Food and Agriculture
Organization of the
United Nations

European Bank
for Reconstruction and Development

ADOPTION OF CLIMATE TECHNOLOGIES IN THE AGRIFOOD SYSTEM

INVESTMENT OPPORTUNITIES IN KAZAKHSTAN

**FAO
INVESTMENT
CENTRE**

COUNTRY
INVESTMENT
HIGHLIGHTS

©EBRD

Country Investment Highlights
Number 1

ADOPTION OF CLIMATE TECHNOLOGIES IN THE AGRIFOOD SYSTEM

INVESTMENT OPPORTUNITIES IN KAZAKHSTAN

Maria del Mar Polo
Nuno Santos
Yerlan Syzdykov

Prepared under the FAO/EBRD cooperation

Food and Agriculture Organization of the United Nations
Rome, 2022

Required citation:
del Mar Polo, M., Santos, N., Syzdykov, Y. 2022. *Adoption of climate technologies in the agrifood system: investment opportunities in Kazakhstan.* Rome, FAO. https://doi.org/10.4060/cb6857en

The designations employed and the presentation of material in this information product do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations (FAO) or the European Bank for Reconstruction and Development (EBRD) concerning the legal or development status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. The mention of specific companies or products of manufacturers, whether or not these have been patented, does not imply that these have been endorsed or recommended by FAO or EBRD in preference to others of a similar nature that are not mentioned.

The views expressed in this information product are those of the author(s) and do not necessarily reflect the views or policies of FAO or EBRD.

ISBN 978-92-5-134966-3
© FAO, 2022

Some rights reserved. This work is made available under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 IGO licence (CC BY-NC-SA 3.0 IGO; https://creativecommons.org/licenses/by-nc-sa/3.0/igo/legalcode).

Under the terms of this licence, this work may be copied, redistributed and adapted for non-commercial purposes, provided that the work is appropriately cited. In any use of this work, there should be no suggestion that FAO endorses any specific organization, products or services. The use of the FAO logo is not permitted. If the work is adapted, then it must be licensed under the same or equivalent Creative Commons license. If a translation of this work is created, it must include the following disclaimer along with the required citation: “This translation was not created by the Food and Agriculture Organization of the United Nations (FAO). FAO is not responsible for the content or accuracy of this translation. The original English edition shall be the authoritative edition.”

Disputes arising under the licence that cannot be settled amicably will be resolved by mediation and arbitration as described in Article 8 of the licence except as otherwise provided herein. The applicable mediation rules will be the mediation rules of the World Intellectual Property Organization http://www.wipo.int/amc/en/mediation/rules and any arbitration will be in accordance with the Arbitration Rules of the United Nations Commission on International Trade Law (UNCITRAL).

Third-party materials. Users wishing to reuse material from this work that is attributed to a third party, such as tables, figures or images, are responsible for determining whether permission is needed for that reuse and for obtaining permission from the copyright holder. The risk of claims resulting from infringement of any third-party-owned component in the work rests solely with the user.

Sales, rights and licensing. FAO information products are available on the FAO website (www.fao.org/publications) and can be purchased through publications-sales@fao.org. Requests for commercial use should be submitted via: www.fao.org/contact-us/licence-request. Queries regarding rights and licensing should be submitted to: copyright@fao.org.

Art direction and design: Sonia Malpeso & Naz Naddaf
Cover photograph: ©EBRD

Contents

Tables and figures

Tables

Annexes

Figures

Acknowledgements

This publication is a joint product of the Food and Agriculture Organization of the United Nations (FAO) and the European Bank for Reconstruction and Development (EBRD). The study was led by Nuno Santos, Economist (FAO), in collaboration with Astrid Motta, Principal, Energy Efficiency and Climate Change (EBRD). The authors of this publication at FAO Investment Centre Division are Maria del Mar Polo, Agricultural Economist, Nuno Santos, Economist, Yerlan Syzdykov, Economist. At an early stage, the team was supported by Arianna Carita, Economist, Tommaso Alacevich, Economist, Geoffrey Dyce, Economist, and other technical officers at FAO. Special thanks are owed to Giulia Conchedda, Agri-environmental Data Analyst, Francesco Tubiello, Senior Statistician, Samvel Ghazaryan, Irrigation Specialist, Jonathan Moncada and Luis Rincon, Energy Specialists, Anne Mottet, Livestock Specialist, and Luis Dias Pereira, Economist.

The authors would also like to thank the experts, government representatives, development partners and private technology providers and adopters operating in the agrifood sector in the Republic of Kazakhstan for the assistance provided to the project team during the data collection and technology assessments.

The authors would like to thank Kairat Nazhmidenov, Investment Support Officer in the Republic of Kazakhstan, and his team for support provided through the implementation of the study, the related field missions and the preparation of the workshop where the study results were presented to stakeholders.

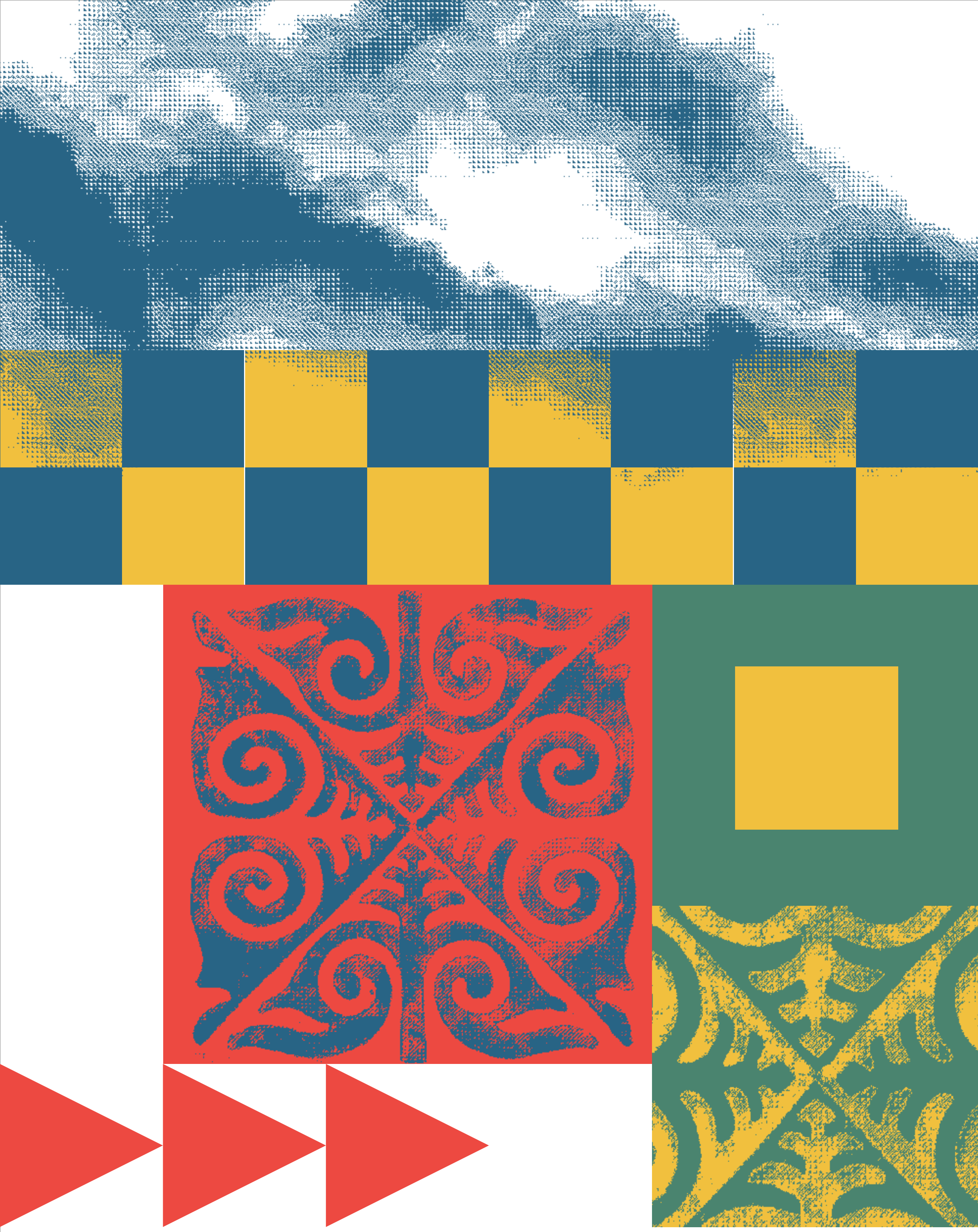
Valuable support at the final stages of publication and dissemination was provided by Hannah Fried, Economist, Naz Naddaf, Graphic Designer, Nada Zvekic, Communications Officer, and Esther Lake, Communications Specialist at the FAO Investment Centre.

he authors would like to thank Mohamed Manssouri, Director, FAO Investment Centre, and Gianpiero Nacci, Head of Sustainable Resource Investments, EBRD, for their overall guidance.

Abbreviations and acronyms

EBRD	The European Bank for Reconstruction and Development
EFA	Economic and Financial Analysis
ENPV	Economic Net Present Value
Ex-ACT	EX Ante Carbon balance Tool
FAO	Food and Agriculture Organization of the United Nations
FINTECC	Finance and Technology Transfer Centre for Climate Change
GDP	gross domestic product
GET	Green Economy Transition
GHG	greenhouse gas
GLEAM	Global Livestock Environmental Assessment Model
IBP	International Best Practices
IRR	internal rate of return
LIFDC	low-income food-deficit country
LU	Livestock unit
MACC	Marginal Abatement Cost Curve
MCA	Multi-Criteria Analysis
NC	National Communication
NDC	nationally determined contribution
NPV	net present value
OECD	Organisation for Economic Co-operation and Development
SHARP	Self-evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nations Statistics Division
USA	United States of America

©EBRD



Introduction

Agrifood systems are important contributors to greenhouse gas (GHG) emissions and are therefore increasingly under pressure to become more resource-efficient and reduce their environmental footprint. At the same time, agrifood system performance is closely dependent on natural resources and faces major threats from climate change. It is urgent to increase the agrifood sector's resilience to climate change through targeted investments that reduce its vulnerability to extreme weather events. Accelerating the adoption of climate technologies is an essential step towards these objectives.

With this in mind, the European Bank for Reconstruction and Development (EBRD) and the Food and Agriculture Organization of the United Nations (FAO) developed a methodology to identify and prioritize climate technologies in the agrifood sector, based on their potential to mitigate GHG emissions and contribute to adaptation to climate change. The assessment and prioritization is based on multiple criteria, including technical and financial parameters, economy-wide impacts and sustainability, and institutional and regulatory aspects.

This report summarizes the results of a rapid assessment of climate technologies in Kazakhstan's agrifood sector based on this methodology. A similar assessment was conducted in the Kyrgyz Republic and summarized in a companion publication. The results of both country assessments were presented to stakeholders in both countries during two workshops held in Bishkek and Astana on 2 November 2018 and 7 November 2018, respectively.

The report contains seven chapters. Following the introduction, the second chapter provides a brief overview of the five-step methodology used for the assessment. The subsequent chapters present the main results of each step of the methodology, as applied to the Kazakhstan agrifood sector. The final chapter presents the overall ranking of climate technologies *vis-à-vis* their mitigation and adaptation potential, and highlights opportunities and challenges to foster the expansion of the most promising technologies to the required scale.

Due to time and resource constraints, the results presented in this report are derived from a rapid assessment. As such, the number of possible technologies has been limited to 11, which were selected based on available data, a participatory process, a series of field missions to the Republic of Kazakhstan and various expert consultations. Future assessments could add other technologies.

Methodology to assess climate technologies

BACKGROUND

The EBRD and FAO recognize that addressing climate change mitigation and adaptation challenges in the agrifood sector will require radical changes in food production systems. Greater adoption of climate technologies is a core element of this transition towards more sustainable food systems. In this context, the EBRD and FAO, within the Finance and Technology Transfer Centre for Climate Change (FINTECC) programme, collaborated to develop a practical tool to inform policy-makers and to orient public and private institutions interested in investments that foster the greening of the agrifood sector. This methodology[1] was first applied in Morocco in 2015–2016 and results are detailed in the respective FAO/EBRD publication.[2] During 2017–2018, the revised methodology was applied in the Kyrgyz Republic and Kazakhstan.

OBJECTIVE AND KEY ELEMENTS

The objective of the methodology is to derive a prioritized list of climate technologies in a country's agrifood sector that contribute to: a) climate change mitigation (reduction of GHG emissions); and/or b) climate change adaptation (enhancement of climate change resilience). The methodology consists of five steps and uses a Multi-Criteria Analysis (MCA) to undertake the assessment of climate technologies from various perspectives. It draws on a wealth of existing data sources including FAOSTAT, World Development Indicators, United Nations Statistics Division (UNSD), Nationally Determined Contributions (NDCs) and National Communications to the United Nations Framework Convention on Climate Change (UNFCCC), as well as studies and interviews with local stakeholders.

