Mitigation options and finance for transition to low-emissions dairy in Kenya

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Abstract

This paper presents potential of low-emission dairy production, investment options, and financial mechanisms in Kenya's dairy sub-sector to better support its necessary transition and enhance contribution to national greenhouse gas (GHG) emission reduction goals. Key GHG mitigation options for the livestock sector in Kenya are improved feed with fodder and hay production (1.57 $MtCO_2e\ y^{-1}$), manure management using biogas plants (0.09 $MtCO_2e\ y^{-1}$), breed improvement production (1.2 $MtCO_2e\ y^{-1}$), dairy processing plants retrofit (0.14 $MtCO_2e\ y^{-1}$), and reduction of milk loss and waste (2.9 $MtCO_2e\ y^{-1}$). The cost of GHG emissions abatement using these options ranges from -US$63/$tCO_2$ (improved feed) to US$80/$tCO_2$ (dairy processing plants retrofit). Economic benefits of these mitigation options include increase in milk production, energy-saving from biogas and dairy plant retrofit, and reduction in milk loss and waste in milk cooling centers. The business case assessments show that all mitigation options are economically viable with a high internal rate of return (IRR) and less than one year to a few years payback period. This assessment shows that a transition to a low-emission dairy sector is possible with economic and environmental gains. More importantly, this transition would support a range of other national policy goals, including improving livelihoods with high food and nutrition security, economic growth, and achieving GHG mitigation targets. In this regard, this synthesis paper is intended to serve as a reference that national and sub-national governments, development organizations, and the private sector can consult as they move forward to invest in mitigation options in the dairy sector.

Keywords

Livestock, greenhouse gas, mitigation options, abatement, investment, benefit

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Contents

Acronyms

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CH_4	Methane
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GHG	Greenhouse gas
GoK	Government of Kenya
IRR	Internal rate of return
KCSAS	Kenya's Climate-Smart Agriculture Strategy
ltr	Liter
MoALF	Ministry of Agriculture, Livestock, and Fisheries, Kenya
NAMA	Nationally appropriate mitigation action
N_2O	Nitrous oxide
NDC	Nationally determined contribution
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development

Setting the scene

Livestock production, which significantly contributes to food security, nutrition, and poverty alleviation for millions, is responsible for more than 60% of all greenhouse gas (GHG) emissions from agriculture (CDP 2015). Cattle production for beef and dairy accounts for 41% and 20% of the GHG emissions, respectively (Gerber et al. 2013). Feed production and processing, and enteric fermentation from ruminants are the two major sources of GHG emissions, followed by manure management. Globally, methane (CH_4) and nitrous oxide (N_2O) emissions from enteric fermentation and manure management are projected to increase by 13.5% by 2030 (FAO 2015). This growth in GHG emissions will be driven by increased demand for livestock products as a result of the growing human population, increased income, and changes in dietary preferences. This emission growth will be greatest in Asia and Sub-Saharan Africa. A decrease in emission intensity and total emissions is necessary to reduce the GHG emissions from the livestock sector to meet global climate change targets.

Livestock is a major source of agricultural GHG emissions in many African countries. This sector contributes more than 70% of total agricultural GHG emissions in the region (FAO 2017). The contribution of the livestock sector to agricultural emissions is relatively high in East African countries such as Ethiopia, Tanzania, Kenya, and Uganda. These four countries account for about 80% of livestock GHG emissions in East Africa. From 1961 to 2017, the average annual GHG emission growth rate in the livestock sector ranged from 2.3 % (Tanzania) to 3.5% (Ethiopia). Kenya has a 2.5% annual growth rate in livestock GHG emissions. Emissions from the livestock sector in this region, particularly from dairy and beef cattle, are projected to increase in future without GHG mitigation measures in place (FAO, NZAGRC 2017).

The outcomes of the December 2015 Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) in Paris laid a foundation for global action to address the effects of climate change on agriculture. Agriculture is well represented in the adaptation and mitigation strategies of many countries as communicated in their nationally determined contributions (NDC). African countries have provided greater specificity on agricultural mitigation measures than other countries by indicating agricultural sub-sectors for mitigation, such as livestock, manure management, grassland, and agroforestry (Richards et al. 2015).

Kenya is a party to the UNFCCC and a signatory to the Paris Agreement. Over the last five years, Kenya has made considerable efforts to mainstream climate change mitigation and adaptation actions into the country's plans, policies, strategies, and programs. These include the National Climate Finance Policy (2016), the Green Economy Strategy and Implementation Plans (2016-2030), the Climate Act (2016), the Kenya Climate-Smart Agriculture Strategy (KCSAS-2017), a proposal for a Dairy Nationally Appropriate Mitigation Action (NAMA-2017), and National Climate Change Action Plan 2018-2022. These policies and programs provide an enabling environment and roadmaps to enhance climate actions with financial investment in agriculture and allied sectors. They also lay the foundation to mobilize domestic, bilateral, and multilateral climate finance to achieve targets set in the NDC under the Paris Agreement.

