sciences of Ukraine	http://naas.gov.ua/
Agriculture	Institute bioenergy crops and sugar beet of the National Academy of Agrarian Sciences Ukraine	http://bio.gov.ua/
Agriculture	The Institute of Agriculture Economy	http://www.iae.org.ua/
Agriculture	The Institute of Plant Protection	http://www.ipp.gov.ua/
Agriculture	The Institute of Water Problems and Land Reclamation NAAS	http://igim.org.ua
Agriculture	Ukrainian Scientific and Research Institute for Forecasting and Testing Machinery and Technologies for Agricultural Production named after L.Pogorilogo	http://www.ndipvt.com.ua/
Agriculture	National Scientific Centre "the Institute of Agriculture of National Academy of Agrarian Science of Ukraine	http://zemlerobstvo.com/
Agriculture	The Institute of Agricultural Microbiology and Agro-Industrial Production of National Academy of Agrarian Science of Ukraine	https://ismav.com.ua/

Agriculture	The Institute of Agroecology and Natural Resource Management	https://agroeco.org.ua/
Agriculture	The National University of Life and Environmental Sciences of Ukraine	https://nubip.edu.ua/
Agriculture	Bila Tserkva National Agrarian University	http://btsau.edu.ua/
Agriculture	Kharkiv National Agricalture University named after Dokuchaev	https://knau.kharkov.ua/
Agriculture	Kherson State Agrarian University	http://www.ksau.kherson.ua/
Agriculture	State Institution "Scientific and Methodological Center for Information and Analytical Support of Higher Educational Institutions Operation "Agroosvita""	http://agroosvita.com/
Agriculture	Lviv Polytechnic National University	http://www.lp.edu.ua/
Agriculture Waste	Public Institution «Institute of Environmental Economics and Sustainable Development of the National Academy of Sciences of Ukraine»	http://ecos.kiev.ua/
Waste	The Institute for Renewable Energy of the National Academy of Sciences of Ukraine	http://www.ive.org.ua/
Waste	Poltava National Technical Yuri Kondratyuk University	https://eco-pntu.in.ua/
Waste	State Enterprise "Institute for Municipal Economy Research and Design and Technological"	http://www.nikti.org.ua/
Waste	The State Ecological Academy of Postgraduate Education and Management	http://dea.edu.ua/
Waste	State Academy for Housing and Communal Services	http://dajkg.com.ua/
NGOs		
Agriculture	Ukrainian Agribusiness Club	http://ucab.ua/
Agriculture Waste	The Bioenergy Association of Ukraine	http://www.uabio.org/
Agriculture	The Non-governmental organization of Manufacturers of Organic Certified products	http://organicukraine.org.ua/
Agriculture	Public Association “The Community Of Pulse Producers And Customers Of Ukraine”	http://ukraine-pulse.org/
Agriculture	The Ukrainian Stock Breeders Association	https://usba.com.ua/
Waste	The Association of Ukrainian Cities	https://www.auc.org.ua/
Waste	Association “Ukrainian ecological alliance”	http://ukrecoalliance.com.ua/
Waste	The Association of Cement Producers of Ukraine “Ukrcement”	http://www.ukrcement.com.ua/