The methodology is implemented by a core team that consults key stakeholders during the various stages. It builds on other conceptual frameworks and tools that contribute to the assessment of mitigation and adaptation benefits – i.e. FAO's Water, Energy and Food Nexus; Global Livestock Environmental Assessment Model (GLEAM); EX Ante Carbon balance Tool (Ex-ACT); Self-evaluation and Holistic Assessment of Climate Resilience of Farmers and Pastoralists and Pastoralists (SHARP); and EBRD's Green Economy Transition (GET) approach.

---

[1] Adoption of climate technologies in the agrifood sector. Methodology. FAO Investment Center, Rome (2018). [URL http://www.fao.org/3/a-i7022e.pdf]

[2] Morocco. Adoption of climate technologies in the agrifood sector. FAO Investment Center, Rome (2016). [URL http://www.fao.org/3/a-i6242e.pdf]

©FAO/Vyacheslav Oseledko

The five-step methodology is depicted in Figure 1. Step 1 identifies the main sources of GHG emissions in the agrifood sector and analyses the vulnerabilities of the sector to climate change. Based on these analyses, a list of climate technologies is identified that contribute to GHG mitigation and climate change adaptation in the national context through a participatory exercise involving key stakeholders and partners. Steps 2 to 4 evaluate and score these technologies according to various criteria. Technologies are assessed using MCA.

Figure 2 shows the criteria used in Steps 2 to 4, respectively: (1) performance compared to international best practices; (2) maturity of technical support services; (3) current technology adoption rate; (4) trends in gap between uptake and potential; (5) financial returns; (6) potential to reduce annual GHG emissions; (7) contribution to adaptation; (8) mitigation cost; (9) negative externalities; (10) positive externalities; and (11) policy reform requirements. The ratings are based on a Likert Scale – scoring from 1 (very low) to 5 (very high) – for criteria that can only be assessed qualitatively (e.g. maturity of technical support service) and on absolute values for quantifiable criteria (e.g. current adoption rate or Internal Rate of Return - IRR).

In Step 5, overall ranking and conclusions are derived concerning the potential of the technologies to contribute to climate change mitigation and adaptation in the agrifood sector. The ranking is based on normalization of scores and weights assigned to the 11 dimensions further described below. Step 5 concludes with suggestions for policy measures to foster the uptake of the prioritized technologies.

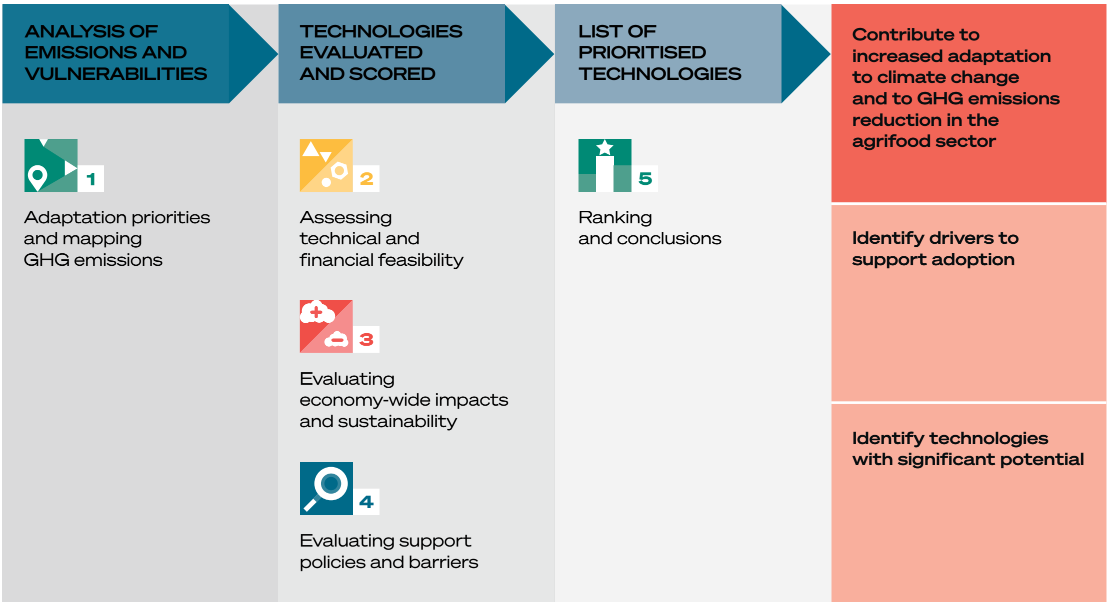
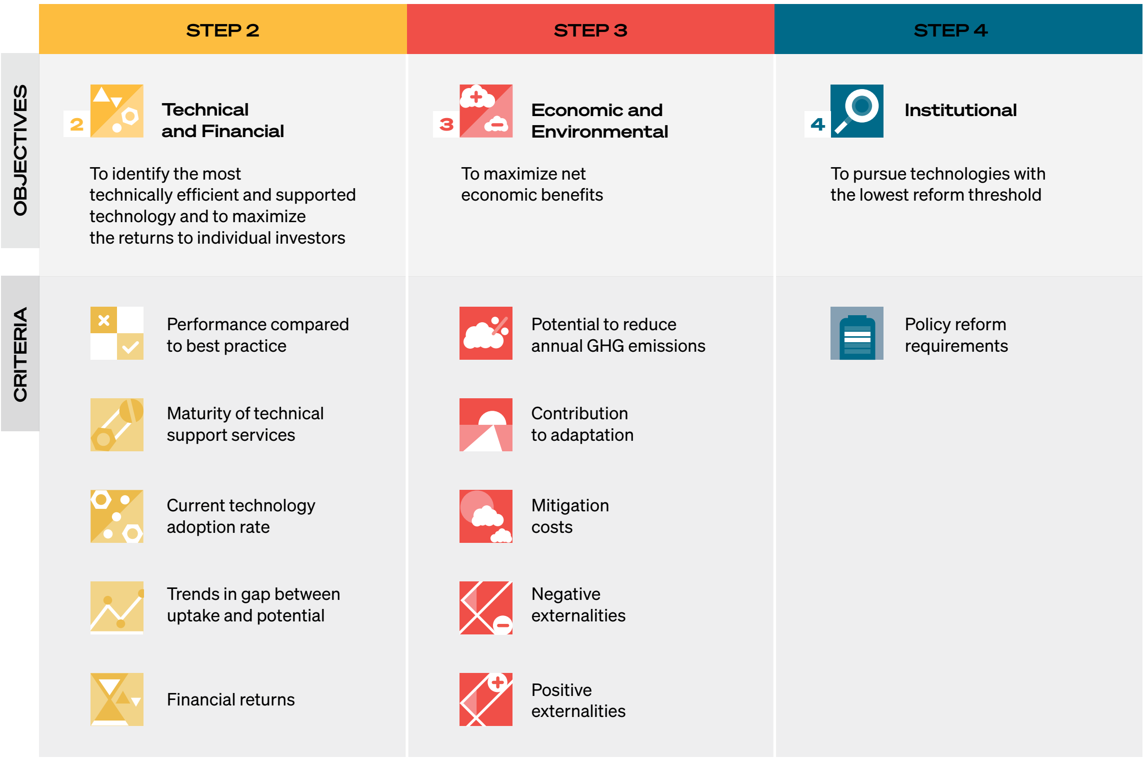


Figure 1
Summary of the five-step methodology

Source: Authors‘ compilation.



	STEP 2	STEP 3	STEP 4
OBJECTIVES	2 **Technical and Financial** To identify the most technically efficient and supported technology and to maximize the returns to individual investors	3 **Economic and Environmental** To maximize net economic benefits	4 **Institutional** To pursue technologies with the lowest reform threshold
CRITERIA	Performance compared to best practice	Potential to reduce annual GHG emissions	Policy reform requirements
	Maturity of technical support services	Contribution to adaptation	
	Current technology adoption rate	Mitigation costs	
	Trends in gap between uptake and potential	Negative externalities	
	Financial returns	Positive externalities	

Figure 2
Objectives and criteria – Steps 2 to 4

Source: Authors’ compilation.

Country context

The Republic of Kazakhstan is an upper middle income country with a population of nearly 18 million, of which 43 percent live in rural area. Since its independence, the economic growth of the country, powered by an abundance of oil, gas, and other minerals, has been quick, and gross domestic product (GDP) per capita increased from USD 1 515 to USD 8 837 between 1991 and 2017. This growth had a strong incidence on poverty that decreased sharply from 65 percent in 2001 to 8 percent in 2015.

Agriculture contributes to only 6 percent of Kazakhstan's GDP (World Bank, 2018), however it remains an important sector for the economy of Kazakhstan. It provides employment to 18 percent of the working-age population, and, as such, is critical for addressing rural income generation as well as food security and poverty reduction. In addition, Kazakhstan is a major producer of agricultural commodities: the country is in the world's top 20 for the production of grains, including wheat and barley, and oilseeds, such as sunflower seed. The export of food and agriculture products accounted for 5 percent of Kazakhstan's total exports; a major part of agriculture exports (USD 1.7 billion in 2018) comes from the export of grain and flour. The export of meat and meat products, which reached USD 44.7 million in 2018, is noticeably higher than the same exports of USD 20.0 million in 2017.

With its vast land resources, Kazakhstan is well suited to extensive crop and livestock production. According to latest data, while forestland accounts for only 1 percent of total land, land used for agriculture accounts for 80 percent of the country total land area, of which 86 percent is used for permanent meadows and pastures and 14 percent is used as arable land. The agrarian reform that took place after the independence of the country led to the shift from large state-owned enterprises to individual land holdings. Regional heterogeneity remains: farms in the north have predominantly larger operations focused on crop production, while smaller farms in the south specialize in meat and dairy production. Smallholder farmer's account for the majority of Kazakhstan's farmworkers: they produce 46 percent of the country's agricultural output and 80 percent of its livestock output.

With its vast land resources, Kazakhstan is well suited to extensive crop and livestock production.

Despite some strong competitive advantage for agricultural production, the sector suffers from past inadequate attention to sustainable production practices, which have led to varying degree of land degradation and desertification in all regions. Desertification is a serious threat to the country and may affect up to 66 percent of Kazakhstan's total area. Up to 30 million hectares are occupied by sand and saline lands account for about 34 million hectares. The country's reliance on wheat production also makes it vulnerable to pests and diseases, which may become more damaging as a result of rising temperatures.

The country is also highly vulnerable to shocks associated with climate change, due to its heavy reliance on dryland crops and livestock production systems. Climate change impacts are projected to jeopardize agricultural livelihoods across the country. The vulnerability of agricultural sector is further increased by its weak adaptive capacity: agriculture is dominated by a small number of crops, which are unsuited to the local environment, and characterized by poor management of water resources, soil erosion, and inefficient nutrient conservation.

The Government of Kazakhstan has adopted an environmental perspective across all economic sectors. Low-carbon development is one of the government's key priorities, with a focus on energy efficiency and renewable energy. However, despite some consistent effort to enhance national policies and plans for climate change mitigation, measures for adaptation have not yet been emphasized in policy and legislation, as reflected in the First Intended Nationally Determined Contribution (INDC) submitted in 2015, with the quantitative target to reduce greenhouse gas (GHG) emissions. Despite existing gaps, the country increasingly recognizes the importance of reducing the country's vulnerability to climate change. Climate-smart technology and practices present opportunities for addressing climate change challenges as well as for stimulating economic growth and promoting sustainable development within Kazakhstan's food and agricultural systems.

©EBRD

Results of Step 1
Analysis of emissions and vulnerabilities

KEY FINDINGS FROM ANALYSIS OF EMISSIONS

The total levels of GHG emissions in Kazakhstan in 2010 were approximately 310 million metric tonnes carbon dioxide equivalent (tCO2eq) (FAOSTAT, 2018) This includes emissions from energy, transport, industrial processes, waste, residential use and agriculture, and excludes emissions and sinks from land use. Energy accounted for the largest share of the emissions. Agriculture emissions were around 7 percent of the total in the country, while the sector represented approximately 6 percent of total GDP.

Total agricultural emissions have increased considerably in past two decades, both in absolute terms and in value intensity, while the share of emissions from this sector has remained constant. More specifically, agriculture emissions have grown by 4.5 million tCO_2eq in 2000–2016 or an increase of 26 percent; by 2016 agriculture accounted for around 22 million tCO_2eq in emissions.

In 2016, value intensity of emissions from agriculture was around 3 tonnes of CO_2eq per USD 1 000 of agriculture GDP (see Figure 3). The value was lower than the regional average, although still noticeably higher than the average in Organisation for Economic Co-operation and Development (OECD) countries.

The increase in emissions over the past 15 years was mainly explained by increases in emissions from the livestock sector due to the growth in livestock numbers. In particular, sheep population nearly doubled during this period (Figure 4).