Why low-emission dairy is essential in Kenya

The dairy sector in Kenya is critical to the economy. Kenya's dairy sector contributes about 14% of the agricultural gross domestic product (GDP) and 3.5% of total GDP (GoK 2016). About 2 million farming households produce milk and most of them (70%) are smallholder farms (GoK 2016). Livestock is the biggest contributor to many dairy farmers' incomes, supporting household livelihoods more than crop production, and self-employment wages (FAO 2018). The country produced over 4.9 billion liters of milk in 2018, and dairy cows contributed 76% of the total milk produced (FAOSTAT 2018). The average growth rate of milk production, processing capacity, and per capita consumption is 5.3%, 7%, and 5.8% per year, respectively (MoALF 2010; KDB 2015). The demand for milk consumption is forecast to increase from 4.9 billion liters y^{-1} to 11.5 billion liters y^{-1} by 2030. To meet this growing demand, the dairy cow population in Kenya would need to increase from 4.3 million head to 7.5 million by 2030 if productivity levels do not change (FAO, NZAGRC 2017).

Total GHG emissions from the dairy sector in Kenya continue to rise as milk production increases to fulfill the growing demand for dairy products and the productivity of dairy animals remains low. The per capita consumption of milk in Kenya is projected to increase from 120 liters to 220 liters by 2030 (MoALF 2010) with a milk demand growth rate of 7% per year. The sustained demand is also projected to grow as a result of increased demand for high-quality milk, diversification in dairy products, and the potential of trading to other countries. There has been a surge of investment in the dairy industry, particularly in processing infrastructure and new dairy processing plants. Such high levels of demand and further intensification of livestock production methods will substantially increase GHG emissions from the dairy sector. Thus, the transition to low-emission dairy production is essential to reduce emissions from the sector.

Kenya's NDC seeks to abate its GHG emissions by 30% by 2030 relative to the business as usual (BAU) scenario of 143 $MtCO_2e$ total economy-wise emissions (MENR 2015). A recent Tier 2 inventory report for the dairy sector in Kenya indicates that the estimated emission from this sub-sector was 5.6 $MtCO_2e$ in 2017 (GoK 2020). This inventory included emissions from enteric fermentation, manure management, and managed soils (emissions from urine and dung deposited on pasture, range, and paddock by grazing animals).

Table 1: National strategies for emissions reduction in Kenya's key policies relevant to agriculture.

Key policies	Strategies
Kenya National Dairy Master Plan	Improve productivity and competitiveness in the dairy sector. Enhance public and private finance for dairy sector development. Increase efficiency of milk collection and supply (reduce losses).
Kenya's NDC	Kenya seeks to abate its GHG emissions by 30% by 2030 relative to the BAU scenario of 143 $MtCO_2e$. This is dependent on finance, investment, technology development and transfer, and capacity building.
Kenya Climate-Smart Agriculture Strategy (KCSAS)	Reduce the rate of emissions from livestock (manure and enteric fermentation). Promote the development and use of low-emissions technologies to manage livestock feed and manure. Enhance livestock productivity through improved breeds and livestock management systems. Promotion of energy-efficient technologies and innovations.
Kenya's Dairy NAMA	Over the 10-year implementation period, the expected emission reductions of 8.8 $MtCO_2e$ come from the following sources: Increased dairy productivity (152,700 households): 4.14 $MtCO_2e$ Energy efficiency in processing (151 facilities): 2.96 $MtCO_2e$ Household biogas adoption (20,000 households): 0.98 $MtCO_2e$

The NDC recognizes agriculture as one of the potential areas for emission reduction to achieve its target. Kenya's KCSAS was developed to support the implementation of the NDC and realize the goals set in Kenya's Vision 2030. This strategy aims to reduce the rate of emissions from livestock by promoting feed and manure management, enhancing livestock productivity through improved breeds, and implementing energy-efficient technologies and innovations in the dairy sector (MoALF 2018). Kenya's Dairy NAMA proposal intends to implement low-emission, climate-resilient, and productivity-enhancing options in the dairy sector. The NAMA anticipates an 8.08 $MtCO_2e$ reduction in GHG emissions by increasing dairy productivity (4.14 $MtCO_2e$), improved energy efficiency in processing (2.96 $MtCO_2e$), and household biogas adoption (0.98 $MtCO_2e$). The NAMA aims to provide effective support to the dairy farmers, double milk output, and increase household net income by at least 50%.

Data and methods

This synthesis on low-emissions dairy development considered mitigation studies conducted in the dairy value chain in Kenya. Various studies have estimated the GHG emission mitigation potential of livestock feed management and breed improvement (FAO, NZAGRC 2017), retrofitting dairy processing plants (Wilkes et al. 2018), installing biogas plants for manure management (MoALF 2017), and reducing milk loss and waste (Gromko, Abdurasulova 2018) at the national level in Kenya. These studies also provided the per-unit cost of emissions reduction (US$/t$CO_2$ abatement y^{-1}) for the mitigation options assessed.

Cost of mitigation options

The per-unit abatement costs for each mitigation option were collected from the studies conducted in Kenya. The per-unit costs of emissions reductions (US$/t$CO_2$ abatement y^{-1}) for all mitigation options were converted to 2020 US$ values using consumer price index (CIP) based inflation rate. The marginal abatement cost of mitigation options (US$/t$CO_2$ abatement) and mitigation potential vary by production system, biophysical characteristics, and current and future climatic conditions of a location. This study relied on case studies conducted in a few locations in Kenya that may not represent dairy production systems throughout the country. In addition, estimated per-unit cost of CO_2 abatement can vary with the level of adoption, the market price of inputs for low-emission options, and fluctuation in dairy product prices. This study assumed that the per-unit cost of emissions reduction for the selected mitigation options does not significantly differ across Kenya.