Waste	The Ukrainian League of Industrialists and Entrepreneurs	https://uspp.ua/
Waste	The Institute of Engineering Ecology, Ltd	http://engecology.com/
Waste	"UKRVTORMA" - Ukrainian environmental business association for use of secondary material resources	http://ukrvtorma.com.ua/
Agriculture	NGO Eco-Action	https://ecoaction.org.ua/
Agriculture	Lviv municipal NGO Ecoterra	http://ecoterra.lviv.ua/
Agriculture	The Organic Federation of Ukraine	http://www.organic.com.ua/
Agriculture	The Association of agroecologists of Ukraine	https://agroeco.org.ua/asotsiatsiia-ahroekolohiv/
Waste	All-Ukrainian Ecological League	http://www.ecoleague.net/
Private Sector		
Agriculture	Agro-Soyuz Holding	http://www.agrosoyuz.com.ua/
Agriculture	LLC SP Nibulon	http://nibulon.com/
Waste	Veolia Ukraine	https://www.veolia.ua/
Waste	Private Joint-Stock Company “Kyivspetstrans”	http://kst.in.ua/
Waste	Lviv Communal Enterprise "Green City"	https://city-adm.lviv.ua/lmr/utilities/lkp-zelene-misto
International Organizations		
Agriculture	WWF in Ukraine	http://wwf.panda.org/uk/
Agriculture	The German-Ukrainian Agricultural Policy Dialogue	https://apd-ukraine.de/
Agriculture Waste	The International Finance Corporation in Ukraine	https://www.ifc.org/
Agriculture	The European Bank of Reconstruction and Development	https://www.ebrd.com/ukraine/
Waste	United Nations Development Program in Ukraine	http://www.ua.undp.org/
Waste	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH	https://www.giz.de/en/worldwide/32413.html
Waste	The Swiss-Ukrainian Decentralization Support Project DESPRO	http://despro.org.ua
Agriculture Waste	The Food and Agriculture Organization of the United Nations	http://www.fao.org/countryprofiles/index/ru/?iso3=ukr
Agriculture	The European Business Association	https://eba.com.ua/
Agriculture	The American Chamber of Commerce Ukraine	http://www.chamber.ua/uk

Annex IV: List of Experts Participated in Mitigation Technologies Evaluation

List of Experts in Agriculture Sector

Name	Affiliation	Position
Georgii Geletukha	The Bioenergy Association of Ukraine	PhD in Technical Sciences, Head of the Board
Oleksandr Baskov	Baker Tilly Ukraine LLC	Head of Sustainability Services
Yuriy Epshtein	Accord Ltd	Director
Olha Sydorchuk	AgroBiogas LLC	PhD in Technical Sciences, Chief Executive Officer
Maryna Mykhailovska	LLC Envitec	PhD in Technical Sciences, Senior Manager of Environmental Systems
Kyryl Tomliak	KT-Energy LLC	Director
Sergiy Galashevskyy	Organic standard, Ltd	General Manager
Kateryna Shor	International Charitable organisation “Information Center "Green Dossier"	Project manager
Daria Krylova	Nibulon Ltd	Leading specialist
Yuriy Nesterov	FAO	MSc
Maksym Pavlenko	The National University of Life and Environmental Sciences of Ukraine	PhD in Technical Sciences, Senior Lecturer in the department of Tractors, Cars and Bioenergetics
Drahniev Semen	The Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine	PhD in Technical Sciences, Senior Researcher
Petro Kucheruk	The Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine	PhD in Technical Sciences, Senior Researcher
Andrii Shatkovskyi	The Institute of Water Problems and Land Reclamation of National Academy of Agrarian Sciences	PhD in Agriculture, Deputy Director of Science
Tetiana Kolesnyk	The National University of Water and Environmental Engineering	PhD in Agriculture, Head of Department of Agronomic Chemistry, Soil Science and Agriculture

List of Experts in Waste Sector

Name	Affiliation	Position
Kateryna Abashyna	Independent consultant/Core member, advisory	Waste expert for GIZ, EBRD, USAID projects in Ukraine
Pavlo Bondarev	The Association of Cement Producers of Ukraine “Ukrcement”	Project Manager, Ecology and Technologies
Alina Dychko	The National Technical University of Ukraine “Igor Sikorsky Kyiv Polytechnic Institute”	Dr. in Technical Sciences, Professor of Engineering Ecology Chair
Georgii Geletukha	The Bioenergy Association of Ukraine	PhD in Engineering, Head of the Board
Taras Kaluzhnyi	Lviv Communal Enterprise “Zelene Misto”	Chief Specialist of Finance and Procurement Department
Borys Kostiukovskyy	NGO " The Bureau of Integrated Analysis and Forecasts"	PhD in Engineering , Senior Research Fellow, Scientific director
Iryna Kozlova	The Department of environmental policy of the Dnipro City Council	Deputy director of the Department - head of division of municipal ecology
Valeriy Mykhaylenko	Taras Shevchenko National University of Kyiv	PhD in Chemistry, Associate Professor
Vadym Nozdria	Lviv Municipal Company "Green City"	Director
Ivan Oleksiyevets	Limited Liability Company "ECOINTECHNO"	PhD in Economic and Social Geography, Managing Partner
Tetyana Omelyanenko	International Solid Waste Association Young professionals group in Ukraine	PhD in Economics, Coordinator
Nonna Pavliuk	The Institute of Engineering Thermophysics of National Academy of Sciences of Ukraine	PhD, Leading Scientific Researcher
Sergej Sokol	Sapsan Engineers & Consultants	CEO, country adviser (Ukraine) of WtERT (Germany)
Iuliia Zakharchuk	Budget Institution «National Center for GHG Emission Inventory»	Chief Specialist of Department Inventory