Emissions from the enteric fermentation of ruminants and swine followed by emissions related to the management and application of manure (Figure 4) were the main contributing factors. FAOSTAT data also estimate that slightly more than 10 percent of total agricultural emissions during the period 2000–2016 were related to fires on natural vegetation (Figure 5).

MAIN VULNERABILITIES OF AGRICULTURE SECTOR

The Republic of Kazakhstan has faced problems of drying up of the Aral Sea, shoaling of the Lake Balkhash, degradation of glaciers, water scarcity and flooding in the coastal regions of the Caspian Sea. According to several sources,[3]

---

[3] Third-VI National Communication to UNFCCC, Climate Risk Profile of Kazakhstan (2017), USAID (only on Thien Shan glaciers data).

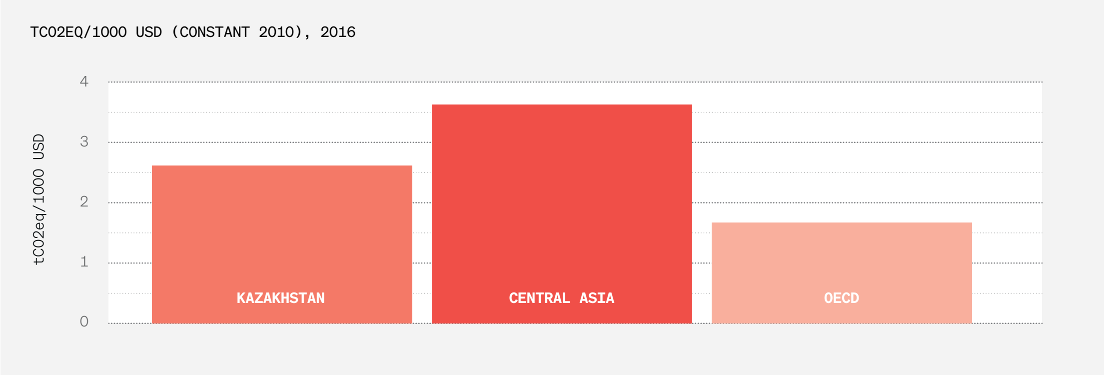


Figure 3
Agriculture emissions relative to agriculture GDP

Source: FAOSTAT and World Bank, 2018 (2016 data).

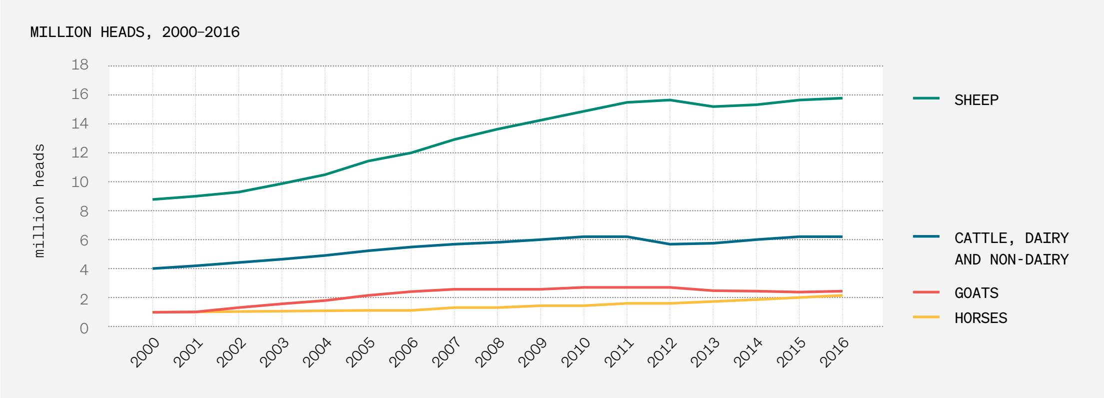
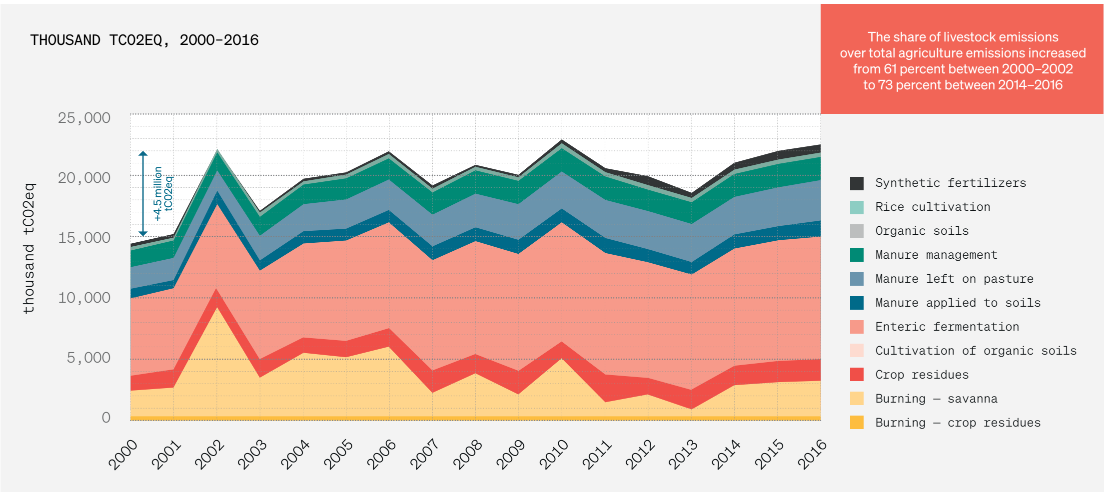


Figure 4
Evolution in stocks of major animal types in Kazakhstan

Source: FAOSTAT, 2018.



The share of livestock emissions over total agriculture emissions increased from 61 percent between 2000–2002 to 73 percent between 2014–2016

Figure 5
Trends in emissions from agriculture activities

Source: FAOSTAT, 2018.

Kazakhstan's agrifood sector faces the following serious challenges as a consequence of climate change:

- **Possible shortages in water resources due to changes in surface water runoff.** Surface water flow is expected to decrease by around 25 percent until 2030. As a result, water supply to agriculture is at risk. Moreover, the country's heavy reliance on transboundary rivers for water supply constitutes an additional risk.
- **Depletion of water resources and temperature increases leading to increase of aridity and, in particular, a shift of the low arid zone to the north.** Areas and productivity of land may be significantly altered with many districts becoming unprofitable for cereal crops.
- **Increase in frequency and intensity of extreme climate events with 75 percent of the country being subject to increased risk of environmental disruption.** More frequent heat stress and droughts are likely, especially in south and central Kazakhstan. The resulting drying up of pastures and reduced water availability for livestock create particularly difficult conditions for livestock-related activities and an increase in risks associated with such activities. Changes in weather patterns may result in spring floods, heavy rains in autumn and early frosts which may result in harvest losses.
- **High expected economic losses in the absence of timely adaptation in agriculture.** According to some estimates, the annual economic cost of desertification and poor agricultural practices reaches up to USD 700 million (Republic of Kazakhstan Technology Need Assessment for Adaptation to Climate Change, 2014).

SELECTION OF CLIMATE TECHNOLOGIES AND PRACTICES TO BE ASSESSED

Based on assessment of the main trends in GHG emissions from agriculture and the vulnerabilities of the sector to climate change, FAO identified 11 climate technologies and practices for further analysis and prioritization. The selection was based on international, regional and national best practices evidenced by literature, expert consultations and discussions with key stakeholders and partners in Kazakhstan.

The technologies considered can be defined as "climate-smart" since they are expected to improve food systems while addressing at least one of three other objectives of EBRD's GET approach: (i) reduction of GHG emissions (mitigation); (ii) enhancement of climate change resilience (adaptation); and (iii) other environmental benefits (including improved resource efficiency, improved resilience and restoration of ecosystems).

Descriptions of these 11 technologies and their opportunities for addressing mitigation and adaptation appear in Annex 1, Table 1. As indicated above, subsequent updates to this study by local or international stakeholders can easily add more technologies as required. For the presentation of the assessment results conducted from Step 2 to Step 4, the above technologies have been grouped as follows:

1. Crop-farming technologies: conservation agriculture, drip irrigation, field machinery, precision agriculture and improved greenhouses;
2. Livestock technologies: pasture improvement and fattening units;
3. Renewable technologies and energy-efficient technologies: production of biogas, wind water pumps, steam boilers and dams.

Results of Step 2
Assessing technical and financial viability

TECHNOLOGY PERFORMANCE AND MATURITY OF TECHNICAL SUPPORT SERVICES

All five **crop-farming technologies** are available in Kazakhstan and perform well when compared to international best practices (IBP), with scores between neutral and high (see Annex 1, Table 1). Precision agriculture and drip irrigation are closer to IBP as the farmers mainly used imported technology from Europe and the United States of America. Therefore, they score high on this criterion (4). In the cases of conservation agriculture, new field machinery and improved greenhouses, farmers mainly use implements imported from Russia, Belarus and China (thermocover) that are less costly and easier to maintain but do not achieve the highest performance levels (3). Technical support services exist for all five technologies but differ in terms of coverage. They are widespread and efficient for drip irrigation (4) but more limited for conservation agriculture, field machinery and precision agriculture (3). In the case of improved greenhouses, only few suppliers provide maintenance services (2).

The two **livestock technologies** (pasture improvement and fattening units) are available and scored high compared to IBP (4). The development of the meat subsector in Kazakhstan has been supported through the promotion of sustainable production methods including pasture management and fodder production, in line with IBP. Large modern feedlot operations of several thousand heads of cattle were established using IBP as a major government priority in this subsector. Technical support services exist for both technologies but not at the desired levels. For pasture improvement, producer knowledge and experience have been strengthened by several development projects but have yet to reach scale. Several projects are in the pipeline to address this shortcoming (3). Feedlots are in need of more qualified veterinary staff and specialists in animal feeding, health and the production of mixed fodder are still in short supply (2).

Technical performance of **renewable technologies** under conditions in Kazakhstan is poor compared to IBP, with scores ranging from low for biogas (2) to neutral for wind pumps (3). Technical support services have limited outreach and most installations are in remote areas and difficult to access. There is a lack of qualified and experienced specialists, and support services are not well developed in the country. Therefore they score very low (1) and low (2) in this criterion for biogas and wind pumps, respectively.

Small dams and reservoirs are built to control floods and to provide water for irrigation and consumption. Most of the infrastructure is from the Soviet era (1922–1991), and many local companies perform rehabilitation and new construction in line with IBP (3). Kazvodkhoz, a state-owned organization, started consolidating and managing the irrigation infrastructure system but 70 percent of irrigation infrastructure has depreciated (deteriorated). Low water tariffs allow only for covering operational expenses. Capital expenditures for renovation and maintenance are not covered and are usually funded by the government. With regard to steam boilers, the most efficient technology is available, mainly imported from Europe, and it performs well compared with IBP (4), although there are no widespread technical support services in Kazakhstan (2).

MARKET POTENTIAL AND ADOPTION RATES

A. Potential adoption

While the full technical adoption potential for each technology was estimated, the assessment was conducted for a base case scenario using conservative assumptions. Table 1 shows the adoption potential of each technology per unit.

Examples showing the assumptions for estimating potential for adoption are given for two technologies as follows. Conservation agriculture is practised on 2.6 million hectares (ha), mostly on large farms (over 5 000 ha) and to a lesser degree on small to medium-sized farms (between 500 ha and 2 500 ha). Adoption rates are particularly high on farms with rich black soils, where high returns generate the capital for purchasing direct seeders. A technical coefficient rate of 40 percent of total area under cereal, leguminous and oil crops was estimated as a base case scenario (7.2 million ha), drawing on expert opinions, land size distribution, and historical adoption patterns.

Regarding drip irrigation, of the total irrigated cropland of 1.1 million ha (national statistics), 80 000 ha are currently equipped with drip irrigation, of which an estimated 9 000 ha contributes to GHG reduction (whereby the energy savings from pumping less water is greater than the energy needed to pressurize the system). According to the Ministry of Agriculture, around 250 000 ha are targeted for conversion into drip systems. Among these, 29 000 ha are estimated to use drip irrigation in a way that contributes to GHG mitigation.

B. Current adoption rate versus potential adoption

Estimated adoption rates of **crop-farming technologies** in the country are low for improved greenhouses and precision agriculture (13 and 17 percent, respectively) suggesting significant potential for deployment.[4] Adoption rates are moderate for conservation agriculture (36 percent) and drip irrigation (31 percent) and high for field machinery (82 percent), due to conservative assumptions of potential units for adoption. The current fleet of field machinery in Kazakhstan consists of 194 000 units, including 153 000 tractors and 41 000 harvesters. An estimated 48 percent of field machinery is over 17 years old and needs to be replaced. Therefore, the current adoption rate (of more modern and improved technology less than 17 years old) amounts to 54 000 tractors and 23 000 harvesters, whereas the adoption potential (base case scenario) is estimated at 69 000 tractors and 25 000 harvesters.