Emissions reduction and economic benefits

This synthesis estimated economic benefits and GHG emissions reduction from the implementation of mitigation options in Kenya's dairy value chain. The total emissions reduction benefit was estimated based on the potential GHG emissions reduction from the implementation of selected mitigation options. The selected mitigation options are technically and economically feasible to implement in Kenya's dairy sector. However, actual emissions reduction may differ based on the implementation of mitigation options and their performance in the field.

Economic benefits from the mitigation options include the increase in milk production from improved feed management and breed improvement, the increase in energy efficiency from biogas plants and dairy processing plants retrofit, and the reduction in milk loss and waste in milk cooling centers. The current farm gate price of milk (Kenyan shilling (KES) 30/ltr equivalent to US$0.3/ltr) and per-unit cost of electricity for business use (US$0.184/kWh) were used to estimate the total economic benefit from the implementation of the mitigation options.

Assessment of business cases

The economic assessment of mitigation options includes the per unit investment, Internal Rate of Return (IRR), and payback period. These indicators were summarized from various studies conducted in Kenya. Studies by van Dijk et al. 2018 (hay production), Kashangaki and Ericksen, 2018 (fodder production), MoALF 2017 and Hamid and Blanchard, 2018 (biogas plant), Wilkes et al. 2018 (dairy processing plants retrofit), and Gromko and Abdurasulova, 2018 (milk loss minimization in the cooling centers) provide economic analyses for these mitigation options.

Finance sources and approaches

Current and potential finance sources and approaches to financing low-emissions options in the dairy sector were assessed based on studies conducted in Kenya. Studies included information about sources of finance for the dairy sector, farmers' access to financial resources, and financing mechanisms (Odhong' et al. 2019). This synthesis discusses potential innovative finance mechanisms for low-emissions dairy development.

Low-emissions options in the Kenya dairy value chain

Enteric fermentation, feed production and processing, manure management, milk loss and waste, and energy use in dairy plants are four major sources of GHG emissions in the dairy sector. GHG emissions (CH_4) from enteric fermentation is by far the largest single contributor to the carbon footprint of dairy products. Manure from livestock and synthetic fertilizer use in feed production are major sources of N_2O emissions. For the rest of the value chain, energy use in processing, transportation, and packaging is the dominant contributor to CO_2 emissions. Milk loss in the value chain, including consumption, represents a waste of resources used in each production stage and contributes to increasing GHG emissions from the dairy sector.

Table 2 presents mitigation options in the dairy sector and their GHG emission reduction potential in Kenya. Enteric CH_4 emissions are related to total feed intake, which can be significantly reduced by changes in the composition of animal feed supply. Increasing the quality of feed, particularly roughage, can reduce enteric CH_4 production from livestock (Grainger, Beauchemin 2011; Danielsson 2009). The GHG emissions abatement potential of the use of different types of fodder across Kenya ranges from 0.6 to 3.0 $MtCO_2e\ y^{-1}$. The increased amount of roughages, such as leguminous fodder, hay, silage, and crop by-products, reduces the use of concentrate feed (which has a relatively high carbon footprint) in the animal feed supply. Other research suggests that promoting balanced feed rations and feeding concentrates according to cows' needs throughout the lactation cycle could provide important opportunities to both increase milk production and reduce the emission intensity of milk production (Wilkes et al. 2020).

Manure from dairy cattle is a significant source of CH_4 and N_2O when broken down under anaerobic conditions. Biogas generation systems can reduce the emission of these gases from dairy farms. The adoption of biogas in the intensive and semi-intensive dairy production systems in Kenya can reduce emissions up to 0.01$MtCO_2eq\ y^{-1}$(1 M tCO_2eq in 10 years). Breed improvement with artificial insemination can also reduce GHG emissions from the livestock sector. The main benefits of dairy cattle breed improvement are the increase in productivity and input use efficiency and a reduction in GHG emissions required to produce the same amount of milk (Wall et al. 2010). This intervention in the dairy sector can reduce emissions by 1.2 $MtCO_2eq\ y^{-1}$.

Table 2: GHG abatement potential of mitigation options for the dairy sector in Kenya

Mitigation Category	Mitigation option	Abatement Potential (M tCO_2 eq/year)
Feed management[1]	Supplementation with sweet potato vines, sorghum silage, and dairy meal	3.00
	Urea-treated crop residues	1.80
	Supplementation: leguminous shrubs/fodder trees	1.40
	Supplementary with sweet potato vines and sorghum silage	1.60
	Establishment of fodder grasses and legumes	1.00
	Feed conservation of fodder as silage- sweet potato vine silage	0.60
	Improved feed with different types of fodder[a]	1.57[*]
Manure management[2]	Biogas	0.09
Breed improvement[1]	Artificial insemination of improved breed	1.20
Dairy processing plant retrofit[3]	Improving energy use efficiency	0.14
Milk loss and waste[4]	Loss minimization in the cooling centers	1.70
	Loss minimization in the dairy cooperatives (collection centers)	1.20

[1]FAO & NZAGRC (2017), [2] NAMA (MALF 2017), [3]Wilkes et al. (2018), [4]Gromko and Abdurasulova (2018). [a]Average abatement potential from the different types of fodder. [*]Average abatement potential of fodder and feed mitigation options.