Annex V. List of participants of the Technology Needs Assessment (TNA) stakeholder workshop: an introduction and basic training in project methodology

(21 August 2018, Aarhus' center at the Ministry of Ecology and Natural resources of Ukraine)

#	Participant	Position	Contacts
1	Mr. Anatolii Shmurak	National TNA coordinator and NDE, The Senior Specialist of Climate Policy and Reporting Division of the Climate Change and Ozone Layer Protection Department of the MENR	a.shmurak@menr.gov.ua, shmurak@i.ua
2	Ms. Svitlana Grynchuk	The Director of the Climate Change and Ozone Layer Protection Department of the MENR, UNFCCC National Focal Point	grynchuk@menr.gov.ua, svitlana.iva@gmail.com
3	Mr. Mykhailo Chyzhenko	The Head of Climate Policy and Reporting Division of the Climate Change and Ozone Layer Protection Department of the MENR, UNFCCC National Focal Point	chyzhenko@menr.gov.ua, chyzhenko@gmail.com
4	Ms.Olesia Shapovalova	The Senior Specialist of Climate Policy and Reporting Division of the Climate Change and Ozone Layer Protection Department of the MENR	shapovalova@menr.gov.ua, alesia.shapovalova@gmail.com
5	Ms. Antonina Platonova	The Senior Specialist of Climate Policy and Reporting Division of the Climate Change and Ozone Layer Protection Department of the MENR	platonova@menr.gov.ua, platonovaantonina@gmail.com
6	Mr. Olexandr Tarasenko	The Head of International Projects Coordination Division of the Strategy and European Integration Department of the MENR	o.tarasenko@menr.gov.ua
7	Mr. Roman Filonenko	The Head of Environmental Security Division of the Environmental Security and Permitting-Licensing Activity Department of the MENR	frs@menr.gov.ua
8	Mr. Evgeniy Shmurak	The Senior Specialist of Waste Management Division of the Environmental Security and Permitting-Licensing Activity Department of the MENR	e.shmurak@menr.gov.ua
9	Mr. Sviatoslav Kurulenko	The Head of the Committee on Climate Change and Ozone Layer Protection of the Public Council at the MENR, Head of the Committee on Environmental Resources Management of the Chamber of Commerce of Ukraine	s_kurulenko@ukr.net
10	Ms. Oksana Moroz	The Senior Specialist of Research and Environmental Activities Coordination and Metrology, Certification and Accreditation	oksana.moroz@mev.energy.gov.ua, oksana.moroz@yahoo.com

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Annex VI. Order of CM of Ukraine #583 of April 14, 1999

CABINET OF MINISTERS OF UKRAINE
Order of April 14, 1999 N 583
Kyiv
On the Interagency Commission on Implementation of United Nations Framework Convention on Climate Change,
{As amended according to the Resolution of the Cabinet of Ministers
N 1262 (1262-2000-р) of 11.08.2000
N 1227 (1227-2001-р) of September 26, 2001
N 635 (635-2003-р) of April 26, 2003
N 123 (123-2004-р) of 04.02.2004
by the Order of the Cabinet of Ministers
N 473-р (473-2005-р) of November 22, 2005
by the Order of the Cabinet of Ministers
N 1150 (1150-2005-р) of 07.12.2005
N 1208 (1208-2007-р) of 10.10.2007
No. 1137 (1137-2011-р) of 07.11.2011
N 616 (616-2015-р) of 12.08.2015}

In order to ensure the organization of the development and coordination of the implementation of the national strategy and the national action plan to fulfill Ukraine’s commitments in accordance with the UN Framework Convention on Climate Change and the Kyoto Protocol thereto (995-801), the Cabinet of Ministers of Ukraine decides:

1. Create an Interagency Commission on Ensuring the Implementation of the UN Framework Convention on Climate Change (995_044).