---

[4] Technologies with high adoption rates currently make a bigger contribution to GHG mitigation than those with very low adoption rates. However, the focus of the study is on identifying those technologies that have a high potential for increased GHG. Therefore, technologies with low current adoption rates are ranked higher as they offer greater scope for expansion.

Table 1
Current and potential adoption levels of climate technologies

Climate technology	Current adoption	Base technical adoption potential	Full technical potential
Conservation agriculture	2. 6 million ha	7. 2 million ha	21.3 million ha
Drip irrigation (*)	9 000 ha	29 000 ha	127 000 ha
Field machinery	Tractors: 54 000 Harvesters: 23 000	Tractors: 69 000 Harvesters: 25 000	Tractors: 153 000 Harvesters: 41 000
Precision agriculture	1.5 million ha	9 million ha	17.8 million ha (**)
Improved greenhouses	20 ha	150 ha	300 ha
Pasture improvement	6 million ha	9 million ha	47 million ha
Fattening units	150 000 heads/year	510 000 heads/year	1.27 million heads/year
Steam boilers	50 units	300 units	740 units
Biogas	0.4 MWt/h (***)	10 MWt/h	10 MWt/h
Wind water pumps (*)	30 units	100 units	100 units
Dams	369 units	679 units	679 units

(*) only include with mitigation benefits;
(**) total area under cereals, legumes and oil crops;
(***) biogas stations capacity

Source: Authors' estimations.

Within the **livestock technologies**, pasture improvement presents the highest adoption rate (67 percent) leaving 9 million ha of pasture still to be improved. As depicted in Figure 5, much lower adoption rates (13 percent) would result if the full technical potential of 47 million ha was assumed. In the case of fattening units, the current adoption rate is moderate (29 percent) and 510 000 heads of cattle could be targeted by this technology under the base case scenario. Using the entire cattle population of 1.2 million in the country as denominator, the adoption rate of fattening units is only 12 percent. The two technologies show room for expanding their current adoption rates of around 30 percent in fattening units and 67 percent in pasture improvement; the analysis applied very conservative assumptions on potential adoption (low share of the full technical adoption).

For **renewable technology,** adoption rates of biogas are very low (less than 4 percent of potential), which suggests opportunities for its promotion. Low adoption rates are estimated for steam boilers, at 17 percent, mostly because of their limited adoption potential. Higher adoption rates are estimated for wind pumps and small dams, at 30 percent and 54 percent, respectively (against adoption potential under the base case scenarios).

While technology adoption rates were estimated against adoption potential under the base case scenarios, Figure 6 shows how adoptions rates could differ if calculation were done with the full technical adoptions.

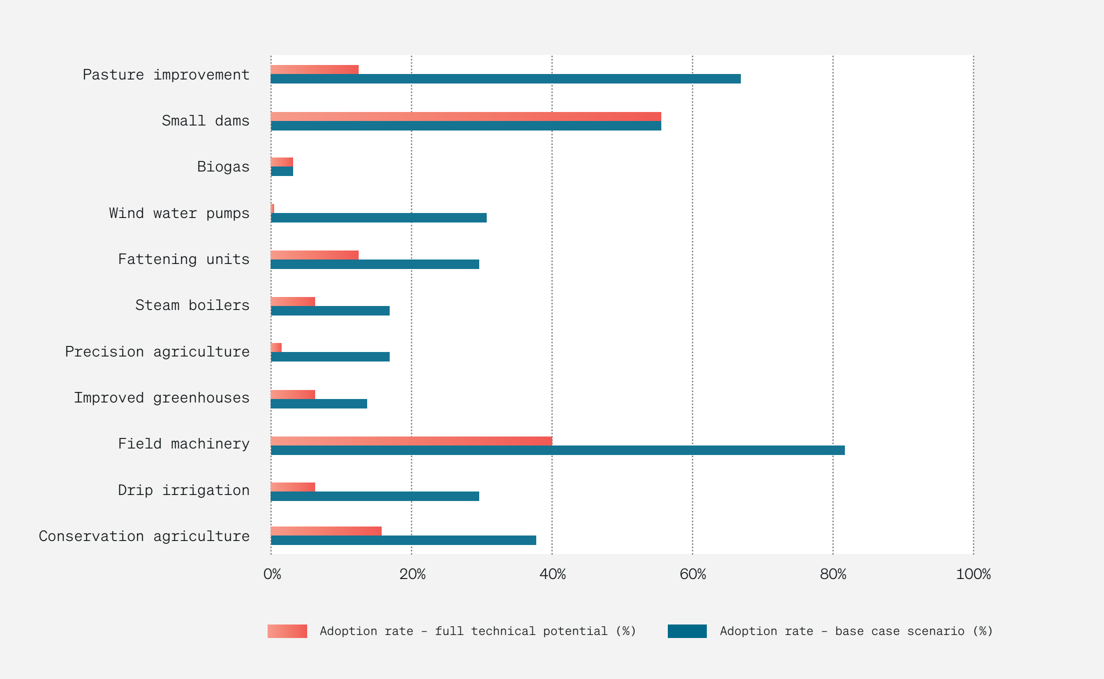


Figure 6
Estimated technology adoption rates (%)

Source: Authors' calculations.

C. Trends in gap between uptake and potential

Gaps between current and potential uptake have remained large and shown little change for most technologies, with scores between neutral (3) and high (4), as indicated in Annex 1. This applies to almost all technologies with the exception of drip irrigation, pasture improvement and fattening units, where the gaps have been decreasing due to recent improvements, government support and donor programmes. Therefore, these three technologies receive lower scores (2) for this criterion. In the case of livestock technologies, the current agricultural policy continues to be focused on beef production and export, providing enough funds to subsidize the livestock industry.

Financial returns

For each technology, representative business models were built based on existing experience. Financial analyses were done for ten-year periods and at financial prices. Technical parameters and assumptions were validated with stakeholders and during expert consultations and financial analyses were conducted to assess the financial viability of each technology. Table 2 summarizes the business models and investment analysis for each technology and Table 3 displays the results of the financial analysis. Investment cost and the net present value (NPV) were rounded at the latest phase of the analysis; the rounding has been done at the highest decimal so to include the cost of the training necessary for the adoption of the technology. For each technology including two crops or farm models, financial parameters were averaged.

Table 2

Business models and investment costs

Technology	Crop/farm models	Investment cost	Financial benefits and costs
Conservation agriculture	1) 1 000 ha farm producing wheat, sunflower, barley and linseed shifting from conventional to conservation agriculture. 2) 5 000 ha farm cultivating wheat, sunflower, barley and linseed.	USD 75 000 to 200 000 for modern direct seeder complex.	Compared with a conventional farming scenario, crop yields decrease by 10% over the first two years and then increase by up to 30%. Production costs such as labour and fuel consumption decrease as the number of field operations decreases. Herbicide costs increase during the first years.
Drip irrigation	30 ha farm producing cucumber, carrots, potatoes and red beets; model analysing a switch of pump systems from surface to drip irrigation.	USD 125 000/30 ha farm, including on-farm drip irrigation equipment (water pipes and pumps) Farmers benefit from a public subsidy of up to 15% of the investment.	Implementation allows savings of more than 35% of water used in irrigation and increases productivity of crops (20%).
Field machinery	Tractor model for 900 ha area (wheat) and harvester model for 500 ha area .	Tractor: USD 96 000; Harvester: USD 121 000	Financial benefits are due to fuel savings, lower maintenance costs, and reduction of post-harvest losses. The government provides investment subsidies to stimulate renovation.
Improved greenhouses	3 ha greenhouse producing tomato and cucumber.	USD 100 000 in a thermocover.	Main financial benefits come from reduced heating consumption (720 Gcal/ha/year, or around USD 8 000 ha/year).
Precision agriculture	200 ha model.	USD 2 000/200 ha served annually by a GPS-connected controller in a farmer's tractor.	Reduces steering errors and any overlap passes on the field, resulting in less wasted seed, fertilizer, fuel and time. Based on experience, a conservative assumption of 5% reduction of inputs has been made for a situation with technology.
Pasture improvement	1 000 ha under minimum till and agropyron.	USD 50 000 for machinery implements (direct seeder, forage harvester, baling machine), technical assistance and training on minimum tillage and dissemination.	Using agropyron with minimum tillage, hay yields increase from 0.3 t/ha (in a situation without technology of degraded pasture producing hay) to 0.9 t/ha.
Fattening units	Building a new feedlot/facility to fatten 5 000 head of bulls It was assumed that the feedlot would operate at full capacity.	USD 4 million for facility construction, tractor/ implements, feed mixer and training to manage the facility.	Without technology, small-scale households keep their bulls at pasture and in stables behind the house. Within 2 years, a bull's weight increases from 30 to 280 kg (live weight) and then sold. With technology, a large and fully equipped feedlot (5 000 head) is built. Young bulls are purchased from households at 8 months old, weighing 220 kg, fattened over 9-10 months, and then sold at 420 kg live weight.
Biogas	4 000 head cattle farm investing in a biogas plant to produce electricity for the grid, with digestate as a by-product.	USD 2.8 million	Biogas station model based on the biogas station constructed on Karaman-K enterprise, a 4 000 head cattle farm in the Kostanay region.
Wind water pumps	Farm-level investment in wind pump equipment to replace existing electric pump for irrigation.	USD 4 000 per wind pump (after a subsidy of 80% received)	Replacing electric pumps and diesel generators with wind pumps saves 0.22 l of diesel/m3 of extracted water or 2.3 m3 of diesel/year/wind pump.
Steam boilers	Food processing firm replacing an old steam boiler with a new one.	USD 20 000 including a new boiler and training	Fuel oil/gas savings from switching to a new energy-efficient steam boiler.
Dams	New dam/water reservoir constructed (with storage capacity of 1 857 million m3).	USD 4.6 million	Additional income from agriculture; value of water for industrial use and household consumption; expected average value of losses avoided from flooding (Disaster Relief Emergency Fund).

Source: Authors' compilation.

Table 3
Financial Analysis Results

Climate technology	Investment costs (USD)	NPV (USD)	IRR (%)	Payback period (years)
Conservation agriculture	USD 138 000	USD 138 000	22%	6
Drip irrigation	USD 125 000	USD 38 000	22%	3
Field machinery	USD 110 000	USD 8000	13%	6
Improved greenhouses	USD 100 000	USD 34 000	21%	4
Precision agriculture	USD 2000	USD 1000	27%	3
Pasture improvement	USD 50 000	USD 13 000	18%	5
Fattening units	USD 4 mio	USD 4 mio	34%	3
Steam boilers	USD 20 000	USD 7000	20%	4
Biogas	USD 2.8 mio	USD - 1.2 million	1%	15
Wind water pumps	USD 4000	USD 6000	44%	2
Dams	USD 4.6 mio	USD - 1.3 million	5%	12

Source: Authors' compilation.

For most technologies, the estimated internal rates of return (IRRs) are higher than the cost of capital (12 percent). As shown in Table 3, the financial return on investments for crop technologies range from 27 percent (precision agriculture) to 22 percent (conservation agriculture and drip irrigation), 21 percent (improved greenhouses) and 13 percent (field machinery). Field machinery offers only moderate returns because of limited diesel savings and limited reduction of harvest losses when investing in regionally produced machinery. Most efficient field machinery technology is available but it is more costly and difficult to maintain.

Good financial returns on investments for fattening units (34 percent) and pasture improvement (18 percent) make these technologies attractive to private investors. Efficient fattening units present one of the highest estimated financial returns of all the technologies, as a result of government support programmes. However, they are very sensitive to feedlot capacity utilization.

Biogas and small dams show considerably lower financial returns (below the cost of capital). Efficient steam boiler technology presents a good financial return, while the wind pump has the highest return on investment due to government subsidies (80 percent of investment).

©EBRD

Results of Step 3
Evaluating economic and environmental benefits, economy-wide impacts and sustainability

MITIGATION POTENTIAL AND INVESTMENT NEEDS

The total mitigation potential for each technology was calculated by multiplying the mitigation potential per unit (e.g. ha, head) by the total incremental adoption potential, as discussed in the previous section. Aggregated over all technologies, an estimated 7 million tCO_2eq, or around 30 percent of agrifood sector emissions, could be mitigated at an aggregate investment of USD 2.3 billion across the various climate technologies. Figure 7 shows the share of each technology in the total investment portfolio.

Figure 8 plots the investment requirements of each technology against the respective mitigation potential. It shows that pasture improvement provides the bulk of mitigation potential (57 percent of total estimated) while only accounting for 6 percent of total investment. This is followed by conservation agriculture, which represents 34 percent of total mitigation potential and 11 percent of total estimated investment. Field machinery, precision agriculture and fattening units show moderate mitigation potential (7 percent) against around 60 percent of total investment.