Dairy processing plants use a large amount of energy, mainly electricity and fossil fuels, for cooling and storage, pasteurization, evaporation, and drying activities. Improvement in energy use efficiency in the major 32 dairy processing plants in Kenya can reduce emissions by 0.14 $MtCO_2eq\ y^{-1}$. Most milk losses in the dairy sector in Kenya occur at the production and processing stages, as milk is transported from farmer to cooperative and to local processors (Gromko, Abdurasulova 2018). The estimated GHG emission reductions from minimizing the loss in milk cooling centers and dairy cooperatives are 1.7 and 1.2 $MtCO_2$ eq y^{-1}, respectively.

Costs of mitigation options

Assessments of mitigation potential in Kenya's dairy sector identify five investment areas that are financially viable and have large potentials for GHG emission reduction in the dairy sector. Table 3 presents the cost of emission reduction for different mitigation options applicable in the dairy sector in Kenya. The per-unit cost of emission reduction, also known as marginal abatement cost (US$/t$CO_2$ abatement y^{-1}), varies from -US$63 to US$80. The negative marginal abatement cost for feed management, breed improvement, and milk loss and waste indicate that the revenues associated with the measure are greater than the costs after applying an appropriate discount rate. Higher negative numbers reflect higher profitability per tCO_2e reduction. The positive marginal abatement costs for a biogas plant (manure management) and dairy processing plant retrofit (improving energy use efficiency) show that the costs associated with the measure are greater than the revenues. Reduction of milk loss in the dairy cooperatives' collection centers and the use of biogas plants for manure management are low-cost mitigation options. The per-unit cost of GHG emission abatement is relatively higher for improved feed with different types of fodders and retrofitting dairy processing plants.

Table 3: Estimated cost of abatement (in 2020 US$ value) for mitigation options in Kenya

Mitigation Category	Mitigation option	US$/tCO2 abatement
Feed management1 (for tCO2 abatement per year)	Improved feed with different types of fodder	-63.00
Manure management2 (for tCO2 abatement per year)	Biogas plant	18.00
Breed improvement1 (for tCO2 abatement per year)	Artificial insemination with improved breed	-41.00
Dairy processing plant retrofit3 (Investment cost /lifetime tCO2e (US$)	Improving energy use efficiency	80.00
Milk loss and waste4 (for tCO2 abatement per cooler)	Loss minimization in the cooling centers	-38.00
	Loss minimization in the dairy cooperatives (collection centers)	-3.16

[1]FAO & New Zealand Agricultural Greenhouse Gas Research Centre (2017), [2]MoALF (2017), [3]Wilkes et al. (2018), [4]Gromko and Abdurasulova (2018).

The highest profitability per tCO_2e reduction is from improved feed management using of different types of fodder. This practice enhances milk production, decreases the use of concentrate feed for livestock production, and reduces enteric methane fermentation in livestock. Breed improvement helps cost saving in CO_2 abatement and increases the resource use efficiency, replaces low production livestock, and decreases the emission intensity per unit of production. Similarly, farmers and cooperatives can minimize milk loss with the installation of new coolers in collection centers. Retrofitting of dairy processing plants and biogas plants both have positive costs of per unit emission (US$/t$CO_2$) abatement.

Total GHG emissions reduction potential (M tCO_2 eq/year) and per-unit cost of abatement (US$/t$CO_2$ abatement) for improved feed with different types of fodder, breed improvement using artificial insemination technology, and reduction of milk loss and waste show that Kenya has a large potential to reduce GHG emissions from the livestock sector with negative emissions abatement cost. However, all livestock farmers may not adopt these options or implement them in all locations. In reality, farmers gradually adopt these options over time depending on suitability to their local conditions, availability of finance, technical capacity, and demand for the dairy products in the market.

Benefits of investment in low-emission options

Mitigation options assessed for the dairy sector in Kenya have the potential to enhance dairy productivity, save energy, and minimize losses in the dairy value chain. The potential economic and environmental benefits from the implementation of selected mitigation options are presented in Table 4. Improved dairy cattle feed with different types of fodder can increase milk productivity from 13% to 35% (FAO, NZ-AGGRC 2017). This intervention can increase milk production by 0.9 billion liters per year in Kenya, equivalent to US$270 million at the farm gate price of US$0.30/ltr. The use of biogas plants for manure management and dairy processing plant retrofits can save a large amount of energy, improve health, and save women's labor use in energy management (MoALF 2017; Hamid, Blanchard 2018; Wilkes, van Dijk 2017). The estimated value of energy saved by the biogas plants and processing plant retrofitting is US$4 million y^{-1} (from 20,000 biogas) and US$409 million y^{-1} (from 4 large, 16 medium, and 12 small dairy industries), respectively.