(Clause 1 as amended according to the Resolution of the Cabinet of Ministers N 1150 (1150-2005-р) dated 12/7/2005)

2. To approve the Regulation on the Interagency Commission for the Enforcement of the UN Framework Convention on Climate Change (attached).

Prime Minister of Ukraine V.Pustovoitenko

The Composition of the Interagency Commission on Ensuring the Implementation of the UN Framework Convention on Climate Change is excluded on the basis of the Decree of the Cabinet of Ministers N 1150 (1150-2005-р) of 12.12.2005)

Approved by the Resolution of the

Cabinet of Ministers of Ukraine of April 14, 1999 N 583

Regulation on the Interagency Commission on Ensuring the Implementation of the UN Framework Convention on Climate Change

(In the text of the Provision, the word "Minekobezpeky" is replaced by the word "Minprirody" according to the Resolution of the Cabinet of Ministers N 1150 (1150-2005-р) dated 12/7/2005)

1. The Interagency Commission on Ensuring the Implementation of the UN Framework Convention on Climate Change (995_044) (hereinafter referred to as the Commission) is created to organize the development and coordination of the implementation of a national strategy and national action plan to fulfill Ukraine’s obligations under the UN Framework Convention on Climate Change (hereinafter - UN Framework Convention) and its Kyoto Protocol.

2. The Commission is guided in its activities by the Constitution of Ukraine (254k / 96-BP) by the laws of Ukraine, acts of the President of Ukraine and the Cabinet of Ministers of Ukraine, as well as these Regulations, decisions of the Conference of the Parties to the UN Framework Convention on Climate Change.

3. The Commission interacts with the relevant committees of the Verkhovna Rada of Ukraine, ministries, other central and local executive bodies, enterprises, institutions and organizations.

4. The main tasks of the Commission are:

organizing the development of a national strategy and a national action plan for fulfilling Ukraine's obligations in accordance with the UN Framework Convention and its Kyoto Protocol;

the coordination of the activities of ministries, other central and local executive authorities, enterprises, institutions and organizations on the implementation of the national action plan to fulfill the obligations of Ukraine in accordance with the UN Framework Convention and its Kyoto Protocol;

the development of proposals for the implementation of commitments provided for by the Kyoto Protocol;

the organization of the preparation of national communications on the implementation of obligations under the UN Framework Convention;

the organization for the preparation of a national inventory of anthropogenic emissions from sources and adsorption through absorbers of all greenhouse gases not controlled by the Montreal Protocol on substances that deplete the ozone layer;

monitoring the implementation of a mitigation plan for climate change by addressing the problem of anthropogenic emissions from sources and adsorption by sinks of all greenhouse gases not controlled by the specified Montreal Protocol, and promoting adequate adaptation to climate change;

the consideration of the materials on the UN Framework Convention and the Kyoto Protocol thereto, which come from the governments of other countries, the Global Environment Facility, the World Bank, other international organizations and the preparation of relevant proposals based on them;

the consideration of reporting documents sent by the Secretariat of the UN Framework Convention on Climate Change (995_044) and draft directives to official government delegations and representatives of the Cabinet of Ministers of Ukraine for international events on climate change and reports on the results of participation in these events. {Clause 4 is supplemented by a paragraph according to the Resolution of the Cabinet of Ministers N 1208 (1208-2007-p) of 10.10.2007}

5. The Commission has the right to:

To submit proposals in accordance with the established procedure on matters within its competence;

To receive in accordance with the established procedure, from central and local executive authorities, enterprises, institutions and organizations the information necessary to carry out the tasks assigned to it;

To form in order to fulfill the tasks assigned to it, expert commissions and working groups, to involve in their work the employees of central and local executive bodies, as well as specialists from scientific and other institutions (by agreement of their leaders).