The five crop-farming technologies combined represent 40 percent of the total potential estimated mitigation. Conservation agriculture has the largest GHG mitigation potential due to lower fuel consumption (from 80 to 60 l of diesel/ha) and soil carbon sequestration. It has the potential to reduce annual GHG emission by 2.3 million tCO_2eq.

By replacing tractors and harvesters over 17 years old, 56 million litres of diesel can be saved annually, equivalent to 260 000 tCO2eq/year. By adopting precision agriculture, 4 litres of diesel/ha can be saved (or 0.02 tCO2eq/year/ha/year). Total mitigation potential is about 120 000 tCO2eq/year. With improved greenhouses, the low GHG emissions reduction potential (45 000 tCO2eq/year) is due to limited area under current greenhouses, but emission reduction per ha is relevant, around 350 tCO_2/ha annually.

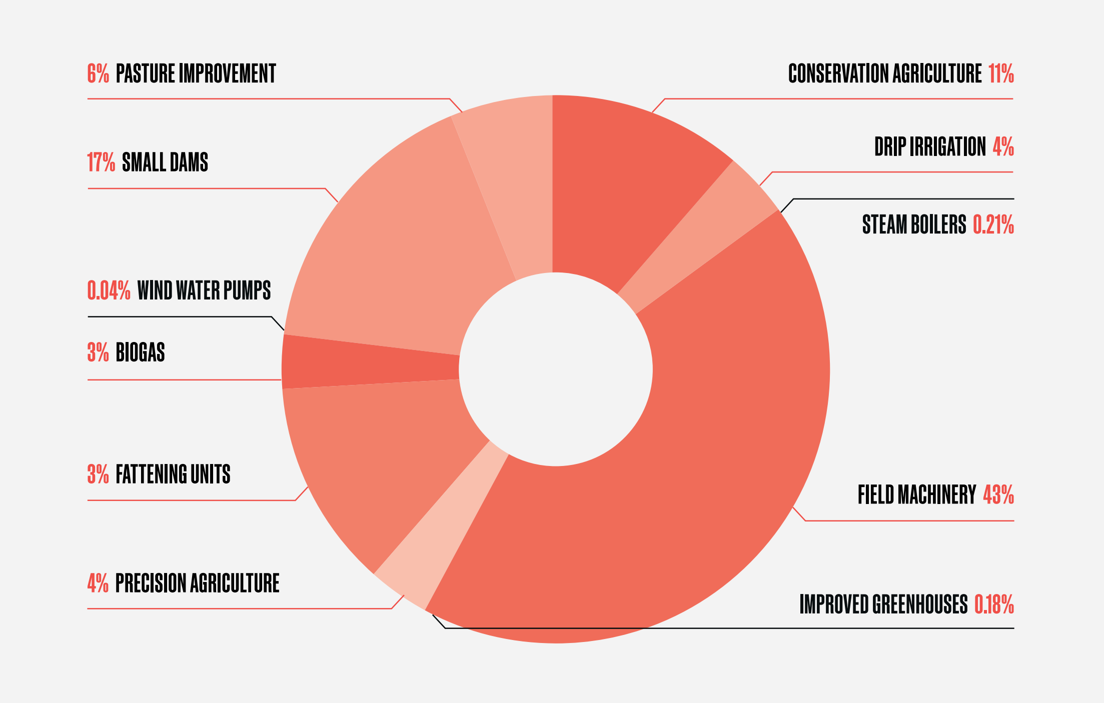


Figure 7
Total estimated investment size and share of each technology

Source: Authors' calculations.

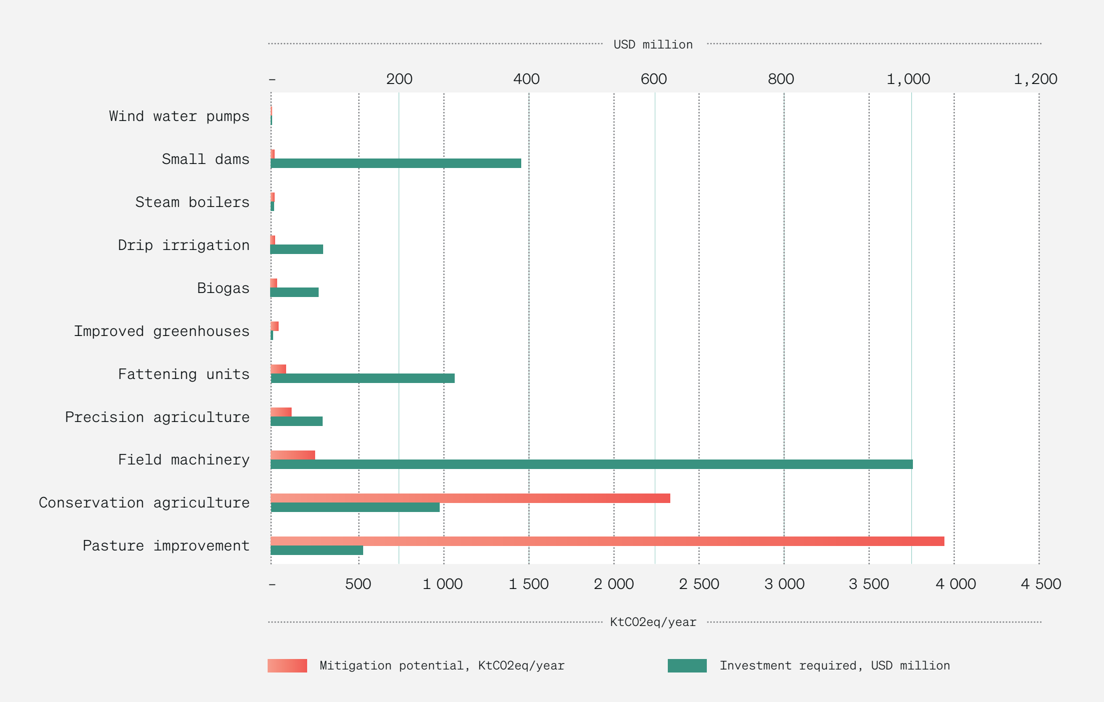


Figure 8
Mitigation potential and investment by technology

Source: Author's calculations.

Assuming areas where drip irrigation would not increase energy consumption, around 2 500 KWh/ha, or 1.2 tCO_2/ha, could be saved when converting surface irrigation into drip. Total energy saved in potential area for drip irrigation is about 49 million KWh. Low Grid Emission Factor results in low potential (2 000 tCO_2eq).

Pasture improvement has the largest GHG mitigation potential because of the significant increase in soil carbon sequestration; very high GHG reduction potential is driven by the large pasture area for potential adoption. For fattening units, low potential to reduce GHG emissions is due to relatively low incremental emission reduction per livestock unit (LU) (176$KgCO_2eq$/LU/year), when comparing the lifetime emissions per kg meat marketed in fattening and grass-fed scenarios. Renewable technologies present very low mitigation potential.

CONTRIBUTION TO CLIMATE CHANGE ADAPTATION

The climate technologies' contribution to climate change adaptation was assessed based on qualitative information and scored using the Likert scale. Where possible, adaptation benefits were quantified in economic terms. The incremental benefits were compared to a reference scenario without investments in climate technologies and include: (i) increased agricultural production; (ii) increased water availability; and (iii) increased energy availability**.**

As shown in Table 1 of Annex 2, drip irrigation and small dams scored highest (5 points) in this criterion due to the large increases in water use efficiency, freeing water for other economic purposes including incremental agricultural production. However, they did not generate the highest monetary adaptation benefits (see Table 4) due to the relatively low price of water.[5] Additional agriculture production and avoided economic losses due to flooding were not quantified under adaptation benefits for small dams.

For conservation agriculture, the main adaptation benefits are related to increased agricultural production, resulting from long-term improved soil health[6] and increased productivity.[7] The economic value of the annual additional production due to adoption of conservation agriculture at incremental technical potential (assuming rotation of wheat, sunflower, barley and linseed) was esti-mated at USD 207 million (7.5 percent of the total value of agricultural production in economic terms in 2016). In the case of drought, the estimated impact of conservation agriculture on production was even higher, despite a lower total aggregate production in the country. The economic value of the annual additional production during a drought year was estimated at USD 237 million (8.5% of the total value of the agricultural production in 2016). Benefits from reduced soil degradation as a result of conservation agriculture were included qualitatively but were not quantified due to lack of information on declining yield trends without the project.

[5] considering the economic price of water of USD 0.008/m^3

[6] increased organic matter, in-soil water and improved structure

[7] wheat yield: from 1.2 t/ha to 1.5 t/ha or sunflower yield: from 0.6 t/ha to 0.8 t/ha

Table 4
Quantification of adaptation benefits

	Annual USD using economic prices (2017)			
Climate technology	**Additional agriculture production**	**Increased water availability**	**Increased energy availability**	**Total estimated USD/year**
Conservation agriculture	USD 207 million (normal year) USD 237 million (drought year)	n/a	USD 44.05 million	USD 251.05 million
Drip irrigation	n/a	USD 1 million[8]	USD 2.4 million	USD 3.4 million
Field machinery	USD 41 million	n/a	USD 22 million	USD 63 million
Improved greenhouses	n/a	n/a	USD 1.04 million	USD 1.04 million
Precision agriculture	n/a	n/a	USD 10 million	USD 10 million
Improved pasture	USD 70 million	n/a	n/a	USD 70 million
Fattening units	USD 72 million	n/a	n/a	USD 72 million
Biogas	n/a	n/a	USD 3.5 million	USD 3.5 million
Wind water pumps	n/a	USD 0.11 million	USD 0.09 million	USD 0.2 million
Steam boilers	n/a	n/a	USD 1.9 million	USD 1.9 million
Dams	n/a	USD 0.4 million	n/a	n/a

Source: Authors' compilation[8].

The renovation of machinery would result in reduced diesel consumption and decreased post-harvest losses, and therefore in increased agricultural production. Total economic value of those benefits was estimated at USD 63 million (Table 4). Installing thermocovers in the potential greenhouses would have benefits of USD 1 million related to the saved energy. Investing in parallel driving would contribute to increased energy availability by reducing aggregate coal consumption at a value of USD 10 million, using economic prices.[9]

The economic value of the annual additional production due to pasture improvement was estimated at USD 70 million/year. These benefits are derived from incremental agropyron production[10] under improved pasture management at incremental adoption level, compared to a base scenario under current management practices (1.8 million tonnes agropyron, considering a potential for adoption of 3 million ha). Feedlots would lead to increased agricultural production and can contribute to pasture regeneration.

Fattening units would contribute to increased aggregate agricultural production and food availability through improved productivity of cattle. Additional annual meat production was estimated at 43 million kg of meat, equivalent to USD 72 million/year. Adaptation benefits from reduced pressure on pasture due to the technology adoption have not been accounted for (pasture released can regenerate more rapidly and contribute to reductions in soil degradation).

---

[8] considering the economic price of water of USD 0.008/m3

[9] savings of 5 percent of fuel. Annual fuel savings (diesel) is 4 l/ha * 7.5 million ha of adoption potential = 26.3 million litres of diesel saved (or 5% out of total diesel used in agriculture in 2017)

[10] hay yields increasing from 0.3 t/ha to 0.9 t/ha

Biogas technology would contribute to climate change adaptation by increasing energy availability. The analysis estimates that a biogas plant of 9.64 MWh capacity would generate 83 thousand MWh/year, which has economic value of USD 3.6 million/year. Aditionally, digestate as part of soil improvement practices can be used to rehabilitate degraded lands. Digestate improves water retention in the soil and provides an effective source of organic matter to be applied to soils most severely affected by climate change (thereby preventing erosion, increasing water retention, etc.) It therefore contributes to stabilizing yields and preventing production losses due to droughts.

Wind water technologies increase energy (electricity) and water availability and can stabilize or increase agricultural production in areas without access to water and energy sources (remote areas can be used for agricultural production; access of animals to remote pastures is improved).

Mitigation costs

The mitigation cost of a technology is the ratio between the estimated economic net present value (NPV) and its GHG emission reduction potential. Based on the analysis in Steps 2-3, it was possible to draw marginal abatement cost curves (MACCs) plotting: (i) the estimated cost of mitigation by technology; and (ii) the technical GHG mitigation potential. Figure 9 provides an indication of the mitigation that would be technically achievable (x axis), with the area underlying the curve indicating the associated total cost (y axis). Technologies are ordered left to right from lowest to highest cost. Those technologies below the horizontal axis offer the potential for economic savings (positive economic NPV), whereas technologies above the axis come at a net cost. The width of each bar represents the emission reduction potential of the technology.