Dairy cattle breed improvement with artificial insemination can increase milk production from 5% to 15% (average 11.6%). The estimated gain from this intervention is increased milk production by 0.43 billion ltr y^{-1} which is equivalent to US$130.5 million at farm gate price of US$0.30/ltr. Reduction in milk loss and waste in the cooling centers across Kenya can minimize milk loss by 204 million ltr y^{-1}. This value was estimated based on the current level of production (i.e., 3.4 billion ltr y^{-1}) and a potential 6% reduction in losses from the cooling centers.

Implementation of five mitigation options by the current dairy farmers, dairy processing plants, and milk coolers in the country can reduce emissions by 5.82 M tCO_2 y^{-1}. This investment case assumes that carbon benefits begin in the first year after the start of capital works and remain the same each year over the 10 years. This potential reduction from the dairy sector represents 15% percent of Kenya's NDC mitigation target of 43 $MtCO_2$ eq. in 2030.

Table 4: Potential benefits of mitigation options in Kenya's dairy sector

Benefits	Amount	Assumption/Estimation
GHG reduction	5.82 $MtCO_2$ y^{-1}. Approx. 68 $MtCO_2$ reduction by 2030	Use of mitigation options by the current dairy farmers, dairy processing plants, and milk coolers and cooperatives in Kenya.
Increase in milk production with improved feed	0.9 billion ltr y^{-1} (Current value US$270 million at farm gate price*)	Use of fodder in dairy cattle feed increases milk production from 13% to 35% (average 24%) [a].
Energy-saving (biogas plant)	Kenya's dairy NAMA plans 20,000 biogas plants that can save US$4.0 million y^{-1}	Cost of biogas: US$916/plant installation, US$50/year maintenance cost, and energy cost saving of US$204 per biogas plant y^{-1}(MoALF 2017).
Increase in milk production with artificial insemination of improved breed	0.43 billion ltr y^{-1} (Current value US$130.5 million at farm gate price*)	Use of artificial insemination of the improved breed in dairy cattle increases milk production from 5% to 15% (average 11.6%) [a].
Energy-saving from retrofitting a dairy processing plant	Total electricity savings of 2,224.29 GWh y^{-1} which is equal to US$409 million at US$0.184/kWh price for business use	Estimated energy-saving potential of retrofit investments in 32 major dairy processing plants (4 large, 16 medium and others are small) in Kenya[b].
Reduction in milk loss and waste in cooling centers	52,560 ltr per cooler y^{-1} (Current value of US$15,768 per cooler y^{-1} at farm gate price*) 204 million ltr y^{-1} milk saving with 6% loss reduction (Current value of US$61.2 million at farm gate price of*)	The cooler capacity of 5,000 ltr Coolers can potentially reduce 6% of milk spoilage losses. Current milk production is 3.4 billion ltry^{-1}.

[a]FAO & New Zealand Agricultural Greenhouse Gas Research Centre (2017), [b]Wilkes et al. (2018), [c]Gromko and Abdurasulova (2018). Note: The amount of benefit for each intervention is estimated nationwide for the dairy sector. *Farm gate price is KES30/ltr equivalent to US$0.3/ltr.

Business case for low-emission options

The economic assessment of mitigation options for Kenya's dairy sector demonstrates financial viability (Table 5). Investment in hay production on 1-acre (small-scale) and 1,500-acres (large-scale) areas can have an IRR of 18% and 41%, and payback periods of 2.3 years and 2.4 years, respectively (van Dijk et. al 2018).

Fodder production and use in zero-grazing dairy production systems (intensive stall-feeding) provide an example of the economic viability of low-emission dairy options in Kenya. Assessments indicate that households are better off growing fodder grasses (e.g., Napier, Boma Rhodes, Brachiaria, and natural pasture/common grasses) on their land rather than purchasing fodder. High-profit margins with fodder production are driven by an increase in milk yields and a reduction in the cost of dairy cattle feed. A large-scale five-year fodder production project can generate an IRR of 62% with a two-year payback period (Kashangaki, Ericksen 2018). Other case studies also demonstrate that fodder production offers viable business opportunities in Kenya (Amua et al. 2018; Ouma et al. 2017).

Table 5: Economic assessment of mitigation options

Mitigation option	Initial investment (US$)	Internal rate of return (IRR)	Payback Period (Year)
Hay production[1]	Small (1 acre): 500 Large (1500 acre): 268,900	Small: 18.01% Large: 40.82%	Small: 2.3 Large: 2.4
Fodder production[2]	US$7.26 million for 10,000 farmers for 5 years project	62%	2
Biogas plant	US$916 per biogas plant[3]	24.5%	
	US$760 per biogas plant[4]	56%	1.6
Dairy processing plant retrofit[5]	Large plant: US$2.84 M Medium plant: US$2.28 M Small plant: US$1.53 M	12.5% for replacing electric chilling plants with solar chilling plants	Large: 0.25 Medium: 2.76 Small: 0.6
Loss minimization in cooling centers[6]	US$5,942 per cooler	303% after five years	2

[1]Dijk et al. (2018), [2] Kashangaki and Ericksen (2018), [3]CDM biogas projects in Kenya (MoALF 2017), [4]Hamid and Blanchard (2018)

[5]Wilkes et al. (2018), [6]Gromko and Abdurasulova (2018)

Economic assessment of biogas plants in various locations in Kenya shows a large potential to scale out this technology in the intensive and semi-intensive dairy production systems. A standard size biogas plant (for 4-5 cattle) requires an initial investment of US$700 to US$900 per plant and US$50 per year for maintenance (Hamid, Blanchard 2018; MoALF 2017). A household can save US$204 per year by replacing fuelwood and other energy sources used in the kitchen with biogas. The IRR ranges from 24% to 56% with a 2-to-5-year payback period, depending on the size of the biogas plant.