6. The Commission consists of the

Minister of Ecology and Natural Resources - the Chairman of the Commission,

the Deputy Minister of Ecology and Natural Resources - the First Deputy Chairman of the Commission,

the Deputy Minister of Economic Development and Trade - the Chief of Staff - the Deputy Chairman of the Commission,

the First Deputy Minister of Energy and Coal Industry - Deputy Chairman of the Commission,

Head of the structural unit of the Ministry of Ecology and Natural Resources, who is entrusted with the functions of ensuring the formation and implementation of state policy on meeting the requirements of the UN Framework Convention on Climate Change, - Commission Secretary,

Deputy Minister of Foreign Affairs - Chief of Staff,

Deputy Minister of Finance - Chief of Staff,

Deputy Minister of Agrarian Policy and Food - Chief of Staff,

Deputy Minister of Infrastructure - Chief of Staff,

Deputy Minister Education and Science, Youth and Sports - Head of Staff,

Deputy Minister of Regional Development, Construction and Housing and Communal Services

deputy secretary of the National Security and Defense Council of Ukraine (by agreement),

Deputy Chairman of the State Land Committee,

Deputy Chairman of the State Forest Agency,

Deputy Chairman of the State Statistics Committee, Chairman of the Committee of the Verkhovna Rada of Ukraine on environmental policy, environmental management and liquidation of the consequences of the Chernobyl disaster (by agreement),

representative of the Secretariat of the Cabinet of Ministers of Ukraine,

as well as by agreement

the representatives of state bodies, local municipality bodies, academic institutions, non-governmental organizations, people's deputies of Ukraine.

{The first paragraph of paragraph 6, as amended by the Decree of the Cabinet of Ministers N 1208 (1208-2007-p) of 10.10.2007; as amended by Resolution of the Cabinet of Ministers N 1137 (1137-2011-p) of 07.11.2011; as amended up to Resolution No. 616 of CM (616-2015-p) of August 12, 2015}

The personal composition of the Commission is approved by its chairman.

The Chairman of the Commission is responsible for ensuring the holding of its meetings, organizing the monitoring of the implementation of decisions taken, coordinating the activities of the Commission with the relevant executive structures of the UN Framework Convention (995_044) and the Kyoto Protocol (995_801) to it.

(Clause 6, as amended up to Resolution No. 1262 (1262-2000-p) of the Cabinet of Ministers on August 11, 2000, as amended by Resolution No. 1150 of the Cabinet of Ministers (1150-2005-n) of December 7, 2005)

7. The organizational and technical support for the Commission’s activities is provided by the Ministry of Environment.

8. The main form of work of the Commission is meetings, which are held quarterly in accordance with the work plan of the Commission, approved by the Chairman of the Commission or, if necessary. {The first paragraph of paragraph 8 as amended by the Decree of the Cabinet of Ministers N 1208 (1208-2007-p) of 10.10.2007}

A meeting of the Commission shall be deemed to be valid, if it is attended by at least half of its members.

The decision of the Commission is considered to be adopted, if more than half of the members of the Commission present at the meeting in order to vote for it.

The decision of the Commission shall be drawn up in a protocol and signed by the Chairman of the Commission and in case of his absence - by his first deputy. (The fourth paragraph of paragraph 8 as amended by the Decree of the Cabinet of Ministers N 1262 (1262-2000-p) of August 11, 2000)