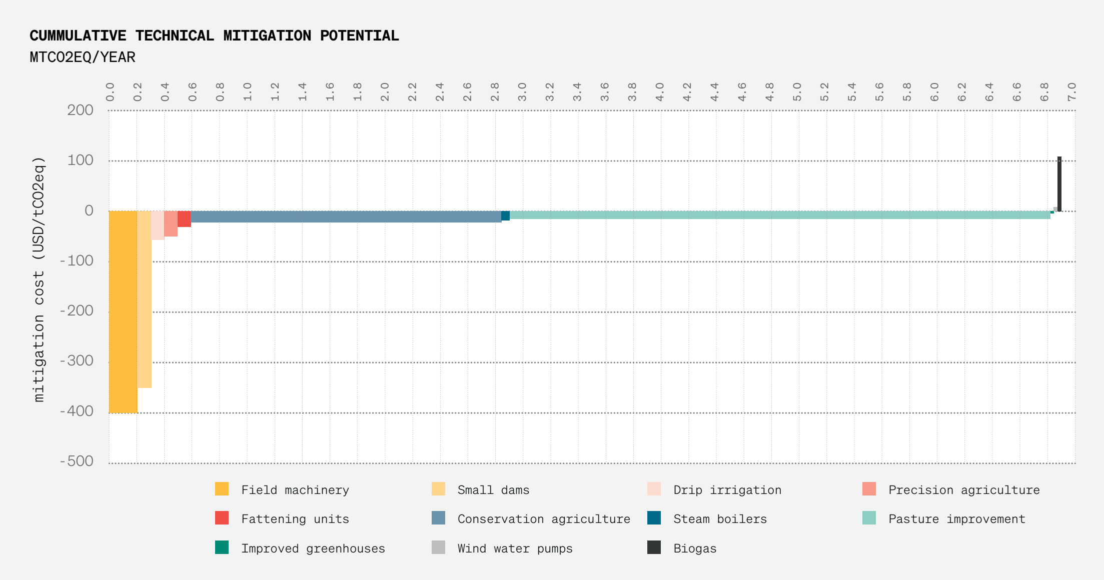


Figure 9
Estimated simplified MACC

Source: Authors' own elaboration.

This analysis shows that field machinery is most profitable per tonne of CO_2eq mitigated but have a relatively low technical mitigation potential – with a high negative mitigation cost of 400 USD/tCO_2 driven by good economic returns on adoption and low mitigation potential. This is followed by dams (-USD 351/tCO_2eq), drip irrigation (-60 USD/tCO_2eq) and precision agriculture (-51 USD/tCO_2eq). Following these are fattening units (-23 USD/tCO_2eq), conservation agriculture (-11 USD/tCO_2eq), pasture improvement (-9 USD/tCO_2eq), steam boilers (-9 USD/tCO_2eq) and improved greenhouses (-4 USD/tCO_2e), and finally wind water pumps (+8 USD/tCO_2eq) and biogas (+109 USD/tCO_2eq).

OTHER EXTERNALITIES

This section provides a brief overview of the externalities and co-benefits generated by the climate technologies. In addition to their contribution to climate change mitigation and adaptation, other environmental and social impacts related to the scaling up of the technologies need to be considered. A comprehensive assessment of externalities is beyond the scope of this study. Nevertheless, some key externalities – positive and negative – are briefly highlighted below. Further information on the scoring for each technology is available in Table 1 of Annex 2.

With regard to negative externalities, crop-farming technologies received scores from moderate (3) for field machinery and drip irrigation to high (4) for conservation agriculture and greenhouses and very high (5) for precision agriculture. While precision agriculture has no negative externalities, conservation agriculture may lead to possible increases in herbicide use in the short term; field machinery to manufacturing footprints of new tractors/harvesters; and drip irrigation to labour impacts, tubing and others. On the other hand, all technologies have positive externalities, as they will contribute to increasing food security in the long term. Drip irrigation can lead to aggregate savings of water in an appropriate regulatory/institutional setting.

While pasture improvements have no major negative externalities (scored 4), fattening units might have a stronger negative environmental footprint in terms of pollution of surface and groundwater and an aggregate increase in water consumption for feed production and fattening (scored 2). Hence, the expansion of such technology needs to be managed carefully. In terms of positive externalities, pasture management (scored 5) improves country food security, value chain development and biodiversity, whereas fattening units (scored 4) improve country food security, produce an aggregate increase in cattle productivity and improve access to export markets.

The main negative externalities of renewable technologies relate to possible water pollution by effluents of biogas and overexploitation of underground water, which need to be managed through adequate regulatory and institutional frameworks. On the positive side, the proposed technologies would contribute to the diversification of energy sources beyond hydropower. Moreover, due to their decentralized nature, they would enable additional agricultural production in remote areas.

Overall, the analysis suggests that no significant negative externalities exist that would seriously undermine the expansion of climate technologies. Care needs to be taken in monitoring herbicide use in conservation agriculture and water pollution in improved livestock technologies.

©Unsplash/Blueberry nights

Results of Step 4
Institutional assessment

ADDRESSING POLICY BARRIERS HINDERING UPTAKE

Step 4 analyses relevant policy, institutional and other barriers and support mechanisms that influence the potential deployment of climate technologies for GHG reduction and climate adaptation in the agrifood sector. Table 5 summarizes the typology of barriers analysed for each technology while further details on the scoring obtained by each technology is available in Table 1 of Annex 2.

Based on the analysis of the above barriers and support mechanisms, an aggregate score has been calculated that is labelled "policy reform requirements/intensity". A low score on this aggregate criterion indicates a substantial need for reforms and supporting instruments in order to speed up technology uptake, and vice versa.

In terms of **crop technologies,** this criterion ranges from very low for conservation agriculture (1), to moderate for precision agriculture and improved greenhouses (3) and high for drip irrigation and field machinery (4). The principal obstacles to the adoption of these five technologies are knowledge and information, regulatory/institutional issues and access to credit and cost of capital for smaller farmers (except for precision agriculture).

Expanding conservation agriculture adoption would require greater knowledge dissemination among stakeholders about the practice and its benefits. Collective actions, such as farmers organized to share equipment, could expand adoption. The use of more efficient field machinery could be stimulated by enhancing farmers' knowledge about practices to reduce fuel consumption, providing technical support services and improving access to capital (for small-scale farmers). Promoting precision agriculture adoption[11] would require greater knowledge dissemination, pilots with lead farmers and further development of support services. Drip irrigation deployment would benefit from improved institutional arrangements for efficient water governance and greater awareness about the technology and its benefits. Adoption of improved greenhouse technologies such as thermocovers could be supported through sensitization campaigns and capacity development.

---

[11] The new Government Program for the Development of the Agrifood Sector 2017-2020 includes precision agriculture technologies, smart farming and adoption of digital technologies among the main priorities and promotion campaigns have begun in the country. The Ministry of Agriculture is also considering providing investment subsidies to farmers investing in precision agriculture.

Table 5
Typology of barriers analysed

Knowledge and information	Organizational / social	Regulations / institutions	Support services / structures	Financial returns	Access/cost of capital
◆ Information asymmetries ◆ Lack of awareness about the technology ◆ Not enough technical expertise to use the technology adequately	◆ Collective action needed for technology to take off ◆ Social norms can hinder adoption ◆ Focus on private/ non-governmental issues	◆ Laws, regulations and other aspects that may prevent adoption ◆ Technology specifications are not well defined ◆ Focus on government/ public domain	◆ Existence of research institutes ◆ Efficiency and coverage of supplier networks ◆ Efficiency and coverage of maintenance companies	◆ Low returns ◆ IRR below the cost of capital	◆ Credit market failures ◆ High upfront investment cost ◆ Too high cost of capital

Source: Author's compilation.

For **livestock technologies**, this criterion ranges from neutral (3) for pasture improvement to high (4) for fattening units, due to the existing government policies and priorities for the development of the livestock sector. Pasture improvement would benefit from additional knowledge and capacity building on rational use of pasture and pasture management practices, organization/social support to manage pastures in a sustainable way, enhancement of existing regulations and public support for initial investment. Supporting pasture improvement would require improved knowledge and information on pasture management for farmers, as well as technical services. It would also require organizational and institutional development, as well as access to capital for initial investments in equipment (for small-scale farmers).

Investing in fattening units would benefit from disseminating knowledge based on ongoing experiences and best practices that illustrate effective livestock feeding and benefits of the practice. It would also benefit from technical expertise on improved feeding and veterinary care, local value chain organization and tailored support for small farmers.

Renewable and energy efficiency technologies include wind pumps, biogas, steam boilers and dams. While national legislation provides higher feed-in tariffs for renewable electricity generated, lack of efficient implementation mechanisms may have adversely impacted the promotion of renewables. Further policy reforms, with clear implementation and financial mechanisms, seem to be required. Wind pumps can be supported in areas with available pumping water and lack of access to the electric grid through provision of concessional financial resources, awareness and capacity development. Promoting biogas expansion would benefit from organizational, logistic and regulatory support for collecting feedstock by small-scale farmers, financial incentives and market development for biogas and digestate. High initial investments and limited knowledge and support services seem to discourage investments in the technology.

The market for steam boilers could develop in parallel with the growth of the country's food industry and would benefit from establishment of binding GHG emission regulations. Supporting dams and irrigation infrastructures would require intensive policy reform to facilitate efficient water use and pricing. Technical and financial capacity would also need to be provided to national water firms responsible for the operation and maintenance of the infrastructure at the farm level.

©FAO/Vyacheslav Oseledko

©FAO/Vyacheslav Oseledko

Results of Step 5
Final ranking and conclusions

Figure 10 provides an index measuring the performance of each technology based on all the criteria assessed under Steps 2 to 4 (except mitigation cost and potential to reduce GHG emissions, which are illustrated in the diagram). Mitigation costs are displayed on the Y axis, while the X axis includes the aggregate final score based on the normalized scores of each MCA criterion for each technology (see Annex 2, Table 2). Moreover, the Figure indicates the technical mitigation potential of each technology through the size of the bubbles.

The ranking of the technologies was established through qualitative and quantitative scores with weights assigned for each MCA criterion.[12] Results could change, even significantly, should the ranges or the weight attributed to the criteria be different.

Interpreting the results of the MCA with a focus on mitigation (30 percent weight to potential to reduce annual GHG emissions and 15 percent to mitigation costs) suggests that pasture improvement, conservation agriculture, field machinery and precision agriculture are among the best technologies in terms of overall score. As shown in Figure 11, renewable technologies rank very low due to low mitigation potential and to weak financial results in the case of biogas (because cheaper alternatives are available). Moreover, since biogas energy is very difficult to transport or store, there is a high risk of wasted energy. Hence, the size of a village is a critical parameter for the viability of biogas plants.

The same analysis with a focus on adaptation (30 percent) suggests that drip irrigation seems most promising through improvements in water availability (especially in areas with water scarcity) and agricultural production. It is followed by pasture improvement and conservation agriculture as they contribute to improved long-term soil health, and higher yields and aggregate production in drought years (Figure 12).

---

[12] Weight (%) applied in the mitigation scenario: 5% for each of the following criteria: performance compared to best practices, maturity of technical support services, current technology adoption rate, trends in gap between uptake and potential; 10% for the following criteria: financial returns and contribution to adaptation; 15% for mitigation cost; and 30% for potential to reduce annual GHG emissions.

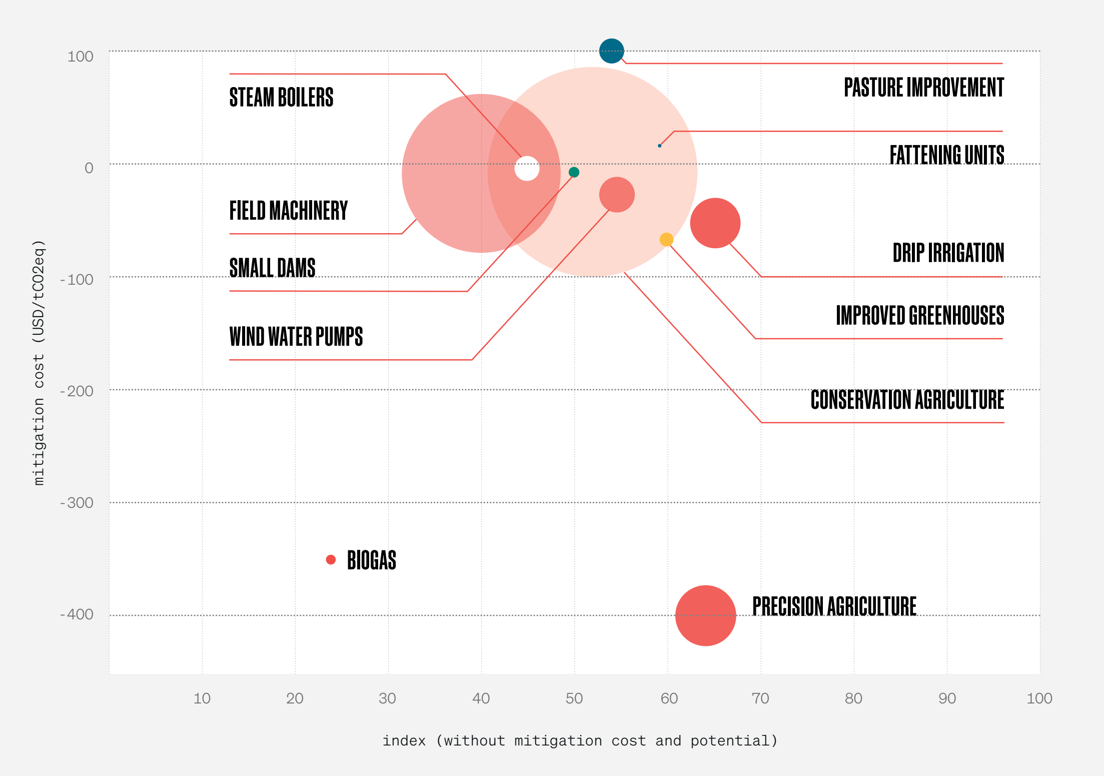


Figure 10
Mitigation costs, potential and weighted scores

Source: Authors' calculations.