The energy consumption abatement potential of the dairy processing plants ranges from 25% to 40% of the total energy demand of the plant (Wilkes et al. 2018). Dairy processing plant retrofit saves electricity, water, and cleaning chemical use and reduce milk losses. The payback period for retrofit of large, medium, and small dairy processing plants in Kenya is 0.25, 2.76, and 0.6 years, respectively. Similarly, the investment in loss reduction measures in the milk cooling centers can provide a large economic return to the dairy cooperatives and processing plants. In this investment, the milk loss reductions range from 4.5% to 6%, IRR ranges from 72% to 303%; and the payback period ranges from 1 to 2 years (Gromko, Abdurasulova 2018).

Financing for low-emissions dairy

Reaching millions of smallholder dairy farmers in rural areas with financial support is one of the major challenges in Kenya. Many smallholder dairy farmers are constrained by inadequate access to financial resources that limit their investment in quality feed, breeds, and animal health which results in poor yields (Mutavi et al. 2016; Odhong et al. 2019). In addition, corporate and financial institutions are reluctant to invest in this sector due to insufficient risk reduction measures. Livestock insurance is one of the options to minimize the risk of investment; however, this program is still in the early stages in Kenya, and this only insures against one of many risks dairy producers face. The perceived high risks of agriculture, combined with the transaction costs of small loan and small farmers and businesses' lack of collateral, hamper lending (EIB 2020). As a result, finance in the dairy sector is insufficient to stimulate more efficient production and the adoption of better technologies including GHG mitigation options.

Current sources of finance for dairy farmers and cooperatives

Few dairy farmers in Kenya use loan services from formal financial institutions, such as banks, microfinance, saving and credit cooperatives, and other sources (Table 6). A recent study indicates that about 80% of farmers have never had a loan from a formal financial institution (Odhong et al. 2019). Most of the rural dairy farmers borrow small loans from their neighbors and family friends. Among the formal financial institutions, saving and credit cooperatives are the most used sources of loans by the farmers. Some dairy cooperatives are well connected with financial institutions (saving and credit cooperatives and banks) to invest in operational capital (e.g., milk cooler and processing equipment). Lack of a perceived need for loans, fear of losing assets, inability to repay, and lack of records are the main reasons given by rural households for not applying for a loan (Central Bank of Kenya et al. 2016). Farmers' credit application refusal rates are between 40% and 60% due to the lack of collateral and a clear business plan (Rambo 2012).

Table 6: Current source of finance for dairy farmers and dairy cooperatives in Kenya

Source of finance	Dairy farmers (% of total farmers, n=608)	Dairy cooperatives (number of cooperatives, n=7)
Accumulating Saving and Credit Association (ASCA)	7	Not used
Rotating Savings and Credit Association (ROSCA)	5	Not used
Savings and Credit Cooperatives (SACCOs)	10	1/7
Mobile banking	4	Not used
Microfinance	1	Not used
Bank	3	3/7
Credit from input suppliers	1	Not used

Source: Odhong et. al 2019

Enhancing financing in the dairy sector

The transition to low-emissions dairy requires a broad set of measures ranging from supporting smallholder farmers to large investments in the dairy value chain and infrastructure projects. Commercial financing from banks, microfinance institutions, and savings and credit cooperatives in agriculture is limited, and only about 5% of the total investment goes to the agriculture sector (AfDB 2016). Increasing investment will have to rely on mostly private-sector sources of finance. A good investment environment can help private sector is therefore needed. In addressing the financial needs of the dairy sector, it is useful to focus on the key strategies and risk management tools for structuring current financing in agriculture.

Capacity building of financial institutions: In this paper, financial assessments of mitigation options in the dairy sector show positive cost-benefit ratios, but they cannot necessarily be commercially financed. The interest rates charged by many commercial finance institutions are significantly higher than the feasible interest rates estimated in studies. Savings and credit cooperatives' interest rates range between 10 and 16%, and the interest rate goes up to 24% for loans provided by other financial institutions (Odhong et al. 2019). In addition, investments in low-emission options tend to have long repayment periods. Therefore, financial institutions need to design and deploy suitable financial products that can address both dairy farmers' credit needs and reduce investment risks to financial institutions. They require capacity strengthening and support to develop targeted products, accurately assess risk, and use appropriate risk-mitigating mechanisms. Equipping financial institutions and other investors with data and risk-assessment tools necessary to execute better risk assessment and management strategies can motivate them to increase their investment in the dairy sector business cases.