Annex VII. Results of the prioritization of technologies

Table A7-1. Performance matrix for the technologies in Agriculture sector

Technologies	**Costs**		Benefits							
			Social		**Environmental**		**Climate Related**		**Other**	
	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F	Criterion G	Criterion H	Criterion I	Criterion J
Using slow- or controlled- release fertilizer forms or nitrification inhibitors	N/A or low	USD 800 per ha	3.4	6.5	7.8	7.0	1.6	6.6	7.2	7.5
The use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture	N/A or low	USD 3 – 100 per ha	6.4	6.9	7.9	8.2	1.6	7.3	7.3	8.5
Conservation tillage technologies (low-till, no-till, strip-till, etc.)	USD 100-200 per ha	N/A	4.7	5.8	6.2	8.9	7	7.8	6.4	6.8
Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	USD 1100-2500 per ha	USD 60-190 per ha	7.2	5.2	6.6	6.7	1.1	7.4	7.9	6.9
Biogas production from agricultural crops products	EUR 3 to 4 million per MW	EUR 0.3 to 0.4 million per MW	8.7	6.8	7.3	6.0	4.4	6.6	8.3	8.5
Biogas production from animal waste	EUR 3 to 4 million per MW	EUR 0.12 to 0.4 million per MW	8.5	8.3	8.8	7.3	1.8	8.0	9.1	8.6
Organic agriculture	N/A	N/A or low	7.7	9.1	8.6	9.3	4	7.6	8.4	7.6
The production and use of solid biofuels from agricultural residues	EUR 0.1-0.3 million per MW for heat EUR 2.5-3.5 million per MW for CHP	EUR 20-100 per ton	7.9	5.7	4.8	5.0	10.2	6.4	8.3	8.1
The production of liquid biofuels	EUR 0.3-2 million	EUR 0.3-1.0 per litre	7.6	4.9	5.1	4.7	0.6	6.1	7.4	6.8

from agricultural products	per 1000 tons										
Improved feeding practices and dietary additives for livestock for the reduction of GHGs emissions from enteric fermentation	N/A or low	10% or more above typical diet cost	5.3	5.1	5.0	4.8	2.2	5.9	6.4	6.7	

Table A7-2. Scoring matrix for the technologies in Agriculture sector

Technologies	Costs		Benefits							
			Social		Environmental		Climate Related		Other	
	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F	Criterion G	Criterion H	Criterion I	Criterion J
Using slow- or controlled- release fertilizer forms or nitrification inhibitors	90	30	34	65	78	70	16	66	72	75
The use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture	70	80	64	69	79	82	16	73	73	85
Conservation tillage technologies (low-till, no-till, strip-till, etc.)	70	90	47	58	62	89	69	78	64	68
Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	40	60	72	52	66	67	11	74	79	69
Biogas production from agricultural crops products	60	60	87	68	73	60	43	66	83	85
Biogas production from animal waste	60	70	85	83	88	73	18	80	91	86
Organic agriculture	80	80	77	91	86	93	39	76	84	76
The production and use of solid biofuels from agricultural residues	70	70	79	57	48	50	100	64	83	81
The production of liquid biofuels	40	50	76	49	51	47	6	61	74	68

from agricultural products										
Improved feeding practices and dietary additives for livestock for the reduction of GHGs emissions from enteric fermentation	90	60	53	51	50	48	22	59	64	67
Criterion weight	12	10	8	12	11	12	13	7	6	9

Table A7-3. Decision matrix for the technologies in Agriculture sector

Technologies	**Costs**		Benefits							
			Social		**Environmental**		**Climate Related**		**Other**	
	Criterion A	Criterion B	Criterion C	Criterion D	Criterion E	Criterion F	Criterion G	Criterion H	Criterion I	Criterion J
Using slow- or controlled- release fertilizer forms or nitrification inhibitors	1080	300	273	780	855	840	204	463	429	678
The use of information and telecommunication technologies in agriculture for GHGs emission reductions in agriculture	840	800	511	830	872	988	204	509	435	765
Conservation tillage technologies (low-till, no-till, strip-till, etc.)	840	900	377	694	685	1063	892	544	386	609
Efficient Irrigation Systems (Sprinkler and Drip Irrigation)	480	600	577	618	723	803	140	520	471	617
Biogas production from agricultural crops products	720	600	699	810	804	720	561	459	496	768
Biogas production from animal waste	720	700	683	990	963	878	229	560	548	774
Organic agriculture	960	800	617	1089	951	1114	510	530	506	688
The production and use of solid biofuels from agricultural residues	840	700	634	686	526	600	1300	445	497	726

The production of liquid biofuels from agricultural products	480	500	606	591	566	568	76	429	446	611
Improved feeding practices and dietary additives for livestock for the reduction of GHGs emissions from enteric fermentation	1080	600	420	611	550	570	280	414	385	600