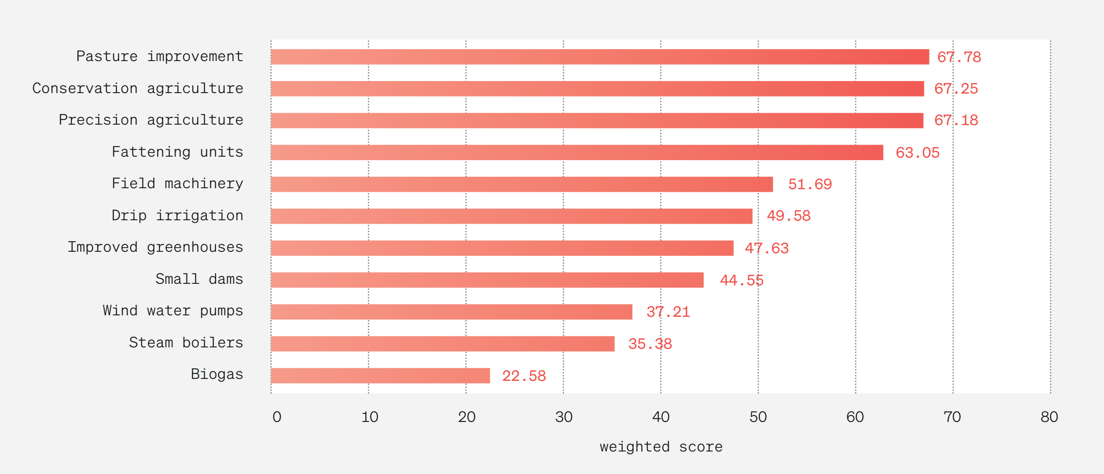


Figure 11
Technology ranking – mitigation-oriented

Source: Authors' calculations.

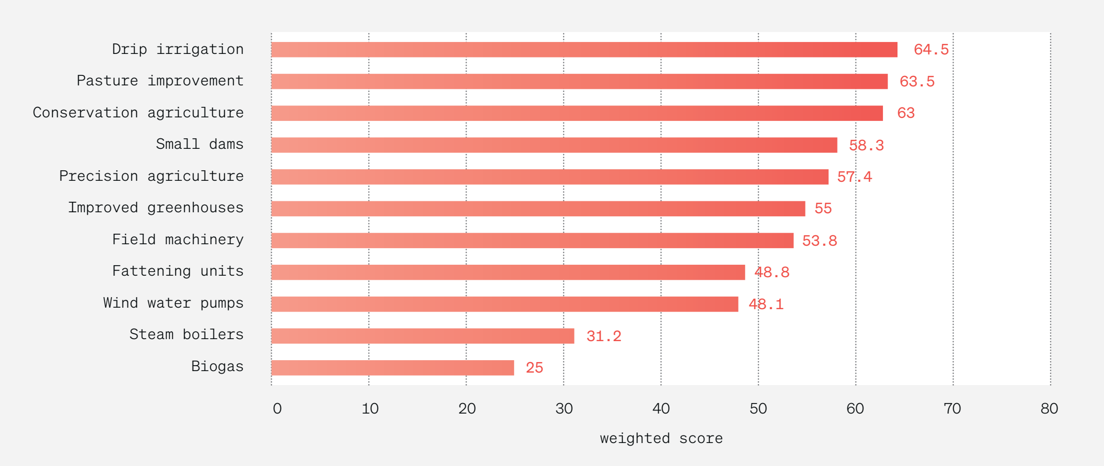


Figure 12
Technology ranking – adaptation-oriented

Source: Authors' calculations.

Figure 13
Technology ranking – financial return-oriented

Source: Authors' calculations.

Figure 13 ranks the climate technologies applying greater weight to their financial returns (30 percent). It shows that precision agriculture, fattening units and conservation agriculture are more attractive to private investors given their high rates of return and shorter payback periods. Wind water pumps scaled up from ninth place (in the two previous scenarios) to fifth place due to the highest financial return (44 percent).

Based on the analysis of Steps 2 to 4 and considering the mitigation scenario, it is possible to identify the key climate technologies that constitute "low-hanging fruit" for an institutional investor or a decision-maker in the area of sustainable development (e.g. government, multilateral development organization or donor). In other words, the climate technologies that can mitigate GHG -emitting activities (identified in Step 1) and that also have good techno-economic performance, good environmental and social performance and do not face barriers to adoption that are too difficult or time-consuming to address, are the

RESULTS OF THE FIVE-STEP ASSESSMENT

STEAM BOILERS

Promising but adoption linked to agrifood sector transition

- Good returns and moderate mitigation benefits
- Limited number of food enterprises

BIOGAS FROM MANURE

Very high potential but insufficient goverment support for a rapid development

- Inefficient use of existing tech; premium for electricity generation is not enough to cover investment
- Servicing companies and manure management are prerequisites for technology deployment

SMALL DAMS

High demand to prevent floods and irrigate, but requires long-term view

- Negative financial returns due to high up-front investment and low level of water tariffs
- Development of fisheries, tourism, recreational services, biodiversity improvements

WIND WATER PUMPS

High potential in remote areas with adaptation benefits

- Very good financial returns due to public support measures
- Only interesting in areas where electicity is not available

IMPROVED GREENHOUSES

Limited market potential but interesting greening benefits

- Financially attractive for industrial greenhouses that operate for the entire year
- Government support and incentives may lead to new investment opportunities

DRIP IRRIGATION

Only a mitigation technology in specific situations

- Significant adaptation benefits if water scarcity and with appropiate governance
- Water/groundwater regulations, clear targets and incentives for water-saving

EFFICIENT FATTENING UNITS

Tackling livestock productivity issues

- Good financial returns; can support sector modernization
- Capacity utilization is crucial for financial profitability

FIELD MACHINERY

Good potential for fleet renovation

- Moderately good mitigation benefits through diesel savings
- Access to capital and availability of best technology concerns

PRECISION AGRICULTURE

Good potential area served by field machinery equipped with tech

- Excellent financial returns due to less wasted seed, fertilizer, fuel and time
- Demonstration farms and activities on promotion of technology are needed

CONSERVATION AGRICULTURE

Very high potential for mitigation and also adaptation

- Good financial returns; best practices dissemination and widespread support services needed
- Despite initial boom, policy reform and financial support needed to foster adoption

PASTURE IMPROVEMENT

Very high potential for carbon sequestration

- High priority for the sustainable development of the livestock sector
- Setting national targets towards the recovery of degraded pastures can help

Figure 14

Results of the five-step assessment

Source: Authors' compilation.

"best-bet" technologies. The remaining technologies were classified as second- and third-best technologies as depicted in Figure 14 and further explained below.

As described in Chapter 4, dissemination and awareness campaigns, training and technical support services should be strengthened for all five technologies. Pasture improvement and drip irrigation will also require strengthening of regulatory frameworks concerning land and water governance (groundwater extraction and livestock densities). Financial support – e.g. in the form of matching grants or concessionary lending – should focus on those technologies (among the top five) that are less attractive from a purely private sector perspective, despite their large mitigation and adaptation benefit. As discussed in Chapter 3, precision agriculture, fattening units and conservation agriculture are more attractive to private investors given their high rates of return and shorter payback periods. In turn, small dams, steam boilers and biogas score considerably lower given their lower returns on investment and payback periods of 7-8 years.

Direct investment support to renewable energy technologies should only be considered in tandem with policy reforms addressing the price disincentives that currently render them less attractive for investors. Given their large potential impact on GHG reduction, these technologies should be prime targets for financial incentives.

State support to agricultural finance and the capacity for innovation and knowledge management, including public investments in agricultural research and a more coherent and effective extension system, will be also crucial. Examining the barriers to deployment faced by these technologies would make it possible to identify the areas for policy enhancement.

©Unsplash/Mikitayev Aidos

Bibliography

GENERAL

DAMU Entrepreneurship Development Fund. 2017. Financial models database.

Jonas Egerer & Roman Mendelevitch & Christian von Hirschhausen, 2014. A Lower Carbon Strategy for the Electricity Sector of Kazakhstan to 2030/50: Scenarios for Generation and Network Development; Technical Report, DIW Berlin: Politikberatung kompakt, DIW Berlin, German Institute for Economic Research, volume 85, number pbk85, October.

FAOSTAT. 2020. URL: http://www.fao.org/faostat/en/#data. Accessed on 13 January 2020.

Institute of Geography. 2006. National Atlas of the Republic of Kazakhstan.

Ministry of Agriculture of the Republic of Kazakhstan. 2013. State Program of Development of the Agro-Industrial Complex 2013-2017. “Agribusiness 2017”.

Ministry of Agriculture of the Republic of Kazakhstan. 2017. State Program of Development of the Agro-Industrial Complex 2017-2021.

Ministry of Agriculture of the Republic of Kazakhstan. Government Support Regulation documents.

Ministry of National Economy of the Republic of Kazakhstan - Economic Research Institute. 2015. Towards Low Emissions and Green Development. Workshop Promotion of Clean Energy in Resource-Rich Countries: Case Study of Kazakhstan.

Ministry of Justice of the Republic of Kazakhstan. Database on legislation of the Republic of Kazakhstan Adilet.kz.

President of the Republic of Kazakshan. 2010. The Strategic Plan for Development of the Republic of Kazakhstan until the Year 2020

President of the Republic of Kazakhstan. The Kazakhstan 2050 Strategy for Development.

Srebotnjak T. & Hardi P. 2011. Prospects for sustainable bioenergy production in selected former communist countries. *Ecological Indicators*.

UNDP and others. Republic of Kazakhstan Technology Needs Assessment for Adaptation to Climate Change, 2014.

UNCOMTRADE. 2020. URL: https://comtrade.un.org/ Accessed on 13 January 2020.

UNDP and others. 2018. National Adaptation Plans in focus: Lessons from the Republic of Kazakhstan.

World Bank. 2016. Kazakhstan: Agricultural sector risks assessment. Report Number 103076-KZ.

World Bank. 2020. World Development Indicators. URL: http://data.worldbank.org/country/kazakhstan. Accessed on 13 January 2020.

Y. Karazhan and KEN Partners. 2015. Positioning of Kazakhstan on a world arena and fulfilment of obligations aligned by the Green Growth Strategy and Kyoto Protocol. Kaz Energy Forum, September 2014, Astana, Kazakhstan.

CROP-FARMING TECHNOLOGIES

ADB. 2017. Kazakhstan: Irrigation Rehabilitation Sector Project.

CAREC. 2012. Technology Needs Assessment for Adaptation in the Water and Agricultural Sector in Central Asia.

CIMMYT. 2013. Water-saving techniques salvage wheat in drought-stricken Kazakhstan .

FAO CIMMYT. 2012. Conservation Agriculture in Central Asia.

FAO. 2013. Conservation Agriculture in Central Asia: Status, Policy and Institutional Support and Strategic Framework for its Promotion.

FAO Investment Centre. 2012. Advancement and impact of conservation agriculture/no-till technology adoption in Kazakhstan.

FAO. 2014. Conservation Agriculture for Sustainable Crop Production in Northern Kazakhstan.

Grichanaya, T.S. & Pepshukov, D.A. 2016. Application of drip irrigation during cultivation of vegetable crops in the south of Kazakhstan, Taraz.

KazAgroInnovations. 2010. Normative unit production costs of main types of agricultural crops, Astana.

Ministry of Agriculture. 2017. Map of Machinery Modernization.

Ministry of Agriculture. 2018. The concept of the investment sectoral program for the development of irrigated agriculture for 2018-2027.

National Research University Graduate School of Economics. 2017. Agricultural machinery market.

Savva, A.P. & Frenken K. 2001. Irrigation Pumping Plant. FAO Sub-Regional Office for East and Southern Africa.

PASTURE AND LIVESTOCK TECHNOLOGIES

Ministry of Agriculture. 2018. National Program of the Development of the Beef Sector for 2018-2027.

World Bank. 2016. Implementation Completion Report: Agricultural Competitiveness Project in Kazakhstan Grant project .