Promotion of digital solutions: The use of digital solutions can play an important role in reducing the cost of primary data collection to assess farmer profitability, develop alternative credit scoring systems, and create alternative forms of collateral (Millan et al. 2019). Addressing these fundamental issues is particularly important to unlock financing from financial institutions for farmers and cooperatives. Many innovative digital solutions to address these challenges already exist in mobile technology (e.g., Climate-Smart Lending Platform for credit risk assessment, Mercy Corps), blockchain (Binkabi in Nigeria using blockchain tokens as movable collateral – Wasses 2018) and big data and machine learning (e.g., FarmDrive with Safaricom to build a credit score for smallholder farmers in Africa – Mugume 2017).

The main weakness of digital financial solutions is that they are not tailor-made for agriculture, the interest rates are high, short term, and only lend low amounts. Digital financial solutions rarely consider farmers' digital literacy, especially women's. Most are based on a saving scheme implying that the amount to be borrowed depends on the savings made and the period the client has used the services. This limitation may reduce the use of digital solutions for investments in small-scale dairy production.

Financing financial institutions: Savings and credit cooperatives are the most used sources of loans by farmers in Kenya, but most savings and credit cooperatives have inadequate funding to provide loans to farmers and dairy cooperatives (Odhong et al. 2019). Many commercial banks receive support for credit lines including credit guarantees and technical assistance from national and international sources. Similar support to the savings and credit cooperatives can help them reach many farmers in rural areas. However, external borrowing by savings and credit cooperatives is limited by law.

Financing aggregators: Aggregators in agriculture can function as investors and facilitators of information exchange and financial resources within each of the segments of a value chain. The process requires investing in well-performing production systems that involve farmers and their cooperatives, input suppliers, and dairy industries. The aggregator may be farmers' cooperatives, dairy industries, other farmer-producer organizations, or an online marketplace. Aggregation brings together small farmers and buyers to achieve economies of scale, create a market signal, and provide access to financial services. Financing aggregators can de-risk investments of commercial financing in the dairy sector.

In Kenya, many farmer cooperatives are playing the role of aggregators in the dairy sector. They finance the farmers through a check-off system, which is a provision of credit to the farmers by dairy cooperatives with repayment made by deductions form the value of milk supplied to the cooperative (Odhong et al. 2019). The check-off system is used to finance dairy inputs such as feed and health services. A new financing option can focus on upgrading this check-off system to large amounts that can allow farmers to invest in dairy cows or biogas plants. This approach not only helps to finance capital operation but also to promote dairy production.

Catalyzing private investments: Blended finance can de-risk investments and catalyze private capital follow, mainly for the large dairy industries. It helps to de-risk investments and catalyzes private capital by standardizing requirements of public capital, realigning returns and leveraging expectations (by first-loss guarantees, subsidized interest rate or offsetting the cost of capital), and increasing the effective application of risk reduction tools (Millan et al. 2019). Ongoing bilateral and multilateral projects, such as the National Agricultural and Rural Inclusive Growth Project and the USAID-funded Kenya Crops and Dairy Market System (KCDMS) are providing various types of funding to support public-private partnerships for investment in fodder and feed and dairy value chains (AFC 2020; NARIGP 2018). Blended finance may incentivize both dairy businesses and financial institutions to invest in climate-smart activities including mitigation options.

Where the public fund is placed and how it is distributed plays a key role in its effectiveness. The public and private sectors can co-develop business operating models in the dairy value chain by integrating mitigation options and social and economic development that can include large number of small and medium-sized dairy enterprises. This can be linked with large commercial dairy farmers and financial institutions that share a stake in the success of small and medium enterprises. The public sector can support the success of such a collaborative venture by addressing governance, market, and financial barriers to the adoption of mitigation options. An investment in commercial dairy farmers by private sector partners with emissions reduction performance targets can catalyze a public-private partnership and finance for GHG mitigation in the dairy sector.

Financial mechanisms: a value chain approach

The dairy sector in Kenya is still largely comprised of subsistence farming. A value chain approach to financial mechanisms can connect subsistence farmers to other value chain actors and help them to move from subsistence farming to running commercial and low-emissions dairy businesses (Geel et al. 2018). In the dairy value chain, farmers, processors, milk collection centers (run by cooperatives, private milk collectors, or dairy processors), and input and service providers are closely interconnected. The business case cannot be profitable without the active participation of these actors in the dairy value chain.

Dairy processors have a crucial role to play as the main actor in creating backward and forward linkage in the dairy product supply chain. They can ensure secured sourcing of milk and promote backward integration with milk collection centers, dairy farms, and input and service providers in the value chain. Investments in business cases, such as fodder or hay production, manure management, breed improvement, dairy processing plant retrofitting, and minimizing milk loss and waste, are only possible with secured access to the market guaranteed by the dairy processors. The dairy processors are also dependent on milk collection centers and farmers to supply dairy products to the market.

The alignment of business cases within the dairy value chain can guarantee the supply and quality of dairy products and return on investment for the business cases (Kilelu et al. 2016; Ngeno 2018; Geel et al. 2018). The business cases for mitigation options discussed in this paper are positive, but a risky transformation. They will only work when market access is guaranteed, and the transformation is supported by the dairy cooperatives and milk processors. Therefore, the financial package should support the different business cases for commercial dairy farms, milk collection centers, commercial fodder and hay production and service centers, and dairy processors. In addition, co-investment in each business case is crucial to ensure financial sustainability in the long run. Medium and large commercial farmers, milk collection centers, and dairy processors can be the co-investors and pursue commercial financing for their business cases.