Table W7-1. Scoring matrix for the technologies in Waste Sector

Technology	Economic				Climate related			Political			Technological				Social				Enviro-mental		
Criteria #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
LFG-to-E	62	71	75	0	69	65	0	72	44	0	80	61	71	0	76	52	49	0	79	51	4
Closure	53	68	12	0	57	43	0	67	43	0	75	77	71	0	76	52	47	0	74	62	6
Construction	45	55	14	0	38	31	0	66	32	0	66	72	66	0	31	47	46	0	61	61	1
Sorting	53	55	51	0	45	45	0	82	79	0	71	73	66	0	66	64	55	0	74	71	5
Composting	66	61	30	0	46	53	0	62	58	0	58	63	72	0	60	50	53	0	63	67	3
MBT-AD	40	43	59	0	61	45	0	59	56	0	46	57	51	0	59	55	45	0	73	73	3
MBT-Cement	39	42	51	4	54	47	0	63	50	0	41	57	64	0	50	54	43	0	67	65	3
MBT-DH	33	41	54	4	49	43	0	58	50	0	37	61	57	0	42	49	38	0	54	59	3
Combustion	20	35	52	0	44	32	0	44	38	0	50	59	41	0	19	45	41	0	49	58	6
Gasification	15	24	47	0	48	29	0	39	41	0	18	41	33	0	29	39	36	0	44	53	4
Biostabilization	56	57	14	0	32	42	0	43	38	0	44	47	61	0	32	40	46	0	52	46	4
AD-sludge	46	43	45	0	55	44	0	52	52	0	55	71	57	0	56	59	45	0	71	61	1
Criteria weight	**4.7**	**6.6**	**4.9**	**2.1**	**5.2**	**4.6**	**1.8**	**4.1**	**5.2**	**5.6**	**3.6**	**6.9**	**5.6**	**1.6**	**1.1**	**6.8**	**7.0**	**1.6**	**4.7**	**6.6**	**4.9**

Table W7-2. Decision matrix for the technologies in Waste Sector

Technology	Economic				Climate related			Political			Technological				Social				Enviro-mental		
Criteria #	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
LFG-to-E	633	434	347	0	460	316	0	376	206	0	324	317	394	0	530	287	77	0	538	358	6
Closure	544	419	56	0	377	210	0	348	199	0	307	399	397	0	530	291	73	0	502	433	10
Construction	463	336	64	0	251	149	0	343	148	0	268	374	370	0	213	263	72	0	412	428	1
Sorting	540	339	235	0	297	219	0	428	368	0	291	382	369	0	458	354	87	0	502	500	8
Composting	674	374	138	0	304	257	0	324	269	0	235	326	401	0	413	281	83	0	429	470	4
MBT-AD	407	266	276	0	406	219	0	307	258	0	186	297	281	0	408	304	70	0	493	508	4
MBT-Cement	402	257	235	17	356	229	0	327	231	0	168	295	356	0	347	298	67	0	452	455	4
MBT-DH	343	249	249	17	325	207	0	304	231	0	152	317	316	0	289	273	60	0	366	413	4
Combustion	206	217	239	0	289	156	0	228	177	0	205	305	227	0	129	253	64	0	332	406	9
Gasification	151	149	220	0	317	139	0	204	190	0	75	214	181	0	201	216	57	0	301	371	7
Biostabilization	572	351	64	0	211	203	0	222	174	0	179	246	342	0	220	223	72	0	354	324	6
AD-sludge	472	263	209	0	365	213	0	273	241	0	226	369	316	0	391	326	70	0	480	428	2
Criteria weight	**4,7**	**6,6**	**4,9**	**2,1**	**5,2**	**4,6**	**1,8**	**4,1**	**5,2**	**5,6**	**3,6**	**6,9**	**5,6**	**1,6**	**1,1**	**6,8**	**7,0**	**1,6**	**4,7**	**6,6**	**4,9**

Annex VIII. The example of spatial visualization of climate technology application potential

The map of soils suitable for organic agriculture has been developed by the National Academy of Agrarian Science of Ukraine.[88]

Fig. A.7 – soils suitable for organic agriculture (green – very suitable, light green – suitable, orange – relevantly suitable, pink – low suitability).

88 National Academy of Agrarian Sciences of Ukraine, http://naas.gov.ua/newsall/newsnaan/5028/