UNEP, GEF, RISO Centre and AIT. 2014. Republic of Kazakhstan Technology needs assessment for adaptation to climate change.

RENEWABLE AND ENERGY EFFICIENT TECHNOLOGIES

One Planet. 2013. Concept of the Republic of Kazakhstan for the transition to a Green Economy.

EBRD. 2011. The low carbon transition. European Bank for Reconstruction and Development Report. Available at: www.ebrd.com.

Karatayev M. & Clarke M.L. 2016. A review of current energy systems and green energy potential in Kazakhstan. *Renewable and Sustainable Energy Reviews*.

Karatayev M., Hall S., Kalyuzhnova Y. & Clarke M.L. 2016. Renewable energy technology uptake in Kazakhstan: Policy drivers and barriers in a transitional economy. *Renewable and Sustainable Energy Reviews.*

Annex 1

Selected technologies and their contribution to climate change mitigation and adaptation

Table 1.1

Selected climate technologies and their contribution to climate change mitigation and adaptation

Climate technology	Description and rational for selection	Contribution to climate change adaptation and mitigation
Conservation agriculture	Farming system defined by three principles: (i) minimum mechanical soil disturbance (No-till /use of direct seeders); (ii) organic soil cover; and (iii) crop rotation. Conservation agriculture results in improved long-term soil health[13] and productivity. It also permits reduction of production costs such as fuel, labour and herbicides/pesticides over the long term. Kazakhstan is one of the world's leading adopters of conservation agriculture. The technology is mostly applied in the north of Kazakhstan for rain-fed crops. Progress towards adoption of the third pillar of conservation agriculture, crop rotation, which would increase land productivity and help farmers to better manage pests and diseases, has been slower.	**Mitigation benefits:** Conservation agriculture reduces on-farm fuel consumption (by lessening field operations) leading to lower GHG. Also fewer mineral fertilizers and pesticides are used due to permanent soil cover and crop rotation. It also contributes to carbon sequestration by agricultural soils.
		Adaptation benefits: (i) Increased agricultural production as a result of soil quality improvements – crop yields become more resilient during drought years; and (ii) increased energy availability.
Drip irrigation	Type of micro-irrigation that permits rational water/nutrient use by allowing water to drip slowly to the roots of plants, from above the soil surface or buried below the surface. Most of the irrigated land is located in the south regions of Kazakhstan, which are exposed to climate change.	**Mitigation benefits**: Drip irrigation can have mitigation benefits in situations when the energy saved from pumping less water to irrigate the same area offsets the extra energy that is required to pressurize the system.
		Adaptation benefits: (i) Increased water availability because of more efficient water usage when compared with surface irrigation; (ii) increased agricultural production, especially in situations of water scarcity; and (iii) increased energy availability, when drip irrigation is introduced in areas with pumped water and electricity is saved.
Field machinery	Investing in new tractors (K700 and MTZ80) and harvesters (Essil KKK-740) with regular and proper maintenance, combined with training to drivers, would allow savings in fuel consumption and reduction in food losses and in maintenance costs. Out of 194 000 units of tractors and harvesters, 55 percent are older than 17 years old and inefficient.	**Mitigation benefits:** New tractors and harvesters under right management would save fuel consumption (up to 20%), leading to decreased GHG emissions.
		Adaptation benefits: (i) Increased agricultural production due to reduction in harvest losses (up to 13%); and (ii) Increased energy availability due to reduction in diesel consumption.

---

[13] increased organic matter, in-soil water and improved structure.

Improved greenhouses	The use of greenhouses has experienced large development in the last ten years. The area covered by greenhouses has increased from 60 ha in 2008 to 1 200 ha in 2017, out of which around 150 ha are industrial greenhouses. The industrial greenhouse sector is developing partly due to government support and credits provided by Kazagro. Current policies promoting greenhouses could lead to increasing new areas under greenhouses. This technology focuses on installing Thermocovers, which retain heat on cold days, in existing industrial greenhouses that are large, modern and operate during the whole year, which could save coal/electricity.	**Mitigation benefits:** Thermocovers and energy-efficient heaters reduce coal consumption and therefore GHG emissions. **Adaptation benefits:** (i) Increased agricultural production (optimal heating can lead to increased yields); and (ii) increased energy availability due to energy savings in coal consumption.
Precision agriculture	In this analysis precision agriculture means implementation of a system of parallel driving based on GPS tracking equipment and sensors. Parallel driving systems provide optimal driving and save fuel, mineral fertilizers and other inputs. The Program for the Agrifood Sector Development 2017-2020 supports precision agriculture, smart farming and adoption of digital technologies among the main priorities.	**Mitigation benefits:** GHG emission reduction is due to fuel savings (diesel) when adopting Precision agriculture. **Adaptation benefits**: Increased energy availability as a result of fuel savings.
Pasture improvement	Degraded pastures have potential for rehabilitation through: (i) integrated pasture management (including capacity development); (ii) pasture vegetation and application of rotational grazing; iii) improved livestock breeds and health; and iv) infrastructure rehabilitation and maintenance (roads/bridges waterpoints). 41 million ha out of 181 million ha of pasture are in different levels of degredation due to overgrazing, natural and human activity, and weeds. Improvement practice was analysed using the experience of a World Bank project (Agricultural Competitiveness Project in Kazakhstan) whereby a simple model was built to rehabilitate pasture through the introduction of agropyron perennial grass on pastures using minimum tillage technology.	**Mitigation benefits:** Improved pastures could significantly increase soil carbon sequestration and improve resistance to climate change impacts. **Adaptation benefits**: (i) Higher pasture and livestock production (average milk and meat productivity raised by 5% to 15% from grazing); and (ii) improved resilience to climate change impacts (temperature and water stress, soil erosion).
Fattening units	Improved fattening units consist of feedlot systems where fattening is supported by nutritious diets in more efficient fattening cycles. In 2011 the government started implementation of a Beef Export Potential Program under which feedlots started to be constructed. The feedlot system, if adequately implemented, results in reductions in GHG emissions by fattening cattle over a shorter period of time, when compared with the most common extensive production systems currently used in Kazakhstan.	**Mitigation benefits**: Methane emission reduction (through the process of digesting feed) is estimated per kg of meat in intensive fattening units vs extensive production systems. **Adaptation benefits:** Efficient fattening leads to increased food (beef) production.
Steam boilers	Steam boilers are used in the agrifood industry for heat treatment, freezing, canning, vacuum capping and sanitizing. Benefits in terms of GHG emission reduction are associated with more efficient energy consumption (natural gas and/or fuel oil). In this analysis, old boilers using natural gas or fuel oil are replaced by energy-efficient ones, which may reduce energy consumption by around 20%.	**Mitigation benefits:** More efficient energy consumption (natural gas or fossil fuel oil) by boilers leads to GHG emission reduction. **Adaptation benefits:** Increased energy availability resulting in natural gas savings.
Biogas	Biogas produced from liquid manure and agricultural waste can be converted into heating and/or electricity. It contributes to the production of green energy, providing an alternative to fossil fuels and avoiding GHG emissions from aerobic fermentation. Digestate, a by-product of biogas, can be used in certain conditions as soil amendment and help regenerate soils which have lost organic matter.	**Mitigation benefits**: By operating biogas plants, it is expected to save coal used for on-farm cooking and heating and thus reduce GHG emissions. **Adaptation benefits:** Reduces pressure on energy sources and increases agricultural production. Digestate improves water retention in the soil, provides an effective source of organic matter to soils and improves long-term soil nutrient management.

Wind water pumps	Wind water pumps (using mechanical energy) may be used in irrigated pastures by substituting sets of electric pumps powered with diesel generators, resulting in energy savings and mitigation benefits. Promotion of wind pump technology in remote areas of Kazakhstan, where electrification is not technically and economically feasible, can have large adaptation benefits (including for livestock breeding).	**Mitigation benefits:** The substitution of electricity-powered water pumps by solar/wind pumps can provide limited mitigation benefits since electricity is mainly produced by hydropower plants (> 90 percent of electricity production) with a very low emissions coefficient.
		Adaptation benefits: (i) Reduced pressure on conventional energy resources; and (ii) good potential in remote areas (with difficult access to electricity grid) to provide farmers with access to irrigation (increased water availability) and additional production (increased agricultural production).
Small dams	Dams and reservoirs are built not only to contain floods but also provide water for irrigation, human consumption, aquaculture, industrial use, etc. GHG emission reduction potential was estimated assuming that the construction of a new dam helps farmers avoid using groundwater powered by electric pumps for irrigation purposes, saving around 1.05 kWh/m3.	**Mitigation benefits:** GHG emission reduction potential was estimated assuming that the construction of a new dam helps farmers avoid using groundwater powered by electric pumps for irrigation purposes, saving around 1.05 kWh/m3.
		Adaptation benefits Small dams construction would contribute to increase water availability and agriculture production; and avoid economic losses due to flooding when snow melts.

Source: Authors’ compilation.

Annex 2
Score of selected technologies

Table 2.1
Scoring selected technologies

Tech/ Criterion	Performance compared to best practice	Maturity of technical support services	Current technology adoption rate (%)	Trends in gap between uptake and potential	Financial returns (%)	Potential to reduce annual GHG (KtCO2eq/ year)	Contribution to adaptation	Mitigation cost (USD/ tCO2eq)	Negative externalities	Positive externalities	Policy reform intensity
Units	Likert	Likert	%	Likert	%	KtCO2eq/ year	Likert	USD/ tCO2eq	Likert	Likert	Likert
Preferred value	High	High	Low	High	High	High	High	Low	High	High	High
Conservation agriculture	3	3	36%	3	22%	2 330	4	-11	4	4	2
Field machinery	3	3	82%	3	13%	260	3	-400	3	4	4
Precision agriculture	4	3	17%	3	27%	122	3	-51	5	4	3
Drip irrigation	4	4	31%	2	22%	24	5	-60	3	4	4
Wind water pumps	3	2	30%	3	44%	1	4	11	2	4	2
Improved greenhouses	3	2	13%	4	21%	45	4	-4	4	4	3
Steam boilers	4	2	17%	3	20%	21	2	-9	5	4	1
Biogas	2	1	4%	4	1%	41	3	109	2	3	1
Fattening units	4	2	29%	2	34%	90	3	-23	2	4	4
Small dams	3	3	54%	3	5%	16	5	-351	3	5	2
Pasture improvement	4	3	67%	2	18%	3 931	4	-9	4	5	3

Source: Authors' compilation.

Table 2.2
Score normalization and final ranking of the technologies

Criteria	Performance compared to best practice	Maturity of technical support services	Current technology adoption rate (%)	Trends in gap between uptake and potential	Financial returns (%)	Potential to reduce annual GHG (KtCO2eq/ year)	Contribution to adaptation	Mitigation cost (USD/ tCO2eq)	Negative externalities	Positive externalities	Policy reform intensity	Weighted scores of each option	Rank
Units	Likert	Likert	%	Likert	%	KtCO2eq/ year	Likert	USD/ tCO2eq	Likert	Likert	Likert		
Preferred value	High	High	Low	High	High	High	High	Low	High	High	High		
Weight	5%	5%	5%	5%	10%	30%	10%	15%	5%	5%	5%		
Conservation agriculture	50	67	40	50	49	100	67	53	67	50	33	67.2	2
Field machinery	50	67	0	50	13	100	33	100	33	50	100	67.5	3
Precision agriculture	100	67	72	50	67	61	33	63	100	50	67	63.1	4
Drip irrigation	100	100	48	0	47	12	100	65	33	50	100	49.6	6
Wind water pumps	50	33	50	50	100	0	67	47	0	50	33	37.2	9
Improved greenhouses	50	33	78	100	43	23	67	51	67	50	67	47.6	7
Steam boilers	100	33	72	50	41	10	0	52	100	50	0	35.4	10
Biogas	0	0	94	100	0	20	33	23	0	0	0	226	11
Fattening units	100	33	51	0	98	45	33	56	0	50	100	51.7	5
Small dams	50	67	9	50	0	8	100	100	33	100	33	44.5	8
Pasture improvements	100	67	0	0	33	100	67	52	67	100	67	67.8	1

Source: Authors' compilation.


INCA Bank

©FAO/Vyacheslav Oseledko

Agrifood systems are major contributors to greenhouse gas emissions and increasingly under pressure to become more resource-efficient. The sector also faces threats from climate change, due to its dependence on natural resources. The Food and Agriculture Organization of the United Nations (FAO) and the European Bank for Reconstruction and Development (EBRD), collaborating within the Finance and Technology Transfer Centre for Climate Change (FINTECC) programme, developed a rapid assessment methodology to identify and prioritize climate technologies and practices in the agrifood sector, based on their potential to mitigate greenhouse gas emissions, support climate change adaptation and contribute to economic development. This report presents findings from the application of this methodology in Kazakhstan to guide policy-makers and inform public and private investments towards greening the country's agrifood sector.

ISBN 978-92-5-134966-3

9 789251 349663

CB6857EN/1/03.22