Gender and investment in low-emission options

Gender relationships and dynamics can influence the way mitigation technologies are prioritized, transferred, and adopted (Edmunds et al. 2013). The roles and interests may vary for women and men in the dairy sector, which can lead to different responses to mitigation options. Given the existing gender inequalities, the outcomes of mitigation initiatives might not be equally beneficial to women and men. In smallholder households across Kenya, women play a predominant role in cattle feeding, milking, cleaning, and, to some extent, delivery of milk to the market and milk collection centers (Gallina 2016; Kristjanson et al. 2014). Men tend to have a larger role in activities related to animal health, such as artificial insemination, seeking veterinary treatment, and in the sale of live animals and animal products. Studies also show that gendered power relationship in dairy sector can materialize and influence formal milk marketing engagement and practice in the rural areas (Tavenner, Crane 2018).

Improved feed management with fodder and hay production in farmlands may increase women's role in livestock production because of the shift in cropping patterns to accommodate fodder cultivation. The impact of fodder cultivation on gender dynamics may differ based on livestock production systems. Dairy intensification by converting open grazing systems to stall-fed can increase the burden on women (Kristjanson et al. 2010). The intensification of the dairy system reduces the labor requirement for herding and grazing, which are mainly carried out by men. However, where women are responsible for fodder collection from the communal lands and forests, fodder cultivation on farmland reduces their labor burden. Therefore, the impact of investment in fodder cultivation on gender dynamics will depend on women's and men's roles in dairy cattle feed management and the shift in dairy production systems.

Gender differences in access to financial resources can play a critical role in potential investment in improved feed management options in the dairy sector. Women dairy farmers tend to be disadvantaged in their access to productive assets and credits for fodder and hay production (Mutoko et al. 2015; Odero-Wanga et al. 2009). Since a lack of access to credit limits women to invest in fodder and hay production, improving women's access to the formal credit system and incentivizing mechanisms would help to promote this mitigation option in Kenya. Even if women can access finance, commercialization of dairy has been shown to primarily increase benefits for men (Tavenner, Crane 2018).

Manure management using biogas plants has a large implication for gender equity in Kenya. Women in Kenya are responsible for cooking food using firewood collected from farmlands, communal lands, and forests (Dohoo et al. 2013). Investment in biogas plants can help to meet growing household energy needs, reduce the burden of firewood collection on women and girls, and provide health benefits (Dohoo et al. 2013). Despite the potential to improve gender inequality, the diffusion of biogas innovation in Kenya is limited due to high initial costs and a lack of regulatory standards (Wilkes, van Dijk 2017). Access to new climate funds and building linkages between biogas activities and entrepreneurship can help to generate mitigation benefits and reduce burdens on women.

Conclusions

Sustainably increasing production, while also reducing GHG emissions from the livestock sector, is a major challenge in Kenya's economy, where the sector plays a critical role in supporting the livelihoods of millions of households across the country. Most dairy sector development strategies focus on increasing milk productivity and expanding production to meet the growing demand for dairy products. The GHG impacts of the dairy sector can be reduced if synergies with mitigation options are recognized and scaled across dairy farmers and industries. This synthesis demonstrates the large potential of investing in low-emission development options in the dairy sector with gains in productivity, resource use efficiency, and a reduction in losses and wastes. The mitigation options considered for this study have both technical feasibility and economic viability to be implemented in the dairy sector. They also can reduce GHG emissions without reducing overall dairy output. Most of the mitigation options considered in this study can also improve dairy productivity and expand production.

This assessment shows that a range of GHG mitigation options are available for transition to a low-emission dairy sector with economic and environmental gains. More importantly, this transition would support a range of other national policy goals, including improving livelihoods with high food and nutrition security, economic growth, and achieving GHG mitigation targets. However, achieving these economic and environmental benefits will require scaling mitigation options with large investments from various financial sources. Broader efforts will be required to support the transfer and uptake of mitigation options, scale-up private finance, and increase access to domestic and international climate finance. Given the critical role women play in the dairy sector, addressing gender issues by promoting gender-responsive mitigation options, such as fodder production and biogas plant installation, can lead to more effective uptake and impact of mitigation options in the dairy sector.

This synthesis can contribute toward an ongoing process of implementing Kenya's dairy NAMA and the Kenya Climate-Smart Agriculture Strategy. These are two tools to implement Kenya's NDC for the agriculture sector and outline the allocation of investment to the key actions. The total potential GHG emissions reduction from the five mitigation options considered in this study is 6.81 MtCO2 y^{-1}. This potential reduction of GHG emissions from the dairy sector represents 15% percent of Kenya's NDC mitigation target of 43 MtCO2 eq. in

2030. Achieving this mitigation benefit requires increasing climate finance flow to the mitigation options through global finance, and annual government budgeting, mobilization, devolution of national climate change funds to the local level.

Total GHG mitigation potential did not consider the current level of adoption of mitigation options. A baseline of low-emission option implementation in Kenya needs to be established to provide additional information to estimate the investment requirement.

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